

Review Article

Research on the Bill of Quantities Pricing Model for Prefabricated Buildings Based on BIM

ABSTRACT

In recent years, advancements in prefabricated construction technology and management levels have significantly improved the precision and quality of prefabricated components. As a result, the practice of manufacturing components in advance and assembling them on-site has become an inevitable method of construction in the building industry. However, the pricing basis in project valuation remains inadequate, and existing pricing models fail to reflect the characteristics of prefabricated buildings as well as the capabilities of construction enterprises. Traditional valuation methods are no longer applicable, which hampers the development of prefabricated construction. Project valuation is a crucial aspect of the construction industry, and with the rise of BIM (Building Information Modeling) technology, the integration of information technology in the sector inherently aligns with the characteristics of prefabricated buildings. Therefore, addressing the aforementioned issues by combining advanced information solutions with cost estimation for prefabricated buildings presents a new pricing model, which is an essential pathway to accelerate the rapid development of prefabricated construction in China. This research explores effective strategies for cost management of prefabricated construction projects within a bill of quantities pricing framework, thereby expanding the application of BIM and offering significant development potential and prospects for promotion.

Keywords: Prefabricated Buildings; Cost Management; BIM.

Introduction :

With the advancement of the new era and technological progress, the industrialization and informatization of the construction industry in China have entered a phase of rapid development, presenting new opportunities and challenges. However, the traditional construction methods, characterized by inefficiency, have led to significant waste of social resources and environmental pollution, which have become obstacles to the development of green buildings and hinder the sustainable growth of the national economy to a certain extent. Consequently, prefabricated and modular construction has garnered widespread attention from experts, scholars, and engineers due to its advantages, such as reduced waste and shorter construction periods. Currently, China is actively introducing prefabricated construction and promoting modular building practices. By manufacturing components with production equipment and transporting them to construction sites for installation, this method effectively shortens construction durations, reduces costs, minimizes environmental impact, and optimizes the allocation of social resources. However, the high costs associated with prefabricated construction in China severely limit the development and application of these methods by construction companies. Thus, the fundamental impetus for the development of prefabri-

cated buildings lies in how to deliver the highest quality construction at the lowest possible cost. As a key driver of the revolution in China's construction informatization industry, BIM (Building Information Modeling) technology must embody characteristics such as high visualization, collaboration, simulation, standardization, and refinement [20]. These features are essential for providing effective information solutions that help reduce costs for prefabricated buildings, improve the cost control level in modular construction, and ultimately contribute to the advancement of green building practices in China.

1. ISSUES IN ESTIMATING COSTS FOR PREFABRICATED BUILDINGS

Prefabricated construction, celebrated as an energy-efficient, effective, and environmentally friendly construction method, is increasingly recognized worldwide. However, like any technological innovation, prefabricated construction faces several challenges in cost estimation, primarily stemming from differences from traditional construction methods in design, production, transportation, and execution. The following are key issues associated with cost estimation for prefabricated buildings:

1.1 Issues in Managing the Prices of Prefabricated Components

The core of cost management in prefabricated construction revolves around the reasonableness of component prices. The quantities within the cost estimates accounting for various PC components are derived based on both purchased finished products and on-site installation. Consequently, component prices play a significant role in the overall project costs [1-3]. Prefabricated components are characterized by diversification and variability, and the low level of standardized design leads to significant discrepancies in cost price information. Additionally, the market prices of components lack a unified standard and do not effectively reflect the dynamic price trends in the market, resulting in a severe scarcity of price information [4]. The prices of prefabricated components are primarily based on market information; however, due to the inadequacy of established pricing standards and the incompleteness of cost estimation norms in conjunction with the production standards for prefabricated components, issues such as distortion of price information and the unsuitability of cost bases and rates commonly arise [5].

1.2 Insufficient Existing Measurement Standards

Currently, in the cost management of prefabricated construction projects, most regions in China lack applicable management and profit costs. The fee calculation standards and details have not been adjusted based on the actual conditions of various regions and types of prefabricated buildings, resulting in untimely and unreasonable adjustments to bases and rates. Although the measurement standards for building construction and decoration include items related to prefabricated components, they fail to encompass all sub-items and only list basic factors affecting comprehensive unit prices without providing thorough explanations regarding the construction methods or quality requirements related to prefabricated buildings. This leads to incomplete project quantity lists that do not capture the essential characteristics of prefabricated buildings, consequently highlighting the limitations of using a bill of quantities pricing model for prefabricated construction.

1.3 Inadequate Measures for Pricing Project Costs

Currently, the basis for cost estimation in prefabricated construction in China primarily follows the standards established for cast-in-place methods, which include vertical transporta-

tion costs, additional costs for height increases, and safety construction expenses. It is important to note that prefabricated construction heavily relies on prefabricated components, resulting in variable measure costs during on-site construction. The demand for formwork and scaffolding is relatively low during prefabricated construction, which correspondingly reduces the workload. However, some management personnel still calculate costs based solely on building area, which is debatable. In addition to inappropriate units for measure project costs, there are instances where financing for supporting work surfaces and on-site storage for components is lacking.

2. FEASIBILITY OF APPLYING BIM IN COST ESTIMATION FOR PREFABRICATED BUILDINGS

2.1 Overview of BIM Technology

Building Information Modeling (BIM) technology has gradually emerged in the construction industry with advances in science and the rapid development of information technology. This technology originated in several developed countries in the West, where scientific research on BIM has been conducted and its informatization and parametrization have been progressively applied in the architectural design process, demonstrating its potential value[6]. BIM technology serves as a carrier for building information, allowing for the addition, modification, and extraction of real data at different stages of a building's lifecycle[7-8]. The core idea is to utilize a single model throughout the entire lifecycle of a building, as illustrated in Figure 1. The models created can be described in terms of data information and can span all phases of a construction project, including design, construction, operation, and management. This facilitates multi-disciplinary collaboration during the design phase and comprehensive information visualization during the assembly phase, thereby being applied across the entire production chain in the construction industry.

BIM technology uniquely integrates components and overall building models with digital information technology[9-10], exhibiting significant characteristics such as simulation capability, visualization of complex nodes, interdisciplinary design collaboration, integrated management optimization, and the capability for generating construction drawings. This enables highly efficient operations among multiple disciplines[11-12]. As BIM technology continues to develop in our country, it has been widely applied in the design phase, assembly construction phase, and subsequent operational phase of prefabricated buildings. It has also achieved positive results in the efficient sharing of project information and collaboration among multiple disciplines. Following the visualization of the three-dimensional scene, there has been a notable increase in work efficiency and equipment utilization, as well as a reduction in construction material waste, which will inevitably enhance economic benefits. Therefore, the emergence of BIM technology is bound to promote the informatization and parametrization of designs in the construction industry, marking it as the future direction of development[13-14].

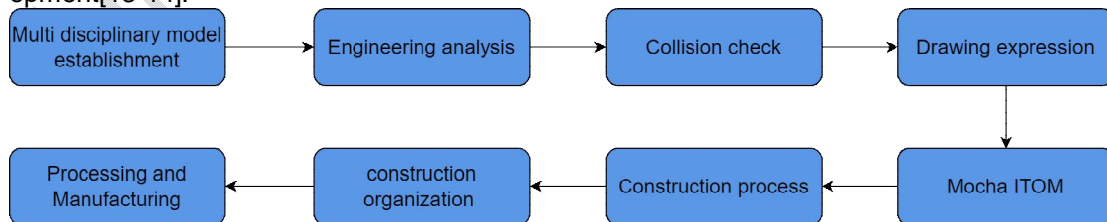


Figure1 Building Lifecycle Based on BIM

2.2 The inherent modular characteristics of prefabricated buildings are intrinsically compatible with BIM modeling.

The modular and component-focused traits of prefabricated concrete structures align intrinsically with mainstream international BIM modeling software. There are also many technical similarities; for example, BIM technology requires the establishment of "families" before modeling the structure, followed by the splicing and assembly of these "families" within project files. Multiple "family" files can thus form a component library. This approach is similar to the way components in prefabricated concrete buildings are produced in factories and then transported to the construction site for connection and assembly. Therefore, the technological compatibility between BIM technology and prefabricated concrete structures provides essential technical support for the measurement and valuation processes in prefabricated concrete construction projects[15].

2.3 The foundation for measurement in BIM

Currently, measurement work can be conducted within BIM. The primary measurement process involves first setting the geometric and physical properties of each component during modeling. Then, during measurement, BIM can query this information and categorize components based on all their characteristics, ultimately measuring and summarizing these components according to BIM measurement rules. This approach exemplifies the data-driven and parametric characteristics of BIM.

Presently, there are three main methods for conducting engineering measurement using BIM: Application Programming Interfaces (API), Open Database Connectivity (ODBC), and the output of component quantities through BIM design software's bill of quantities. However, there are discrepancies between BIM measurement and China's bill of quantities pricing standards, prompting scholars to adopt various approaches to align with these standards. For example, Lin Hanhua and Zhou Hongbo utilized the ODBC development method to create a quantity calculation plug-in attached to Revit, modifying the measurement rules within Revit. This enabled the mapping of the inherent properties of components to the data from the quantity calculation plug-in, ultimately producing quantity results that conform to China's bid price regulatory standards[16]. Similarly, An Pei, Yu Dihua, and others employed the GCL software plug-in to import results from the Revit model directly into the Guanglianda GCL quantity calculation software via the plug-in, followed by conducting measurement and pricing tasks[17].

3. KEY ASPECTS OF BIM APPLICATION IN THE VALUATION OF PREFABRICATED BUILDINGS

3.1 Changing BIM measurement rules

The quantities directly calculated using Revit software clearly do not meet China's calculation standards. For the measurement of concrete engineering quantities in China, it is necessary to adjust the internal concrete structure models in Revit and establish a matching relationship for the bill of quantities model. According to Chinese regulations on the deduction of structural volumes, the intersections of columns, shear walls, and slabs are not deducted from the volumes of slabs. Specifically, the volumes of slabs are not reduced for the intersecting portions with columns and beams.

However, the internal deduction standards in Revit differ from those stipulated in China's bill of quantities. Revit specifies that for the intersections between slabs and columns or

beams, the slab volume is reduced by the volume of the columns and beams, which results in the volumes of columns and beams being disproportionately larger than the specified quantities in standard engineering practices. Consequently, the volumes at the intersections where columns and beams overlap are deducted from each other.

To comply with standardized quantities before conducting quantity statistics for the model, it is only necessary to interchange the connection sequence between slabs and beams, as well as between slabs and columns, as illustrated in Figure 2. This adjustment ensures compliance with the stipulated engineering quantities.

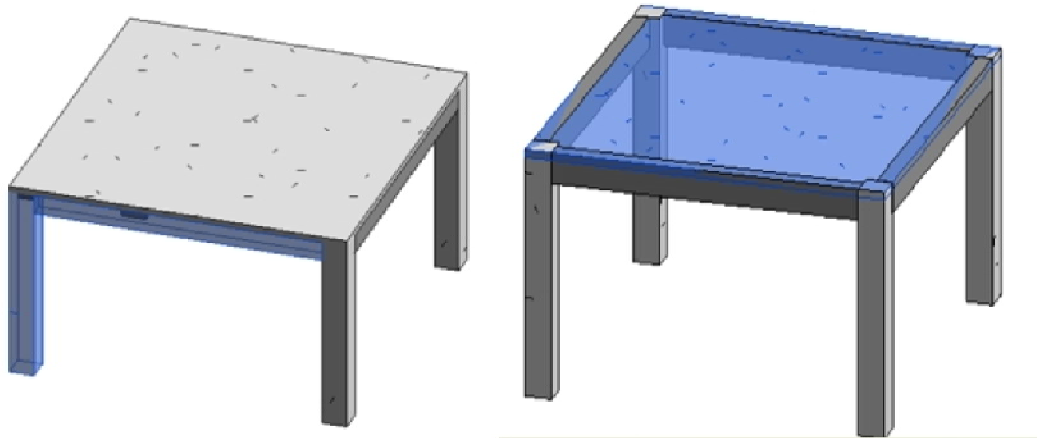


Figure2 Modify the deduction order of the concrete structure model

3.2 Measurement Units Based on Components

For prefabricated buildings, the application of modular standards is a crucial aspect of industrial production; thus, the costs of molds and the number of mold sets are significant parameters. To facilitate the segmentation of components, each component is treated as a basic unit designated as a "piece" [18]. From the perspective of BIM, current BIM software predominantly uses "elements" as the fundamental unit. When modeling with BIM, it is essential not only to consider the inherent features of the BIM software but also to account for the measurement and pricing requirements specific to the building being designed.

The information related to measurement output from modeling in Revit software primarily includes physical and geometric data. Physical information refers to the component types, characteristics, and identification numbers, while geometric information pertains to dimensions such as length, width, height, area, and volume. For the valuation process, having only the aforementioned physical and geometric information is insufficient; additional extended measurement information is also required.

The extended valuation information consists of five major categories: geometric features, functional roles, material types and requirements, construction techniques, and construction methods. This extended information can be incorporated into the software by creating "new parameters" for components, selecting "shared parameters" as the parameter type, and defining names in the parameter data. Furthermore, the types of parameters can be selected as "text" or "length," where length, width, and thickness are designated as "length," and attributes like material grade, cross-section type, and mortar strength level are categorized as "text." Taking the example of adding project characteristic parameters and project codes for hollow core slabs, as illustrated in Figure3:

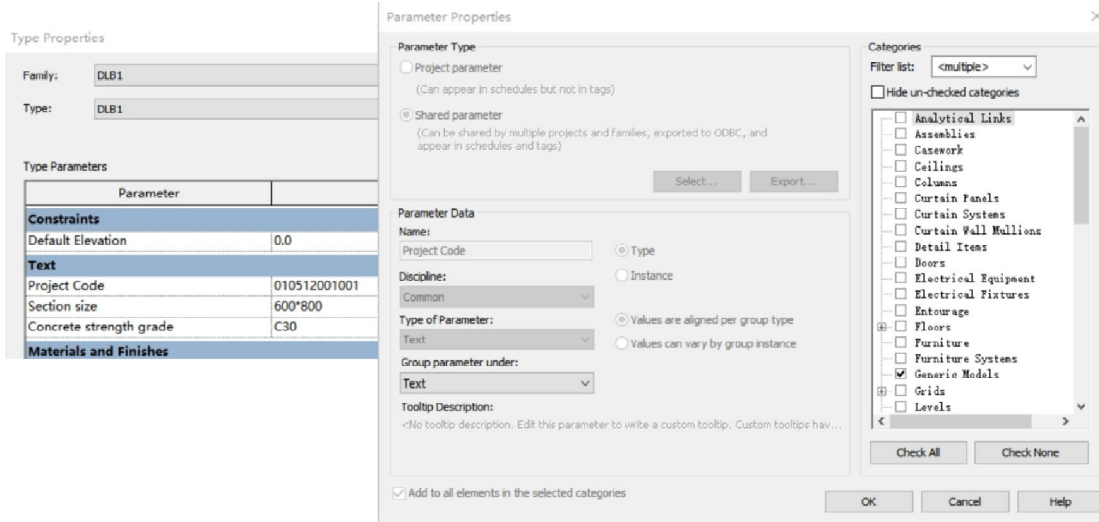


Figure 3 Expand pricing information for laminated panels

In conjunction with the previously introduced modular pricing process based on BIM technology, this study calculates the cost composition of unit prices in the bill of quantities for prefabricated concrete construction projects, using precast (PC) components as the basic unit and adopting a comprehensive unit price format. The direct engineering costs, management fees, and profits for each component are included within the precast component. The direct engineering costs consist of labor, material, and equipment costs, which are calculated based on the corresponding quantities and respective prices, and then summed up accordingly. Additionally, the costs related to measures, regulatory fees, and taxes need to be listed separately. Thus, the cost for a single component can be expressed as follows: Cost of the component = Direct engineering cost of the component + Management fee of the component + Profit of the component; Direct engineering cost of the component = Labor cost of the component + Material cost of the component + Equipment cost of the component; Total cost of components = Component 1 + Component 2 + ... The specific price breakdown is illustrated in Figure 4.

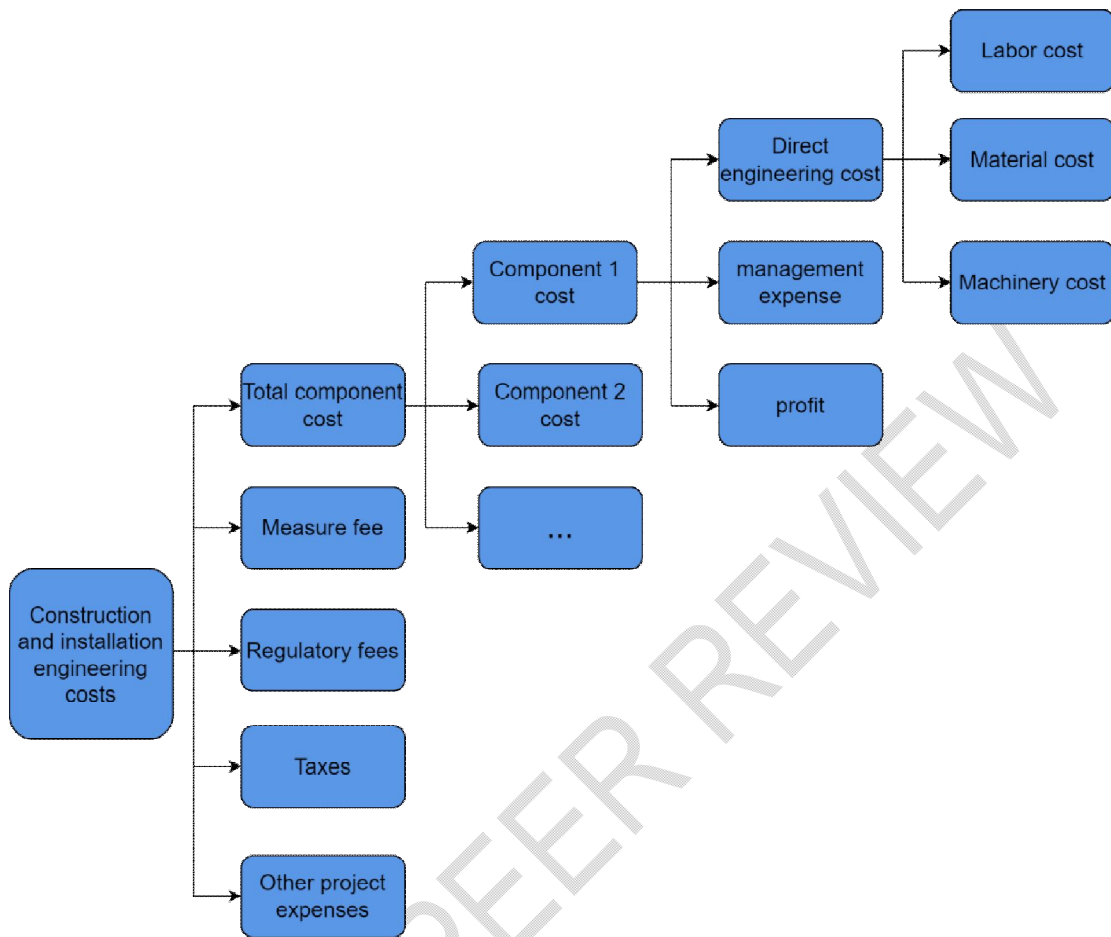


Figure4 Valuation based on the bill of quantities of components

3.3 Quantification of Non-Physical Projects Based on BIM

BIM models can quantify physical components, but there are no clear rules for quantifying non-physical projects. The costs in this category mainly include measures costs, regulatory fees, taxes, and management fees. In a BIM model, these costs can be separately listed for calculation. This can be achieved by creating the corresponding "families" to establish modes for quantifying measures project costs, regulatory project costs, and fee rate entities for these non-physical components [19]. This is illustrated in Figure 5.

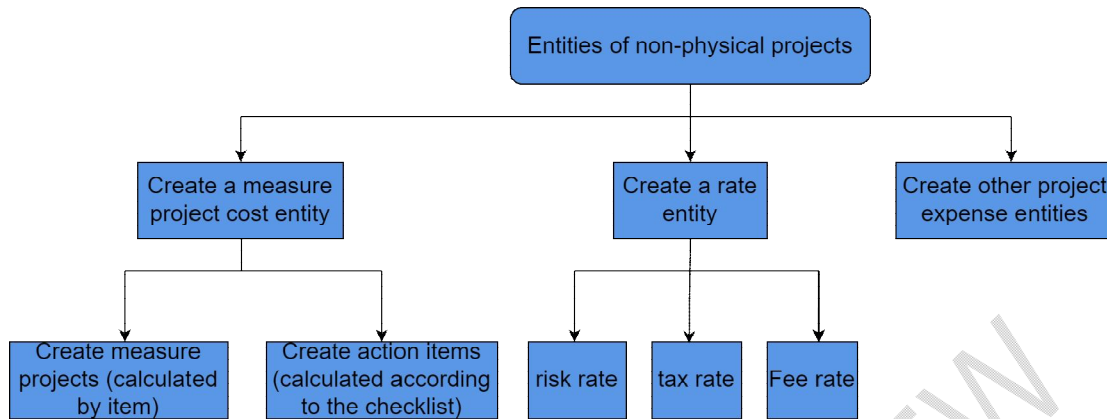


Figure5 Entity construction of a non-physical project

4. CONCLUSION

Compared to conventional cast-in-place concrete construction methods, prefabricated concrete structures offer significant advantages, including standardized component dimensions, resource conservation, and higher construction efficiency. Therefore, it is inevitable that the future development trend of the construction industry in our country will be the vigorous promotion of prefabricated buildings. BIM technology provides substantial technical support for the informatization of the modern construction industry and accelerates the establishment of a series-based and standardized system for prefabricated concrete components.

This paper discusses the existing issues in the current state of prefabricated construction and analyzes the feasibility of combining BIM technology with the cost estimation of prefabricated buildings. It proposes a pricing process for prefabricated buildings: by modifying the measurement rules of BIM to make them suitable for calculating the quantities of concrete works in our country, PC components can be established within BIM software, along with the addition of cost information. For non-physical projects, corresponding "families" can be created for quantification, ultimately resulting in a BIM-based bill of quantities for prefabricated construction.

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