Journal of Engineering Research and Reports

Volume 26, Issue 12, Page 95-105, 2024; Article no.JERR.127482
ISSN: 2582-2926

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

Lu Zhao [a*]

[a] *School of Civil Engineering and Transportation, North China University of Water Resources and Electric Power, Zhengzhou 450045, China.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: https://doi.org/10.9734/jerr/2024/v26i121343

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/127482

Review Article

Received: 24/09/2024
Accepted: 28/11/2024
Published: 03/12/2024

ABSTRACT

In recent years, with continuous advancements in prefabricated construction technology and management practices, the accuracy and quality of prefabricated components have improved. As a result, the practice of pre-manufacturing components off-site and assembling them on-site has become an inevitable construction method for the development of the building industry. This paper discusses the current issues faced by prefabricated buildings and analyzes the feasibility of integrating BIM (Building Information Modeling) technology with cost estimation for prefabricated construction.The paper proposes a cost estimation process for prefabricated buildings, which involves adapting BIM's measurement rules to suit local requirements for concrete quantity calculations. By creating precast (PC) components in BIM software and adding cost-related information, a BIM-based quantity take-off list can be generated.This study provides valuable insights into the application of BIM in the cost management of prefabricated buildings and the further research on quantity take-offs for such projects. It also broadens the scope of BIM applications, offering significant potential for the development and widespread adoption of BIM technology.

**Corresponding author: Email: 1186049362@qq.com;*

Cite as: *Zhao, Lu. 2024. "Research on the Bill of Quantities Pricing Model for Prefabricated Buildings Based on BIM". Journal of Engineering Research and Reports 26 (12):95-105. https://doi.org/10.9734/jerr/2024/v26i121343.*

Keywords: Prefabricated buildings; cost management; BIM.

1. 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 prefabricated 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 (Zhang and Guo 2021). 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.

2. PROBLEMS IN PRICING OF 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:

2.1 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 (Zhao et al. 2019, Guo Lili 2019, Su and Zheng 2020). 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 (Qin Jianming 2023). 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 (Chen Bin 2019).

2.2 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 (Chen Yueping 2024).

2.3 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 transportation 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.

3. FEASIBILITY OF APPLYING BIM IN COST ESTIMATION FOR PREFABRICATED BUILIDINGS

3.1 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 (Al-Ashmori et al. 2020). 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 (Akula et al. 2013, Liu et al. 2014). The core idea is to utilize a single model throughout the entire lifecycle of a building, as illustrated in Fig. 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 (Wang Jiafeng 2013, Sydora and Stroulia 2020), 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 (Zhang et al. 2020, Yang et al. 2020). 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 (Santos et al. 2020, Baldwin et al. 2008).

3.2 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

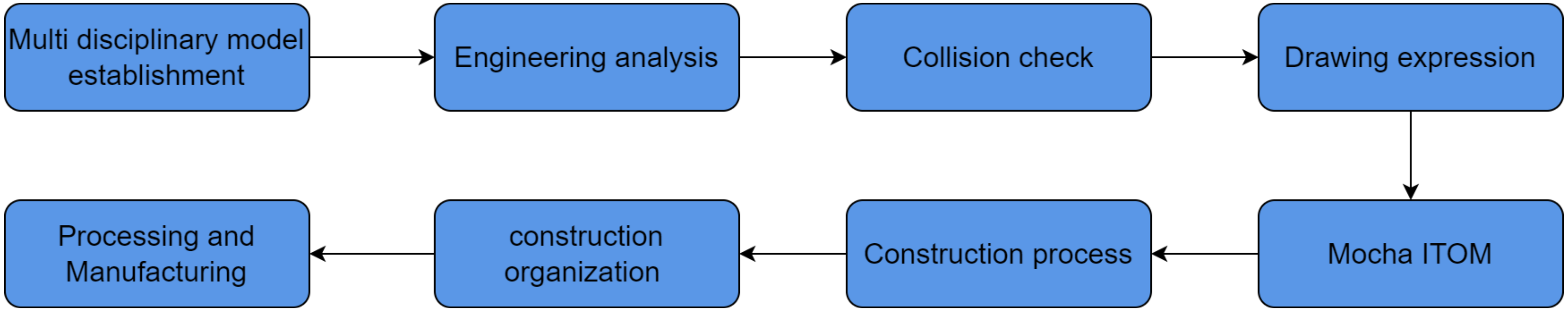

Fig. 1. Building lifecycle based on BIM

technology and prefabricated concrete structures provides essential technical support for the measurement and valuation processes in prefabricated concrete construction projects (Xu Chuangxin 2020).

3.3 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 (Lin et al. 2015). 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 (Ampere et al. 2015).

4. KEY ASPECTS OF BIM APPLICATION IN THE VALUATION OF PREFABRICATED BUILIDINGS

The application of BIM technology in the construction management of prefabricated buildings is an important area of research in current construction engineering management. However, issues such as the low integration capability between BIM technology and intelligent equipment, as well as the inefficiency in the integration between different BIM software, are still subjects of debate (Yang Fei 2020, Zhang and Guo 2021, Song et al. 2023). Therefore, it is necessary to fundamentally address the discrepancies between BIM and the quantity take-off lists for prefabricated buildings in China.

4.1 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 Fig. 2. This adjustment ensures compliance with the stipulated engineering quantities.

4.2 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" (Lin et al. 2023). From the perspective of BIM, current BIM software predominantly uses "elements" as the

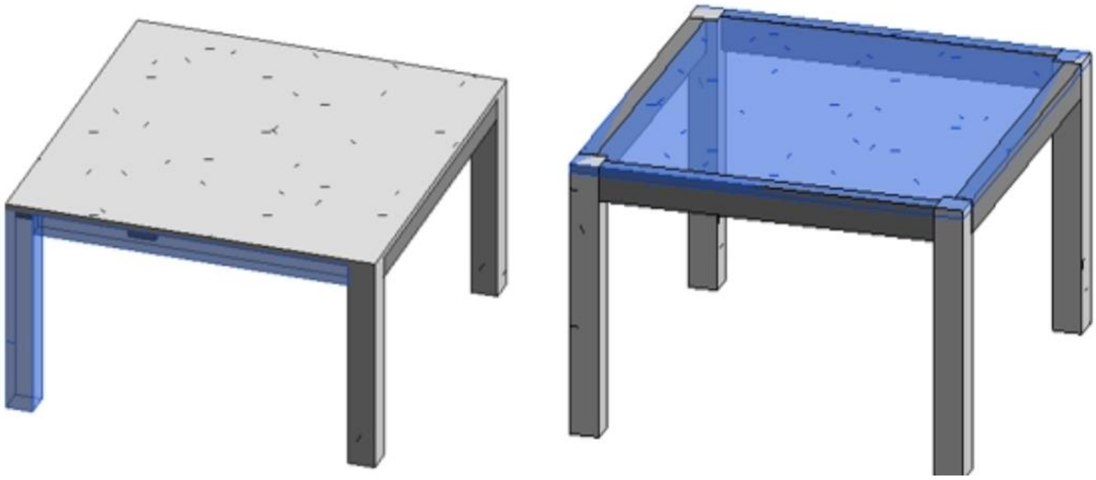

Fig. 2. Modify the deduction order of the concrete structure model

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.”

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 (Wang et al. 2024. 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 Fig. 3.

4.3 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 (Pupeikis et al. 2021). This is illustrated in Fig. 4.

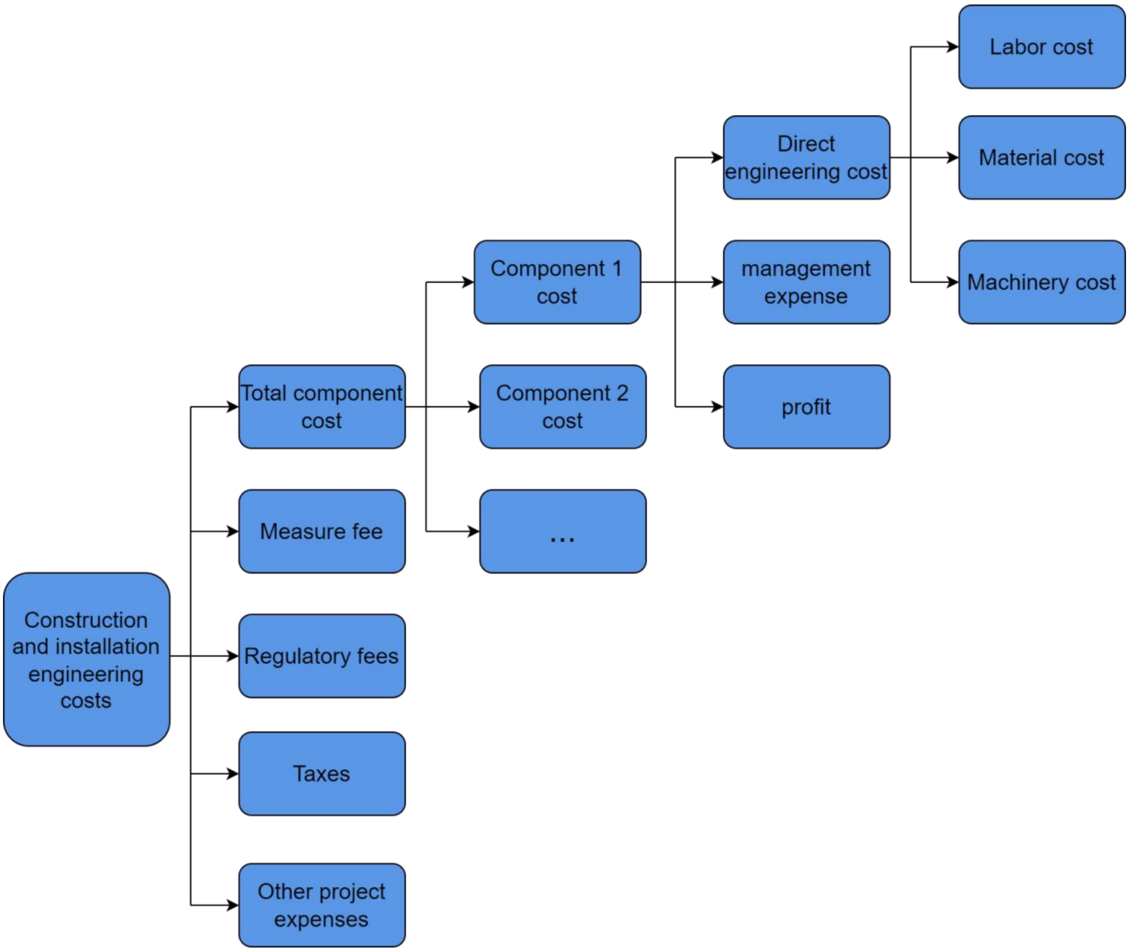

Fig. 3. Valuation based on the bill of quantities of components

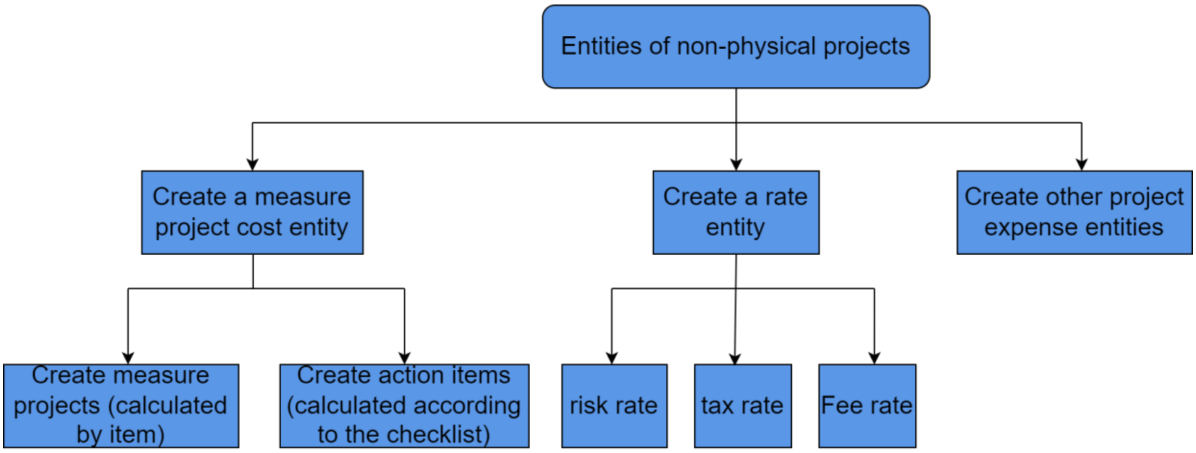

Fig. 4. Entity construction of a non-physical project

5. CASE APPLICATION

5.1 BIM Modeling

The case study selected in this paper is a prefabricated concrete building with one basement level and four above-ground floors (with the second and third floors being standard floors). Fig. 5 shows the BIM model of the building.

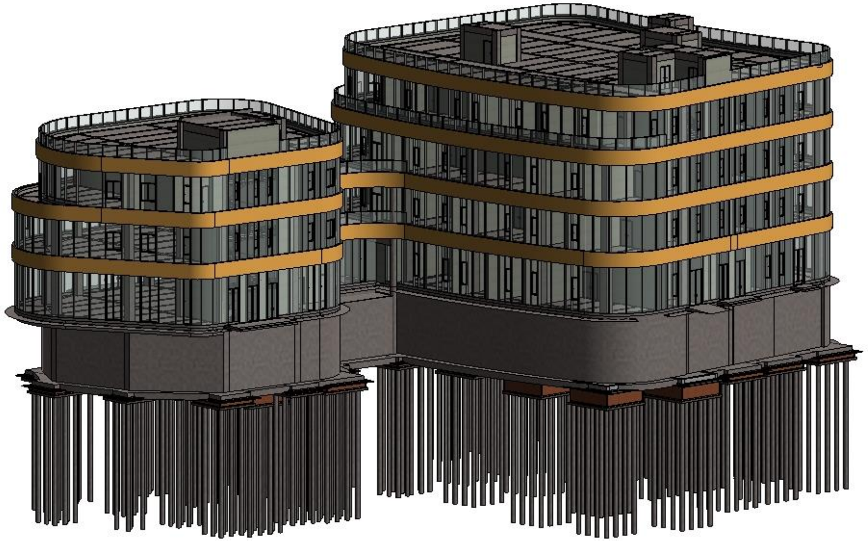

Fig. 5. BIM model of prefabricated buildings

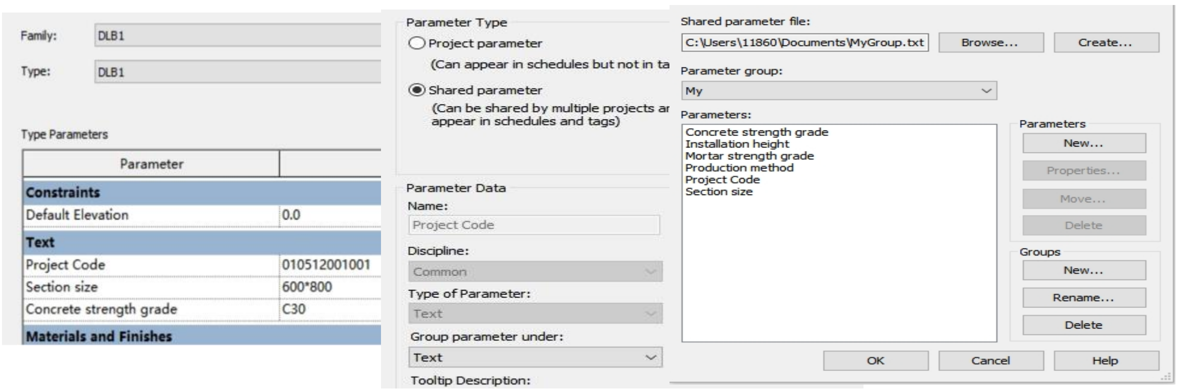

Fig. 6. Expand pricing information for laminated panels

	A	B	C	D	E	F	G	H	I	J	K	L	M
1					Schedule of PC Panels								
2	project code	family	installation height	Concrete strength grade	Mortar strength grade	Mortar mix ratio	Construction	mode of transport	length	width	thickness	volume	合计
3													
4	010512001001	PC Panel	3	C30	M10	01:05.1	Precast concrete	road transport	3500	3000	300	0.74 m³	1
5	010512001002	PC Panel	3	C31	M11	01:05.1	Precast concrete	road transport	3000	2000	300	0.58 m³	1
6	010512001003	PC Panel	3	C32	M12	01:05.1	Precast concrete	road transport	3000	2000	300	0.58 m³	1
7	010512001004	PC Panel	3	C33	M13	01:05.1	Precast concrete	road transport	3600	3000	300	0.77 m³	1
8	010512001005	PC Panel	3	C34	M14	01:05.1	Precast concrete	road transport	3600	3000	300	0.77 m³	1
9	010512001006	PC Panel	3	C35	M15	01:05.1	Precast concrete	road transport	3200	2800	300	0.67 m³	1
10	010512001007	PC Panel	3	C36	M16	01:05.1	Precast concrete	road transport	3400	2800	300	0.69 m³	1
11	010512001008	PC Panel	3	C37	M17	01:05.1	Precast concrete	road transport	3000	2500	300	0.65 m³	1

Fig. 7. Expand pricing information for laminated panels

5.2 Adding Cost Information to Components

Select one of the components, then choose "New Parameter" → "Shared Parameters," and click "New." In the parameters list, find and select "Project Code" and "Project Feature Parameters." Afterward, input the project code and project features in the component properties. Taking the example of a PC (precast) slab to add project feature parameters and project code, as shown in Fig. 6.

5.3 Exporting the Quantity Take-Off List

In the "View" menu, select "Schedule" → "Standard Model Schedule" → "Building Component Schedule." Add all the parameters of the quantity take-off items that need to be exported into the "Schedule Fields."

Taking prefabricated concrete slabs as an example, sequentially add parameters such as "Project Code," "Family," "Concrete Strength Grade," and "Mortar Mix Ratio." Afterward, click "Export" to generate the model schedule, which is the required quantity take-off list. Fig. 7 shows an example of the schedule after being exported to Excel.

6. CONCLUSION

Prefabricated buildings, which are constructed by assembling pre-manufactured building components, represent an advanced form of construction. However, their development and application are influenced by various factors such as technology, economics, and scale, which may lead to increased project costs. This paper focuses on prefabricated buildings and proposes a BIM-based cost estimation process, providing a fundamental solution to the differences between BIM measurement methods and China's quantity take-off standards.

Through case studies, it is demonstrated that using BIM to create a quantity take-off list for prefabricated buildings is feasible. The newly developed quantity take-off list offers valuable reference material for cost estimators in the prefabricated construction sector. However, the established quantity take-off list requires further validation through real-world projects. It is important to monitor the ongoing development of the prefabricated building market and adjust accordingly. Future research could focus on establishing a BIM-based collaborative management platform for prefabricated buildings, which would enhance the overall development and efficiency of prefabricated construction.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

Akula, R., Lipman, R. R., Franaszek, M., et al. (2013). Real-time drill monitoring and control using building information models augmented with 3D imaging data. *Automation in Construction, 36*, 1-15.

Al-Ashmori, Y., Othman, I., Rahmawati, Y., et al. (2020). BIM benefits and its influence on the BIM implementation in Malaysia. *Ain Shams Engineering Journal*.

Ampere, Yu., Lihua, Y., Ai, X., et al. (2015). Research and application of BIM based 3D computing in super high-rise building projects. *Construction Technology, 44*(23), 15-18.

Baldwin, A. N., Shen, L. Y., Poon, C. S., & Wong, et al. (2008). Modelling design information to evaluate prefabricated and precast design solutions for reducing construction waste in high-rise residential buildings. *Automation in Construction, 17*(3), 333-341.

Chen, B. (2019). *Research on cost management of prefabricated buildings based on the bill of quantities pricing model* (Master's thesis, Southwest Petroleum University). Southwest Petroleum University, Sichuan.

Chen, Y. (2024). Cost management of prefabricated residential buildings under the list pricing model. *Jushe*, (18), 177-180.

Guo, L. (2019). A brief analysis of cost budgeting and cost control in prefabricated construction projects. *Jiangxi Building Materials*, (11), 206-207.

Lin, H., Zhou, H., & He, X. (2015). Research on the implementation method of engineering quantity calculation based on BIM design software. *Building Economics, 36*(4), 59-62.

Lin, Y., Wang, H., Zhao, D., & Sun, Y. (2023). Research on BIM-based information management platform for the whole life cycle of prefabricated buildings. *Building Economy, 44*(1), 77-83.

Liu, R., Xu, Y., & Zeng, X. M. (2014). BIM application implementation plan and roadmap in the cost management of electric power engineering. In *2014 International Conference on Construction and Real Estate Management* (pp. 208-216). Reston: American Society of Civil Engineers.

Pupeikis, D., Morkūnaitė, L., Daukšys, M., Navickas, A. A., & Abromas, S. (2021). Possibilities of using building information model data in reinforcement processing plant. *Journal of Sustainable Architecture and Civil Engineering, 28*(1), 80-93.

Qin, J. (2023). Research on cost management of prefabricated construction projects under the list pricing model. *Residential and Real Estate*, (5), 54-56.

Santos, R., Costa, A. A., Jose, D., et al. (2020). Development of a BIM-based environmental and economic life cycle assessment tool. *Journal of Cleaner Production, 265*, 1-15.

Song, X., Li, Z., & Yao, X. (2023). Research on quality management of the whole industry chain of prefabricated buildings based on BIM. *Journal of Engineering Management, 37*(5), 30-35.

Su, J., & Zheng, X. (2020). Research on the bill of quantities pricing of prefabricated concrete engineering based on WBS value engineering. *Tan Jianming*, (11), 41-43.

Sydora, E., & Stroulia, E. (2020). Rule-based compliance checking and generative design for building interiors using BIM. *Automation in Construction, 120*, 1-13.

Wang, J. (2013). *Research on structural analysis and design methods of BIM in construction engineering* (Master's thesis, Wuhan University of Technology). Wuhan University of Technology, Hubei.

Wang, S., Qin, Z., Xu, J., Deng, H., Xie, L., & Li, D. (2024). Research on the pricing model of prefabricated building construction projects. *Building Economy, 45*(10), 67-75.

Xu, C. (2020). The application of BIM technology in the design of prefabricated and assembled buildings. *Building Materials and Decoration*, (20), 81-88.

Yang, F. (2020). *Analysis and research on modular pricing method of prefabricated concrete buildings based on BIM* (Doctoral dissertation, Hebei University of Science and Technology).

Yang, F., Zhang, X., Wang, L., et al. (2020). Application analysis of BIM and VR technology in the decoration engineering design stage. *Hebei Industrial Science and Technology, 37*(1), 48-53.

Zhang, X., & Guo, J. (2021). Research on the construction of bill of quantities for prefabricated construction projects based on BIM. *Engineering Management Report, 35*(5), 30-35.

Zhang, X., Wang, L., & Yang, F. (2020). Research on the application of BIM and VR technology in hotel decoration engineering. *Information Technology in Civil and Architectural Engineering, 12*(2), 81-86.

Zhao, H., Zheng, M., & Sun, R. (2020). Research on cost index scheme for prefabricated building engineering. *China National Building Materials Technology, 29*(1), 85-86.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/127482