BIM Collaborative Design Solutions for Super High-Rise Buildings Over 250 Meters

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Abstract. Super high-rise buildings are the product of human economic activities and technological progress. Construction of super high-rise buildings is difficult and involves many participants. Super high-rise buildings over 250 meters are facing more implementation difficulties, and design stage is the initial stage of the construction process. How to promote the design work of all participants in the design phase is a problem that must be solved in the design of super high-rise buildings. This research aims at 4 special difficulties in the design of super high-rise buildings with a height of 250 meters: multi-specialty collaborative design and management, Multi-party collaborative design and management, lightweight interaction of BIM models, data format exchange between software. This study adopts an integrated design platform to propose corresponding solutions to promote the collaborative design of super high-rise buildings. Finally, a super high-rise building design project is used as a case to demonstrate the research method.

1. Introduction
In recent years, with the rapid development of economy and the progress of science and technology, the number of super high-rise building projects has also increased rapidly. Super high-rise buildings increase the utilization rate of land, help improve the urban environment and alleviate the tension in urban land use. Super high-rise buildings over 250 meters (subsequent mentions of super high-rise buildings refer to super high-rise buildings over 250 meters) have become implementation benchmarks in the construction field. The characteristics of various types of super high-rise buildings are also more prominent, and various implementation standards to be followed are also more stringent, more lean management is required [1, 2]. The design stage is the initial stage of the construction process of super high-rise buildings. In addition to the complexity of the design work itself, it also faces many difficulties in coordination with the participation of multiple parties [3].

The design stage is the initial stage of construction. Existing super high-rise building projects do not have special multi-party collaboration methods or standards, but they are designed in accordance with the general building collaborative design method. The particularity of the refined design of super high-rise buildings requires that all disciplines and parties conduct conflict inspections in advance, and carry out a comprehensive comparison of multiple professional comprehensive plans, and propose higher requirements for multi-specialty collaborative design and multi-party collaborative design.

With the rapid development of computer technology, informatization work in all walks of life has gradually begun, and the construction industry has also introduced computer technology as an important tool to improve design efficiency and management efficiency. At the same time, BIM provides a solution for multi-specialty and multi-party collaborative design, which usually includes
two approaches. One is the secondary development of design software represented by Autodesk Revit to improve the efficiency of certain stages in the collaborative design process to meet the needs of collaborative design work [4, 5], and the other is an integrated platform based on BIM in order to improve the efficiency of collaborative design and collaborative management [6-8]. BIM has become a popular method to solve the problem of multi-specialty and multi-party collaborative design by introducing BIM into the design stage of super high-rise buildings [9].

However, two major problems have emerged in the BIM collaborative design process of super high-rise building projects, the large amount of model data and the barriers to data format exchange. The reason for the amount of model data mainly comes from the refined design of super high-rise buildings and the large-scale model. It is usually necessary to perform model segmentation operations to match the current computer hardware. In addition, super high-rise buildings are sensitive to the natural conditions of the site, so it involves a variety of green building performance analysis, such as chimney effect analysis, wind tunnel test analysis, seismic performance analysis. Different specialized analysis mostly uses different specialized software to perform different types of performance analysis, which involves the problem of BIM model format conversion [10, 11].

For the design of super high-rise buildings, this research summarizes four main problems including multi-specialty collaborative design, multi-party collaborative design, large amount of model data, and data format exchange in super-high-rise buildings, and proposes corresponding solutions for multi-professional systemic collaboration. BIM collaborative design is adopted to solve the problems of multi-specialty and multi-party collaborative design, lightweight technology is adopted to solve the problems of large amount of model data, and the method of multi-software pair interaction or common data format interaction is adopted for data format exchange, so as to cope with the difficulties of collaborative design and management in the design stage of super high-rise buildings.

2. Research Methods

2.1. Collaborative Design Platform for Super High-Rise Buildings

To solve problems about multi-specialty collaborative design, multi-party collaborative design, large amount of model data, and data format exchange, this research used super high-rise buildings BIM collaborative design platform. The frame for this platform is shown in figure 1.

![Figure 1. BIM collaborative design platform architecture for super high-rise buildings.](image)
The platform architecture is composed of six layers: basic support layer, basic data layer, underlying architecture layer, data services layer, business functions layer, and applications layer. The levels increase in order and follow unified log management and authority management. The basic support layer is the computer technology support of the platform, which is the basic condition for the smooth operation of the platform. The platform will run in the form of cloud, with various cloud technologies, and can complete most of the design management work through the browser. The BIM model and its related resource library and component library are the main sources of basic data layer. Together with user information and process information, they constitute the basic data of the platform. The underlying framework layer is the basic logic of platform operation. For example, "microservices" can split platform functions to prevent a single application from being unable to cope with huge data processing situations, and can enhance the robustness of the platform. Data services layer can integrate and transfer it in the form of data streams. For example, the WebGL lightweight engine can convert the BIM model into a JSON data format for lightweight display on web pages. Business function is an integrated service of various basic tasks. In this study, it is carried out for super high-rise building design management, collaborative design, personal design management and resource management. Application layer is the top-level expression of integrated services, embodied in the form of expression in different application scenarios of the platform.

2.2. Multi-Specialty Collaborative Design

Multi-specialty collaborative design requires collaborative design work between various specialties. Most construction projects face difficulty of multi-specialty collaborative design. However, due to the particularity of the refined design of super high-rise buildings, major specialty are required in the plan stage, completing the fineness of the design and construction drawing stage of ordinary construction projects. This approach puts forward higher requirements for multi-specialty synergy. In this study, BIM collaborative design is used as a solution to the difficulties of multi-specialty systematic collaborative design. The route of BIM multi-specialty and multi-party collaborative design method is shown in figure 1.

![Figure 2. BIM multi-specialty and multi-party collaborative design method.](image-url)

As shown in figure 2, there are two collaborative design methods based on BIM, one is the central file mode and the other is the link mode. The central file mode is a mode in which data is on the server side and supports real-time collaborative work of multiple designers. In central file mode, the design data of multiple designers can be integrated in the same central file, and real-time data interaction can be performed problems can be identified in a timely manner in the design work. The link mode is a working mode that links the mapping of one or more BIM models on the basis of one BIM model. In this working mode, multiple BIM model files can be integrated into the same central file database, and
the model data of each specialty can also be updated synchronously in real time. The central file mode is suitable for collaborative design work within a specialty, and the link mode is suitable for collaborative design work between specialties. In addition, a unified authority service is required to limit the authority of designers and design managers. By deploying Revit server and the corresponding super high-rise building collaborative design platform authority service on the server, it can complete the multi-specialty design work of super high-rise buildings.

2.3. Multi-Party Collaborative Design and Design Management

2.3.1. Multi-Party Collaborative Design. Revit collaboration methods are divided into local area network (LAN) and wide area (WAN) network collaboration. The collaboration in the local area network is suitable for multi-specialty collaborative design work within a team, and the WAN collaboration is suitable for the collaborative design work of multiple teams. In this research, WAN is used as the basis of multi-party collaborative design, and the route is shown in figure 3.

![Figure 3. Multi-party collaborative design route.](image)

As shown in figure 3, the Revit server firstly stores the central files of each design participant and synchronizes data with the Revit server acceleration server through the WAN. Secondly, the data is subsequently synchronized with the model file server host in the LAN. In addition, strictly controlling the authority of all parties and logging the design work of all parties are needed to solve the difficulties of multi-party collaborative design in super high-rise building projects.

2.3.2. Multi-Party Collaborative Design Management. Meanwhile, the collaborative design of super high-rise buildings also faces difficulties in design management. Collaborative design management mainly includes design management process and project-level document management, as shown in figure 4.

![Figure 4. Collaborative design management schematic.](image)
In this study, under the unified authority management and log service, all parties and various design files and input files are managed in a unified manner to form project-level folders. The project-level folders are mainly divided into folders by stages, and there are still internal on demand subfolders. In addition, the design management process is a means to control the quality of design input documents and design results at different stages, mainly including design document input review process, inter-specialty data exchange process, design review process, and design management processes are all completed on the platform. Project-level folders management provides data support for the design management process, and the design management process controls the design input data and design results quality in project-level folders.

2.4. Lightweight BIM Model
Models in the design stage of super high-rise buildings are often large in size, which makes it difficult to carry out effective collaborative design and collaborative management. In this study, the BIM model is serialized in JSON to achieve the purpose of lightweight BIM model. The lightweight information is shown in figure 5.

![Figure 5. Revit model information JSON serialization.](image)

The particularity of the BIM collaborative design platform lies in the data transmission of the three-dimensional BIM model. Compared with the large-scale BIM model, JSON is a lightweight data exchange format with a simple and clear hierarchical structure, which can effectively improve network transmission efficiency. In the process of lightweight Revit model, mesh geometry information is obtained through class libraries and interfaces according to two and three dimensions, and text, graphics, component properties, materials and other information are obtained through function analysis in callback method, and JSON format files are generated, which can be passed on the platform. The lightweight BIM model transfer process and application are shown in figure 6.

![Figure 6. Lightweight BIM model transfer process and application.](image)

Autodesk Revit is relatively commonly used architectural BIM design software. Through the secondary development of Revit software, the design file is released to the super high-rise building
BIM collaborative design platform and then analyzed and displayed the lightweight BIM model. In order to give full play to the role of lightweight BIM models, this research develops a series of basic tasks for lightweight BIM models. With the support of authority management and log services, those tasks can meet multiple application scenarios in the collaborative design of super high-rise buildings.

2.5. *Data Format Exchange between Software*

Super high-rise buildings are sensitive to the site environment than general buildings, and involve a lot of performance analysis, such as elevator operation effectiveness analysis, sound and light thermal analysis, chimney effect analysis, etc., which also involves the comprehensive use of a large number of analysis software. Good data interaction capabilities between software can promote the use rate of BIM models and design efficiency.

At present, there are two widely applied methods for data format exchange between software. One is the pairwise data format exchange between software, and the other is the exchange of common data formats as an intermediate key. At present, there are some softwares that can interact with each other. For example, the completed model of Revit can export the ifc data to interact with the evacuation analysis software pathfinder.

3. *Case Study*

This research takes a super high-rise building project as a case study to explore the BIM multi-party collaborative design method of super high-rise project. The super high-rise tower has a total capacity of more than 300,000 square meters, a total curtain wall area of more than 110,000 square meters, a total of 90 floors, and a building height of more than 250 meters. All kinds of superimposition effect is obvious, and the fine design requires high requirements. The building has the characteristics of super-high structure, large scale, various functions and high construction standard, which puts forward higher requirements on structural system, vertical traffic design, elevator, safety and stability of power supply, fire-fighting, measurement, lateral wind influence, chimney effect and other aspects. Due to the particularity of super high-rise buildings, there are many participants in the design. How to effectively coordinate all parties to coordinate the design and ensure the smooth implementation of the project is a common problem faced by project managers and participants.

3.1. *Multi-Specialty Collaborative Design*

In this super high-rise building project, through the exploitation and encapsulation of Autodesk Revit collaboration mechanism, BIM multi-party collaborative design platform of super high-rise project for jurisdiction and log service docking. Work tasks within the major are divided according to different architectural elements, and collaborative design between majors is carried out in form of links, as shown in figure 7.

![Figure 7. Case project of super high-rise building multi-professional collaborative design.](image-url)
3.2. **BIM Model Lightweight**  
In this study, through the secondary development of Revit, the .RVT format file is converted into JSON data format in the background, and the mode view that needs to be lightweight is selected and displayed on the web platform, as shown in figure 8. After the BIM model is lightweight, a series of design collaboration and design management can be carried out.

![Lightweight BIM model of super high-rise building Case Project](image8.png)

**Figure 8.** Lightweight BIM model of super high-rise building Case Project

3.3. **Multi-Team Design Management**

3.3.1. **Design Management Document Management.** All teams and their members in the project can perform file operations on the platform within the permissions, including uploading, deleting, modifying, and viewing of files. The design managers can manage permissions on project folders to maintain consistency in the project process. Design folders and design files can be intercommunicated with the webpage management platform and design software, and the project files can be opened in the design software and the properties related to the files can be viewed, as shown in figure 9.

![Multi-team design document management of super high-rise building case](image9.png)

**Figure 9.** Multi-team design document management of super high-rise building case

3.3.2. **Inter-Specialty Data Exchange.** With the support of the BIM multi-party collaborative design platform for super high-rise buildings, the data and information exchange between the cloud management platform and Revit software is realized through the secondary development of Revit software. Designer can select the confirm and receiver in Revit software, and initiate data interoperability to multiple majors in the project. Content of data interoperability includes design model, model view, and relevant design files. The design manager can view all data interoperability information in the data interoperability management tool, as shown in figure 10.
Figure 10. The case and project data of super high-rise buildings are presented between inter-specialties.

3.3.3. Exam of Design. In this study, BIM model lightweight tool is adopted as the main way of design verification. In this study, the BIM multi-party collaborative design platform for super high-rise buildings has a variety of lightweight tools, which can be used to annotate the model on the web side, and to specify, confirm and receive the model. The validator can view the annotation on the web side or Revit software side, and the recipient can view the annotation information and locate the annotation position in the design software, as shown in figure 11.

Figure 11. super high-rise buildings project review process

4. Conclusion
This research aims at the problems existing in the design process of super high-rise buildings, including multi-specialty collaborative design, multi-party collaborative design, and large amount of
model data. This study also proposes to use the BIM collaborative design platform to solve super high-rise buildings for design collaboration and design management. In this process, the authority and log management are emphasized for fine-grained work. The data exchange format is a common problem in BIM collaborative design at present. In the future development of BIM application, data change will be an important development direction.

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