

Auditing of Building Information Modeling Application in Decoration Engineering Projects in China

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Abstract—In China's construction industry, it is a normal practice to separately subcontract the decoration engineering part from construction engineering, and Building Information Modeling (BIM) is also done separately. Application of BIM in decoration engineering should be integrated with other disciplines, but Chinese current practice makes this very difficult and complicated. Currently, there are three barriers in the auditing of BIM application in decoration engineering in China: heavy workload; scarcity of qualified professionals; and lack of literature concerning audit contents, standards, and methods. Therefore, it is significant to perform research on what (contents) should be evaluated, in which phase, and by whom (professional qualifications) in BIM application in decoration construction so that the application of BIM can be promoted in a better manner. Based on this consideration, four principles of BIM auditing are proposed: Comprehensiveness of information, accuracy of data, aesthetic attractiveness of appearance, and scheme optimization. In the model audit, three methods should be used: Collision, observation, and contrast. In addition, BIM auditing at six stages is discussed and a checklist for work items and results to be submitted is proposed. This checklist can be used for reference by decoration project participants.

Keywords—Audit, evaluation, dimensions, methods, standards, building information modeling application, decoration engineering projects.

I. INTRODUCTION

REVIEWING or auditing is an activity or process to check the compliance, validity, and suitability of a quality management system. An audit should be systematic and independent. Herein, "systematic" means that all the factors will be covered; "independent" means ensuring that the audit or review is independent of the reviewed departments and units, so that the activity is impartial and objective.

The main purpose of the BIM audit is to check whether the model information complies with the existing information or newly obtained information. At every stage of the entire BIM application process, the model should be evaluated by the participating parties. Only if modifications are done and the problems are solved, should the audit proceed to the next stage. Therefore, model quality is a key factor in judging the success of BIM applications.

In China, the work flow of building construction and decoration is different from that used in other countries.

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Usually the construction and decoration engineering parts are undertaken by different companies; these companies need to apply BIM in their respective areas of responsibility. This practice makes application of BIM in decoration engineering very difficult and complicated.

In 2013, application of BIM technology in the field of decoration engineering in China began. BIM application in decoration involves two main parts: Decoration design and decoration construction. Because the decoration engineering is carried out by a separate decoration company, rather than the construction company, the BIM application process can be divided into six stages: Early Model Audit Stage; Early Design Stage; Late Design Stage; Construction Stage; Construction Completion Stage, as well as Operation and Maintenance Stage. At different stages of BIM application in decoration projects, professionals of different types from concerned parties would review and evaluate the models, including the construction project owner, architectural design institute, decoration design institute, decoration construction company, general contracting party, mechanical and electronic equipment company, and project supervision department, etc..

Currently, there are four obstacles in BIM application in decoration engineering in China. First, there is a heavy workload involved in auditing these BIM models under current software and hardware conditions. Second, audit work lags far behind due to a lack of qualified professionals, which has become a bottleneck in the promotion of BIM technology in decoration engineering. Third, there is a paucity of literature concerning mature and unitary audit specifications. Fourth, the coordination of the audit involves many units and professionals, which makes the audit work very complicated.

The audit specifications, such as the qualifications of the auditors, contents, methods, and principles, are significant in the promotion of BIM technology application in the decoration engineering industry. However, no research has been conducted concerning the auditing of BIM application in decoration engineering in China. The aim of the present work is to conduct research on every stage in the entire process of BIM application in decoration projects, i.e., what (contents) should be evaluated at which stage by whom (professional qualifications). The results of the study could be used by companies as a reference; from this, the use of BIM could be better promoted in China.

II. CURRENT STATUS OF APPLICATION OF BIM TECHNOLOGY IN THE DECORATION INDUSTRY AND BIM MODEL AUDIT RESEARCH

As mentioned above, in China, decoration engineering is separate from building construction, and BIM application is retarded relative to other disciplines in China. These conditions have meant that there has been little research on BIM auditing of decoration projects in China. In addition, all the relevant international research has been based on the integration of construction engineering and decoration engineering; thus, these studies are not applicable to the situation in China.

A. Current Status of BIM Technology Application in the Chinese Decoration Industry

If BIM technology could be applied under ideal conditions, all problems, particularly that of workflow, could be resolved. However, currently BIM technology application in the decoration industry is still in an initial stage. Very few enterprises are willing to invest in BIM technology, few technical professionals can use the technology, traditional workflow problems are still applicable [1], and BIM technology is seldom used in projects, such as special decoration projects, key space, or small decoration projects. In addition, the promotion of BIM technology in the decoration industry is very slow, the application of BIM technology is superficial, and the costs at this early stage are quite high, resulting in low enthusiasm for and participation in BIM application. In addition, the collaborative modeling work involving different participants is very complicated.

B. Research on BIM Audit in the Chinese Decoration Engineering

In China, a number of projects have applied BIM technology; some research has been done involving these projects. However, due to the separation of decoration and structural construction engineering, the problems encountered are not the same as in most countries. At present, some researchers in China work on the following aspects of BIM: theoretical research, for example, BIM application process in decoration projects and difficulties in BIM application [2]; application of different software in decoration engineering [3], [4]; case studies and summaries of experience [5], [6]; development of BIM software, especially for decoration projects [7]; and decoration of residences using BIM [8]. As decoration engineering is considered to be an independent discipline in China, research on this type of engineering is diverse. However, few studies have included auditing of BIM application for decoration projects, and no special research has been done until now.

There is only one previous study on BIM model auditing, which is related to fire control [9]. Other BIM-related papers mention BIM model auditing occasionally, and no research has been performed concerning BIM application in the decoration industry.

C. Research on BIM Application in Decoration Projects outside China

Most research concerning BIM outside China integrates civil

structure construction and decoration: there are a few studies on BIM application in decoration engineering. These studies can be grouped into several categories: first, protection of historical buildings [10] using technologies such as 3D scanning and digital modeling [11]; second, instruction design methods for interior decoration design using BIM software [12]; third, development of intelligent interior design components [13]; and fourth, methods to build a BIM model at the Construction Completion Stage in an interior space [14].

In terms of studies concerning BIM model auditing, some architects have developed standards for the submission of BIM models for building design [15]. For example, a BIM quality audit research in South Korea [16] discusses how to improve the quality of architectural design and management in the open BIM environment. That study also summarizes and puts forward a check list for the purpose of quality management. No further literature concerning decoration engineering audit could be found.

III. PROBLEMS AND PRINCIPLES IN BIM APPLICATION IN DECORATION ENGINEERING PROJECTS

Various problems are often detected in BIM model auditing, making the audit work difficult. Therefore, these problems must be identified, after which some common principles or standards should be established, so that different methods can be adopted at different stages in line with these principles or standards.

A. Problems in BIM Model Auditing

There are some problems in application of BIM in Chinese decoration engineering, of which some are commonly faced by all disciplines, some are limited to certain disciplines, and some are unique to the field of decoration engineering.

Common problems include the following: some engineers do not like to use BIM, they submit an outer view of an architecture building; files and views are given different names; there are too many datum marks; there are too many clashes between components or objects; the interfaces of the model by different working units are not defined clearly in line with the contract; there are unreasonable model partitions; there are too many nested or linked files; there are no attached documents for files; there are inappropriate family making models; there is lack of exported construction drawings, detailed drawings, and BOM (Bill Of Material), or the stage goals could not be achieved based on the files exported.

Major problems in other disciplines involve civil engineering and MEP (Mechanical, Electrical & Plumbing). The main problems in are that demands at different stages are dealt with using the same version of a model, and models are created in the simplest way and cannot be used by other participants. For example, if the floor slabs in the BIM model provided by the civil engineering company are not created considering with the room sizes, the decoration company cannot decorate the surfaces of the building and must make new floor slabs for each room independently. The main problems of MEPs are: lack of required equipment and pipelines in the models at different stages; malpositioning of pipelines or equipment; equipment

without supports and hangers in the detailed design model; no space left for the construction of the pipeline arrangement; and incomplete information, such as on equipment type, specification, manufacturer, and price, etc.

The main problems of decoration engineering are as follows: the designer did not provide the documents of decal (texture mapping) that selected by himself; decals and colors are not matched under different view display; base keels and decorative finishes do not match; base keels are not based on the layout of the construction materials; modeling and color are not artistically pleasing; calculation mistakes are often present in decoration models that are constructed from structural models; and costly component arrangements in the BIM model at the Detailed Design Stage.

The most important problem is professional collaboration during auditing. Professionals in the fields of decoration, architecture, structure, MEP need to perform modeling and audit work jointly, and a common modeling standard and audit standard should be established. However, at present different parties use their own standards. In some extremely large projects, the decoration part will be subcontracted to a number of different companies. The decoration company must cooperate with the aforementioned professionals of different disciplines, and also must build and audit models together with other subcontracted decoration companies.

B. Problems in BIM Model Auditing

Based on the frequent problems in BIM auditing, herein some general principles for examining BIM models in decoration engineering are proposed.

The first principle is comprehensiveness. In order to make an accurate calculation of component quantity and give guidance to construction, the information obtained must be as comprehensive as possible. To realize this principle, it is necessary to check whether there are sufficient components, objects and information. Before examining BIM models, the auditors should collect all kinds of data and information at different stages, such as the requirements of the owner, building design drawings, specifications, size of the construction site, construction organization design, and design changes, etc... Then the auditors should check the quantity of components, objects, the comprehensiveness of data information, the parameters or properties/attributes, the application purposes served or not at the current stage, and the quantity of files or documents (especially attached documents).

The second principle is accuracy. Accuracy of components ensures the quality of the BIM model and the quality of construction. To examine the accuracy of the BIM model, it is necessary to check the sizes or locations of components first, and then examine whether they conform to the specifications for the building design. In addition, the names of documents, files, family, objects and components should be checked.

The third principle is aesthetics. An important function of decoration engineering is to protect the building structure and beautify the building. To ensure the effect of design and quality of construction, aesthetic attractiveness is a very important indicator. When checking the model, the auditor should assess

both the overall decoration effect of the architectural space and whether the decal, color, and shapes of each decoration component satisfy the aesthetic requirements. In addition, the aesthetic quality of the BIM file pictures should be checked, and judgments made concerning the composition, viewpoint and marking.

The fourth principle is optimization. Optimization helps to obtain a more reasonable design and construction plan; to save space, materials, energy, time, and money; to improve efficiency; and to protect the environment. Compared with the above mentioned three principles, optimization is a higher requirement. To accomplish this, the auditors should assess whether the most optimal solution is chosen in terms of the space function, structure, construction organization and cost in the BIM model. Template settings in the BIM model should also be considered so as to help the engineers construct the model effectively. In addition, the BIM model should facilitate efficient cooperation between different companies.

C. Methods Used in BIM Model Auditing in Decoration Projects

At present, the most commonly used method of BIM auditing is collision checking with software. However, the collision check only examines the location of the model components, and is not the whole picture of the audit work. The main auditing work should be performed utilizing both professional experience and computer software. In addition to collision checking, commonly used methods include observation and contrast. Contrast might be performed using images or data, or scanning to BIM; or sometimes models can be compared with real building work at construction sites.

IV. SIX STAGES OF WORK IN BIM MODEL AUDITING

As mentioned above, BIM model auditing in decoration engineering in China involves six stages. Herein, these six stages are analyzed and lists are made concerning the participants, work items to be examined, processes, contents, standards, and results.

A. Work Items and Results for Submission at Different Stages in BIM Application in Decoration Engineering

The application of BIM in decoration engineering is achieved in six stages, which are listed in Table I.

As listed in Table I, the audit work runs through six stages of the project. At each stage, the internal audit should be carried out first, then the external audit. Both the internal and external audits must be done in line with all-round quality management PDCA (Plan-Do-Check-Action), i.e., first, put forward goals, develop plans, and propose specific measures; second, check the model in accordance with the plan, identify problems and their causes and modify the model accordingly; and third, repeat the checking and modification process until no mistakes remain. In addition, the experience should be summarized and formulated as auditing standards and system.

B. Participants of the BIM Audit in Decoration Projects

Due to the separation of decoration from structural construction, many parties need to take part in the audit work,

and a great deal of coordination work is required. At different stages, different parties are needed as listed in Table II.

audited, the work items, and the standards are different, as listed in Table III.

C. Parties Being Audited, Work Items, and Standards in Model Auditing of Decoration Projects

At different stages of the BIM audit, the parties being

TABLE I
APPLICATION OF BIM AT VARIOUS STAGES OF DECORATION ENGINEERING AND SUBMISSION OF THE RESULTS

stage	Work Items	Submitted Results
Early Model Review Stage	Integrate BIM models of different disciplines, run clash detection, contrast with the site, study spatial patterns, split or modify models in accordance with different functions of the construction area	early model audit report, split models of building space
Early Decoration Design Stage	Make decoration design scheme based on construction drawings and early models, create BIM model for interior space decoration, evacuation analysis, daylighting analysis, illumination analysis, acoustic analysis, make decoration families, run clash detection, modify model, review model, render effect drawing, make animation, calculate materials, estimate cost, make budget	BIM model of the decoration scheme design, evacuation analysis report, lighting analysis report, illumination analysis report, acoustic analysis report, decoration family, clash detection report, model audit report, model effect diagram, animated cartoon, material list, cost estimation table, budget table
Detailed Decoration Design Stage	Create model for the hidden part based on the decoration design scheme, divide the surface of the decoration BIM model to arrange materials, prepare components, sketch construction site layout, run clash detection, rearrange pipeline, check and update model, give guidance to construction, coordinate different disciplines, calculate materials, estimate project cost, export cost and budget plan. This part of BIM modeling work should be done and completed at the same time as the decoration design scheme	Detailed decoration design BIM model, construction drawing, detailed drawing, detailed drawing for component manufacturing, site layout, clash detection report, audit report, complex node drawing, construction guidance, BOM, cost estimate table, budget plan
Construction Stage	Add information to the primitives in the model such as materials, quality, safety, time, cost, operation and maintenance, scan field data and adjust the model, realize the arrangement of site layout, conduct joint audit of drawings and robot lofting, manufacture components, manage design modification, audit model, calculate materials, make construction process simulation for difficult parts, material transportation simulation, realize schedule control, quality control, safety management and cost control, make budget and final accounts	Construction BIM model, 3D scanning record, site layout of different phases, joint audit record, robot lofting records, detailed drawing of component manufacturing, design change negotiation record, model audit records, BOM, animation for key points and difficult part construction simulation, schedule, quality record, safety record, cost control results, budget and final accounts
Completion stage	Add information concerning project completion acceptance check and maintenance to primitives in the BIM model, including manufacturers of decoration materials and components, brands, models, price, acceptance check documents for different parts; prepare 2D completion drawings, completion and acceptance check documents of project completion used for project management, operation, maintenance, settlement and final accounts.	BIM model at the Completion Stage, BOM, as-built drawings, final acceptance data, settlement, final accounts
Operation and Maintenance Stage	Converse model for operation and maintenance, maintain and manage models, add operation and maintenance information	Operation and maintenance of BIM model, asset distribution, asset statement

TABLE III
PARTICIPANTS IN BIM AUDITING IN DECORATION PROJECTS

Project	Stage	Early Model Review Stage	Early Decoration Design Stage	Detailed Decoration Design Stage	Construction Stage	Completion Stage	Operation and Maintenance Stage
Parties being Audited and Internal Auditors		Architectural design unit	Decoration company, other project construction participants of different disciplines	Decoration company, other project construction participants of different disciplines	Decoration company, other project construction participants of different disciplines	Decoration company, other project construction participants of different disciplines	Property management company
External Auditors		Parties responsible for decoration design and construction; other project design and construction participants of different disciplines	Owner, supervisor, Design Institute	Owner, supervisor, Design Institute	Owner, supervisor, Design Institute	Owner, supervisor, design institute, operation and maintenance property management company	Owner

D. Application of BIM Audit Specification in Decoration Projects

The above-mentioned six stages of audit work define the process under ideal conditions, in which BIM could be applied successfully. Currently, BIM has not been applied in most decoration projects, so in practice it is difficult to adopt the whole process. Currently, the whole internal audit and part of the external audit is being adopted successfully in some projects. Collaborative modeling and the collaborative audit have been successfully realized, and basic collaborative

modeling criteria and audit criteria have been established. To some extent, some common problems of different disciplines and of each discipline have been solved. For example, all the participants in a project for a high-rise building in Beijing have established common modeling and audit criteria together, with support from the contractor and the owner. Most floors of the building are office space; nearly one hundred floors of the building are the same. There are five decoration subcontractors, and all the subcontractors have begun to learn to apply BIM to their parts of the project. At the beginning of the modeling

stage, each subcontractor made a sample model of the building space, but the quality of the models was not satisfactory. In the first audit, it was suggested that each subcontractor should make only one part of the building space, and each different subcontractor should conduct modeling collaboratively. In this way, each subcontractor could put in more effort and spend a longer time on their own part, and the model could be more precise. In the second audit, all models were put together to perform clash detection, and approved models were distributed to every subcontractor. This practice greatly reduces the

workload, reduces the quantity of BIM staff, shortens the modeling time and also saves a large amount of money. The models are accurate and good-looking, and the information is comprehensive. The collaboration is efficient, and the effects have exceeded expectations. However, because only some working staff of the owners, designer, and constructors are involved in the BIM application, and other participants are not involved in the project, there is a lack of auditors. At the same time, due to the lack of experience and audit staff, part of the process is not fully implemented.

TABLE III
WORK ITEMS TO BE AUDITED IN DECORATION PROJECTS

Stage	Audit object	Work items	Audit standard	Audit results
Early Model Review Stage	Models of different disciplines at early stage	1. Space check: Is there space for decoration design? 2. Effect check: Does the model have favorable conditions for decoration design?	Architectural scheme design model, Level of Detail LOD200-300	Early BIM Model Audit Report
Decoration Design Stage	Decoration design BIM model, BIM models of different disciplines	1. Space check: Is the scheme good for decoration construction? 2. Effect check: Does the effect meet the requirements of the owners? 3. Have different analysis, optimization and modifications been performed?	Decoration design BIM model, Level of Detail LOD200-300	Decoration Design BIM Model Audit Report
Detailed Decoration Design Stage	Detailed decoration design BIM models, detailed BIM models of different disciplines	1. Examination of details: the decoration of the skin and the details of the hidden works are to be checked. Are the effects of design being realized? Could the construction be guided? 2. Is the industrial parts and complements processing model reasonable?	Detailed decoration design BIM model, Level of Detail: LOD200-350; Prefabricated components, LOD400	Detailed Decoration Design BIM Model Audit Report
Construction Stage	Detailed decoration design BIM model, detailed BIM model of different disciplines	1. Have all the design changes being indicated in the model accurately? 2. Has construction information got supplemented and improved?	Decoration construction BIM model design, Level of Detail: LOD300-400; Prefabricated components, LOD400	Detailed Decoration Design BIM Model Audit Report
Completion Stage	decoration project completion BIM models, completion models of different disciplines	1. Is all the information complete when the model is submitted as part of completion data? 2. Has the model been modified in accordance with information at the site?	Decoration completion BIM model, Level of Detail, LOD300-500	Decoration Completion BIM Model Audit Report
Operation and Maintenance Stage	The professional operation and maintenance BIM model of different disciplines	1. Do the models modified after being used meet requirements?	Decoration operation and maintenance BIM model, Level of Detail LOD400-500	Operation and Maintenance BIM Model Audit Report

Note: In addition to those listed in the above table, work items also include the following:

- ① Name check: are all the documents and files named in accordance with relevant regulations?
- ② Model template check: does the template file meet the professional requirements?
- ③ External reference and exported documents: are there missing of decal attachments, export documents or linked files?
- ④ Effect check: are the color, texture, and shape of the model component beautiful?
- ⑤ The standard function check: are the functions in compliance with building design specifications and functional requirements?
- ⑥ Clash detection: is there a collision with components of other models for other disciplines? Does clash detection meet the requirements?
- ⑦ Detail check: is the structure or component reasonable? Are the notations of dimensions or sizes complete? Are attributes or parameters complete?
- ⑧ Setting check: Is the model in compliance with the set standard? Does the setting set facilitate different parties to use the model and work together?
- ⑨ Optimization inspection: Is the partition reasonable? Could the partition be used to control costs at each stage? Is the cost reasonable? Is the model conducive to construction and maintenance?

V. CONCLUSIONS

Based on the problems in BIM application in Chinese decoration projects, it is suggested that the four principles need to be observed when auditing BIM model in decoration engineering: comprehensiveness of information; accuracy of data; aesthetical attractiveness of appearance; and optimization of the scheme. For auditing methods, the methods of observation and contrast should also be used as well as collision checking. In addition, a check list for work items and results to be submitted at six stages is presented for reference.

To mitigate two other difficulties encountered in BIM model review, it is suggested that: first, software vendors should try to develop BIM model auditing software integrating the

above-mentioned four principles, so that most of the audit work could be performed by software instead of people; second, the decoration engineering industry should train engineers in BIM model application, the architectural background, construction experience, BIM model building ability and interpersonal skills of engineers should be considered when choosing qualified BIM reviewers; third, auditors should pay close attention to the latest audit methods, modify standards, simplify audit processes, and improve the efficiency of quality auditing; and fourth, common audit criteria should be established for different disciplines.

It is high time for the Chinese architecture and decoration industry to adopt BIM technology in the entire construction

process. If BIM technology cannot be used in the decoration industry, it cannot be called a real BIM application in the whole process, and it will consume large amounts of manpower, material, and financial resources, and also waste a great deal of valuable time. In view of the current situation in China, the decoration industry should first pay close attention to the problems holding back application of BIM technology, draw close to international practice and standards, and integrate architectural engineering and decoration engineering, to solve the work-flow problem that has plagued BIM application in this industry for a long time. Second, the enterprises should calculate profits gained in BIM application, to attract and motivate decoration companies to apply BIM technology. Third, practitioners should carry out in-depth research on the whole process of applying BIM in decoration projects. In this way, real whole-process BIM application could be achieved in China.

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