BIM Information Classification and Codification for manufacturing Heritage Buildings

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Abstract. Heritage buildings have gained great popularity lately due to the attraction of the unique culture embedded in the heritage building elements and the incentive policies of the government to publicize traditional culture. Manufacturing construction has been adopted in the construction industry due to many advantages over traditional on-site construction. However, the construction industry is still dominated by traditional on-site construction methods, and existing research in manufacturing construction mainly focuses on modern architecture styles. There is little discussion on the application of manufacturing construction to heritage buildings, especially on the integration of digital technology. This article proposes a BIM information classification method and the key information codification system to support the lifecycle management of manufacturing heritage buildings with BIM as the basic digital technology carrier, and two cases are used to verify its effectiveness.

1. Introduction

With the rapid economic development and continuous promotion of traditional culture, the Lingnan style heritage architecture has been incorporated in the buildings of many places of interest and urban public areas to exhibit the unique culture of the region. In the context of national construction industrialization and smart construction promotion, manufacturing construction has become a popular way of production in the construction industry. Chinese heritage buildings are characterized by a stable structure with a large number of components. Some scholars note that the traditional Chinese wooden buildings are essentially a primitive manufacturing building [1], so in one sense, heritage buildings are suitable for manufacturing construction. However, the current construction practice is still dominated by traditional on-site wet operation methods, and the collaboration system of manufacturing construction has not yet been established. Additionally, prefabrication-related research mostly focuses on modern architecture. Few discussions on the application of manufacturing construction to heritage building styles have been initiated, research for a support system by integrating digital technology is rarely carried out systematically, making the development of such a system very difficult.

Recently, the application of BIM in the manufacturing construction has become a soaring trend. Several studies related to heritage buildings have been performed. For instance, Yang proposes a classification method to categorize manufacturing heritage buildings [2]. According to the existing building information classification system, Xue puts forward a classification content that the classification system of BIM components can refer to [3]. Wang et al. studied introduced a quantitative extraction technology based on BIM and proposed an information classification management system for heritage building components [4,5]. Ramaji et al. proposed a framework for modular information
transmission of BIM models to improve the application to industrialized building products [6]. Ke et al. developed a system to collect the information in the prefabrication process to improve the efficiency of the on-site assembly of manufacturing construction projects [7]. Based on a case study of a framing system, Wang et al. explored a BIM model of the heritage building components [8]. Jia et al. introduced the process of the BIM model development of heritage building component library using GIS and BIM technology and developed the heritage building information management system for the Jinfen area [9].

It is shown that most of the existing research is about the application of BIM to particular phases or prefabrication. There misses a systematic discussion on the BIM lifecycle management, especially the classification, transformation, and transmission of information to form an effective coding system. Hence, based on the preliminary research, this paper attempts to establish a BIM information classification and coding system for heritage buildings by taking account of the characteristics of the BIM model of prefabrication components and the manufacturing construction methods in the project lifecycle.

2. Information classification and codification system

2.1. Overview

The concept of project lifecycle is adopted from the manufacturing industry. The traditional construction industry can be divided into planning, design, construction, and operation stages. The lifecycle of manufacturing buildings typically consists of five stages: planning, design, production and processing, on-site installation, and operation and maintenance (O&M). The manufacturing construction process of heritage buildings involves a large number of participating entities, a large amount of information, and multiple types, rendering the use of BIM to carry out lifecycle control of the buildings an important technical direction in the construction industry.

During project implementation, it requires not only a clear BIM project management method but also a clear project information classification and coding method, otherwise, the project information will be chaotic and difficult to coordinate and manage. A systematic analysis shows that building components are the most important information carrier in the manufacturing construction process throughout the project lifecycle. Therefore, this research attempts to build a project information classification and coding system centered on prefabrication components of a project lifecycle.

Information classification means to place all information in a systematic manner, while coding is an important technical solution to achieve the convergence of information at different stages. On the one hand, this process needs to consider the technical specifications of the industry, such as the Basic Principles and Methods of Information Classification and Coding (GB/T 7027-2002). To ensure versatility in the industry, it needs to take account of the effectiveness of manufacturing construction and the interpretability of project information by humans and computers in each phase, in addition to the various types of organically connected and integrated information.

2.2. BIM information classification method for prefabrication project

Manufacturing construction requires a complete industrialized collaboration system amongst the participants in various stages. The information system is an important link for effective information storing and bonding participants. Therefore, for the information classification purpose, it considers not only the lifecycle management of a project but also the relationship in the information database between the ongoing project and the previous projects. Project can also be archived as an information resource after completion to inherit the information and experience of the completed project. Fig. 1 is the relationship diagram of the information system with various information data of manufacturing construction projects. As the carrier of information—components, they are divided into nine categories: foundation, footing, floor, column, bucket arch, beam frame, roof, enclosure, and decoration by taking account of the composition logic and position of heritage building components.
Figure 1. the relationship diagram of the information system with various information data of manufacturing construction projects.

For a specific project, information classification will be closely centered around the entire project lifecycle. This article mainly discusses the information classification method for a single project with BIM technology. As BIM is mainly used for the components, so the information can be classified and defined according to their geometric features. As shown in Table 1, the information is divided into two categories: geometric and non-geometric information.

Geometric information refers to the information that constitutes a three-dimensional space model, including size information and positioning information (elevation, grid) of components, etc. which is directly fused into the model geometry and spatial position, and does not need to be processed separately as an attribute field. The other type is non-geometric information, which is divided into attachment type and non-attachment type according to its attachment relationship with the components. The attachment type includes information, such as material, color, load, and fire resistance of the component, as well as production and installation information at each stage. This type of information is generally attached to the component as an attribute field, which can be added, deleted, and edited separately. Non-attachment information, including project information, project original documents, report materials, multimedia, manufacturer information, etc., can be attached to the BIM project model file. They can also be stored separately from the BIM model through a folder server mode or orderly management mode through a unified information system. Based on the above classification and storage management methods, complex information can be stored in an orderly manner in project models and components and used organically.

Table 1. manufacturing Construction Project Information Classification Based on BIM.

| Information type       | Information Details                                                                 | Information Management                  |
|------------------------|-------------------------------------------------------------------------------------|-----------------------------------------|
| 1. Geometric information | 1) The main parameter information of heritage building components, the size information of the components; 2) Positioning information, the layout of elevation grid and column grid; | Model library management                |
|                        | 1) Attribute information, such as material, color;                                   |                                         |
| 2.2 Non-attachment information | 2) Physical and mechanical information, such as load value, fire resistance, corrosion resistance 1) Project information, project text, project documentation, audio and video, pictures 2) Basic information, such as project time, project location, project description | Establish the corresponding information database |
2.3. Coding method for key information of manufacturing construction project

2.3.1. Overall rules for information coding. The key information in the manufacturing construction process of Lingnan heritage building is coded according to the characteristics of the manufacturing construction process of heritage buildings and the corresponding national standards in the information classification regulations, including project code, component code, production code, and installation code (see fig. 2).

![Diagram of information coding]

**Figure 2.** Information coding corresponding to the manufacturing construction process.

2.3.2. Overall design and implementation of information coding. The purpose of information coding is to facilitate information transmission, sharing, and usage among different components, models, and operating platforms in all stages of manufacturing construction. Meanwhile, standardized information coding is also the foundation of the information platforms. According to the characteristics of different stages of manufacturing Lingnan heritage buildings and the requirements and types of information, the main codes are stipulated as follows.

1. **Project code.** It refers to the coding of the basic project information, including location, name, unit, etc. The coding format is project location code-project name code-single building code. The project code is mainly used for linking the internal and external information of the project, such as project permit application, identification of project participants, the establishment of internal project library, integrated management of project documents and models, etc. The specific coding method is as follows:
   - The location of the project refers to the zip code assigned to each administrative district in China. For example, a project is located in Zengcheng District, Guangzhou, Guangdong Province, and then its location code is 440118. 44 stands for Guangdong Province, 01 stands for Guangzhou, and 18 stands for Zengcheng District.
   - The name of the project is based on the actual name used when the project was submitted for a construction permit. After removing the repetitive information like location, the abbreviation code is expressed in the initials of Chinese pinyin. For instance, Zhixin Middle School–Experimental School, its project code is ZXZXSYXX.
   - Single building refers to one project divided by the overall function and structure boundary. It is mainly used for the situation where there are multiple monomers in a designated zoon. If there is only one unit, the code segment may not be used. The individual name can use the abbreviation of the name used for permitting, its code can be represented by the Chinese pinyin initials. If the same type of building is numbered in the project, it can also be combined with the digital code to improve the recognition rate. For example, the classroom building 1, its code is "01JXL".

   In summary, for the Building 1 of Zhixin Middle School-Experimental School, the Project code can be expressed as "440118-ZXZXSYXX-01JXL". According to the Basic Principles and Methods of Information Classification and Coding (GB/T 7027-2002) regarding the code format issues, the code length should be a fixed number of characters. For example, the project location code is fixed at six characters; the project name code is fixed at eight characters under the condition of ensuring the relative integrity of the content. When it is less than eight digits, it is supplemented with "0" at the end; the single building name code is fixed at five characters, and the project name encoding method is also used to handle cases of over or under the character limit.

2. **Component type code.** It refers to the specific classification code of the component. The manufacturing heritage buildings are designed, processed, and installed on-site centered by various components. Components are concrete information carriers throughout the lifecycle. Therefore, rational classification and coding of components are conducive to the conveying and transmission of information.
According to the composition logic and prefabrication components of heritage buildings, it can be divided into the foundation (J), footing (T), floor (D), column (Z), bucket arch (G), beam (L), roof (W), enclosure (H), decoration (S), etc., which can be subdivided.

As the shape of heritage buildings is relatively stable. In theory, it is feasible to classify the components of heritage buildings through a linear method to form a tree shape categorization system. The three-level coding of nine major categories consists of major, medium, and small categories. A specific component can be coded in a three-level way, for example, a front body canopy column, the coding level is column type (Z)-canopy column (Y)-former body canopy column (01), so its component type code is ZY01, which can be used as a rigid code segment for various heritage building components.

However, construction projects with modern design typically adopt heritage architecture elements that are in the form of traditional space charm and decorative symbols. Therefore, it is difficult to achieve a clear hierarchical classification of heritage buildings in practice, so it is recommended to only use the first level code when using the rigid code segment of the component type code, and the second- and third-level codes are directly integrated into the component name and put into the flexible code segment, which has stronger versatility and practicality.

(3) Production code. It refers to the code used for the identification of component production in the manufacturing construction process, which includes component type information, production information, and production serial number. By referring to the heritage construction coding method [4], production code is divided into three segments: rigid code, flexible code, and running code. The code of the component type information is the above-mentioned component type code, which falls in the rigid code segment; the production information is the main character description of the components, belonging to flexible coding, and the inside items can be appropriately increased or decreased according to the characteristics of the components. The component production serial number is the identification number for production of the same type of components, which is optional and is mainly used for tracing the production process.

To facilitate identification, the three code segments are separated by "/", and the horizontal broken line "." is used to separate the information items within the code segment. Therefore, the structure of the production code is component type code/production information code/serial number code (see fig. 3). To enable the model operator and the computer to quickly understand the component information at the same time and form a peer-to-peer relationship, the naming of the BIM model component can be derived from the content of the production code, that is, the production code content without the production serial number, such as component type information/production information /.

The production information coding convention includes component name, color, material, and size information. The components are named by the manufacturer according to the corporate standard, which generally includes the specific features and classification of the components, such as a round gold pillar, using acronyms like YZZSJZ. Color is coded by capital letters in English, such as blue-green (BG), blue (BU). Material is coded using the abbreviation of Chinese pinyin initials, such as huanghuali (HHL), camphor (XZ). Size is coded by the size of each component, its numerical representation is specified by length*width*height, such as 1000*1000*1000; for cylindrical components, it uses radius* height for coding, such as 500*2000, the unit is mm. The coding format of the component production serial number is a three-digit number from 000 to 999. If it exceeds three digits, the production serial number can be supplemented by additional code segments. For instance, if the component production code is Column/Round Eaves Pillar-Light Yellow-Cherry Wood-600X3200/Component Production Serial Number, then the production code is Z/YXZSYZ-YE-YTM-600X3200/070, the production code can be
directly used as the name of the BIM component after removing the serial number, that is a column/round eaves column-light yellow-cherry wood-600X3200.

(4) Installation code. It refers to the code used for the component installation in the manufacturing construction process, and it includes the floor where the component is installed and the information of installation location, etc. The code is floor information-the intersection of the installation axis number at or near it. Floor information can adopt the coding method of the floor number + F, for example, the code of the third floor is 3F. The intersection of the installation axis number at or near it can adopt the coding method of horizontal axis number + & + longitudinal axis number, such as axis 2, the code for the position of the intersection of the axis B is 2&B, so if the component of single unit is installed at the intersection of the third layer, axis 2, and axis B, the installation code is 3F-2&B.

3. Case study

3.1. Project overview
Guangzhou Zhixin Middle School Zengcheng Experimental School is located at Zengcheng District, Guangzhou. This project is designed for 48 junior high school classes, which can accommodate about 2,400 students. The planned land area of the project is 5,692.5 square meters, and the total construction area is 73,485.62 square meters. The buildings include gymnasium (5-story), student dormitory (13-story), teacher dormitory (15-story), canteen (2-story), administrative complex (6-story), classroom building (5-story), performing arts center (6-story), etc. The classroom building and dormitory are built by manufacturing construction, and the BIM model is shown in fig. 4.

Figure 4. Classroom building and dormitory BIM model.

3.2. Coding method application.
In the project planning stage, the information classification and coding method were defined and clarified, and a consensus was reached with all participants. This method was integrated into the BIM management method of the project, mainly in modeling and use of model standards.

3.2.1. Information classification method. This project incorporated many elements of Lingnan heritage buildings but it is built by modern architecture and large spaces. The seven information categories, such as foundation, floor, column, beam, roof, enclosure, and decoration, are all reflected. The storage and transmission of information mainly rely on the core model, in which project information and component attribute information are attached. Information is transmitted from design to production, processing, and installation stages through models, schedules, and drawings.

3.2.2. Application of coding method. This project uses four main types of codes. The project code is reflected in the project information, the component type code is integrated into other code segments, and the production code and installation code are reflected in the component attribute field. Table 2 shows the coding of the classroom building and the column facade of the project.
Table 2. Coding system of the case project.

| Code Type         | Code Serial NO.       | Details                                                                 |
|-------------------|-----------------------|-------------------------------------------------------------------------|
| Project Code      | 440118-ZCSYXX-01JXL   | No. 1 teaching building of the Zengcheng Experimental School Project of Zhixin Middle School in Zengcheng District, Guangzhou City, Guangdong Province |
| Component Code    | ZY01 Z/YQZSYZ-YE-YTM- | Columns-Eaves Columns-Front Eaves Columns                                 |
| Production Code   | 0600X0600X3200-100    | Columns/Eaves Columns Front Eaves Columns-Light                           |
| Installation Code | 3F-2&B                | The position of the intersection of the layer 3-axis 2 and axis B       |

Through information classification and coding, the management efficiency of this project information has been significantly improved compared to previous projects. The participants of the project carry out their work based on the core model, and communicate and transmit information from all parties in an orderly manner. Corresponding production and installation codes can also guide production operations on site. Fig. 5 shows the actual scene of the project.

Figure 5. Component production and installation site.

4. Conclusion
Based on the research of the structural characteristics of Lingnan heritage buildings and the lifecycle of manufacturing construction, combined with the characteristics and advantages of BIM technology, this paper puts forward a method and principle of BIM information classification of heritage buildings with components as the core. With the goal of information sharing and transmission at all stages of the entire lifecycle of manufacturing construction, the key information was coded to a relatively complete coding system, which was verified by a case project. In future research, the assembly process can be incorporated to further improve the information classification and coding at all levels, and a more complete classification and coding system will be formed through practice and technological innovation.

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