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An Analysis of Standardized Design and Intelligent Construction of ERAD: A Case Study in Sanya *

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Abstract

Purpose: Assembly decoration is an important way to enhance the quality of existing residences and improving the living environment. **Research design, data and methodology:** Compared to traditional method of decoration, assembly decoration has obvious advantages in terms of construction efficiency, environmental protection and product quality. **Results:** When renovating existing residences with assembly decoration,, standardised design can be achieved using modulus coordination for non-standard size spaces, while the use of standardised components is the basis for the realisation of intelligent construction. **Conclusions:** This study conducted a case study in an assembly decoration project in Sanya, with the help of BIM big data platform, through the application of standardised design and intelligent construction technology, helped achieve the project's goals of a shortened construction cycle, reduced on-site pollution, and superior product quality.

Keywords: Existing Residence, Assembly Decoration, Standardised Design, Intelligent Construction

JEL Classification Code: R00, R21, R30

1. Introduction

Under the background of China's real estate market entering the ‘stock era’ from the ‘incremental era’, urban renewal and upgrading of existing residences have become the main tasks of the industry. According to the ‘14th Five-Year Plan’ issued by the Ministry of Housing and Urban-Rural Development, by 2025, the area of energy-saving renovation of existing residence will reach more than 350 million square metres[1]. This clearly indicates a significant market demand for the renewal and renovation of existing residences in China. Existing residences can be renovated to improve the quality of living and extend the service life. In a specific case in Sanya, China, an existing residence in Sanya, Hainan, adopts the

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assembly decoration renovation mode, and through the application of standardised design and intelligent construction technology, has successfully met the renovation objectives of a shortened construction cycle, reduced on-site pollution, and high product quality.

1.1. The concept of existing residential assembly decoration (ERAD)

Existing residence refers to the residence that has been completed and delivered to the owner, including the old residence that has been renovated and used and the rough delivery of unused sub-new residence; assembly decoration, also known as 'assembly decoration', refers to the use of non-wet construction, will be factory-produced interior parts in the field of a combination of installation of a kind of decoration mode[2]. Assembly decoration is one of the main ways of building industrialisation, and it has been widely used in new industrialised houses with full decoration. However, its widespread application in the renovation of existing residences has been limited.

The scope of assembled wall finishing in existing residence include wall, ceiling, floor, kitchen, bathroom, internal doors and windows, as well as pipelines and storage systems, etc. The whole process includes standardised design, factory production, on-site non-wet construction, and intelligent operation and maintenance.

1.2. Advantages of assembly decoration of existing residence

After years of renovation and use, the functional layout of existing residence often fails to meet the new usage of needs , and at the same time, leading to problems such as aging facilities, poor living comfort, and increased safety hazards, and need to be renovated. The traditional renovation mode of existing residences presents numerous challenges,, such as long renovation period, high noise and dust, excessive concentration of indoor environmental pollutants, and uneven quality of renovation.

Compared with the traditional decoration and renovation mode, the use of assembly decoration and renovation mode for existing residence offers many advantages, for example, components are produced in the factory and installed on-site, which greatly shortens the construction cycle; components are modularised and standardised, and there is no on-site cutting and slotting, which reduces the noise and dust pollution; components have been inspected at the factory, which guarantees the quality of the products; and the HVAC, water and electricity pipelines are separated from the structural parts, which convenient later overhauling and maintenance (Table 1).

Table 1: Advantages of assembly decoration and renovation of existing residence

	Traditional decoration	Assembly decoration
Construction cycle	The construction cycle of traditional decoration for 120m2 residence is about 100 working days	The construction cycle of assembly decoration for 120m2 residence is about 18 working days
On-site environment	On-site cutting, wet work, high noise and dust	No noise, no construction waste, neat construction environment
Indoor air	The concentration of indoor pollutants such as formaldehyde and TVOC is easy to exceed the standard	The materials have high environmental protection requirements, and the concentration of pollutants can be controlled more effectively
Quality of products	Decoration materials are processed on site, the quality is not controllable	Components are produced in factories, the quality is guaranteed
Inspection and maintenance	Pipelines are pre-buried or trenching, inconvenient for inspection and maintenance	Pipelines are separated from the structure, combined with pipeline wells, convenient for inspection and maintenance

1.3. Current status of research on assembly and renovation and remodeling of existing residence

Existing residential renovation and transformation is closely related to building renovation. Taking the Japanese Skeleton and Infill (SI) system housing as an example, the large space created by the skeleton facilitates the modification and renewal of the Infill. Offering significant flexibility in indoor space adjustment. The dismantling and installation of the interior infill has no damage the structural support body, contributing to a long building life. Countries with advanced industrialized housing development pay great attention to the study of building modulus coordination, which greatly promotes the standardization and generalization of building and decoration components. Japan's modulus standard (JIS standard) and ISO standard convergence, has a comprehensive set of modulus coordination standards and a residential parts system that achieves completeness, generalization, and standardization, providing a technical foundation and production base for renovation and transformation activities.

Research on China's assembly decoration has achieved a series of theoretical and practical contributions in recent years. Liu et al., (2023) draw on the international perspective of Open Building and SI building theory and method, and proposed a Long-life sustainable housing system applicable to China [3]. The integrated renovation of existing buildings based on the above theory is the future development trend [4]. Zhou et al., (2020) conducted a practice of assembled interior system renewal in an existing residence in Shanghai, which verified the feasibility of industrialized interior technology and components in the renovating of existing houses to achieve sustainable, high-quality performance housing [5]. In addition, scholars such as Liu et al. (2023) have conducted systematic research on interior modularization, assembled decoration parts and components and digital applications. A group of decoration enterprises have carried out practical research on assembly decoration of existing residences. For example, Suzhou Kelida Decoration Co., Ltd. has applied assembly decoration technology and intelligent construction attempts in the renovation of a freestanding existing residence in Sanya.

1.4. Problems of Assembly Decoration of Existing Residences

The construction environment of existing residential renovation is complex and can easily disrupt the households and surrounding areas. Therefore, it is necessary to minimize the construction cycle, reduce the construction noise, and reduce the construction waste. The use of assembled renovation is an effective approach to achieve these goals. Currently, two main problems exist in assembly and decoration of the existing residence in China. First, there’s a low level of standardization, poor component universality, and interchangeability, leading to low-quality results and high decoration costs. Secondly, there’s a lack of digitization and informatization, which hinders the implementation of intelligent assembly and decoration construction.

2. Methodology

Intelligent construction represents the developmental direction of the transformation and upgrading of the construction industry, with construction as the carrier, supplemented by intelligent technology and modern information technology, and human-machine synergy, which can effectively improve the construction efficiency, reduce costs and reduce energy consumption [6]. ERAD intelligent construction covers the stages of design, production and construction, and is based on the premise of standardisation, modularisation and digital design.

2.1. Standardised design for ERAD

2.1.1. Concept of standardised design

Standardized design involves the establishment of common conditions for typical products over a certain period and the development of uniform standards and models for widespread design application [7]. The standardised design in assembly decoration can be understood as the conversion of traditional decoration design ideas into industrialised component design ideas, and the design results are directly transformed into factory-processed components. Standardised design in assembly decoration includes plan standardisation, internal parts standardisation and interface standardisation [8].

The standardised design of assembly decoration adopts standardised and modular components for installation and connection, which is conducive to improving the quality of the decoration project and achieving economic rationality. Furthermore, the standardised design is also conducive to the factory production of assembly components, which improves the high precision, speed, safety and environmental friendliness of residential decoration.

2.1.2. Modal coordination of standardised design for assembly decoration of existing residence

The industrialised residential house consists of a three-level modulus grid system consisting of support body space modulus grid, unit space modulus grid and plane modulus grid[9]. For the ERAD transformation design, if it involves the re-separation of indoor space, the coordination of its modulus involves the second level of unit space modulus grid and the third level of plane modulus grid; if it does not involve the space segregation transformation, it is sufficient to consider only the coordination of the plane modulus grid in the third level (see Figure 1).

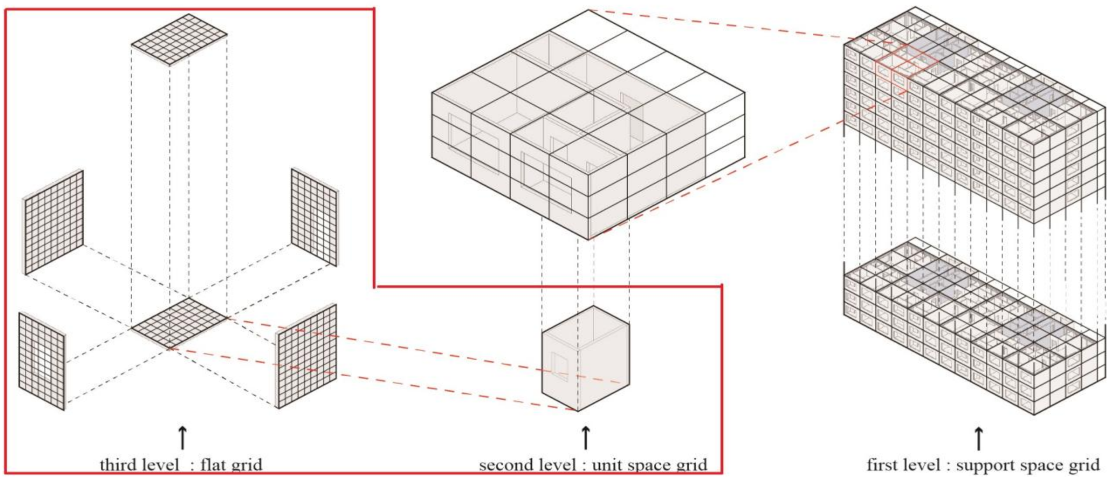


Figure 1. Schematic diagram of the modal grid system for existing residence at different levels

Unlike the case of new industrialised dwellings where the degree of standardisation is relatively high, the building dimensions, unit space dimensions and spatial interfaces of existing residences have non-highly standardized. Assembly decoration requires the use of standardised and modular components assembled on spatial interfaces. Therefore, the application of modular co-ordination means is particularly critical in the design of assembly decoration renovation of existing residence.

Since the six interfaces of each space in existing residence are mostly in non-modular dimensions, grid interruption zones or technical dimensions can be established in the modular grid of each sector during assembly decoration design. Thees grid interruption zones or technical dimensions can be non-modular and used as a means of modular coordination to install non-standardised components in the grid interruption zones. Outside the range of the grid interruption zones or technical dimensions are standardised dimensions, which are used for the installation of standardised components (see Figure 2).

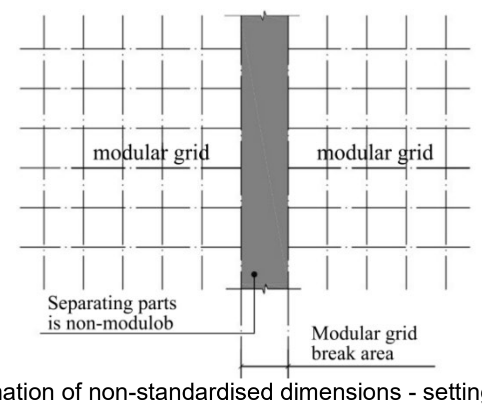


Figure 2. Modulus coordination of non-standardised dimensions - setting up grid interruption zones

2.1.3. Path to standardised design of assembly decoration for existing residence

Before proceeding with the design of assembly decoration for existing residence, although it is possible to manage to obtain the architectural design drawings, the original decoration scheme drawings or the preliminary measurement drawings, it is an essential part of the process to carry out on-site re-sizing. This step is essential to avoid potential installation issues due to dimensional errors. On-site re-sizing involves confirming the measurements using digital or manual methods, setting the stage for standardized and modular design. The re-sizing can ensure that the dimensions of the interior space are accurate, avoiding the inability to install the interior components in place due to dimensional errors.

Similar to traditional decoration design, assembly decoration design begins with a schemed design and then progresses into a more detailed plan. Throughout the process, the focus remains on standardization and modularization to achieve a cohesive assembly decoration design.

(1) Standardisation of space dimensions in the scheme design stage. For the non-standardisation of the indoor space size of existing residence, the priority size of each indoor space should be determined by combining the functional needs of the space and the conventional size of the components, which refers to the net size between the finished surfaces of the decoration. The space dimensions resulting from the scheme design should facilitate the selection of standardised component parts, with non-standardised component parts as a supplement. This stage can be effectively managed through digital design, enabling the generation of diverse design solutions by modifying relevant parameters, facilitating the quick generation of various programs for comparison and optimization. (2) Standardise the size of components in the deepening design stage. it is important to develop standardized component sizes, encompassing surface components, base components, connectors, and etc.. Deepening the design stage should not only consider the standardisation of the size of components, but also consider the arrangement and combination of components, installation order and connection structure. In cases where non-standard wall, roof, and floor sizes are encountered, the modular coordination method depicted in Figure 2 can be employed to facilitate standardized design.

2.2. Pathway to intelligent construction of ERAD

Intelligent construction of ERAD includes the stages of digital design, digital production, and digital installation, and the commonly used technical means is to build a big data platform on the basis of building information modelling (BIM) technology, to carry out data sharing and intelligent collaborative work in the construction process, to improve efficiency, control costs, and to achieve effective quality management (see Figure 3) [10].

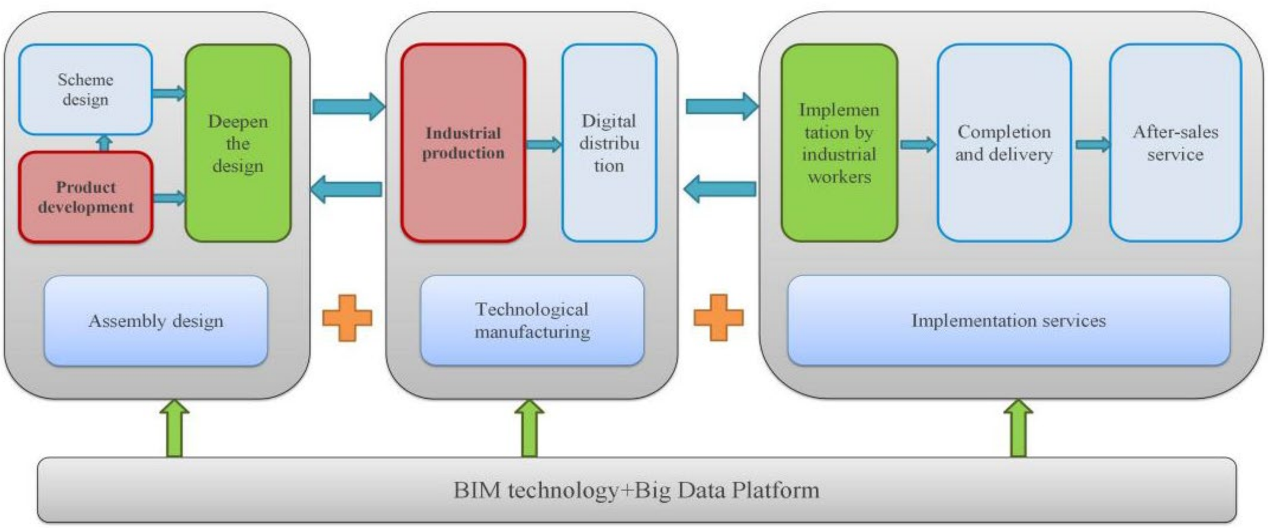


Figure 3. BIM technology big data platform

During the deepening design phase of assembly decoration, a data list of components is generated, which is sent directly to the factory to place an order through the BIM platform. This streamlined process enhances material procurement efficiency, reduces project timelines, and minimizes communication costs. In the digital production phase, the factory produces components according to the order, and transships the products to the construction site in accordance with the requirements of the work process. During the digital construction phase, the BIM platform provides three-dimensional graphs and simulated construction animations to guide the installation of parts and components installation. After construction, the owner receives an as-built model to support easy operation and maintenance.

3. A case study of assembly decoration for an existing residence in Sanya [11].

3.1. Project Overview

The project is located in Sanya City, Hainan Province, for the independent single-story existing residence, has been in use for more than 10 years, the construction area of 115 square metres, the type of 2 rooms, 2 halls and 2 bathrooms (see Figure 4). The interior decoration transformation adopts assembly decoration mode, and the whole process of design, production and construction adopts digital technology. The process involves scanning to obtain site data, followed by detailed design based on the scanned data, simulation of installation using BIM, component ordering, and on-site installation. The on-site construction cycle is estimated to be 18 working days.

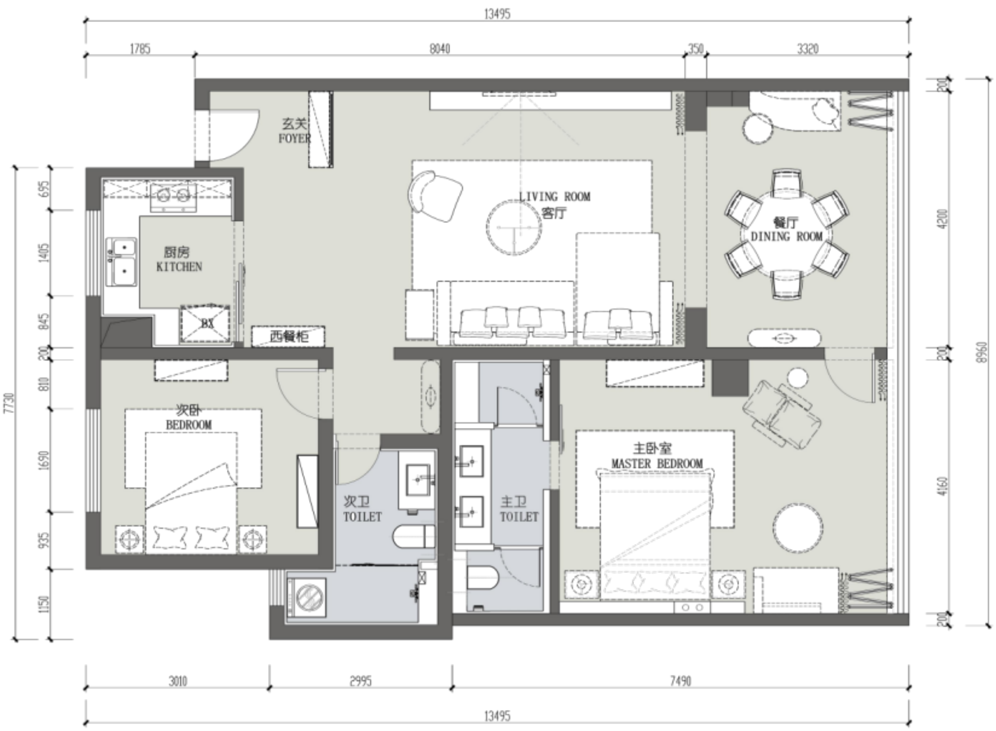


Figure 4. Household type drawing

3.2. Standardised Design

3.2.1. Preparation work of re-sizing

The renovation program for the project was designed according to the architectural design drawings provided by the owner, and after the program was approved by the owner, the original decoration was dismantled. Then the on-site re-sizing stage was began, using a 3D laser scanner to scan the dismantled indoor space, collecting point cloud data, importing the model data into BIM, and generating a 3D model with an error of 1mm or less from the actual data. This detailed model served as a basis for the standardized design phase that followed.

3.2.2. Deepening Design

The BIM design software is used to deepen the design of assembly decoration for the residence. A comparison is made between the BIM model from the pre-program design and the 3D model generated using the on-site re-scaled point cloud data to identify any existing issues and make timely adjustments to the design scheme (refer to Figure 5 and Figure 6). In the deepening design stage, the specifications, materials, quantities and other information of components are refined according to the principle of modular design. It is essential to ensure that the relevant data is consistent with the components used in the subsequent construction phase.

Figure 5. Deepening design based on point cloud data

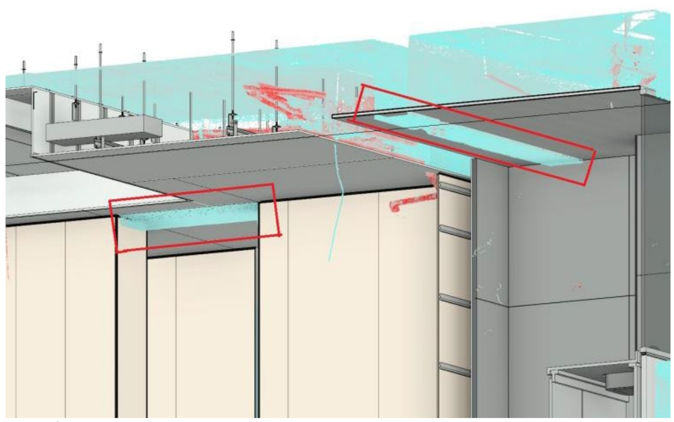


Figure 6. Collision check - the structure elevation is lower than the ceiling

In the deepening design phase, whether it is wall system, floor system or ceiling system, all are combined by modular surface components, base components and installation connection components. The design of components is in accordance with the principle of fewer specifications and more combinations, and standard sizes are used as much as possible. For the non-standard size of the space interface set a small number of non-modular areas for modular coordination, to ensure that the interface mainly adopts standardised, modular components. For example, in this project, the top surface of the living room primarily features with white bamboo wood fibre boards with a size of 600mm×1600mm, and the hemming part with a smaller area and free size can be used as a modular adjustment space; the living room façade is clad with beige and grey bamboo wood fibre boards with a width of standard sizes of 650mm and 150mm, a height of standard sizes of 2400mm, and the end of the 560mm wide boards is used for hemming. Non-standard size panels are utilized for header and modulus adjustment (refer to Figure 7 and Figure 6).

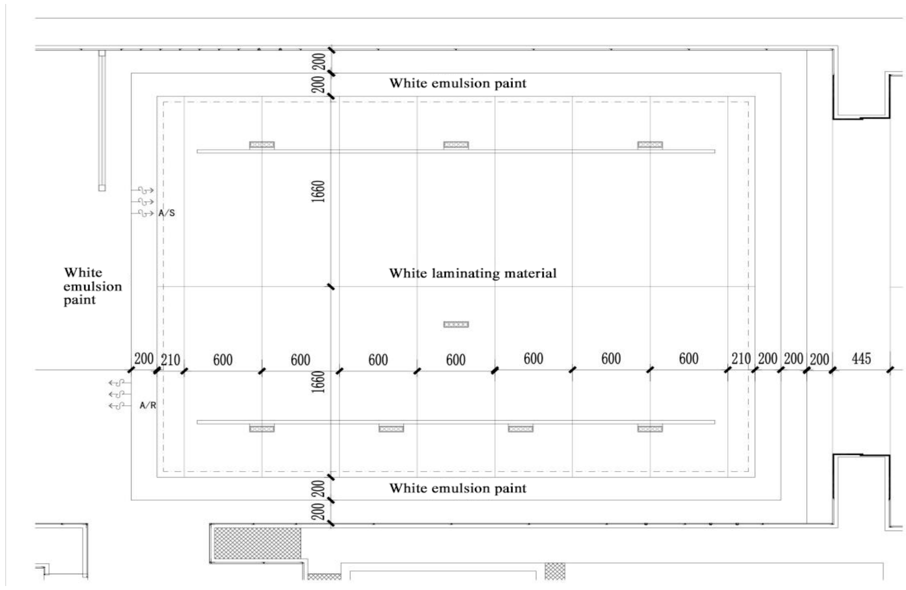


Figure 7. Standardised design of living room roof

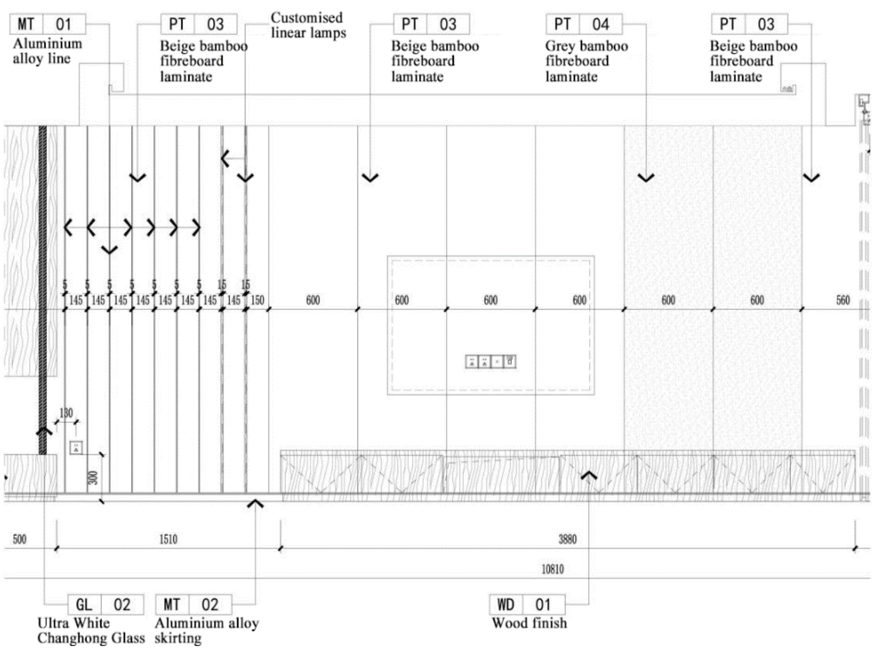


Figure 8. Standardized design of living room elevation

3.3 Intelligent construction

3.3.1 Simulated construction

Throughout the digital design process of the project, a continuously refined simulated construction process is accompanied. Due to the adoption of BIM design software, preliminary simulation construction is carried out at the scheme design stage; after the completion of point cloud scanning model generation and deepening design, the data of the component module is more accurate, and the accuracy of the virtually-built digital model is consistent with that of the actually-built components.

The total assembly model simulated in this project mainly encompasses several parts, including wall system, floor system, roof system and water and electricity system model. These models demonstrate the combination relationship of components through 3D views and video animations, serving as a tool for demonstration and guidance in the subsequent physical construction (refer to Figure 9).

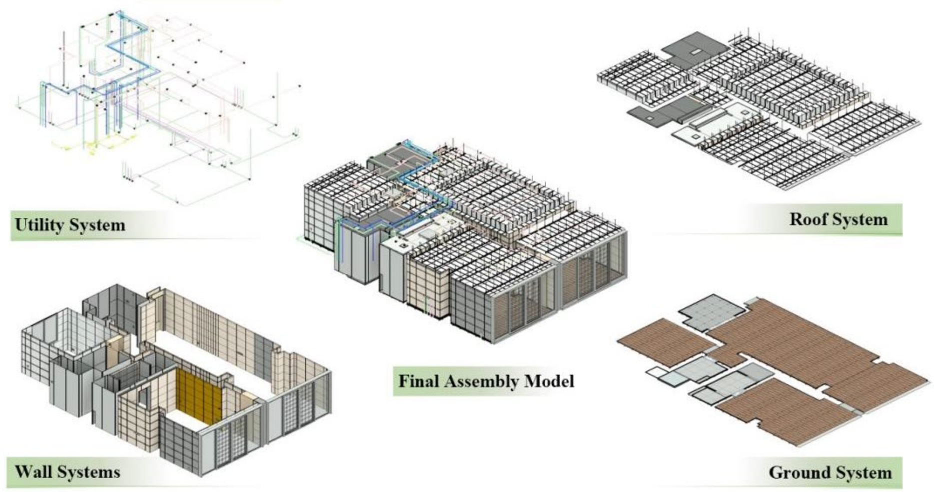


Figure 9. Simulated construction

3.3.2 Data export and order placement

After the deepening design is completed, each component has its own code and parameter information, each component is assigned a unique code and parameter information. The component data in the BIM model is exported to generate a detailed table, facilitating the classification and statistical analysis of materials.. The information of components includes length of keel, length of skirting, number of expansion screws, number of corner screws and more. Based on the detailed table, a procurement plan is made and an order is placed with the respective factory (see Figure 10).

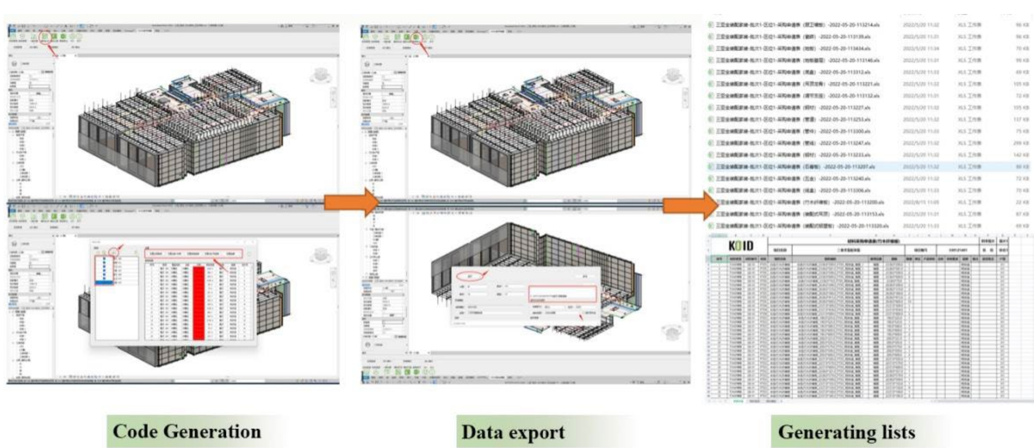
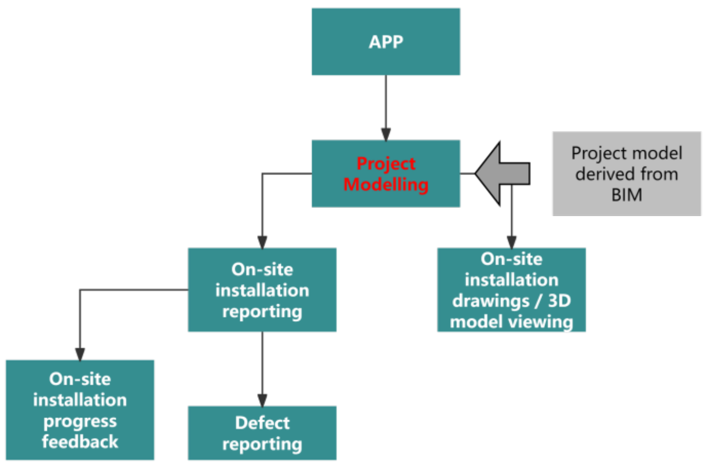


Figure 10. Data export and order placement

3.3.3 Digital management of procurement and installation

After the procurement order for components is provided to the manufacturer, the production schedule and delivery time of the components are carried out according to the construction plan. Major components are labelled with QR codes containing their data information, and the data information of all component products is consistent with the parameters of the components in the BIM model. This not only streamlines material delivery management but also enhances on-site construction management. During the on-site construction stage, staff scan the QR code of components through mobile phone APP for installation confirmation, identify the installation position and process of components with the help of BIM 3D model, and provide real-time feedback on the construction progress through the BIM big data platform (see Figure 11).

After the completion of the project, the BIM model is modified according to the on-site construction situation to form a BIM as-built model. This model is then uploaded to the BIM big data platform to provide data information and 3D graphics for project operation and maintenance.



Material Code	01 Adjustment support ___Koidi___1
Material Name	01 Adjustment support
Quantities	1.00
Batch Number	
Material Barcode	330121401_1#_1L_H1_101_secondary bathroom_10_01 Adjustment support ___Koidi___1

Figure 11. Mobile construction management

4. Discussion

The use of standardized components is a prerequisite for the assembly decoration and intelligent construction in interior decoration. To achieve the assembly decoration and transformation of existing residences for intelligent construction, the following steps need to be taken:

Firstly, the indoor space of existing residences should be standardized as much as possible. This is difficult for mixed structure houses built before the 1980s and 1990s due to the limitations imposed by load-bearing walls, which restrict the possibility of space re-separation. However, for SI system residences and other frame structure residences, adopting standardized dimensions for each space during the re-separation process is conducive to realizing assembled interiors.

Secondly, standardized sizes of components should be used as much as possible when designing the interface of interior spaces in existing residences. The modular coordination is one of the key technologies of standardized design, for the interface of non-standardized dimensions, the modular coordination space is left at the appropriate position, and non-standardized components are used in the area with mon-standardized size.

Thirdly, the whole process of design, production and installation of assembly decoration and transformation of existing residence should use digital technology to achieve intelligent construction and intelligent control with the help of big data platform.

Finally, in addition to the establishment of the big data platform, assembly decoration and renovation also need to achieve fast, accurate and safe intelligent construction with the help of three-dimensional laser scanners, various types of installation and leveling robots and other equipment.

Compared with the traditional mode of decoration and renovation of existing residences, assembly decoration fully embodies the characteristics and advantages of industrialized production methods. Currently, standardized design is critical to the industrialization of residential and renovation products, and its importance is widely recognized. However, standardized design is not adequately implemented in residential and renovation projects, particularly duo to the large number of non-standardized existing residential spaces, which increase the difficulty of realizing assembly decoration. In fact, standardized design can be achieved through modal coordination, which further enables the promotion of assembly decoration and renovation in existing residences.

The assembly decoration and renovation case in Sanya has digital technology intervention throughout the whole process, which effectively improves the efficiency of on-site installation. Its intelligent construction method provides a reference case for the renovation and renovation of existing residences. The standardized components of this case were produced in the factory, and the installation process was intelligently controlled through a big data platform, with on-site installation taking only 18 working days. The on-site construction of this project primarily involved manual installation, the installation cycle could be further shortened with the use of more automated installation equipment for interior components.

5. Conclusion

Most of the existing residential decoration adopts the traditional decoration method, resulting in extended construction period, prominent quality and environmental problems, and has a lot of negative impacts on the lives of the many residents. The adoption of assembly decoration mode, featuring standardized design and intelligent construction technology, presents an effective solution to the challenges associated with traditional decoration methods.. This approach not only enhances the quality of residential decoration and living comfort, but also promote the development of modernisation of the construction industry. In the future, it is necessary to increase the proportion of ERAD mode, and further study the standardised design method of decoration and transformation.

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Chart source:

Figures 1 and 2 are drawn according to reference [5]
Figure 3 - Figure 11 Suzhou Kelida Decoration Co.
Table 1. Self-drawn by the author