

# *Evaluation on Digital Design System of Assembled Building Based on Machine Learning Algorithm*

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**Abstract:** In manufacturing, high-quality products require a combination of efficient digital design tools, intelligent automated production equipment, and integrated online collaborative management systems. This study proposes an intelligent design and automated production solution for prefabricated buildings and develops a digital design system for prefabricated buildings, along with its supporting intelligent design software and a full-process online collaborative management platform. Low cost and high standardization are the most important characteristics and advantages of prefabricated buildings, which is why they are widely used globally. Based on machine learning algorithms, this study investigates the digital design system for prefabricated buildings, analyzes existing problems, and proposes suggestions related to the application of the digital design system to achieve full-process information management in prefabricated building construction.

## 1. Introduction

Prefabricated buildings play an important role in the construction field. Wang Haining explored how to establish a mathematical model to reflect the calculation of carbon emission coefficients in the actual assembly component transportation stage [1]. Sun Wei proposed a simulation analysis method for the continuous collapse resistance of prefabricated building structures under multidimensional seismic action [2]. Lin Min studied, identified and analyzed the key risk factors affecting prefabricated buildings. Based on the foreseen risks, the challenges faced by the improvement schedule project and corresponding functions were identified [3]. Based on the dual innovation theory and service innovation theory, taking steel structure prefabricated building developers as the research object, Liu Liangjun constructed a theoretical model of "dual innovation service innovation performance of green building policy" [4]. The application of machine learning in the construction field is conducive to improving the safety and intelligence of building construction. Tamke Martin evaluated the impact of machine learning on performance-based design and manufacturing building practices [5]. Nicholas Paul pointed out that robotic 3D printing technology is developing rapidly in the construction field [6]. Ramsgard Thomson Mette believes

that machine learning is opening up new prospects for building manufacturing because it can help the industry simplify the current cumbersome and expensive digital integration design to manufacturing workflow [7]. Saidzad Saleh proposed a general artificial intelligence and machine learning technique [8]. The above are studies on the application of machine learning in the field of architecture, but some of them still lack practical verification.

In order to ensure that the degree of assembly and construction quality are unified, assembled buildings need to be strictly inspected to ensure compliance with all specifications and to provide a reliable guarantee for subsequent works. In the next section, the digital design system of assembled buildings is analyzed and corresponding solutions are proposed according to the problems of assembled buildings.

## **2. Digital Design System for Prefabricated Buildings**

### **2.1 Prefabricated building concept**

The prefabricated building is a highly integrated industrial product, which uses the prefabricated parts of the factory. The prefabricated architectural design system is the source of all construction work and the starting point of construction activities.

The prefabricated building design should adhere to the principle of “less specifications, and more combinations”. The goal of “less specifications” is to improve the construction efficiency, reduce the complexity of the project, reduce the difficulty of management, and reduce the cost of mold manufacturing, laying a good foundation for cooperation between enterprises and professionals. “Multi combination” refers to the combination of a small number of parts to form a variety of products to meet the needs of various users.

### **2.2 Problems in prefabricated buildings**

Prefabricated building is one of the many architectural forms. Compared with traditional construction methods, prefabricated buildings have unique advantages, low manufacturing cost and environmental friendliness [9]. Therefore, prefabricated buildings have received extensive attention in the construction industry.

#### **2.2.1 BIM design is very costly and inefficient**

Currently, the deepening and designing software is still facing the coming issues. First, the intelligent level of the software is not enough. Most prefabricated parts are assembled manually, lacking parametric and fast design functions. Compared with graphic design, 3D design requires more modeling work. If the level of software intelligence is not enough, the design efficiency would be greatly affected. Secondly, the current level of software development is low. The BIM (Building Information Modeling) software currently utilized for the design deepening phase is mostly from other regions.

#### **2.2.2 Poor data interactivity makes it difficult to reflect the value of digital technology application**

Construction information transfer is not timely. Traditional paper files have problems such as inability to effectively preserve, copy and share electronic files. In the file management work, most units currently use manual collation, which has low efficiency and easily causes file loss. Low degree of informationization cannot meet the development needs of modern enterprises. The design data cannot be docked to the production equipment. The current lack of unified data transmission

and production management system and supporting automated production equipment leads to the design data that cannot be docked to the industrial software-driven component automation production. Most parts are currently manufactured by workers according to design drawings, which makes it difficult to play the role of digital technology [10].

### **2.2.3 Design, production, transportation and construction are disconnected**

At present, the digital systems of prefabricated buildings are diverse, and their requirements are also different [11]. However, the traditional designers' lack of understanding of assembly technology, the state of prefabricated component manufacturers' equipment and on-site assembly process, and the imperfect online collaborative management platform unified by each construction company lead to various problems in the component facilities and make the project cost increase greatly.

### **2.2.4 Development is uneven**

In recent years, the gap has been gradually widened in terms of promoting regional and inter regional industrial scale, technical capacity and talent reserve. At the same time, there are great differences in the level of implementation standards in different regions, resulting in differences in the level of different projects. Through the preliminary evaluation of local prefabricated buildings, some regions have added points on new technologies according to the actual situation, with emphasis on new technologies in standardized design, BIM, green construction and local construction. In order to seek a higher share of assembly development in some regions, the demand for assembly rate has declined, and the low assembly rate has limited the development and utilization of technology to some extent [12].

### **2.2.5 The current situation of industrial chain coordination needs to be further improved**

In the design of prefabricated buildings, due to the lack of a complete solution to the characteristics of prefabricated buildings and insufficient attention to the design standardization of prefabricated buildings, some structures of prefabricated buildings are difficult to split in the later stage, and the reuse rate of materials is low, which greatly increases the cost of construction and management, leading to problems in the production process of some prefabricated manufacturers.

## **2.3 Construction of digital design platform for prefabricated buildings**

### **2.3.1 Construction of digital management platform based on BIM mode**

The digitalization of prefabricated buildings refers to the realization of centralized and integrated digital management of projects and relevant data management of projects through BIM technology and the characteristics of distributed buildings. Through the establishment of BIM model, the data and process information of buildings can be collected, sorted, analyzed and processed in detail, and the whole process of prefabricated buildings can be evaluated scientifically. The cooperation of various departments can be strengthened to ensure the orderly assembly construction [13].

### **2.3.2 Digital expression of prefabricated buildings**

The data processing layer is an intermediate filter layer that can effectively transmit data to the digital twin layer. In the actual project, the Internet of Things technology is used to analyze, clean and integrate a large amount of data from various data sources collected during the project construction, providing efficient data information flow for the project schedule. In the process of

policy driven construction, due to the complexity of data, it can be achieved in a variety of ways. The scheduling data obtained from different sensors and wireless identification technologies often have problems such as non-standard data format, data conflict, data duplication, etc.

### **2.3.3 Reasonable formulation of information interaction criteria**

The whole process management of prefabricated buildings is a complex and systematic project, which involves the management of architectural design, production, assembly, installation, management and other aspects. Because of different objects and different information systems have different characteristics, information exchange becomes more difficult. On the basis of the existing information resource management platform, a set of reasonable construction information criteria is established to realize the information exchange and learning of various departments.

### **2.3.4 Virtual safety and environmental protection warning space**

Through the virtual space, the staff responsible for the progress can easily understand all aspects of the data, and more accurately infer the project completion time, schedule adjustment, construction capacity, etc. This forms a virtuous circle, that is, model, information input, virtual reality and feedback. In terms of tunnel monitoring, dust monitoring and other aspects, the construction of “virtual environment safety early warning space” is mainly to enter hazard sources, problem points and equipment according to the workflow in the project schedule, and timely remind and schedule monitoring tasks according to the workflow in the schedule.

## **3. Application Value of Digital Design of Prefabricated Buildings**

Applying machine learning algorithm to digital assembly design can greatly reduce the work efficiency of designers. Especially in the deepening stage, the drawing and calculation time is shorter, which improves the quality of BIM model. The accurate bill of materials provides the basis for the fine management of production and construction, avoids the mistakes caused by manual calculation, and reduces the waste of materials. Meanwhile, it significantly lowers the communication expenses of design, production and construction, and improves the management level of prefabricated assembly and decoration projects.

### **3.1 Improving organizational decision-making efficiency**

Through the application of the BIM software package of the assembly decoration, with the help of the three-dimensional visual characteristics of the model, a visual assembly decoration project management tool is provided for different levels and managers, which enhances the understanding of all parties in the project in terms of design intent, project difficulty, construction scheme communication and review, and is conducive to the smooth realization of consensus in all aspects of the project.

### **3.2 Improving the efficiency of design deepening and improving the quality of design results**

Through the BIM software of assembly decoration, intelligent design is realized. It only takes a few hours for each type. Compared with traditional CAD (Computer Aided Design), it saves a lot of manpower and improves the accuracy of design. Through the analysis of engineering examples, the communication between the construction unit and the designer can be effectively improved, and the accurate modeling can be carried out. The processing and installation of parts can also be accurately guided.

### 3.3 Improving the ability of project construction technology management and control

Through the disclosure of 3D visualization technology for BIM model and the application of “two-dimensional code” scanning technology, the communication and technical management between engineering technicians and construction personnel would be more effective. The BIM technology is used for accurate modeling and accurate control, so that the direct benefit of the project on materials is more economical than the traditional method, and the situation of supplement and omission is greatly reduced.

### 3.4 Assisting in intelligent management of assembly decoration

Assembly decoration has the characteristics of design standardization, industrial production, assembly construction, etc., which places a higher demand on the delivery and management of decorative material information throughout the project process. The project shows that the assembled decoration BIM software can significantly improve the efficiency of engineering design, production, installation and construction, and lay a good foundation for the information operation and maintenance of enterprises. Using the assembled BIM technology, a complete set of files and a traceable operation and maintenance system would be established from the design, assembly, and operation to maintenance, and then from the full life cycle of materials, installation, replacement, to achieve the value of serving the society.

### 3.5 Reducing decoration costs and improving project benefits

As assembly decoration requires all components to be prefabricated in the factory, requiring higher design depth and more design workload, BIM can greatly improve the efficiency of the design process. Because the system has the characteristics of one key typesetting and automatic calculation, the workload of designers is greatly reduced. Especially in the deepening stage, the time for design and calculation is shortened. Compared with the traditional design software, it can save the total labor cost and greatly reduce the communication costs for design, production and construction.

The combination of advanced assembly decoration technology and BIM technology makes the design result meet the requirements of each component. Then, BIM technology is used to optimize the typesetting of precision cutting, decorative plates and blanking, which can greatly reduce the loss of waste products and materials.

## 4. Evaluation on Image Reconstruction Algorithm of Machine Learning

In the support vector classifier, it is necessary to find a hyperplane through training samples to correctly distinguish the given data samples  $\{(a_i, b_i), i = 1, \dots, l\} \in (P^n, b_i \in T \subset P)$ . The decision function is expressed as:

$$b = g(a) = \text{sgn}(f(a)) \quad (1)$$

The optimization problems are considered:

$$\min_{\varpi, \varpi_0} \frac{1}{2} \|\varpi\|^2 + H \sum_{i=1}^l \eta_i \quad (2)$$

$$b_i (\varpi^T \cdot a_i + y)_i \geq 1 - \eta_i, i = 1, \dots, l \quad (3)$$

In the formula,  $H$  is the penalty parameter, which is used to adjust the balance between the

complexity of the classification model and the approximation error.

## 5. Influence of Machine Learning Algorithm on Digital Design of Prefabricated Buildings

### 5.1 Experiment purpose

Based on the background of machine learning algorithm, in order to study its impact on the digital design system of prefabricated buildings, two groups of buildings are selected. Group A is the digital design of prefabricated buildings based on machine learning algorithm, and Group B is the traditional architectural design. The research is carried out from five aspects of architectural design approval, energy conservation, environmental protection, construction completion time and construction quality, and the impact of the two models on architectural design is compared.

### 5.2 Experimental data

#### 5.2.1 Recognition degree of construction design

The recognition degree of residents to the construction design reflects the quality of the design. Based on the machine learning algorithm, the recognition degree of residents to the digital design system of prefabricated buildings in 2016-2019 is taken as the research subject, and the results are shown in Table 1.

Table 1. Construction design recognition

	2016	2017	2018	2019
Very approved	28.97%	33.69%	35.31%	37.47%
General	34.45%	34.64%	36.33%	36.84%
Not approved	36.58%	31.67%	28.36%	25.69%

Among residents' recognition of construction design, residents' recognition of prefabricated building design system was increasing, while their disapproval was decreasing. Among them, residents' recognition of prefabricated building design was about 28.97% in 2016 and 37.47% in 2019, with an increase of 8.5%. The digital design of prefabricated buildings was constantly improving in the construction industry, and the recognition of residents was also increasing.

#### 5.2.2 Energy saving

Taking the energy-saving of the building design system as the research content, the energy-saving value range is 0-100%, and the results are shown in Figure 1.

In the energy efficiency of prefabricated building design, the energy efficiency of Group A presented an unstable trend and was lower than that of Group B; the energy conservation of Group B showed a steady upward trend. Under the machine algorithm, it is beneficial to improve the accuracy of construction materials of prefabricated buildings. The digital design system of prefabricated buildings strengthened the intellectualization of buildings, reduced unnecessary material consumption in building construction, and greatly improved the energy efficiency of the design of prefabricated buildings.

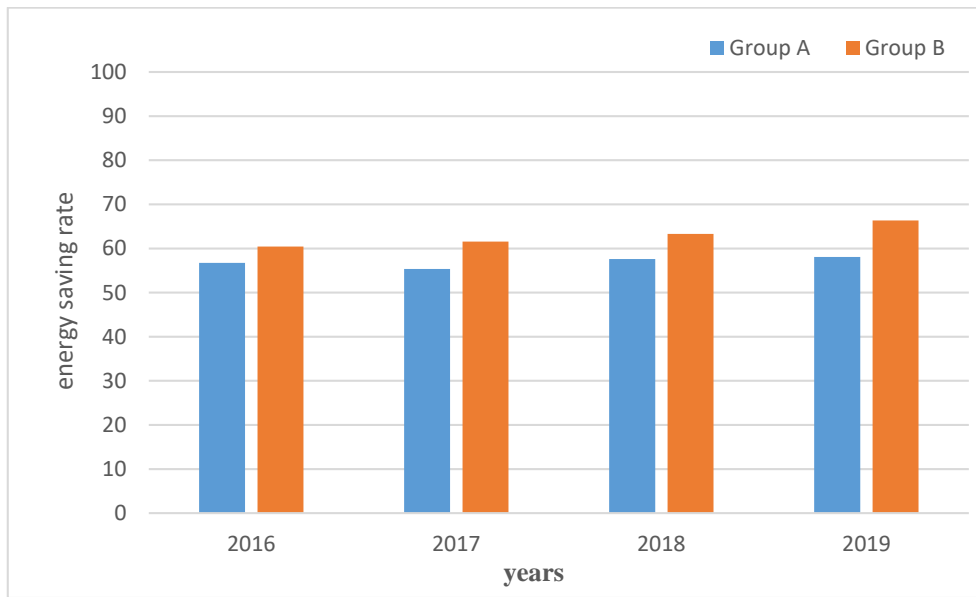


Figure 1. Comparison of energy efficiency of assembled buildings

### 5.2.3 Environmental protection

The environmental protection of architectural design affects the health of the environment. The comparison of the environmental protection of buildings A and B is shown in Figure 2.

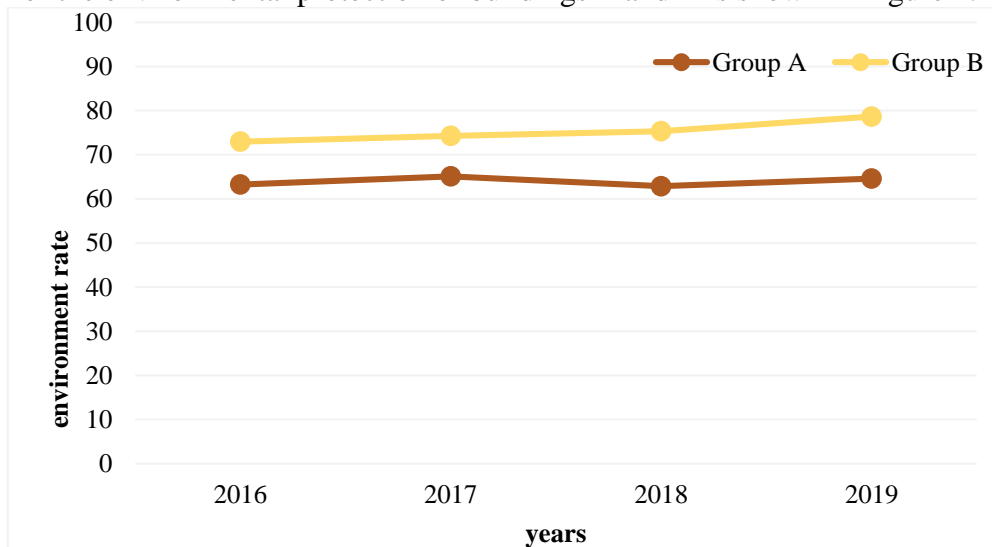


Figure 2. Comparison of environmental friendliness

In the environmental protection design of prefabricated buildings, the environmental protection of B prefabricated buildings is always higher than that of Group A. From the current situation of green building design, material and technology innovation should be strengthened. The assembly type digital design system based on machine learning algorithm can optimize the construction process to ensure the effectiveness of construction supervision, so as to ensure the smooth construction of green buildings. On this basis, the prefabricated buildings further optimize the building structure, make the space layout more reasonable, and promote the design system of prefabricated buildings more scientific.

### 5.2.4 Construction completion time

The construction completion time is affected by various factors. The value range of the completion time is 6-15 months. The construction completion time of Groups A and B is shown in Figure 3.

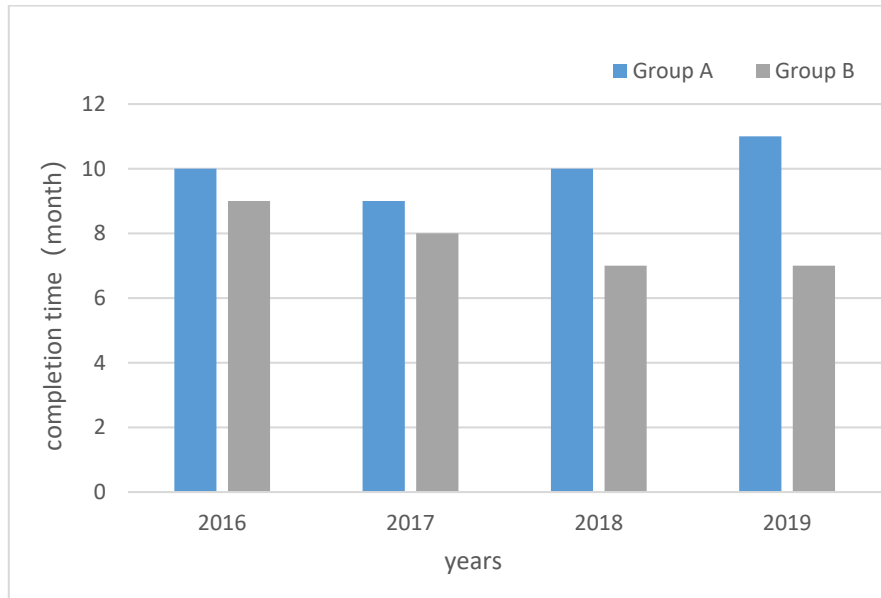


Figure 3. Construction completion time comparison

In the completion time of prefabricated buildings, the completion time of A prefabricated buildings was significantly higher than that of B prefabricated buildings. In the construction of machine learning algorithm assembly type digital engineering, the management of engineering progress would be related to the engineering quality and economic benefits of the project. Therefore, the progress management of distributed building operation is an important link in engineering construction. At present, the machine learning algorithm assembly type digital design system has become an important competitive advantage in architectural design. The reasonable duration management can not only improve the economic strength of the engineering unit, but also improve the overall strength of the engineering construction and improve the quality of the project.

## 6. Discussion

Building information modeling technology is being promoted and applied more and more widely and deeply internationally to provide information integration for assembled buildings. With the transformation and upgrading of the construction industry, the assembled building will become one of the main forms of the construction industry in the future. The assembled building is centered on "integration", and building information modeling technology serves as an "integration" tool. At present, China's assembled buildings are developing rapidly, and it is especially necessary to conduct an in-depth study on them. This article analyzes the development trend of assembly building and some problems in its practical application. From the current application status of assembly building, this article summarizes the application scope and value of building information modeling technology in the building system, and points out the suggestions on the application of building information modeling technology in assembly building, the promotion of hierarchy, the strengthening of marketization, and the promotion of demonstration projects. It also points out the suggestions on the application of building information model technology in assembled buildings, stratified promotion, strengthening marketization, and promoting demonstration projects, hoping to

provide some ideas and methods for the mature application and promotion of building information model technology. Focusing on the application of building information modeling technology, integrating the integrated system of assembled buildings in all aspects of design, manufacturing and construction transformation, and operation management, integrating the whole industrial chain of construction, and realizing the integration of informationization of the whole process and all aspects, is the direction of the development of assembled buildings. By analyzing and summarizing the relevant literature, the study found that there is still a lack of domestic exploration of information transfer and sharing mechanisms between various links of the whole life cycle of assembled buildings. However, the current assembled building and building information modeling technology is not perfect, and there are still many problems in its design specification, interprofessional collaboration, and technical and management personnel training, so future research can explore the key technologies of each link of assembled building and the multi-level collaborative management more deeply. In this paper, based on a synthesis of relevant information, we discuss how to coordinate the various aspects of assembled buildings. Through the study of collaborative design of assembled buildings, the traditional design thinking is changed, which provides a theoretical basis for the implementation of collaborative design; a reasonable design process is an effective guarantee for the realization of collaborative design; construction information technology lays a good foundation for the data transmission and cross-industry parallel processing of enterprises in the whole collaborative design industry chain. From the perspective of the whole life cycle of building products, the collaborative design of the whole industry, the whole process, the whole chain and the multi-technology system is formed to promote the integrated management of assembled buildings among all links. At the same time, an engineering information management platform based on building information model model and big data is established to provide efficient and convenient information service for enterprises.

## 7. Conclusion

Assembly building is a modern form of construction with a wide range of applications, it is comprehensive and systematic, and under the development of the information technology era, it needs to combine the joint efforts of various industries to ensure the coordination, science and integrity of construction work. By combining machine learning methods with an interactive information platform for integrated data integration in assembly construction, it can effectively promote the construction of applied scientific information for assembly construction. At the same time, the function of information sharing and integration is incorporated into the digital design of assembly buildings, which enables closer collaboration among participants of various processes, fields, and projects. The goal of digitalization of assembly building is realized, which provides strong support and guarantee for improving the economic efficiency and quality of the project, and provides a reference for future assembly building research.

The limitation of this paper is that the safety risk table of the assembled building lists the main safety hazards, but there are still omissions. In the next work, it is necessary to continue to combine the actual situation of the project and scientific theoretical analysis to supplement the risks. In the future research, it will be deepened, enriched and improved the safety risk collection of assembled buildings and analyzed the main influencing factors.

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