

Original Paper

Significance and Challenges of Prefabricated Building Development

Jiekun Zhu^{1*}

¹ Department of Railway Engineering, Sichuan College of Architectural Technology, Deyang, Sichuan 618000, China

* Jiekun Zhu, Department of Railway Engineering, Sichuan College of Architectural Technology, Deyang, Sichuan 618000, China

Received: June 29, 2024

Accepted: July 22, 2024

Online Published: August 17, 2024

doi:10.22158/se.v9n3p100

URL: <http://dx.doi.org/10.22158/se.v9n3p100>

Abstract

In recent years, with the promotion of urbanization, the construction industry has made great progress. However, problems such as high energy consumption, low efficiency and high environmental pollution still exist in the traditional construction mode of the building industry. In comparison, assembly building has the advantages of short construction cycle, low resource consumption, low environmental pollution and fast information exchange. With the requirements of high-quality development of China's construction industry, it has become an important means of transformation and upgrading of China's construction industry. However, at the same time, there are still various hindering factors that restrict the development of assembly building in the process of promotion, such as high cost, lack of technical personnel, and low consumer recognition. This paper mainly discusses how to realize the sustainable development of assembly building under the basic concept of sustainable development of economic development, resource utilization and ecological environment protection.

Keywords

Prefabricated Buildings, Green Construction, Sustainable Development

1. Analysis of the Development of the Prefabricated Building Industry

1.1 Concept of Prefabricated Buildings

Prefabricated buildings refer to a construction method where components are manufactured in a factory and then transported to the site for assembly. Compared to traditional cast-in-place construction, prefabricated building methods significantly enhance construction efficiency, saving labor while minimizing the impact of environmental conditions. Additionally, they offer benefits such as energy

conservation, reduced emissions, rapid construction, and environmental sustainability (Yang, 2018).

1.2 Comparison of Characteristics between Prefabricated and Traditional Buildings

(1) Design Phase

1) The traditional building construction mode will focus on the spatial planning of the project and the design of the single building in the program design stage. Less attention is paid to the basic function of individual projects and the satisfaction of living space.

2) The assembly construction mode extends the whole process and seeks the overall planning of the whole process. In the design, it is necessary to satisfy the most basic functional requirements, but also to make a comprehensive consideration of the factory production and assembly construction mode, in order to achieve a win-win situation between the functionality and economy of the project.

1.3 Production Phase

(1) Conventional buildings are constructed by conventional cast-in-place method, which requires the production of parts on the site, which is a cumbersome process, and the production of parts outdoors is also affected by rain, snow and strong wind. In the construction of frame structure, it is necessary to go through the process of measuring and placing lines, rebar binding, supporting formwork, concrete pouring and maintenance, and mold removal, etc., which makes it difficult to control the quality of its production (Zhou, 2019).

(2) After the design layout and deepening of the assembly components, they are produced through the processing factory by discharging the materials, and then transported to the site, they can be directly installed and constructed on the site without being restricted by the construction conditions on the site, and they can be standardized in the factory after completing the determination of the layout drawings.

1.4 Construction Phase

(1) Conventional buildings use the conventional cast-in-place method of concrete pouring, which not only takes time, but also causes a lot of dust and waste during the pouring process. Because the level of mechanization used is not high, there is a great demand for on-site labor. Therefore, in terms of the site working environment and labor safety environment, the use of traditional methods will have great potential risks.

(2) The high degree of automation of assembly buildings on the site not only saves labor on the site, but also improves the efficiency of work. After the completed components arrive at the site, lifting and construction can begin, and the whole construction process has little impact on the environment and can be green at the same time.

1.5 Advantages of Prefabricated Buildings

(1) High Construction Efficiency

Prefabricated buildings utilize modular components that are manufactured in factories and assembled on-site, significantly shortening construction timelines. Workers only need to perform simple assembly tasks, eliminating complex traditional construction processes. This approach enhances work efficiency while reducing labor costs.

(2) Resource Conservation

The factory-based production of prefabricated buildings optimizes resource utilization and minimizes waste. Standardized and mass production of materials allows for precise calculation of material requirements, thereby avoiding the common wastage seen in traditional construction practices.

(3) Environmental Protection and Energy Efficiency

Prefabricated buildings often utilize green materials, such as steel structures and innovative composites, reducing reliance on traditional resources. They generate less waste during construction, leading to a smaller environmental impact. Moreover, the design of prefabricated buildings can better incorporate energy-saving and environmentally friendly requirements, thereby reducing energy consumption and carbon emissions. Future optimization of production processes for prefabricated components is also feasible.

(4) More Professional Construction Approach

The construction of prefabricated buildings follows an integrated model that encompasses structural systems, external maintenance systems, equipment systems, and plumbing systems, ensuring comprehensive functionality and superior performance. This integration allows prefabricated buildings to meet functional demands while enhancing performance and durability.

Despite the numerous advantages of prefabricated buildings as an emerging construction method, there are still several constraints facing their development (Huang, C.,2018).

2. Constraints on the Development of Prefabricated Buildings

Prefabricated buildings, based on factory-produced components assembled on-site, have gained attention as a low-carbon, energy-efficient, and environmentally friendly construction method amid current efforts toward sustainability. However, several constraints remain (Zhang, & Qiu, 2022):

2.1 Insufficient Technology Level

Prefabricated buildings require advanced design and production technologies. Currently, both domestic and international efforts in the research and application of new materials and processes are lacking. In some regions, construction units lack relevant technical training, leading to a superficial understanding and application of prefabricated buildings, which hinders their promotion and development.

Insufficient technological capability is a significant constraint on the development of prefabricated buildings. The successful implementation of prefabricated construction relies on advanced design concepts and efficient production processes; however, many regions still face technological shortcomings.

Prefabricated buildings demand that designers and engineers possess high levels of expertise, including a deep understanding of Building Information Modeling (BIM), modular design, and prefabricated components. Unfortunately, many traditional architectural firms have not fully mastered these new technologies, resulting in a lack of innovation and scientific rigor during the design phase, which limits the potential benefits of prefabricated construction.

In terms of production technology, while some advanced prefabricated component production lines are emerging, overall quality varies significantly. Some companies continue to rely on traditional production methods, which hinder automation and standardization, thus restricting improvements in production efficiency and product consistency. Furthermore, the research and application of new materials, such as lightweight, high-strength building materials and environmentally friendly composites, require further enhancement as they have not yet been widely adopted.

Technical training for construction units is also critical. Given that the construction methods for prefabricated buildings differ considerably from traditional approaches, workers need specialized training to acquire the necessary skills. Currently, many regions lack systematic training mechanisms, resulting in frontline workers being insufficiently informed about prefabricated construction processes and safety protocols, ultimately affecting construction quality and timelines.

2.2 Low Market Awareness

Although prefabricated buildings are widely used abroad, awareness of this construction method remains low in developing countries. Many clients and investors are skeptical about its advantages and cost-effectiveness, resulting in insufficient market demand and hindering industry growth.

2.3 Insufficient Policy and Regulatory Support

The development of prefabricated buildings requires appropriate policy support and regulatory frameworks. However, in some regions, existing policies do not adequately consider the unique characteristics of prefabricated construction and lack targeted incentives. This creates policy barriers for the industry, limiting investment and innovation by enterprises.

The growth of prefabricated buildings relies heavily on policy support and regulatory standards, which can provide clear development direction and safeguard investments and innovations. However, in many areas, especially those less developed, relevant policies and regulations fail to address the specific needs and uniqueness of prefabricated construction, leading to various constraints.

Many regions' building regulations primarily focus on traditional construction, lacking specific provisions for prefabricated buildings. This results in unnecessary obstacles during design, construction, and acceptance phases, adversely affecting their promotion and application. For instance, existing building review and acceptance standards may not be applicable to prefabricated components and systems, increasing compliance costs for enterprises.

Additionally, incentive policies for prefabricated construction are scarce. In some areas, governments have yet to establish a range of incentives such as tax breaks, financial subsidies, and funding support for prefabricated construction companies. This absence of policy benefits diminishes enterprises' enthusiasm and confidence in investing in prefabricated buildings.

The lack of targeted standards and technical specifications also significantly constrains the development of prefabricated construction. Existing industry standards and technical guidelines have not kept pace with advancements in prefabricated building techniques, leaving companies without clear guidance during production and construction, thus increasing project implementation risks and

uncertainties.

Furthermore, insufficient implementation and regulatory oversight of policies have negatively impacted the development of prefabricated buildings. Although some regions have introduced supportive policies, a lack of effective monitoring and evaluation mechanisms has hindered their actual implementation, leading to reduced trust among enterprises.

To promote the healthy development of prefabricated construction, governments at all levels should take proactive measures. First, they should promptly revise and enhance relevant laws and regulations to ensure compliance in design, construction, and acceptance phases, tailored to the characteristics of prefabricated buildings. Second, the establishment of dedicated funds, along with tax incentives and financial support, is essential to attract more enterprises to invest in the research and application of prefabricated construction. Additionally, developing and refining industry standards and technical specifications is crucial to ensure the quality and safety of prefabricated buildings. Finally, reinforcing policy oversight and evaluation is necessary to ensure effective implementation, creating a favorable environment for industry growth.

2.4 Insufficient Standardization

Despite the emphasis on modularity and standardization in prefabricated buildings, practical implementation often falls short due to the diversity of architectural designs and functions. This results in lower production efficiency and increased complexity and costs in construction.

Different building projects typically have unique design requirements and functional needs, limiting the applicability of standardized components. For instance, residential, commercial, and public facilities differ significantly in spatial layout, functionality, and aesthetic requirements. This diversity forces designers to customize standardized components, necessitating additional modifications that complicate design and production processes.

Although modularity is a core principle of prefabricated construction, varying geographical, climatic, and cultural factors lead to distinct building needs and regulations across regions. This makes it challenging to achieve a one-size-fits-all solution in standardized production, restricting the flexibility of manufacturing processes. Enterprises must often balance product standardization with market demands, exacerbating declines in production efficiency.

While the assembly of each module is relatively straightforward, the overall construction process requires high coordination. Projects involving multiple module combinations suffer from a lack of effective standardization and modular design, complicating workflows and increasing construction complexity. Factors such as site spatial constraints and varying transportation conditions can lead to misalignment between modules, adversely affecting project timelines and quality.

Moreover, due to insufficient standardization, companies frequently need to invest additional manpower and resources for on-site adjustments and adaptations, further increasing construction costs. The complexity and uncertainty of on-site construction can result in delays, material waste, and additional labor costs, ultimately impacting the project's economic viability.

2.5 Incomplete Supply Chain

Prefabricated construction requires stable and efficient supply chain management to ensure timely production and transportation of components. However, in some regions, the supply chain system is underdeveloped, leading to difficulties in material procurement and logistics, which impacts construction schedules and cost control.

To address these challenges, the industry needs to establish a robust supply chain management system for prefabricated construction. This includes optimizing material procurement processes and enhancing supplier management and evaluation to improve efficiency and quality. Government and industry associations can support the development of transportation infrastructure to enhance logistics conditions and reduce transportation costs and time. Additionally, leveraging information technology to create real-time supply chain management platforms can improve communication and collaboration among stakeholders, facilitating transparent information sharing and better coordination of supply chain operations.

2.6 High Initial Investment

Although prefabricated construction can save costs during long-term operation, the initial investment is relatively high, encompassing equipment procurement, factory establishment, and personnel training. This cautious approach to investment decisions by some enterprises limits the widespread adoption of prefabricated construction.

2.7 Cultural and Habitual Barriers

In some regions, traditional construction methods are deeply entrenched, leading to low acceptance of prefabricated buildings among construction units and workers. These cultural and habitual barriers complicate the promotion of new building techniques.

In traditional construction, workers can flexibly adjust their methods based on specific site conditions, whereas prefabricated construction emphasizes standardization and modularity, requiring adherence to strict operational protocols. This shift in working practices may cause discomfort or even fear among some workers, reducing their acceptance of new technologies and processes.

In summary, the development of prefabricated construction faces multiple constraints, including technical, market, policy, standardization, supply chain, investment, and cultural factors. To promote its healthy development, a collaborative effort is needed from all stakeholders, focusing on policy guidance, technological innovation, and market promotion to address these challenges.

3. Framework for Constructing a Sustainable Development Indicator System for Prefabricated Buildings

The construction of sustainable development index system of assembled building is a comprehensive work, which needs to be considered from multiple dimensions, mainly including economic, technical, environmental and social aspects. The following is a basic framework for the construction of sustainable development index system of assembly building:

3.1 Economic Indicators

Cost-effectiveness: Evaluating construction, operational, maintenance, and lifecycle costs.

Payback period: Assessing the timeframe for investment recovery.

Economic benefits: Evaluating both direct and indirect economic impacts of the project.

3.2 Technical Indicators

Technological innovation capacity: Assessing the degree of innovation and speed of updates in prefabricated construction technologies.

Standardization level: Including the standardization of building components and construction processes.

Production efficiency: Evaluating production cycles and the efficiency of component manufacturing.

3.3 Environmental Indicators

Resource consumption: Measuring the consumption of water, energy, and raw materials.

Waste emissions: Quantifying waste and pollutant emissions generated during construction.

Energy-saving and environmental performance: Assessing energy consumption levels and the proportion of renewable energy used.

Ecological impact: Evaluating effects on the surrounding environment, including noise, dust, and soil erosion.

3.4 Social Indicators

Employment: Quantity and quality of job opportunities created.

Residential Comfort: Livability of the building, including spatial layout, lighting, and ventilation.

Social Acceptance: Level of societal recognition and acceptance of prefabricated buildings.

Public Safety: Building resilience to earthquakes and fire safety performance.

3.5 Sustainable Development Indicators

Life Cycle Assessment: Evaluating impacts at all stages from raw material extraction to design, construction, operation, and demolition.

Modular Design and Recyclability: Degree of modular design of building components and potential for recycling.

Long-term Performance: Durability and adaptability of the building over time.

3.6 Policy and Regulation Indicators

Policy Support: Government support policies, funding, and regulatory frameworks for prefabricated construction.

Compliance: Adherence of construction projects to relevant laws, regulations, and standards.

3.7 Innovation and Education Indicators

R&D investment: the enterprise or project's investment in technology research and development.

Talent Cultivation: Cultivation and continuing education of professionals in related fields.

Constructing such an indicator system can not only comprehensively assess the level of sustainable development of assembled buildings, but also provide decision-making support for policy makers and

industry participants, and promote the healthy development of the assembled building industry. In the process of implementation, the indicator system should be continuously optimized and improved in the light of the specific situation to meet the needs of industry development and market changes.

4. Conclusion and Outlook

Currently, China is rapidly advancing its urbanization, with the construction industry serving as a pillar for economic development. However, the sector faces several challenges, including excessive resource and energy consumption and significant pollution, which must be addressed. In this context, the development of prefabricated buildings emerges as an effective solution and aligns with China's sustainable development strategy, contributing to the goals of economic, social, environmental, and energy sustainability.

5. Conclusion

In terms of technological innovation, prefabricated buildings enhance construction quality and efficiency through standardized design, factory production, and assembly-based construction, thereby reducing resource consumption and environmental pollution. They also shorten construction timelines, lower labor costs, and improve productivity, yielding significant economic benefits. From an environmental perspective, prefabricated buildings align with the principles of green architecture and sustainable development, aiding the construction industry in transitioning towards greener, circular, and low-carbon practices.

Outlook:

(1) Technological Breakthroughs

Future advancements in prefabricated construction will likely focus on structural design improvements and material selection to enhance overall performance and durability. Additionally, the development of smarter, automated construction equipment and techniques will reduce labor costs.

(2) Green Development

Prefabricated buildings will continue to embrace green architecture and sustainable development principles, promoting the application of environmentally friendly, energy-efficient, and low-carbon technologies to increase the market share of green buildings.

(3) Industry Chain Improvement

As industrialization progresses, the steel manufacturing industry's supply chain will become more refined, providing favorable conditions for the development of prefabricated buildings.

(4) Design Innovation

Future designs for prefabricated buildings will emphasize human-centric, intelligent, and aesthetic qualities to meet diverse and personalized architectural needs.

(5) Rural Market Expansion

Prefabricated buildings hold significant potential in rural housing renovation and rural revitalization,

offering strong support for the construction of beautiful villages.

(6) International Development

With the maturation and promotion of prefabricated construction technologies in China, these innovations are expected to play a significant role in the international market, advancing the modernization of the global construction industry.

Finally, given that prefabricated buildings, as vehicles for industrialized construction, are still in their early stages, authoritative data remains limited. Overall, it is hoped that future efforts will focus on these areas to meet the fundamental requirements for the sustainability of prefabricated buildings, thereby achieving an ideal level of sustainability in domestic construction.

References

- Huang, C. (2018). Quantitative Analysis of the Impact of Prefabricated Components on Construction Costs. *Building Materials and Decoration*, 520(11), 198-199.
- Yang, Y. (2018). *Study on the Comprehensive Benefits of Prefabricated Buildings (Master's thesis)*. Anhui University of Architecture.
- Zhang, W., & Qiu, G. (2022). Current Status and Outlook of the Evaluation Index System for Sustainable Development of Prefabricated Buildings. *Jiangxi Building Materials*, 000-001.
- Zhou, Y. (2019). *Research on Cost Management of Prefabricated Buildings Based on Lean Theory (Master's thesis)*. Huazhong University of Science and Technology.