



The Global Trajectory of Prefabricated Construction: Rationale in the Face of Population Decline and Existing Bottlenecks

Zhiwei Cao^{1*}, Jinpeng Zhang¹, Pei Li¹, Lijian Lei²

¹ Shanghai China Construction Overseas Development Co., Ltd., Shanghai 200126, China

² China Construction Eighth Engineering Division. Corp, Shanghai 200135, China

*Email: czwscsec@163.com

Abstract. This paper comprehensively explores the prefabricated construction industry. While the United States and Japan have achieved a high level of industrialization in prefabricated construction, boasting advanced manufacturing and installation technologies, developing regions lag behind with relatively low adoption rates. With the global decline in the working - age population, prefabricated construction, known for its high efficiency and low labor - dependence, emerges as an essential solution for the sustainable development of the construction industry. Nevertheless, it faces challenges such as high initial investment, insufficient standardization, and a shortage of specialized talents. Therefore, concerted efforts from the government, enterprises, and research institutions are needed to address these issues, fully unlock the potential of prefabricated construction, and create a more efficient, sustainable, and resilient construction industry.

Keywords: Prefabricated construction; Construction industry development; Population decline; BIM technology; 3D printing technology

1 Introduction

In recent years, the construction industry has been undergoing a significant transformation, with prefabricated construction emerging as a crucial trend. Prefabricated construction, also known as prefab construction, involves the manufacturing of building components in a factory - controlled environment and then transporting and assembling them at the construction site. This method offers numerous potential benefits, such as reduced construction time, improved quality control, and lower labor requirements.

This paper aims to comprehensively explore the prefabricated construction industry. It will analyze the development history of prefabricated construction both overseas and domestically, discuss the impact of population decline on the construction industry and the role of prefabricated construction in addressing this issue, and identify and propose solutions to the existing bottlenecks in the development of prefabricated construction. By doing so, we hope to contribute to a better understanding of the prefabricated construction industry and provide insights for its future development.

2 Overseas Prefabricated Building Development

The development of prefabricated buildings can be traced back to the period of the First Industrial Revolution. In response to the design requirements of rapid construction and reusability after demolition, the British architect Joseph Paxton was the first to adopt the design concept of pre - manufacturing unit components in the factory and transporting them to the construction site for assembly^[1]. In 1850, he built the design exhibition hall for the British International Exposition, commonly known as the "Crystal Palace", as shown in Figure 1.



Fig. 1. The Crystal Palace in London, UK.

The Crystal Palace in London, UK, is an important achievement of the British Industrial Revolution. Evidently, the development of prefabricated buildings is closely related to the process of industrialization. The development process of prefabricated buildings in developed countries and regions can be divided into the following four stages:

1. Construction Industrialization 1.0 (Mechanized)

With the rise of the Second Industrial Revolution, the urban industries in developed countries witnessed rapid development, and a large number of rural people flocked to cities. The demand for housing and factory construction in cities increased significantly. Prefabricated buildings came into the public eye due to their short construction cycle, laying the foundation for the development of construction industrialization. Moreover, after World War II, the infrastructure in developed countries was severely damaged, and the available labor force in each country decreased sharply due to years of war^[2]. The extensive damage to housing and factory buildings in various countries, along with the shortage of available labor, made it urgent for developed countries to seek a construction method that could liberate the labor force and ensure efficient construction. As a result, prefabricated buildings experienced rapid development. At this time, the development of prefabricated buildings in each country was mainly government - led. Prefabricated components were produced in factories and then mechanically assembled on - site to achieve rapid construction and labor - force liberation.



Fig. 2. Khrushchev Building.

The representative prefabricated building of this era is the "Khrushchevka". In 1951, to address the serious shortage of housing in Moscow, Khrushchev proposed the development goal of improving residents' living conditions with the minimum cost in the shortest time. Subsequently, a large number of prefabricated residential buildings called "Khrushchevka" were constructed, as shown in Figure 2.

It can be seen that in the Construction Industrialization 1.0 era, prefabricated buildings achieved innovation in the concepts of industrialization and mechanization. However, due to the immaturity of management experience and related technologies, the cost of prefabricated buildings was relatively high, so they lacked corresponding market competitiveness. Most prefabricated projects were completed under government leadership.

2. Construction Industrialization 2.0 (Standardized & Modular)

With the advent of the Third Industrial Revolution, the economies of developed countries experienced rapid growth. At this time, due to the development of technologies related to prefabricated buildings and the improvement of management systems, prefabricated buildings gradually gained certain market competitiveness, and their product quality was significantly enhanced compared to the Construction Industrialization 1.0 era^[3].

Japan witnessed the most rapid development of prefabricated buildings during this period. Japan first proposed the concept of prefabricated buildings in 1968 and subsequently introduced a mid - to - high - rise residential building system with variable internal structures, which adopted a component - based and industrialized production approach^[4]. The strong intervention and support of the Japanese government played a crucial role in the development of prefabricated buildings. Firstly, the government ensured the quality of prefabricated buildings through legislation. Meanwhile, it adhered to technological innovation, formulating a series of guidelines, policies, and unified modulus standards for construction industrialization, thus resolving the contradiction among standardization, mass production, and housing diversification.

During this period, the United States also introduced a series of industry - standard specifications that are still in use today^[5]. The standardization, serialization, specialization, and socialization of components and parts have reached 100%. Users can purchase the required products through product catalogs. In addition to meeting quality requirements, American prefabricated buildings also set higher standards for aesthetics, comfort, and personalization.

It can be seen that in the Construction Industrialization 2.0 era, prefabricated buildings achieved conceptual innovation in standardization and modularization. However, during this period, prefabricated buildings mostly adopted the large - panel structural system. In fact, the large - panel structure has poor integrity, with stress concentration often occurring at the joints^[6]. Under seismic action, failures of horizontal and vertical joints are common.

3. Construction Industrialization 3.0 (Informatized & Industrialized)

The invention of the computer marked the official transition of humanity from the industrial age to the information age^[7]. With the research and development of planar - mapping software technology, Building Information Modeling (BIM) technology, 3D laser scanning technology, 3D printing technology, and network communication technology, prefabricated buildings have gradually shifted from standardized and modular construction forms to personalized and stylized ones.

By integrating BIM technology with prefabricated buildings, an integrated design covering architecture, structure, mechanical, electrical, and plumbing (MEP), and decoration disciplines can be achieved. This strengthens the synergy among various disciplines, thereby enhancing design efficiency. Moreover, BIM technology enables refined project management and optimal resource allocation. Common applications of BIM technology in prefabricated buildings currently include five - dimensional dynamic cost control, visual technical disclosure, and construction site management.

Five - Dimensional Dynamic Cost Control: The innovation of five - dimensional dynamic cost control based on BIM technology lies in the introduction of the dimensions of time and cost on the basis of the original three - dimensional building model. This technology can achieve rational resource allocation and project - duration optimization by simulating the actual on - site construction process.

Visual Technical Disclosure: The three - dimensional building model based on BIM technology can provide a full - scale three - dimensional spatial display of each building node. During the technical disclosure process from designers to construction workers, it can effectively prevent construction errors caused by misunderstandings of the drawings, thus improving the efficiency of the technical disclosure process.

Construction Site Management: Based on BIM technology, it is possible to carry out site layout and simulate the construction process of the actual site, which is of great significance for guiding the pre - construction site layout and construction - progress control.

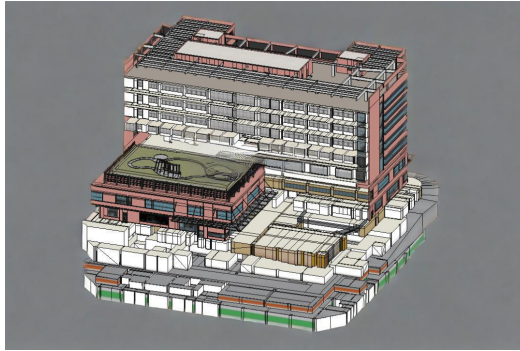


Fig. 3. 3D Laser Scanning Technology.

3D laser scanning technology represents a revolutionary advancement in surveying and mapping technology. It employs a laser scanning measurement method and can rapidly establish the three - dimensional spatial coordinates of the measured object. Compared with traditional surveying and mapping technologies, it features high precision, speed, and non - contact measurement. Additionally, traditional surveying and mapping technologies mostly adopt a single - point measurement mode, resulting in limited data. In contrast, 3D laser scanning technology uses a surface - measurement mode and can quickly obtain spatial coordinate data based on the surface of the measured object. 3D laser scanning technology is typically integrated with BIM technology. By uploading the spatial coordinate data obtained through 3D laser scanning technology to relevant BIM software, a three - dimensional spatial model of the measured object can be rapidly established. The application of 3D laser scanning technology in pre-fabricated buildings is shown in Figure 3.



Fig. 4. Mobius House.

As a technology that subverts the traditional construction mode, 3D printing technology has currently become a research focus in developed countries. The traditional concept of prefabricated buildings is to construct buildings in a manner similar to manufacturing cars, while the concept of 3D printing technology is to directly use robots for building construction. 3D printing technology integrates technologies such as 3D scanning, software design, mechanical construction, and material management for engineering construction. It offers numerous advantages, such as liberating the labor

force, improving construction accuracy, and reducing material costs. 3D printing technology can realize building forms that are difficult to achieve with traditional construction methods. For example, in 2015, architect Janjaap Ruijsenaars from the Amsterdam University of Architecture in the Netherlands designed the world's first 3D - printed building, the "Mobius House", as shown in Figure 4.

4. Construction Industrialization 4.0 (Intelligent & Energy - efficient)

With the advent of the Fourth Industrial Revolution, which is mediated by the Internet of Things, the German government was the first to include Construction Industrialization 4.0 as one of the top ten future development projects. The main characteristics of the Construction Industrialization 4.0 era consist of two parts. Firstly, it involves the establishment of "smart factories", which can achieve the intelligent production of prefabricated components through the integration of design software, communication systems, and sensors. The other characteristic is the "intelligent production" mode. Through Building Information Modeling (BIM) technology, refined project management can be realized, enabling better human-machine interaction, cost savings, and improved construction efficiency.

In addition, the Construction Industrialization 4.0 era places greater emphasis on requirements such as energy conservation, environmental protection, comfort, and aesthetics. The design of prefabricated buildings is gradually evolving towards a people-oriented approach, personalized customization, and intelligent building concepts.

3 Domestic Prefabricated Building Development

Since the founding of the People's Republic of China, China has been actively and vigorously developing prefabricated buildings. In the process of development, it has drawn on the relevant experience of developed countries. The development of prefabricated buildings in China has gone through the initial exploration stage, the development stagnation stage, and the restart stage.

1. Initial Exploration Stage

From the founding of the People's Republic of China to 1980, the Chinese government issued a large number of policies and regulations to promote the development of prefabricated buildings. The whole country made great efforts to develop prefabricated buildings and built a large number of precast component factories. In the "Decision on Strengthening and Developing the Construction Industry" issued by the State Council, it was proposed that prefabricated buildings should adhere to the design concept of mechanization and standardization.

2. Development Stagnation Stage

In 1976, a magnitude 7.8 earthquake, known as the Tangshan Earthquake, occurred in Tangshan City, Hebei Province. In the subsequent on - site earthquake damage investigation, it was found that the popular prefabricated large - panel shear - wall structure at that time was severely damaged in the earthquake. Many buildings had the phenomenon of entire floor slabs falling off. As a result, the seismic performance of prefabricated buildings was greatly questioned, and the development of prefabricated buildings entered a stagnation stage.

3. Restart Stage

After 2008, with the innovation of theories and the improvement of relevant technologies, more attention was paid to the connection performance of joints in prefabricated buildings. A more reliable monolithic prefabricated shear - wall structure came into view. At the same time, the government has strongly supported the development of prefabricated buildings. In September 2016, the "Guiding Opinions on Vigorously Promoting Prefabricated Buildings" issued by the State Council pointed out that prefabricated buildings should be developed in a way that suits local conditions across the country, and a strategic approach of giving priority to promotion in key areas and actively promoting in other areas was proposed. In addition, the Department of Science and Technology pointed out in the "Notice on the Key Points of Work in 2018" in 2018 that it was necessary to further promote the standardization process of prefabricated buildings and enhance the overall technical level of the prefabricated building industry.

Therefore, in order to achieve the goal of promoting construction industrialization, encouraging policies have been introduced in various places. The number of prefabricated residential projects built industrially has gradually increased, and the modernization of the construction industry has shown a rapid development trend.

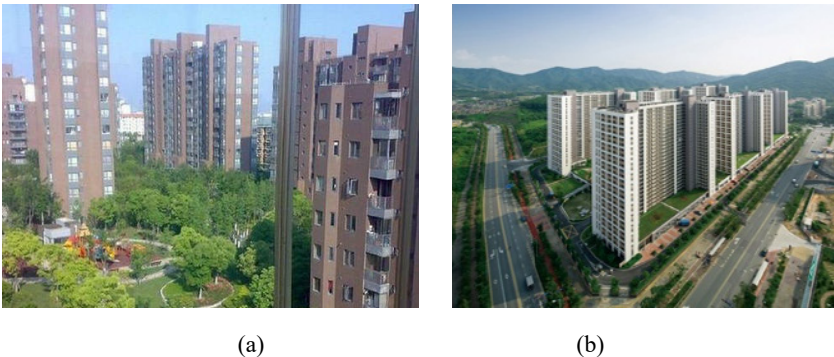


Fig. 5. Typical Prefabricated Buildings in China. (a) Vanke Xinlicheng, Shanghai; (b) Affordable Housing in Longhua Expansion Area, Shenzhen.

With the successive introduction of measures by local governments to compulsorily promote prefabricated buildings, prefabricated buildings have entered a stage of rapid development. Various technical standards have been gradually improved, and a number of influential prefabricated buildings have been built, as shown in Figure 5.

Despite the many achievements made in the development of prefabricated buildings, there are still many difficulties, which are specifically manifested in the following aspects:

(a) Innovation of Design Concept Urgently Needed

Currently, the design of prefabricated structural systems mostly directly adopts the design methods of cast - in - place structural systems, following the "equivalent to cast - in - place" design principle. However, the research on design theories suitable for prefabricated structural systems has not received sufficient attention, which has affected the development of prefabricated buildings.

(b) Complex Steel Bar Connection Process

The connection method of joint steel bars has always been a key focus in the research of prefabricated buildings. Currently, existing connection methods such as sleeve connection and restrained grouted anchor connection have disadvantages such as high cost, large on - site workload, and difficult quality assurance. The complex construction process also leads to high training costs for industrial workers, resulting in a shortage of experienced industrial workers on the actual site.

(c) Difficulty in Ensuring Component Quality

Currently, the production automation level of components for prefabricated structural systems is still seriously insufficient, especially for concrete - structure buildings. Many manual - operation processes are merely transferred from the construction site to the factory, resulting in no significant improvement in the actual production quality of components. At the same time, the transportation process of prefabricated components and the complex on - site installation process also lead to an extended construction period.

4 Population Decline: the Inevitable Rise of Prefabricated Buildings

The construction industry is inherently a labor - intensive sector, characterized by a high reliance on a substantial workforce. This reliance on human labor is deeply ingrained in its operational fabric. From the excavation of building foundations to the intricate installation of interior finishes, every stage of construction projects demands a significant input of manual labor. In the past, China's construction industry has greatly benefited from the demographic dividend. The abundance of young and relatively low - cost labor has provided a solid foundation for the rapid development of the industry. During the era of the demographic dividend, construction companies could easily access a large pool of workers, which not only ensured the smooth progress of construction projects but also contributed to cost - effectiveness. This cost - advantage, in turn, has been a driving force behind the construction of numerous large - scale infrastructure projects and real - estate developments across the country.

However, the Seventh National Population Census shows that since 2016, the number of newborns in China has been decreasing year by year. In 2016, the number of newborns in China was 17.86 million, while in 2020, it was only 12 million, a 33% decrease compared to 2016, as shown in Figure 6. At the same time, China's total fertility rate dropped to 1.3 in 2020, lower than the international warning line of 1.5. The continuous decline in the number of newborns indicates that the aging of China's population will inevitably deepen year by year, and the country will face long - term pressure of population aging in the future.

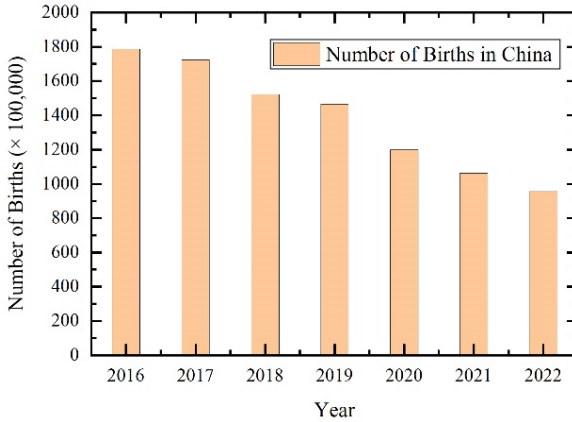


Fig. 6. Number of births in China.

According to relevant United Nations standards, when the population aged 60 and above in a country or region exceeds 10% of the total population, or the population aged 65 and above exceeds 7% of the total population, the country or region can be defined as an aging society. The distribution of the proportion of the population aged 60 and above in China is shown in Figure 7.

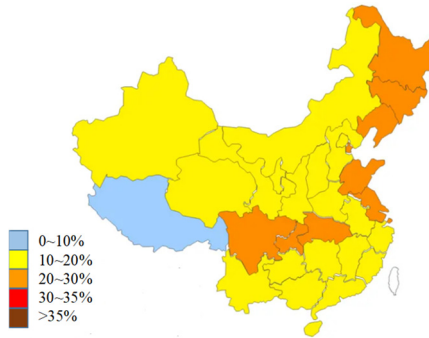


Fig. 7. Distribution of the Proportion of the Population Aged 60 and Above in China.

Based on the distribution of the proportion of the population aged 60 and above in China, among China's 34 provincial - level administrative regions, only the Tibet Autonomous Region has not entered an aging society at present. Among the ten provincial - level administrative regions that have entered a moderately aging society, the three northeastern provinces rank among the top four, and the rest of China's provincial - level administrative regions have entered an aging society.

With China's entry into an aging society and the continuous decline in the total fertility rate, it is inevitable that there will be changes in China's future population structure, and the labor - force population in the appropriate age group (16 - 60 years old) will continue to decrease. Taking the international total fertility rate baseline of 1.5 as

a standard, the prediction of China's population age structure in the next 40 years is shown in Figure 8.

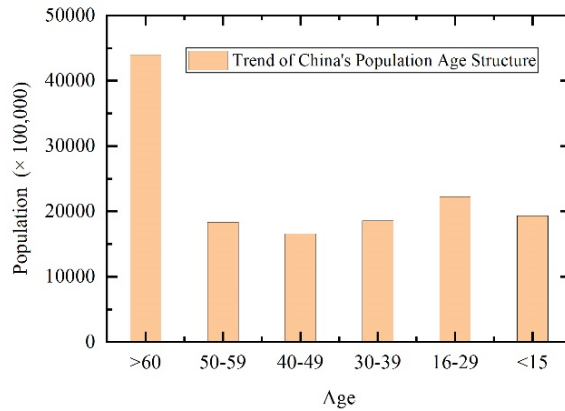


Fig. 8. Trend of China's Population Age Structure in 2050.

As can be seen from the prediction results of the trend of China's population age structure in 2050 in Figure 8, the labor - force population in the appropriate age group in 2050 will be reduced to 64% of that in 2020. The data on the trend of China's population age structure in the figure is sourced from the official database of the National Bureau of Statistics of China.. The model is constructed based on the United Nations' population projection methodology, with adjustments made in light of China's national conditions. Specifically, this model comprehensively takes into account historical data of China's birth rates, death rates, population migrations, etc. over the past few decades. It employs methods such as time - series analysis and multi - factor regression analysis to simulate and forecast the future population age structure. Through the dynamic analysis and integration of these factors, a relatively scientific and reasonable development trend of China's population age structure is presented. China's demographic dividend is facing disappearance. As the construction industry is a traditional labor - intensive industry, the cost advantage of cheap labor will be difficult to sustain. Therefore, it is particularly important to develop prefabricated buildings to liberate the labor force.

It can be seen that the difficulties encountered in the promotion of prefabricated buildings do not fundamentally deny the many advantages of prefabricated buildings^[8]. Instead, they indicate the necessity of further in - depth research and innovation on various technologies of prefabricated buildings. Due to its large lateral stiffness and bearing capacity, the monolithic prefabricated shear - wall structure is a commonly used prefabricated structural form in China at present. In view of the current problems of prefabricated buildings, such as the urgent need for innovation in design concepts, complex steel - bar connection processes, and difficulty in ensuring component quality, carrying out research on new prefabricated structures is the top priority in the development of prefabricated buildings today.

5 Overcoming Hurdles for Sustainable Development

Despite its potential, the development of prefabricated construction at present is confronted with multifaceted challenges, which can be grouped into technical, cost - related, market - driven, and human - resource - related categories.

1. Technical Hurdles

From a technical perspective, poor design collaboration is a significant issue. Designing prefabricated buildings requires the coordination of multiple disciplines, including architecture, structure, plumbing, and electrical engineering. However, incompatibility among design software used by different disciplines impedes data sharing, leading to frequent design conflicts. For instance, clashes between the positions of holes reserved in structural designs and the routing of mechanical and electrical pipelines often occur, necessitating substantial rework. Additionally, the reliability of component connections remains a concern. The integrity of prefabricated buildings highly depends on connection quality. Existing connection techniques are vulnerable to the skill level of construction workers. Under extreme loads such as earthquakes and strong winds, connection nodes are prone to looseness and cracking, jeopardizing the safety and durability of the structure. Moreover, the application of emerging technologies, such as 3D printing and Building Information Modeling (BIM), is hindered. The strength and durability standards for 3D - printed materials are yet to be fully established, and the depth and breadth of BIM implementation fall short, with software functionality not fully meeting business requirements.

To address these technical challenges, industry stakeholders should collaborate to develop interoperable design software platforms. This would facilitate seamless data transfer across different disciplines, reducing design conflicts. For connection technologies, research efforts should focus on developing more reliable and fool - proof methods, perhaps through the use of advanced composite materials. Standardization of 3D - printed materials and the improvement of BIM software functionality should be prioritized, with industry - wide standards established for their implementation.

2. Cost - Related Barriers

Cost - related obstacles are also prominent. Prefabricated construction demands significant upfront investment^[9]. Enterprises must build dedicated precast component manufacturing plants, purchase production equipment and molds, and invest in technology research and development as well as personnel training. The transportation of large - sized and heavy precast components further escalates costs. Additionally, due to the relatively small market scale of prefabricated buildings, manufacturing enterprises struggle to achieve economies of scale, resulting in high unit production costs. Fluctuations in raw material prices further complicate cost control.

To mitigate cost - related issues, government subsidies can play a crucial role in reducing the initial investment burden on enterprises^[10]. Encouraging the clustering of precast - component manufacturers can lead to shared resources, effectively lowering production and transportation costs. Additionally, long - term contracts with raw - material suppliers can help mitigate the impact of price fluctuations^[11].

3. Market - Oriented Difficulties

In the market domain, low consumer awareness poses a challenge. Most consumers lack understanding of the performance, quality, and safety of prefabricated buildings. Influenced by traditional cast - in - place construction concepts, they harbor biases against prefabricated buildings, believing them to be inferior in seismic resistance and construction quality, thus hampering market promotion. Moreover, the industrial chain for prefabricated construction is underdeveloped. The industry encompasses multiple stages, from design to operation, yet there is a lack of effective coordination among these stages, creating information silos. For example, poor communication between precast component manufacturers and construction companies often leads to untimely component deliveries, delaying construction schedules^[12].

To boost market acceptance and optimize the industrial chain, targeted marketing campaigns are needed to educate consumers about the advantages of prefabricated buildings, such as shorter construction times, higher quality control, and environmental friendliness. Strengthening the industrial chain requires the establishment of information - sharing platforms, enabling better communication between all parties involved, from design to construction^[13].

Human Resource Shortages

Finally, there are shortages in human resources. There is a dearth of interdisciplinary professionals who are proficient in design, production, and construction. The education system in higher - education institutions lags behind industry demands, with curricula misaligned with practical requirements. Insufficient corporate investment in employee training also restricts the upgrading of workforce skills. Additionally, front - line construction workers lack the necessary skills. The construction techniques for prefabricated buildings differ significantly from traditional cast - in - place methods. Most front - line workers, with limited educational backgrounds and insufficient systematic training, struggle to grasp new construction techniques, undermining construction quality.

To overcome human resource shortages, higher - education institutions should update their curricula to incorporate the latest trends in prefabricated construction. Enterprises should also increase their investment in employee training, providing on - the - job learning opportunities. Offering attractive incentives can help attract and retain interdisciplinary talent, while vocational training programs can enhance the skills of front - line workers.

By implementing these comprehensive measures, the prefabricated construction industry can overcome current bottlenecks, contributing to more sustainable, efficient, and high - quality construction practices.

6 Conclusion

This study embarked on a comprehensive exploration of the global prefabricated construction landscape, underscoring its crucial role, especially in the context of the global decline in the working - age population.

1. Existing Deficiencies

Presently, the prefabricated construction sector confronts substantial technological bottlenecks. Despite the emergence of advanced technologies like 3D printing and

BIM, integration among these technologies remains fragmented. Design software used across different stages—from design to construction—exhibits poor compatibility, leading to data transfer issues and inefficiencies.

Connection techniques for prefabricated components are unreliable, with their integrity highly dependent on workers' skills. Standards for novel construction materials and 3D - printed elements are still in the nascent stage. These technological lacunae not only impede the adoption of innovative construction methods but also undermine the industry's potential to enhance productivity, reduce costs, and ensure long - term structural integrity.

2. Future Prospects

Moving forward, prefabricated construction is set to embrace technological innovation, policy - driven development, market expansion, and talent - based progress. The integration of 3D printing, AI, and BIM will drive technological breakthroughs. Governments globally are expected to roll out more incentives. Surging demand in emerging economies will fuel global market expansion. Moreover, the cultivation of interdisciplinary talents and upskilling of front - line workers will inject impetus into the industry's development.

By addressing these existing bottlenecks and capitalizing on future opportunities, prefabricated construction indeed holds the key to revolutionizing the construction industry, making it more efficient, sustainable, and resilient. This will enable it to better meet the housing and infrastructure demands of a changing global population, thereby contributing significantly to the long - term prosperity of the construction sector and society at large.

In conclusion, prefabricated construction holds the key to revolutionizing the construction industry, making it more efficient, sustainable, and resilient. By addressing existing bottlenecks through a multi - pronged strategy, we can create a future where prefabricated construction meets the housing and infrastructure demands of a changing global population, contributing to the long - term prosperity of the construction sector and society at large.

Acknowledgments

This work was financially supported by Science and Technology Research and Development Project of China Construction Eighth Engineering Division (2024-3-08)

References

1. Liang, X. and Zeng, S., "Research on the Application of BIM Technology in Prefabricated Building Projects," SAE Technical Paper 2020-01-0012, 2020, doi:10.4271/2020-01-0012.
2. Wang, Y. and Li, H., "Analysis of the Cost - control Factors in Prefabricated Construction," SAE Technical Paper 2020-01-0034, 2020, doi:10.4271/2020-01-0034.
3. Zhang, H. and Chen, X., "Study on the Market Promotion Strategies for Prefabricated Buildings," SAE Technical Paper 2020-01-0056, 2020, doi:10.4271/2020-01-0056.

4. Chen, J. and Yang, Y., "The Impact of Population Decline on the Development of Prefabricated Construction Industry," SAE Technical Paper 2021-01-0023, 2021, doi:10.4271/2021-01-0023.
5. Li, X. and Liu, Y., "Technical Challenges and Countermeasures in Prefabricated Building Construction," SAE Technical Paper 2021-01-0045, 2021, doi:10.4271/2021-01-0045.
6. Zhao, Y. and Wu, Z., "Research on the Innovation Design of Prefabricated Buildings," SAE Technical Paper 2022-01-0018, 2022, doi:10.4271/2022-01-0018.
7. Qian, H. and Sun, L., "Quality Control of Prefabricated Building Components," SAE Technical Paper 2022-01-0037, 2022, doi:10.4271/2022-01-0037.
8. Wang, Z. and Huang, X., "Development Trends of Prefabricated Construction in the Context of Intelligent Manufacturing," SAE Technical Paper 2022-01-0059, 2022, doi:10.4271/2022-01-0059.
9. Han, X. and Zhou, H., "Optimization of the Industrial Chain of Prefabricated Construction," SAE Technical Paper 2023-01-0021, 2023, doi:10.4271/2023-01-0021.
10. Zhu, Y. and Deng, X., "Solutions to the Shortage of Talents in the Prefabricated Construction Industry," SAE Technical Paper 2023-01-0044, 2023, doi:10.4271/2023-01-0044.
11. Liu, Z. and Cai, Y., "Cost - effective Analysis of Prefabricated Buildings with Consideration of Environmental Factors," SAE Technical Paper 2024-01-0015, 2024, doi:10.4271/2024-01-0015.
12. Sun, X. and Chen, Z., "Improving the Market Acceptance of Prefabricated Buildings through Public Awareness Campaigns," SAE Technical Paper 2024-01-0036, 2024, doi:10.4271/2024-01-0036.
13. Ma, Y. and Xu, J., "The Application of 3D Printing Technology in Prefabricated Construction: Challenges and Opportunities," SAE Technical Paper 2024-01-0058, 2024, doi:10.4271/2024-01-0058.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

