

# *Retrospection of Research on the Development of Domestic Prefabricated Buildings Based on Citespace*

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**Abstract:** In order to objectively and quantitatively sort out the development and research status of prefabricated buildings in China, based on the first 5,000 papers in the database of China CNKI, which are ranked in the order of correlation with the keyword "prefabricated buildings+modular buildings", this paper uses Citespace software to co-occurrence analyze the keywords in the literature, and draws a cluster map for research, and analyzes and summarizes the development status, research hotspots and keywords of prefabricated buildings in China in recent years. The results show that, although its development almost stagnated before the 21st century, since the 21st century, China's prefabricated buildings have developed very rapidly, and the state attaches great importance to it and advocates the use of prefabricated buildings as a construction method. In addition, in recent years, domestic scholars have focused on the following seven aspects: fabricated building construction technology, fabricated building design foundation, fabricated building cost research, fabricated building development, fabricated building earthquake resistance research, fabricated building and green building, fabricated building construction safety research. Based on the research results and the research experience and application status of prefabricated buildings abroad, this paper looks forward to the development and research hotspots of prefabricated buildings in the next 3-5 years, and thinks that the combination of high-tech and prefabricated buildings will attract the attention of scholars.

## 1. Introduction

After the end of the Second World War, many western European countries began to vigorously promote prefabricated buildings because of the serious damage to domestic residents' houses. Since then, prefabricated buildings have gradually become popular in the world. Compared with traditional methods, prefabricated buildings have unique advantages in shortening the construction period, saving energy and reducing consumption<sup>[1]</sup>. Hamad et al. think that compared with

traditional methods, the social, environmental and economic costs of prefabricated construction methods are 21 percent, 52 percent and 60 percent better than those of traditional methods on average<sup>[2]</sup>. At present, prefabricated buildings have developed well in some developed countries such as the United States and Japan. Although our government issued a document advocating prefabricated construction in 1956, for various reasons, the development of prefabricated buildings in China was not ideal until the 21st century.

In view of the development of prefabricated buildings in China, domestic scholars have combed it. For example, Qi Baoku, etc., through analyzing the development status of prefabricated buildings at home and abroad, analyzed the problems faced by the development of prefabricated buildings in China from the aspects of policies, regulations and technical systems<sup>[3]</sup>. Through investigation in Yang Yingying, it was found that the project cost was too high, the components could not be mass-produced, and the management mechanism was relatively backward, which restricted the development of prefabricated buildings<sup>[4]</sup>. Zhang Jun and others analyzed the present situation and existing problems of prefabricated buildings in Tai 'an City, Shandong Province, and put forward some countermeasures and suggestions on how to promote their development<sup>[5]</sup>. All these studies have made necessary contributions to the development of domestic prefabricated buildings, but there are still some limitations. Most of the existing studies rely on subjective content interpretation, and few scholars use measurement tools to analyze it. In addition, there are few scholars who sort out the development history of prefabricated buildings in China, mostly focusing on the research hotspots of prefabricated buildings in China in the last ten or twenty years. Quantitative research based on Citespace can objectively reflect the research hotspots and trends in a certain field and better sort out its development situation.

To sum up, it is necessary to sort out the development and research status of domestic prefabricated buildings objectively and quantitatively. In this paper, Citespace-6.1.3 software is used as a tool to study the development and research status of prefabricated buildings, and the database of China CNKI is searched. On this basis, Citespace software is used to co-occurrence analyze the keywords in the literature, and a cluster diagram is drawn.

## 2. Research Methods

Citespace, also known as "citation space", is a visual analysis tool. It can intuitively reflect the distribution and law of scientific knowledge, and the graph obtained by this software is called "Knowledge Map", which uses graphs to express the current research trend of a certain discipline<sup>[6]</sup>.

## 3. Data Sources

Searching the keyword "prefabricated building+modular building" in China CNKI database, up to the time of searching, a total of 10,682 results were retrieved. According to the order of correlation, 5,000 papers were selected, and the keywords were co-occurrence analyzed by Citespace, and the related knowledge map was obtained by cluster analysis.

## 4. Development Status of Domestic Fabricated Buildings

Through the study of the development history of prefabricated buildings in China, it can be found that the official promotion of prefabricated buildings in China should start from 1956. In the Decision of the State Council on Strengthening and Developing Construction Industry issued by our government in 1956, prefabricated structures and components were officially introduced for the first time, which marked the beginning of prefabricated buildings in China<sup>[7]</sup>. In 1980s, prefabricated buildings developed rapidly. However, in the 1990s, the problems such as earthquake resistance,

water leakage and poor thermal insulation performance of prefabricated buildings have not been solved. At this stage, the development progress of prefabricated buildings in China has almost stagnated, and the building construction mode has changed from prefabricated construction to cast-in-place concrete structures that are well known to the public and are now popular<sup>[8]</sup>. After entering the 21st century, with the progress of construction technology, prefabricated buildings reappear in people's sight.

Based on the above-mentioned retrieval data, this paper uses Citespace to make a time chart as shown in Figure 1 and a mutant word list as shown in Table 1.

Comprehensive analysis of the time chart in Figure 1 and the mutant word list in Table 1 shows that:

1) When setting the analysis indicators in the software, the starting and ending years of the analysis are from January 1956 to August 2022, but the first node shown in the time chart is around 2002, which shows that before 2002, the prefabricated buildings did not attract the attention of domestic scholars, and only in 2002 did the more obvious keyword nodes appear, after which the prefabricated buildings gradually entered the scholars' field of vision, which is consistent with the trend reflected in Figure 2. Figure 2 is a graph generated by visual analysis of the data of papers in 2013 and before after the key word of China How Net database is "prefabricated buildings". In Figure 2, the horizontal axis represents the year, and the vertical axis represents the number of articles published (unit: articles).

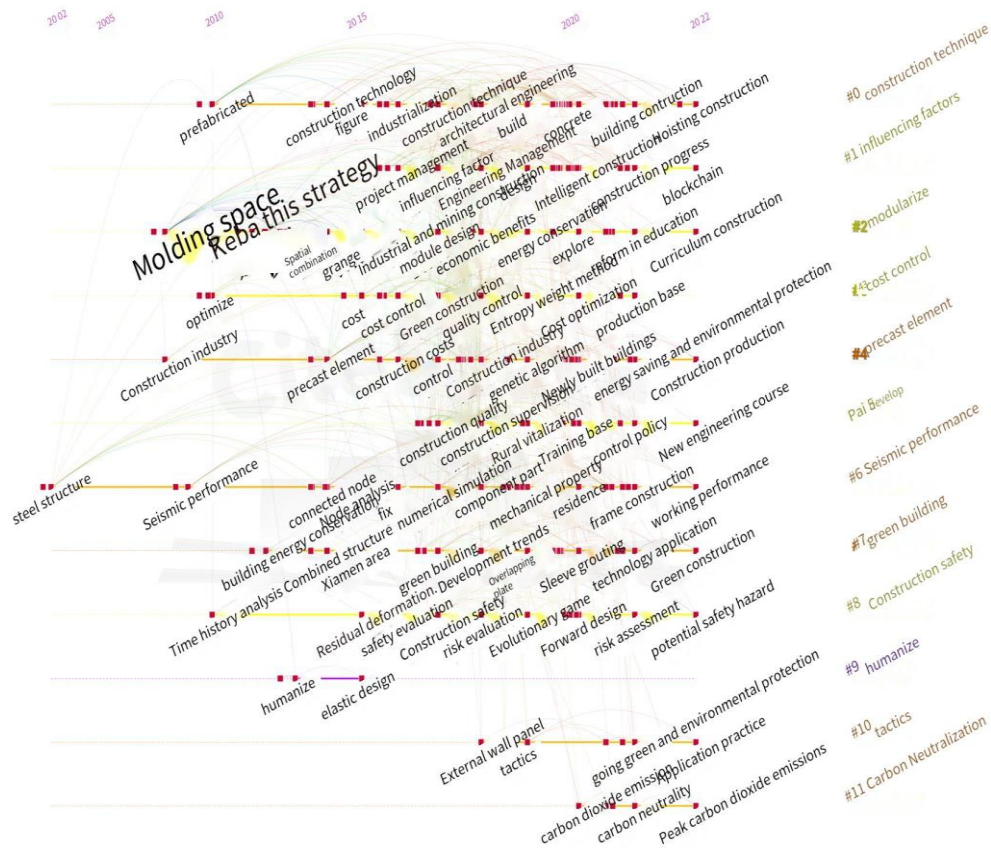


Figure 1: Time line diagram of assembled building research.

Table 1: Mutation word list of fabricated building research.

Keywords	Year	Strength	Begin	End	2000 - 2022
modularize	2000	23.96	2008	2017	
standardization	2000	4.32	2012	2018	
project management	2000	3.38	2016	2018	
develop	2000	8.14	2017	2019	
restraining factor	2000	5.97	2017	2019	
quality	2000	5.2	2017	2019	
Construction quality	2000	3.35	2017	2018	
counter-measure	2000	8.86	2018	2019	
status	2000	4.8	2018	2019	
development situation	2000	4.67	2018	2019	
application research	2000	4.41	2018	2020	
Cast-in-place building	2000	4.18	2018	2020	
suggestion	2000	3.91	2018	2019	
cost	2000	3.75	2018	2019	
Bottleneck of development	2000	3.42	2018	2019	
Development countermeasures	2000	3.42	2018	2019	
development prospect	2000	3.4	2018	2019	
question	2000	4.33	2019	2020	

2) From 2002 to 2016, scholars gradually began to pay attention to prefabricated buildings, a new building style. The key words in this stage were mostly modularization and standardization, and the intensity of abrupt words reached 23.96 and 4.32, respectively. At this stage, as prefabricated buildings just entered people's field of vision, scholars' research focused on their own construction technology, seismic performance, modular assembly and so on. At the same time, because it is a new technology, some scholars are also discussing the standardization of its technical system<sup>[9]</sup>. In addition, in 2010, the State Council issued a notice requiring all units to carry out safety production standardization work such as "post standard", "professional standard" and "enterprise standard"<sup>[10]</sup>. Some scholars also study the connection between prefabricated buildings and them<sup>[11]</sup>.

3) From 2016 to 2020, scholars are most concerned about the development of prefabricated buildings and the countermeasures to deal with the difficulties in development, and the corresponding mutation strengths of two keywords are 8.14 and 8.86 respectively; In addition, at present, domestic scholars have studied the factors affecting the development of prefabricated buildings, construction quality, development bottlenecks, problems, costs and other issues. During this period, China's prefabricated buildings developed rapidly. Figure 3 also confirms this conclusion from the side. In Figure 3, the horizontal axis represents the year, and the vertical axis represents the number of articles published (unit: articles).

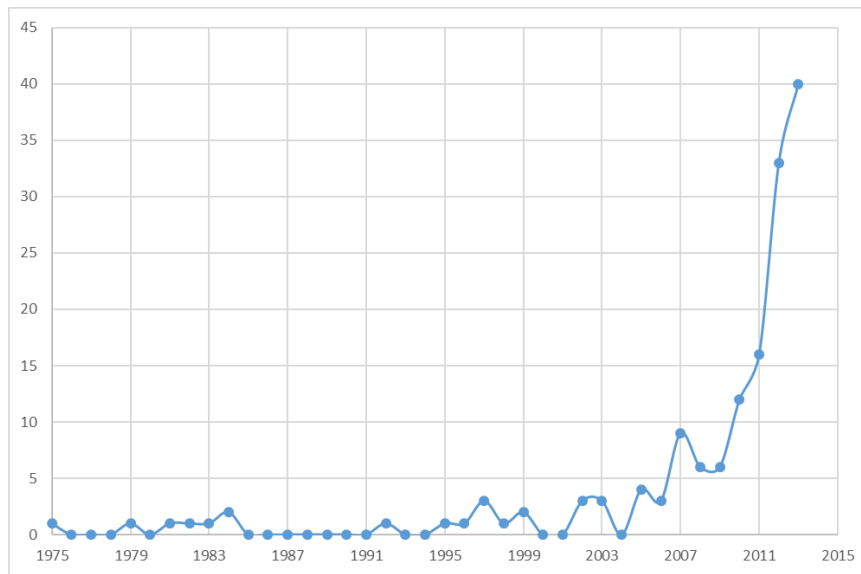


Figure 2: The general trend of the number of papers published on prefabricated buildings (until 2013).

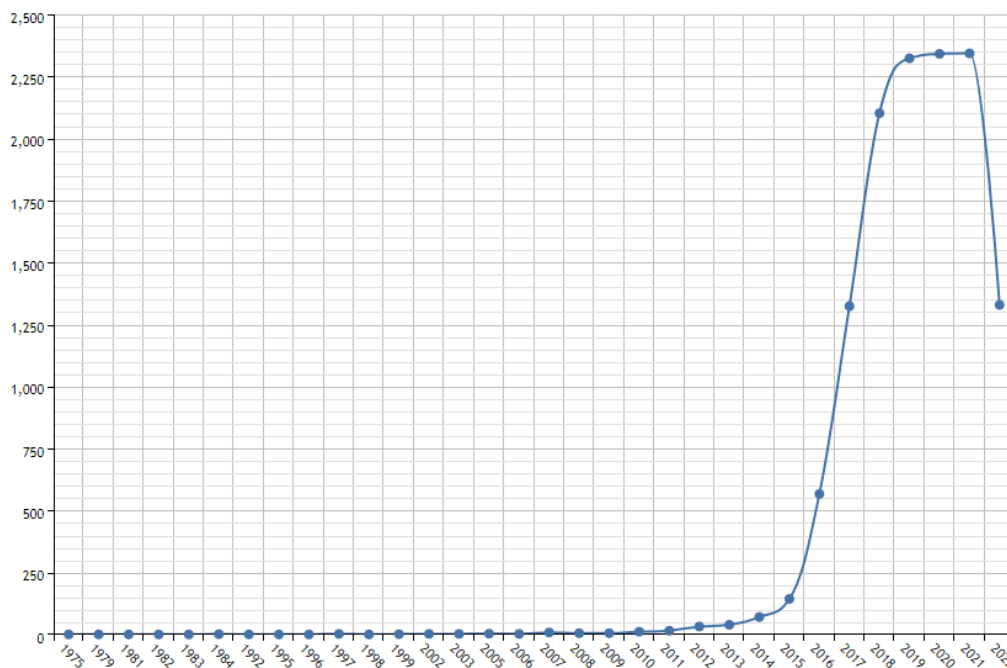


Figure 3: The general trend of the number of papers published on prefabricated buildings (until 2021).

The reason, this paper thinks, is the progress of technology and the attention and advocacy of the state. In 2016, the Guiding Opinions of the General Office of the State Council on Vigorously Developing Prefabricated Buildings was released, which stipulated that within 10 years, the proportion of prefabricated buildings in new buildings would be increased to 30 percent<sup>[12]</sup>. At the same time, many provinces and cities in China have also made corresponding responses. For example, Beijing issued the Implementation Opinions of the General Office of Beijing Municipal People's Government on Accelerating the Development of Prefabricated Buildings<sup>[13]</sup>. Shenzhen issued the Notice of Shenzhen Housing and Construction Bureau on Accelerating Prefabricated Buildings, which ushered in a new chapter in the development of prefabricated buildings.



## 5. Domestic Research Status of Prefabricated Buildings

Based on the above-mentioned retrieval data, this paper made a co-occurrence map as shown in Figure 4 and a cluster map as shown in Figure 5 by Citespace.

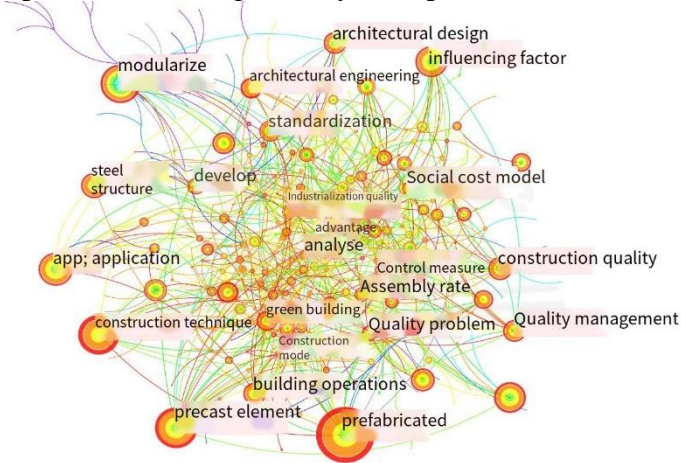


Figure 4: Co-occurrence Atlas of Key Words in the Research Field of Prefabricated Buildings in China from 2000 to 2022.



Figure 5: Cluster map of key words in the research field of prefabricated buildings in China from 2000 to 2022.

A node in the map is a keyword, the size of the circle represents the frequency of the corresponding keyword, and the connection between nodes indicates the co-occurrence relationship between the two keywords<sup>[14]</sup>.

A total of 540 keyword nodes (N=540) were generated in the map, and 897 links (E=897) of different keywords appeared in the same article, with a network density of 0.0062 (Density=0.0062).

Statistics and detailed interpretation of the clustering results in Figure 5 will help researchers sort out the research contents in this field in recent 20 years and understand the research hotspots. The statistical results of keyword clustering are shown in Table 2.

Table 2: Statistical table of clustering results.

Serial number	Keyword representation	Core keywords
0	construction techniques	...
1	Influencing factor	...
2	modularize	Architecture design; Honeycomb structure; Precast concrete; Assembled concrete building; Design basis; Assembled building; Structural optimization; Finite element analysis; Lifting platform; economic benefits
3	Cost control	Assembled building; Cost control; Value engineering; Dematel model; Ant colony algorithm; Pc components; Construction cost; Hierarchical analysis; Green construction; be imperative (under the circumstances)
4	Precast elements	Prefabricated components; Genetic algorithm; Production scheduling; Optimization model; Guangdong-Hong Kong-Macao Greater Bay Area; Assembled building; Construction quality; Tower crane; Optimization of layout; Crane selection
5	develop	Prefabricated components; Genetic algorithm; Production scheduling; Optimization model; Guangdong-Hong Kong-Macao Greater Bay Area; Assembled building; Construction quality; Tower crane; Optimization of layout; Crane selection
6	Seismic performance	Assembled building; Cast-in-place technology; Dry connection; Strong column and weak beam; Shaking table test; Seismic performance; Connecting nodes; Modular building; Finite element analysis; ultimate bearing capacity
7	Green buildings	Assembled building; Green building; Technology; Development trend; Fuzzy comprehensive evaluation; Sleeve grouting; Waterproof and heat preservation; Complete assembly; Flowability; Grey relational analysis method
8	Construction safety	Assembled building; Optimization model; Affordable housing; Evaluation model of mutual clearance promotion; Construction safety; System dynamics; Dynamic supervision mechanism; Factor analysis method; Fuzzy analytic hierarchy process
9	humanize	Medical building; Reconstruction and expansion; Space; Streamline; Modularization; humanize

As can be seen from the co-occurrence diagram, from 2000 to 2022, the research of Chinese scholars is mostly related to the construction technology, cost control, quality management, architectural design, seismic performance, green building, etc. of prefabricated buildings.

According to the statistical table of clustering results, the ten largest clusters in the field of prefabricated buildings in China from 2000 to 2022 are: #0 construction technology; #1 influencing factors; #2 Modularization; #3 Cost control; #4 prefabricated components; #5 Develop #6 seismic performance; #7 Green building; #8 Construction safety; #9 Humanization. According to the core keywords, it is found that the main research content at this stage are:

### 1) Assembly building construction technology

Sun Xiao and others analyzed the construction technology of concrete prefabricated buildings<sup>[15]</sup>. Liu analyzed and discussed the application of prefabricated building construction technology in construction management<sup>[16]</sup>. Zhang Tiezhong analyzed the advantages and disadvantages of fabricated construction technology and studied its application strategy<sup>[17]</sup>. By analyzing and summarizing the project examples, Wang Fengqi elaborated the related construction technology<sup>[18]</sup>. Ling-KunChen et al. introduced the application of high-tech such as BIM in prefabricated construction in emergency engineering projects<sup>[19]</sup>.

### 2) Prefabricated building design foundation

Xu Yong and others found that PKPM developed PKPM-PC by BIM technology to meet the demand of prefabricated buildings, which can improve the design efficiency<sup>[20]</sup>. Peng Linli et al. summed up the highly integrated construction mode of architectural design, construction, fabrication and installation in China in the engineering design and construction practice of Thunder God Mountain hospital, and pointed out that modular assembly system has a broad development prospect in engineering practice<sup>[21]</sup>. Xiang Yiming optimized the existing engineering recording methods, introduced the building requirements into the architectural design, and improved the design quality of prefabricated buildings<sup>[22]</sup>. Qing Yin, etc. made research on the construction technology of steel structure prefabricated buildings<sup>[23]</sup>. Jing Zhou et al. designed a quantitative evaluation model to analyze the external benefits of prefabricated buildings<sup>[24]</sup>. Yixu et al. developed a BIM-based life cycle assessment system to assess the carbon emissions of prefabricated buildings<sup>[25]</sup>. Tan et al. revealed the main obstacles to the application of BIM in prefabricated buildings in China, and their research results can promote the combination of BIM and prefabricated buildings<sup>[26]</sup>.

### 3) Study on the cost of prefabricated buildings.

Li Qi, et al. obtained the cost structure of prefabricated building projects through project verification, and analyzed and explored the phenomenon of high cost of prefabricated building projects<sup>[27]</sup>. Chang Chunguang, etc. analyzed the cost control in the production process of prefabricated components from the angles of component processing drawing design and mold design, and summarized the principles and control methods of cost control in construction enterprises<sup>[28]</sup>. In order to solve the contradiction between production technology and industrial organization mode, Gu Shujia put forward the complete mode of design and construction integration and the cooperation mode of design and construction integration<sup>[29]</sup>. Through the construction of SD model of cost control of prefabricated buildings in Jia Lei and the demonstration in the project, the key factors affecting the cost of prefabricated buildings are obtained, and the cost control measures are put forward<sup>[30]</sup>. Qin Hongbo analyzed the cost of prefabricated buildings, analyzed the cost difference with traditional buildings, and found out the reasons for the cost increase. He believed that the cost in the design and construction stages should be paid more attention to<sup>[31]</sup>.

### 4) Development of prefabricated buildings

Zhang Zhaobi and others introduced the current situation at home and abroad. Finally, they put forward some views on how to develop prefabricated buildings in China<sup>[32]</sup>. Guo Liang analyzes the development and restrictive factors of prefabricated buildings under the current situation of green building development in China<sup>[33]</sup>. Combining the development history and the present situation at home and abroad, Zhang Xin analyzes the problems faced by the development of prefabricated buildings in China at present<sup>[34]</sup>. From the perspective of sustainable development, Seo Woo Meng established an evaluation model for the sustainable development of prefabricated buildings<sup>[35]</sup>. Yu Longfei and others summarized the research progress of fabricated buildings at home and abroad and pointed out the key research direction of fabricated buildings after a period of time<sup>[36]</sup>. Yang



Xiaowei analyzed the technology of prefabricated buildings at home and abroad from many angles, and summarized the development trend and research results of prefabricated buildings suitable for our country<sup>[37]</sup>. Menqiyuan et al., based on the evolutionary game theory, explored the evolutionary decision-making behavior of three stakeholders in prefabricated building industry: government, real estate developers and buyers<sup>[38]</sup>. Yuan Chang et al. studied the advantages and disadvantages of prefabricated buildings from the perspectives of productivity, resources and environmental sustainability<sup>[39]</sup>.

#### 5) Research on earthquake resistance of prefabricated buildings.

Through comparative study, Li Jun found that the overall seismic performance of prestressed fabricated structure is basically the same as that of cast-in-place structure, but the residual deformation is far less than that of cast-in-place structure<sup>[40]</sup>. Lai Zhongyi put forward a superimposed (combined) prefabricated building system, which can be applied to high-intensity seismic fortification areas<sup>[41]</sup>. Wu Jingjing, et al. consulted a large number of literatures, made a comprehensive analysis of them, and came to the conclusion that it is feasible to use prefabricated buildings in earthquake-prone areas<sup>[42]</sup>.

#### 6) Prefabricated buildings and green buildings

Liao Liping analyzed the problems existing in the development of prefabricated buildings from the perspective of green buildings<sup>[43]</sup>. Yang Meilin put forward a comprehensive evaluation system of green prefabricated buildings<sup>[44]</sup>. Hou Sijie and others discussed the factors that influence the combined development of prefabricated buildings and green buildings<sup>[45]</sup>. Sisi Yu et al. summarized the effect and influence of prefabricated buildings on emission reduction<sup>[46]</sup>. Xiaoyan Wang et al. discussed the implementation effect of low-carbon practice from the perspective of prefabricated building supply chain, and the research results can help the government formulate policies on carbon emission reduction<sup>[47]</sup>. Xiao-Juan Li et al. investigated the carbon footprint of prefabricated buildings and their materialization stages, which provided a theoretical basis for the formulation of policies and regulations on building energy conservation and emission reduction<sup>[48]</sup>.

#### 7) Research on construction safety of prefabricated buildings.

Li Haoran, etc. used structural equation model to analyze the correlation between risk factors, and ranked the risks in each stage of prefabricated building construction<sup>[49]</sup>. Chang Chunguang et al. put forward WBS-RBS-G1 risk assessment method for qualitative and quantitative analysis of the construction safety of prefabricated buildings<sup>[50]</sup>. Ou Shu analyzed the safety problems existing in building construction, and gave relevant countermeasures<sup>[51]</sup>. Chen Wei and others established SD-MOP model, analyzed the key factors of emergency safety investment, and evaluated the optimal allocation of its resources<sup>[52]</sup>. Duan Yonghui and others used SEM model to study the safety of prefabricated building construction, and believed that the fundamental strategy to improve the safety of construction lies in vigorously improving the transportation and unloading of prefabricated components on site, regularly checking the control of hazard sources on site and strengthening the safety awareness of construction personnel<sup>[53]</sup>.

## 6. Conclusion

### 6.1. Summary

In this paper, the first 5000 papers in the database of China CNKI, which are ranked in the order of correlation with the keyword "prefabricated buildings+modular buildings", are used as data sources. Citespace software is used to review the development of prefabricated buildings, and its recent research focuses and keywords are analyzed. The conclusions are as follows:

1) From the development trend, China's prefabricated buildings began to develop in 1956. Although the development almost stagnated for a period of time, with the progress of technology

and the attention and advocacy of the state, its development ushered in a new chapter, and it developed more rapidly in the last decade.

2) From the research hotspots and key words, domestic scholars mainly study fabricated buildings in seven aspects, namely: fabricated building construction technology, fabricated building design foundation, fabricated building cost research, fabricated building development, fabricated building earthquake resistance research, fabricated building and green building, fabricated building construction safety research.

The main deficiency of this paper is that the data source is limited to China HowNet, which does not involve foreign data. Therefore, the analysis of this paper is not comprehensive, and the follow-up research will further consider adding foreign data.

## 6.2. Outlook

Based on the development and research status of prefabricated buildings in China, this paper holds that:

1) In view of the national advocacy and the characteristics of prefabricated buildings in shortening the construction period and saving resources, prefabricated buildings will still have a large development space in China in the future. With the gradual maturity and improvement of the construction technology and technical system of prefabricated buildings, its market share will continue to expand, and it will probably replace cast-in-place buildings as the mainstream of the market in the future.

2) From the research results of this paper, at present, domestic scholars tend to study "self-products" such as development countermeasures, seismic performance and construction quality of prefabricated buildings, while there are few in-depth and multi-faceted studies on them. However, foreign countries with better development of prefabricated buildings are not limited to their own research on this construction mode. They begin to turn their attention to other aspects of prefabricated buildings, such as construction planning and coordination, application of prefabricated buildings in high-rise building construction, etc., and combine some digital tool technologies with them. To sum up, referring to foreign scholars' research experience and application status of prefabricated buildings, this paper holds that with the maturity of China's prefabricated building technology and technical system, the research direction of China's prefabricated buildings will gradually shift to the project management and scheduling of prefabricated buildings, and the combination of BIM, RFID and other high-tech and prefabricated buildings. The combination of high-tech and prefabricated buildings will become a new research hotspot.

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