

Analysis of the Development History of Green Building Design in China Based on CiteSpace

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Abstract. As environmental problems become more and more prominent, green building, as a sustainable design concept, has become the dominant trend in the future development of the construction industry. In this paper, using China Knowledge Network (CNKI) as the literature database, by searching the literature related to green building design in China and using CiteSpace to visualize and analyze the literature, it is concluded that the development history of green building in China is divided into three phases: the beginning, the development, and the maturity. The starting stage is the stage where researchers study foreign materials and explore the direction of green building development in China after coming into contact with the emerging concept of green building; the development stage is the stage where researchers study the relevant technologies of green building after the theoretical accumulation of the previous stage and carry out a certain amount of practice in order to explore their rationality; the maturity stage is the stage where, on the basis of the theoretical and technological accumulation of the previous two stages, mature technologies are applied to China's domestic green buildings and the development of green building design. The mature stage is based on the accumulation of theories and technologies in the previous two stages, and the mature technologies are applied to the construction of green buildings within China. This paper analyzes the development history, summarizes the achievements made so far, and puts forward suggestions for the future development of green buildings in China.

Keywords: Green Building, Design, Development History, CiteSpace, Visualization Mapping.

1. Introduction

With the rapid development of the global economy, environmental problems are becoming more and more serious, and the concept of sustainable development has gradually become the focus of attention of all sectors of society. Green building combines the concept of sustainable development with the traditional construction industry, which promotes the development of the construction industry, but also makes the environmental burden not too serious, and is the dominant trend in the future development of buildings [1].

Green building is a new definition of architectural design, also known as sustainable building design, which is defined as a high-quality building that saves natural resources as much as possible during the whole life cycle of the building, so that the environment can be protected and pollution can be reduced, maximizing the realization of the harmonious coexistence of human beings and nature, and providing people with healthy and comfortable living conditions [2]. However, in practice, the promotion of green buildings faces challenges such as technical constraints, unequal distribution of benefits, and practical construction difficulties. In addition, due to the low level of public awareness and attention to green buildings, the concept of green buildings has not been widely popularized, and the government urgently needed to promote its development through policy guidance publicity, and education.

The purpose of this paper is to analyze the literature on green building design and development in China in the past two decades by using Cite Space literature data analysis software to summarize the data. This paper aims to analyze the literature on green building design and development in China in

the past two decades by using Cite Space literature data analysis software and summarize the data, in order to sort out the timeline of the development of green building design in China in the past two decades and look for the key time nodes in the process of development, and at the same time, put forward an appropriate amount of strategies for the development of green building design in China in the future, for the industry's reference and reference and to provide ideas for similar research in future.

2. Data sources

In this study, China Knowledge Network (CNKI) was chosen as the search database, which is the most comprehensive academic resource database in China, with a wide range of literature coverage and research significance. The "academic journals" were used as the sample data source to ensure the interpretability, credibility and quality of the original data [3]. When searching, "advanced search" is used, with "subject" as the search path, and "China green building design" and "China green building construction technology" as the search path. Building construction technology" as search terms to search data, as of September 30, 2024, a total of 1008 articles were searched. After eliminating the literature that did not match the theme and research direction of the articles through human search, we imported them into CiteSpace software for de-weighting and obtained 386 effective literature after data screening.

3. Citespace

3.1. Trends in the publication of related articles

The 386 Chinese green building design-related pieces of literature retrieved from China Knowledge Network were imported into CiteSpace software, and with the help of Excel statistical tools to carry out the issue statistics, which resulted in the trend chart of the publication of related kinds of literature in the field of green building design in China during the 25 years from 1999 to 2024, and the results are shown in Fig. 1. from which it is found that the development of China's green building design can be categorized into three stages, which are. They are the starting stage from 1999 to 2006; the development stage from 2007 to 2019; and the maturity stage from 2020 to 2024.

In the initial stage of green building design research in China, due to the unfamiliarity of this emerging concept, some Chinese researchers first explored the origins and practice methods of green building as well as the development of green building in China by studying the relevant concepts and literature in foreign countries, for example, the articles clutched by Liu Kecheng [4], Chen Xiaowen [5], and Wan Jin [6] focused on this aspect of the research. The other part of the researchers focuses on the study of green evaluation systems and green technologies and materials, such as the articles written by Jie Li [7], Ping Zhao [8], Jifeng Tong [8], Yi Jiang [9], Tongbo Sui [10], etc. The literature in the beginning stage is focused on this aspect. By analyzing the literature of the initial stage, it can be seen that although the development of green buildings in China lagged behind international development in this period, Chinese researchers still explored green building design methods in line with China's national conditions through the accumulation of continuous research.

During the development stage of green building design research in China, Chinese researchers focused more on the development and application of technology, with researchers such as Ma Weina [11], Mei Hongyuan [11], and Lin Rong [12] focusing on this aspect of research. There are also some researchers who focus on exploring and evaluating green design methods for different types of buildings, such as public buildings and educational buildings, and articles written by researchers such as Zhigang Su [13], Xiaoting Wu [14], Yuxuan Wang [15], and Qun Zhang [15] focus on this aspect of the research. Through this stage of the relevant literature can be seen, in this period of China's green building design into the specific function of the building research and construction stage, the relevant policies began to be introduced and increasingly improved, and the development of related technologies began to gradually mature and applied to the specific construction process.

At the mature stage of China's green building development, researchers began to focus more on analyzing completed green buildings, analyzing the green building technology used in them, elaborating on the advantages and disadvantages of the technology used, and providing new ideas for the future development of China's green building, so that it meets the needs of the times.

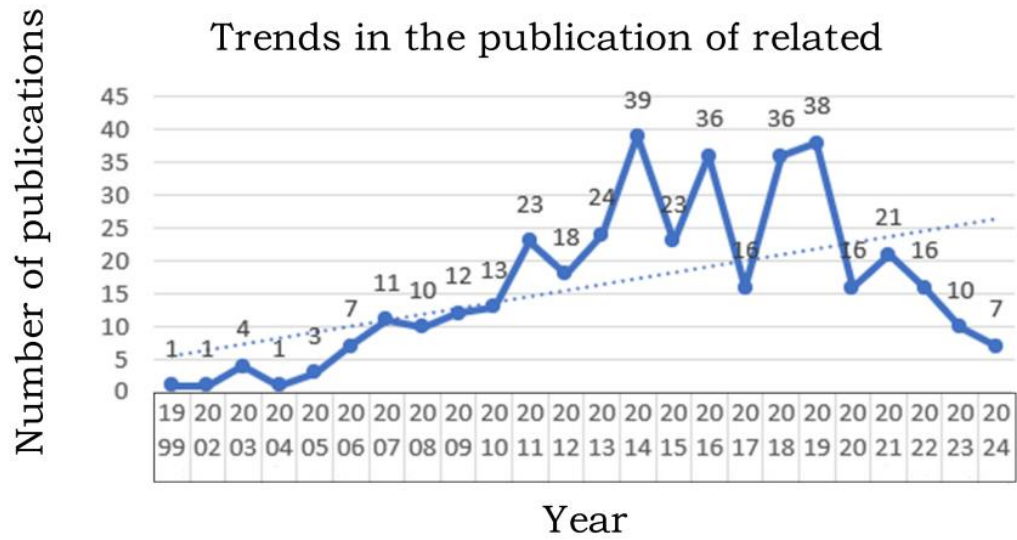


Fig. 1 1998—2024 Trend chart of the publication of research articles on green building design in China

3.2. Keyword knowledge graph analysis

3.2.1 Concrete operation

The keywords of an article are the essence of the main research content of the article, and the main research direction and research content of the article can be clearly understood from the keywords, so using Citespace to analyze the keywords of the article, we can understand the hot trend of the research field, and we can also understand the main research hot spots. Firstly, the literature retrieved from China Knowledge Network (CNKI) will be exported in reworks format, and then enter the Citespace data import interface, find the option of CNKI, click on it to import the literature data and convert the format, so that these data can be searched and clustered in Ciespace. In the Citespace main interface will be converted to the format of the data for import, node type selection "keywords", the streamlined part of the selection of "Pathfinder" and "various time periods The node type is "Keywords", and the concise part is "Pathfinder", "Time periods" and "Comprehensive network as a whole". Since the number of documents to be imported is 386, the k-value of the node screening method needs to be adjusted appropriately so that Citespace can perform the operation smoothly. In this study, after setting the k value to 15, we started to visualize and analyze the literature data and obtained the keyword co-occurrence map, keyword frequency table, keyword clustering map, keyword clustering time zone map, and keyword emergence map.

3.2.2 Keyword co-occurrence mapping

The the number of total nodes $N=292$, the number of connecting lines $E=384$, and the center density $Density=0.009$. The threshold of keywords is adjusted to 3 to show the keywords whose frequency is greater than 3. The larger the font size of keywords is, the higher the frequency of their appearances, and the hotspots of the research can be shown more clearly. The results show that in the research field of green building design in China, the high-frequency words are green building, architectural design, green design, design strategy, etc., which indicates that these points are the research direction that focuses on in the research field of green building design in China, so based on this, the chart of keywords that appear in the top ten frequency is organized, and the results are shown in Table 1.

Table 1 High-frequency keywords in the field of green building design in China

Ordinal number	Frequency	centrality	First Appeared Year	Keywords
1	201	0.91	1999	Green Building
2	46	0.96	2005	Architectural design
3	39	0.58	2005	Green design
4	16	0.2	2006	Design strategy
5	15	0.08	2012	apply
6	14	0.02	2010	energy conservation
7	11	0.14	2010	devise
8	8	0.11	2008	Energy efficiency in buildings
9	8	0.02	2010	Public buildings
10	7	0.01	2009	Design Concept

3.2.3 Keyword Clustering Mapping

In the visual operation interface of Citespace, the upper-left toolbar selects the clustering label optimization option to get the keyword clustering diagram of China's green building design-related research, and the results are shown in Fig. 2. As can be seen in Fig. 2, Citespace divides the clustered keywords into 9 major categories, and the Q value = 0.8142 > 0.3 (network modularity evaluation index), indicating that the network structure of the cluster is more obvious; S value = 0.9875 > 0.5 (weighted average contour value), indicating that the clustering of the keyword is more reasonable. Clustering the keywords of the literature can classify and merge different keywords of different literatures so that the researcher can more intuitively understand the different research directions of the related research field, so as to better summarize the research field. The important clustered keywords and their identifiers of the first five categories are collated and the results are shown in Table 2. and the keywords of the category with the highest number of clusters are analyzed.

Green Design. Different from the traditional design method, green design is based on the green ecological sustainable development of environmental protection concept, people's requirements for the designed products are no longer to meet the needs of daily life, but more on its aesthetics, safety, and quality to put forward new requirements [4]. Buildings, for example, incorporating the green design methodology of the building will in its life cycle, maximize resource conservation, to meet the basic needs of people on the building at the same time to achieve a harmonious coexistence of man and nature. The primary design principle of green building design is to protect the environment, which is because green building design is based on the green design concept as its primary theoretical support and the fundamental purpose of the green design concept is to realize the sustainable development of green buildings [5], so the green design has been the hot spot in the field of China's green building design research and will play an important role in promoting the development of China's green building design in the future.

Table 2 Keyword network clustering table

Cluster number	Number of documents	Tightness	Average year	Identifiers
0	68	0.997	2014	green design; green buildings; Architectural design; green building design; green
1	35	0.97	2013	Architectural design; Green; public buildings; Environmental protection; practice
2	31	0.99	2014	green design; green buildings; Lingnan area; low carbon; Urban complexes
3	27	0.971	2015	Develop; Apply; Ponder; Devise; Evaluation system
4	23	0.982	2013	design strategy; Low; overall design; convention and exhibition architecture; Green Building Evaluation Criteria

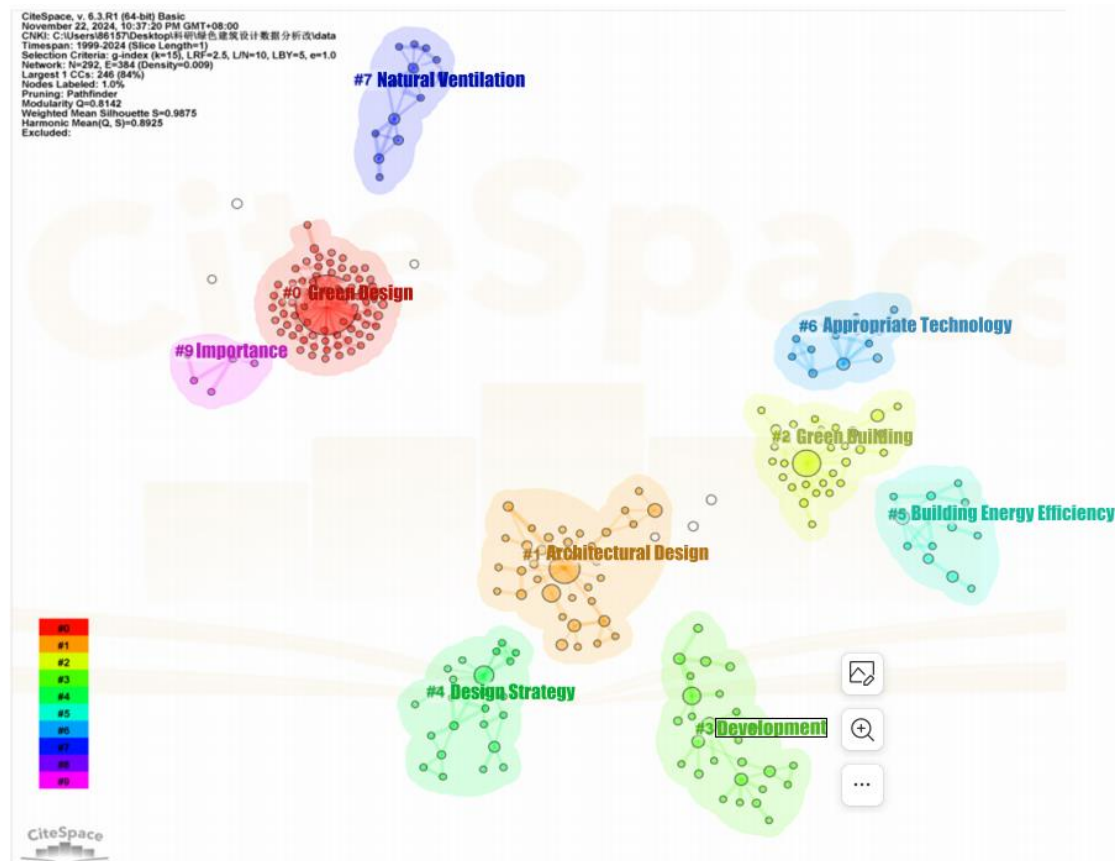


Fig.2 1999—2024 Cluster diagram of keywords related to green building design in China

3.2.4 Keyword clustering time zone map

Keyword clustering time zone map. In the control panel of CiteSpace's visualization page, selecting time view can obtain the keyword clustering time zone map shown in Fig.3, which can visualize the development of the research field of green building design in China.

As can be seen from Fig. 3, the keywords that run through the time period (1999-2024) in which the retrieved documents are located are green design, architectural design, green building, and development, so it can be known that these directions have always been the research hotspots in the field of green building design in China. On the other hand, the keywords of design strategy, building

energy efficiency, appropriate technology, and natural ventilation only lasted for a period of time in the timeline and did not run through the timeline. The weakening of these research hotspots may be related to the integration and innovation of technology, for example, the weakening of "building energy efficiency" may be related to the maturity and successful application of various energy-saving technologies in buildings; the weakening of "natural ventilation" may be related to the development of mechanical ventilation devices in buildings; and the weakening of "natural ventilation" may be related to the development of mechanical ventilation devices in buildings. The study of "natural ventilation" is weakening, probably related to the application of mechanical ventilation devices in buildings.

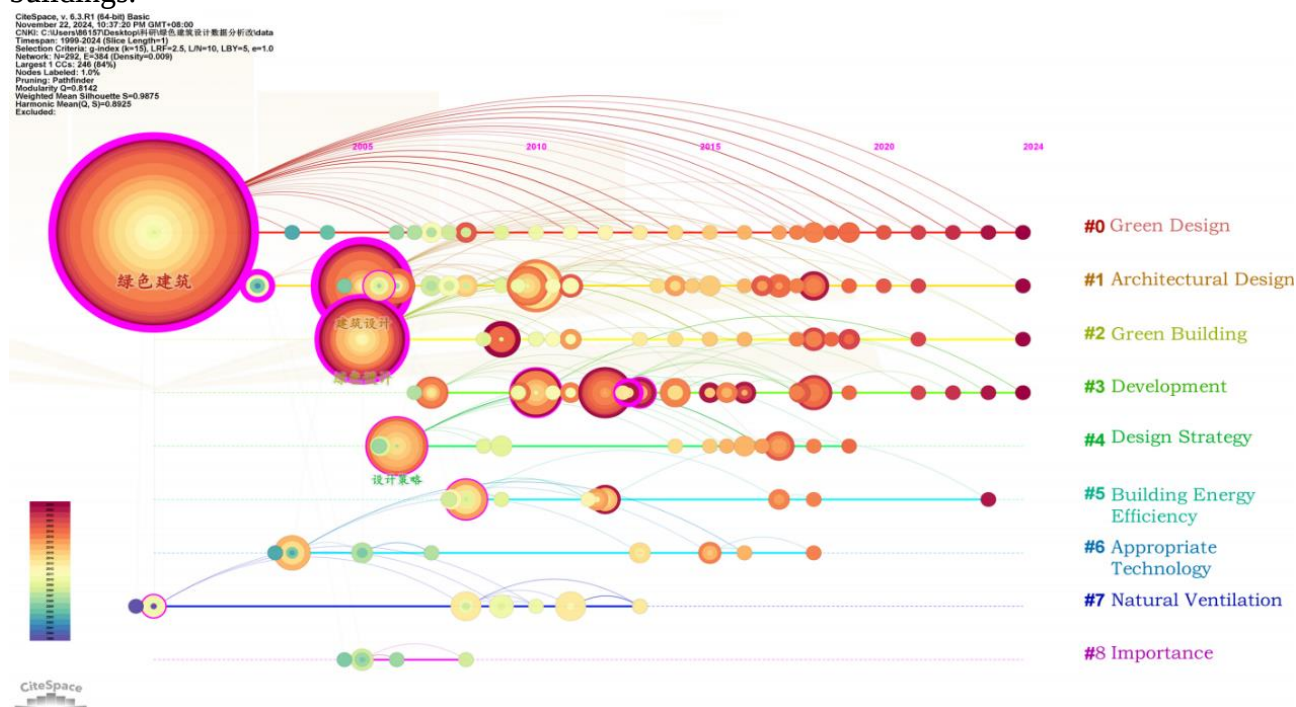


Fig.3 1999—2024 Time zone map of keyword clustering of green building design research in China

3.2.5 Keyword Surfacing Chart

The keyword emergence mapping can show the main research direction of each time period more clearly, which is supportive for sorting out the development history of green building design in China.

In this keyword emergence map, the earliest year of emergence is used to sort the keywords. As can be seen from Fig.4, the earliest keyword appearing in the literature is design methodology, and its emergence year is from 2005 to 2008, which indicates that the main research direction in this period is to explore appropriate design methodology to carry out green building design. From 2008 onwards, keywords related to green design began to appear and were mainly concentrated in the decade from 2008 to 2018, which indicates that green building design in China has developed rapidly during this period, and green building design concepts have been integrated with China's domestic architectural design, and more and more scholars have been investing in this research field to promote the development of green building design methods in China. From 2020 to 2024, after more than a decade of theoretical research and technical accumulation, China's green building enters the social construction stage, and the main research direction in this stage is how to build green buildings that meet the contemporary Chinese national conditions, and after designing these buildings with green design methods, green construction technology is applied to the construction of the building, so that the project can be constructed and utilized in accordance with the green building concept, promoting the development of China's green building methods. Green building concept, to promote China's green building in the new era of continued development.

Top 14 Keywords with the Strongest Citation Bursts

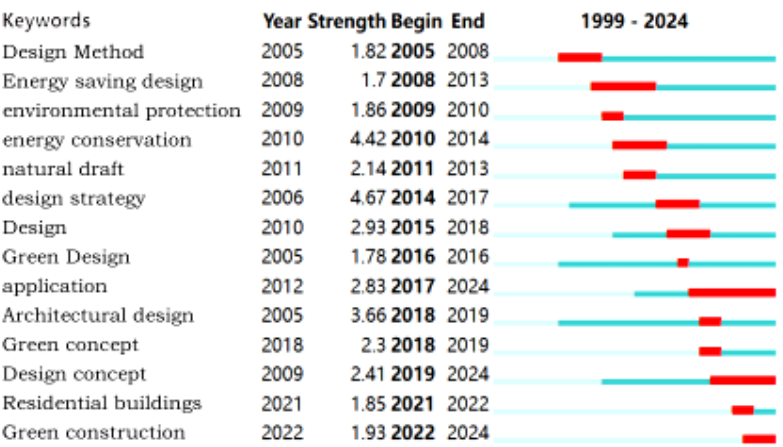


Fig.4 1999—2024 Emergent diagram of key words in China's Green Building Design Research

4. Prospect

The research field of green building design in China still has a broad development prospect in the future, so this paper proposes a future outlook from several aspects.

In terms of technological innovation, the utilization efficiency of renewable energy sources such as solar, wind, and geothermal energy will be dramatically improved, and building surfaces may be transformed into miniature energy-gathering stations, which not only achieve self-sufficiency but also the use of surplus electricity. Meanwhile, the use of recyclable and biodegradable building material materials for fast and precise customized construction greatly reduces building waste and construction energy consumption.

In terms of design concepts, green buildings will be deeply integrated with urban ecosystems, and designs such as roof gardens and vertical greening will become part of building biodiversity. The internal space of the building will also become more adaptable and flexible, and the functional layout can be adjusted according to the needs of users at any time.

As people's awareness of environmental protection increases and relevant policies and regulations are improved, green building will become the mainstream choice for Chinese buildings. The popularization of green buildings will also drive the green transformation of various industries, forming a complete green industrial chain, contributing irreplaceable power to the global response to climate change and sustainable development, and making the human living environment more comfortable, more ecological, and more potential for development.

5. Conclusion

This paper mainly uses Citespace and all kinds of literature to research and analyze the development of green building design in China. After the above research and analysis, the development history of green building design in China can be divided into three stages, which are the beginning stage, the development stage and the maturity stage. After more than twenty years of continuous research by many researchers, the formulation of relevant policies and the development and application of relevant technologies have been perfected, and a considerable part of the technology has been applied to the construction of large-scale public buildings. From the initial stage of ignorance, groping forward, to the development stage of technological innovation and application, and then to the stage of maturity of the construction of a wide range of international standards, and even some of the technology leading the world, relying on countless scientific research workers day after day of hard work. It is their countless hardships that have brought about China's rapid

development in the field of green building design, making China's domestic green building design development more in line with China's national needs and better serve the population.

However, due to the limitation of the amount of literature, this paper has only roughly sorted out the overall development history of green building in China and has not elaborated on too many specific successful practice cases to analyze the details within the development history. Future research can analyze the specific practice cases in detail, study the various technologies used within different types of green buildings and evaluate their reasonableness, so as to find out the shortcomings and summarize these shortcomings accordingly. At the same time, according to these summarized irrationalities, we can conduct relevant research to explore whether the existing mature technology can solve these problems, if not, we can carry out technological research and innovation according to the relevant feedback, so as to make the technological development to meet people's needs, and to promote China's green building in the future development of both comfort and rationality.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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