

# Analysis of Hot Spots and Trends of Domestic Intelligent Construction Research Based on CiteSpace

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Abstract. To analyze the hotspots and trends of intelligent construction research in China, bibliometric methods and CiteSpace software were used to analyze and compare the number of Chinese literature releases, disciplinary distribution, institutional cooperation network, emergent keywords, and evolutionary trends, utilizing the main database of the China National Knowledge Infrastructure (CNKI)'s intelligent construction literature from January 2000 to July 2023 as the materials. The results show that the number of Chinese literature on intelligent construction from January 2000 to July 2023 shows an overall increasing trend. Engineering applications dominate China's intelligent construction research, with research hotspots primarily focusing on technology development and application. The degree of cooperation among researchers is average, and no significant core group of authors has been formed. Although research institutions have formed a core group of institutions, it is not stable enough. With the global advancement of artificial intelligence, it is speculated that the research of intelligent construction intelligence and informatization may become the future research hotspot and trend.

**Keywords:** intelligent construction; CiteSpace; bibliometrics; China National Knowledge Infrastructure (CNKI)

## 1 Introduction

Traditionally, the construction industry is a human resource-based industry that consumes a great deal of materials, manpower and time. With the development of the global economy and the acceleration of urbanization, the construction market has become increasingly competitive<sup>[1]</sup>. The introduction of intelligent technologies, such as Building Information Modeling (BIM), Internet of Things (IoT), and Artificial Intelligence (AI), can realize the digitization and automation of the construction process, which can greatly reduce the construction cost, optimize the process, reduce the wastage, and improve the work efficiency. Intelligent technology can provide more accurate and comprehensive data, which can help monitor and manage all aspects of the construction project, thus reducing the occurrence of quality problems and improving the quality of the project.<sup>[2]</sup>. Intelligent development is a necessary demand to adapt to

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social development. With people's pursuit of livable environment and intelligent life, the requirements for building design and construction quality are getting higher and higher. Intelligent buildings can realize the goals of energy saving, environmental friendliness, intelligence and convenience, and meet people's expectations for high quality life. At the same time, intelligent development is also a way to promote the transformation of China's construction industry towards high-quality and sustainable development<sup>[3]</sup> The study was conducted through CiteSpace and In this study, through CiteSpace and bibliometric methods, To clarify the research hotspots and research develops of intelligent building published in the core database of the China National Knowledge Infrastructure (CNKI), with the goal of providing references and references for in-depth research on intelligent construction.

## 2 Materials and Methods

## 2.1 Data sources

This paper's literature data was collected from the China National Knowledge Infrastructure's core collection database. In CNKI advanced search, the Chinese literature published from January 2000 to July 2022 with the themes of "intelligent construction", "intelligent construction" and "digital construction" was taken. A total of 222 articles were obtained; after manual cleaning and screening of the data, and excluding irrelevant articles such as the call for papers, journal statements, news and duplicated content, a total of 191 effective Chinese articles were obtained. The full record of the obtained literature and the cited references were exported by Refwork, the knowledge map was drawn by CiteSpece.6.2. R4 visualization and analysis software, also analyzed and discussed were the research hotspots and trends in intelligent construction.

### 2.2 Research methodology

Firstly, we use Note Express to analyze the descriptive statistics of the number of publications, authors, research institutions, and journals of publications, and then we visualize the knowledge graph of authors' and institutions' partnerships and keywords through CiteSpace and analyze the research hotspots and trends.

Use Price's Law to screen for "core authors" using the following formula.<sup>[4]</sup> The formula is as follows:

$$N = 0.749 \sqrt{(\eta_{max})}$$

In the formula:  $\eta_{max}$  is the number of titles by the author with the highest number of publications; N is the minimum requirement for achieving "core authorship". In general, a "core group of authors" is considered to have been formed when the number of publications by "core authors" reaches 50 percent of the total number of publications.

### **3** Results and analysis

#### 3.1 Trends in the number of publications and distribution by discipline

The number of publications reflects the overall development of research in the subject area, and the growth rate of articles corresponds to how quickly the field's research is developing.<sup>[5]</sup> The number of publications reflects the overall development of research in this discipline, and the growth rate of articles published reflects the speed of research development in this field. Based on the 191 pieces of literature in this study for the annual data distribution chart, the overall trend of article publication is shown in Figure 1, and there has been a general rising trend in the material published in the subject of intelligent construction. From 2002-2016, the number of domestic articles issued was extremely small; from 2017 to 2020, domestic intelligent construction has ushered in the initial development, which indicates that domestic researchers have gradually gained awareness of intelligent construction; by 2022, the degree of attention to intelligent construction research was high, and although the first half of 2023 fell back slightly, the overall number of studies was still high. The last five years is the "golden period" of the intelligent development of China's construction industry, which has greatly promoted the prosperity of related academic research.



Fig. 1. Trends in the number of articles published

Analyzing the distribution of disciplines in the literature can provide an in-depth understanding and grasp of the background and status of research in the field, to more accurately analyze and predict research hot spots and trends.<sup>[6]</sup> As shown in Table 1, The most frequent discipline in Chinese literature is architectural science and engineering, accounting for 50.26%. The discipline with the highest frequency of Chinese literature is building science and engineering, accounting for 50.26%, followed by highway and waterway transportation, accounting for 25.13%, indicating that China's research on intelligent construction is mainly in engineering construction, and the development direction is relatively single.

Serial No.	academic discipline	frequency	percentage
1	Building Science and Engineering	96	50.26%
2	Road and waterway transportation	48	25.13%
3	Computer software and computer ap- plications	26	13.61%
4	hydraulic engineering	19	9.95%
5	industrial economy	17	8.9%

Table 1. Disciplinary distribution of smart construction literature (partially)

#### 3.2 Analysis of core research institutions and authors

The research maturity of a subject area can be judged by the number of core research institutions and core authors in the field, and whether a core group of research institutions and authors is formed<sup>[7]</sup> Using CiteSpace software, Knowledge mapping is used to examine the key research institutions and authors in the area. Figure 2 and Figure 3 exhibit the knowledge mapping of research institutions and research authors, respectively.

As can be seen from Fig. 2, the core research institutions of intelligent construction are represented by China Yangtze River Three Gorges Group Co. Ltd. and China Railway Engineering Design and Consulting Group Co. Ltd. and other institutions such as the Chinese Academy of Engineering, the Tsinghua University State Key Laboratory of Water and Sand Science and Hydropower Engineering, and the China Railway Economy Planning and Research Institute Ltd. There are 152 nodes and 138 connecting lines between the institutions, indicating that these research institutions have a certain degree of independence and a relative lack of communication and exchange of knowledge. Calculated by Price's law, the core institutions are those with 2 or more publications. Using this as a criterion for classification, a total of 43 institutions belong to this field. According to the statistics, 43 research institutions have published a total of 126 articles, accounting for 54% of the total number of articles, which is greater than 50%, so it is considered that a preliminary core group of institutions has been formed in this field.



Fig. 2. Knowledge map of research organizations

The analysis shows that the cooperation between research institutes is both geographically based, such as China Institute of Water Resources and Hydropower Research (CIWRH), China Railway Research Institute Group Corporation (CRIRG) & Tsinghua University's State Key Laboratory of Water and Sand Science and Water Conservancy Engineering (SKLWSHE), and geographically based, such as Huazhong University of Science and Technology (HUST) and Chinese Academy of Engineering (CAE). Most of the organizations with more publications have significant advantages in civil engineering, energy management and other disciplines, and their main research disciplines are natural disciplines; enterprises are mainly engaged in the research of related applied technology, and universities mainly conduct basic theory and methodology research, and in recent years, the trend of collaborative research between enterprises and universities has been significantly strengthened.



Fig. 3. Knowledge spectrum of the study authors

From Figure 3, it can be seen that the core authors in the field of intelligent construction mainly include Fan Qixiang, Li Guo, Li Qingbin, etc., but the cooperation between the core authors is not obvious. According to the calculation of Price's law, it can be seen that those with more than 2 publications are core authors. Taking this as the division standard, a total of 47 authors belong to the core authors in this field, with a total of 112 published papers, accounting for 42% of the total number of papers, which is less than 50%, so it is considered that the field has not yet formed a stable core author group.

#### 3.3 Analysis of Research Hot Spots and Trends

#### (1) Keyword co-occurrence analysis.

Keywords that appear more or are used more frequently in a specific period are called emergent keywords, keywords are highly summarized and condensed to the research content, analyzing the keyword mapping of the literature can grasp the hot words of the related literature, the intensity of emergent keywords is related to the change of their word frequency, which helps to dig out the hot topics of the research, and the intensity of emergent keywords can effectively determine the trend of the frontiers of the research field. As can be seen from Table 2, the top 10 emergent keywords in the core database of China National Knowledge Infrastructure are ranked according to the time of emergence. The keyword co-occurrence map of intelligent construction-related research is shown in Figure 4, the amount of word frequency occurrences is determined by the font size; the larger the font, the more occurrences, and the keyword node grows as word frequency increases.<sup>[8]</sup> From Figure 4 and Table 2, it can be seen that in addition

to "intelligent construction" and "smart construction", the research hotspots include digital construction, informationization, artificial intelligence, BIM technology, full life cycle, building industrialization, construction technology, and assembly building. Figure 4 shows that there are 227 nodes and 386 lines, with a network density of 0.015, a modularity index (Q) of 0.7031>0.3, and an average contouring index (S) of 0.9661>0.5, which means that the co-occurrence results are reasonable.<sup>[9]</sup>



**Fig. 4.** Keyword co-occurrence map ( $\geq$ 7)

By analyzing the high-frequency keywords in the literature, after removing the initial search terms "intelligent construction", "intelligent construction" and "digital construction", the top 15 keywords were counted, as shown in Table 2. It is obvious that "informatization" is the keyword with the highest attention and the highest frequency of use. According to the order of frequency and the magnitude of central intermediation, "informatization", "artificial intelligence", and "whole life cycle" are the primary foci of research in this discipline, as well as crucial nodes on the path of future knowledge evolution, while the keywords related to intelligence, artificial intelligence, and whole life cycle are the important nodes of future knowledge evolution path. The number of papers involving intelligentization and specific projects is small, and the overall proportion is not high.

Serial No.	Keywords	Count	Centrality	Year
1	informatization (the Infor- mation Age analog of indus- trialization)	9	0.21	2015
2	artificial intelligence (AI)	9	0.14	2017
3	BIM technology	8	0.05	2018
4	4 full life cycle		0.08	2016
5	digital twin	6	0.01	2021
6	railroad tunnel	6	0.01	2019
7	Construction technology	5	0.02	2020
8	hydroelectricity	5	0	2019
9	dike	4	0.01	2022
10 industrialization of construc- tion		4	0.02	2022
11	bridge project	4	0	2021
12	blockchain	3	0.05	2019
13	building industry	3	0	2022
14	value creation	3	0	2021

Table 2. Keyword frequency rankings (partial)

#### (2) Keyword emergence analysis.

Research trends are generally reflected through keyword emergence. The emergent words are used to explore emerging trends in disciplinary development and sudden changes in the center of gravity of research, which can be used to identify trends in the topic over time.<sup>[10]</sup> The top 10 keywords with the strongest emergence intensity from 2002-2023 are shown in Figure 5. In terms of emergence intensity, the top three keywords are digital construction (4.17), digital twin (1.58), and building information modeling (1.24); in terms of emergence duration, the keyword with the longest duration is digital construction, which has been in the spotlight of researchers since its emergence in 2012, and the keyword with the shortest duration under emergence is construction technology, which lasts for only 1 year. The keywords of whole life cycle and value creation have persisted until now, which indicates that they are the latest and hottest research topics. 2021 "14th Five-Year Development Plan" clearly states that "the development of intelligent construction, the promotion of green building materials, assembled buildings, and steel structure houses," "14th Five-Year Plan of the Construction Industry" also states that we should accelerate the development of intelligent construction and the construction of steel structure houses, and the construction industry should be more efficient. The 14th Five-Year Plan for the Construction Industry also elaborates the need to accelerate the synergistic development of intelligent construction and new building industrialization and improve the intelligent construction policy and industrial system. The above shows that standing on the new starting point of the 14th Five-Year Plan, China's construction industry has entered a period of development centered on intelligent construction and realizing the value of social co-creation.

## **Top 10 Keywords with the Strongest Citation Bursts**

Keywords	Year	Strength	Begin	End	2002 - 2023
Digital Fabrication	2012	4.17	2012	2017	
<b>Building Information Modeling</b>	2015	1.24	2015	2017	
Informatization	2015	0.82	2015	2018	
Collaborative Management	2019	0.96	2019	2020	
Construction Technology	2020	1.2	2020	2021	
Digital Twin	2021	1.58	2021	2023	
Bridge Engineering	2021	1.04	2021	2023	
Value Creation	2021	0.78	2021	2023	
Total-life Cycle	2021	0.52	2021	2023	
<b>Development Status</b>	2021	0.52	2021	2023	

Fig. 5. Keyword bumping map

#### (3) Keyword clustering analysis.

Each cluster is a composition of multiple closely related words, and the smaller the tag number, the more keywords the cluster contains. Through the cluster analysis, six meaningful clusters were selected: #0 smart construction, #1 full life cycle, #2 digital construction, #3 collaborative innovation, #4 blockchain, and #5 construction technology, as shown in Figure 6.



Fig. 6. Keyword clustering diagram

#### (4) Timeline clustering analysis of major keywords.

Analyzing the keyword evolution trends of smart construction research papers can reveal changes in research hotspots.<sup>[11]</sup> Figure 7 shows that in the period 2000-2023, the first half of almost no words appear, which is consistent with the change in the

number of papers issued in Figure 1. 2012 after the digitalization of keywords began to appear, and after 2016, the intelligent construction with the development of artificial intelligence research, became the main research keywords, with which at the same time the informationization, BIM, technological innovation and intelligent keywords also increased, indicating that the research perspective of intelligent construction tends to the development of technology, and domestic researchers pay more attention to the application of actual technology. So far, the application of digital technology under the whole life cycle has been favored by the majority of researchers.



Fig. 7. Keyword timeline chart

## 4 Conclusion

Econometric analysis and visualization were conducted to understand the current status, hotspots and trends of intelligent building research in China. The following are the results obtained. This research was conducted by scanning the core database of the China National Knowledge Infrastructure from 2000 to 2023 using CiteSpace software. Between January 2000 and July 2023, the distribution of documents and disciplines revealed a noticeable upward trend in the number of studies conducted. Before 2016, there was very little research about intelligent construction. However, the number of related research documents began to grow rapidly in China in 2016, indicating the exploration and utilization of the value of intelligent construction. This growth was mainly concentrated in the field of building science and engineering applications. From the perspective of the author and the institution, the author Fan Qixiang studies more, but the research field of the institution is relatively narrow. From the perspective of research in China

is on technology development and application. As artificial intelligence develops globally, we hypothesize that a prominent research trend may emerge in the future. This trend is hypothesized to focus on intelligent construction throughout the entire life cycle.

In conclusion, China's construction sector will continue to develop intelligently. However, the development has been relatively slow in China. Additionally, the research direction tends to be narrow. To promote the effective integration of architecture, engineering, management, and other disciplines in the field of intelligent construction, it is necessary to combine theory and practice. This will further enhance applied research in intelligent construction and contribute to the standardization and scientific development of the field. Academic research should be integrated into the layout of major national development strategies and focus on the requirements of these strategies. As the transformation and upgrading of China's construction industry accelerate, it is important to continuously explore the relationship between intelligent construction and the implementation of the "dual-carbon" strategy. Furthermore, it is crucial to examine its connection to regional coordinated development and industrial restructuring. This exploration is necessary to align with the country's top-level design of the country in the new situation.

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