Bibliometrics-based Cloud Model and Research Hotspot Analysis in Construction Risk Management

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Abstract: With the help of bibliometric methods and visualization tools, this paper analyzes the literature of cloud model and construction risk research, and analyzes the application of this method in its field, in order to provide reference for further research in the future. VOS viewer and Citespace were the software which used to analyze the quantity of published articles and journal distribution of the writing included in the Web of science and CNKI databases. The co-occurrence analysis of authors, countries and keywords was carried out. According to the consequence, the number of published papers come out a fluctuating growth trend, and the research in this field has not yet entered a stable stage. Domestic research focuses on the combination of theory and method, while foreign research focuses on the practice of specific projects.

Keywords: Bibliometrics; Construction; Cloud Modeling; Risk Management; Citespace

1. Introduction

In 1995, Professor Li is an academician from Chinese Academy of Engineering, advanced a new theoretical model, the cloud model, in view of the limitations of fuzzy mathematics and probability theory in dealing with uncertainty problems [1]. It captures the uncertainty characteristics of concepts through three core parameters—expectation, entropy, and super entropy—and uses specialized algorithms to realize the conversion between qualitative concepts and quantitative data. This conversion mechanism not only enhances the expressiveness of concepts, but also deeply reveals the ambiguity and randomness of objective things, providing an effective quantitative and qualitative method for the understanding and analysis of uncertainty concepts.

In recent years, China has vigorously developed infrastructure construction such as railways, highways, urban railways and housing buildings, and various construction projects are constantly increasing, and the demand of risk control are much higher than before. Good risk management capabilities can effectively reduce the incidence of accidents, reduce various losses caused by accidents, and ensure the smooth completion and smooth operation of construction projects. Scholars at home and abroad have used a variety of methods in the study of risk management, such as analytic hierarchy process [2,3], fuzzy comprehensive evaluation method [4], entropy weight method [5], etc., however, these methods generally face the problems of high subjectivity or lack of intuitive and clear interpretation of results, which is difficult to ensure the accuracy of risk assessment. However, the cloud model can deal with the uncertainty in construction risk assessment, and transform qualitative risk factors into quantitative risk measures, so as to achieve quantitative risk analysis.

2. Research Methods and Data Sources

2.1 Research Methods

After years of development, bibliometrics tools have been very abundant, the common ones are Citespace, CopalRed, Endnote, Vosviewer, CitNetExplorer and other software, this paper selects the most widely used Citespace and Vosviewer for analysis. CiteSpace is an analysis tool which used for scientific literature statistics. It was developed by Dr. Chen from the School of Information Science and Technology of Drexel University in the United States. He cooperated with the WISE Laboratory of Dalian University of Technology. CiteSpace is able to output specific data and take shape a knowledge

graph to conceptualize and visualize it. VOSviewer is a bibliometrics visualization tool developed by VANECK professor and his team at Leiden University in the Netherlands, which is capable of converting complex data sets into 2D or 3D visualizations.

2.2 Data Sources

In order to ensure the comprehensiveness of the data sources, literature data were collected and studied from both foreign and domestic literature. Web of Science (WOS) was selected as the foreign language database, and 186 English documents were retrieved by entering the search query in the database: TI = (construction risk and cloud model), and 182 valid data were obtained after screening. The journal sources selected in the Chinese database are core journals such as EI, Peking University, CSSCI, and CSCD included in CNKI. The search subject terms were "construction risk + cloud model" and "construction safety + cloud model", and the search time was not limited, and 239 core journal articles with relatively high academic level and quality were obtained after screening.

3. Basic Analysis of the Literature

3.1 Situation Analysis of the Number of Literatures

Citespace 6.3.R1 was used to calculate the number of publications in the field of study, and the annual number of publications and development trends are shown in Figure 1. In the past 20 years, domestic and foreign literature has been in the stage of starting from scratch, and the overall trend has shown a fluctuating growth trend. In 2020 and 2021, the number of publications has declined, indicating that the application of cloud models in risk management has not yet entered a stable period.

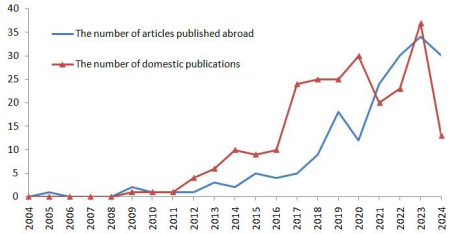

Figure 1. Publication Trend Chart

By analyzing Figure 1, we can summarize: the application of cloud models in risk management in 2011 was in its infancy, with only one or two articles appearing. From 2011 to 2015, scholars began to use the cloud model for risk management, and the quantity of published papers increased slowly compared to the preceding stage, but none of them exceeded 10. In 2016, the research results in China showed an extremely significant explosive growth trend, and cloud models gradually became a popular method. In the following four years, it maintained a relatively flat trend until it reached a relatively high number of publications in 2023.

3.2 Journal Distribution Analysis

The publication of the literature was analyzed, and the results were summarized in Table 1. In the WOS database, the journal with the most publications is stochastic environmental research and risk assessment with 24 papers, automation in construction with 21 papers in second place, and earthquake engineering & structural dynamics in third place.

Table 1. Ranking of Journal Publications Based on WOS And CNKI Data

Name of the journal	Number of publications
Stochastic environmental research and risk assessment	24
Automation in construction	21
Earthquake engineering & structural dynamics	19
Journal of Civil Engineering and Management	17
Journal of Safety and Environment	16
Journal of Railway Science and Engineering	14

In the CNKI database, the journal with the largest number of articles is the journal of civil engineering and management, with 17 articles, followed by the journal of safety and environment and the journal of railway science and engineering.

3.3 Author Analysis

The strength of research is reflected in the number of publications and cooperative relationships between authors, and the cooperation between authors helps to strengthen the integration between disciplines and deepen the research content. From Price's law, it can be known that the quantity of

papers published by core authors in the professional field is calculated as follows:

$$M_p = 0.749 * \sqrt{N_{p\max}} \quad (1)$$

In the formula, the number of papers published by the core authors is used to indicate M_p, and N_{pmax} is the quantity of papers published by the most prolific authors [6]. The amount of papers published by the most prolific authors in the WOS and CNKI databases was 7 and 10, respectively, and the calculated Mp was 1.987 and 2.368, respectively, and the whole number was 2. Therefore, when the author cooperation analysis was performed in VOSviewer, the minimum quantity of published papers was set to 2, and the author cooperation at home and abroad was obtained. In Figures 2, the shape of the circle presents the amount of articles published by the writer, and the larger the circle, the more the author has published. There are 758 authors in the English literature, with the team with Chen Guoming as the core being the most extensive with 7 members, the team with Li Xiao as the core containing 6 members, and the team with Galasso and Hu Shenping as the core containing 5 members. The rest of the research groups had no more than 5 authors.

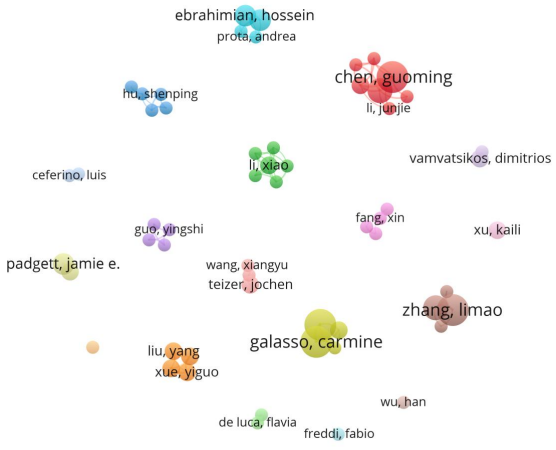

Figure 2. WOS Literature Author Cooperation Network

According to the Table 2, there are a total of 989 authors in the Chinese literature, mainly forming a cooperative group with Wu Xianguo and Wang Jing Chun as the core. The authors' cooperation networks at home and abroad show a pattern of "overall decentralization and partial concentration", and the scope of cooperation needs to be further expanded in future research.

Table 2. CNKI Author Cooperation

Core author	Number of articles published by core authors	Team members and the number of posts they have posted
Wu Xianguo	10	Chen Hongyu(6 articles)
		Chen Fada(4 articles)
		Zhang Limao(4 articles)
		Wang Xiang(3 articles)
		Qin Yawei(3 articles)
Bao Haiying	7	Li Haiwen(6 articles)
Wang Jingchun	5	Zhang Fa(3 articles)
		Lin Jiaxiu(3 articles)
Xu ping	3	Jiang Xin(3 articles)
		Zheng Xiazhong(2 articles)
		Jin Hailiang(2 articles)

3.4 Analysis of Domestic and Foreign Cooperation

VOSviewer software was used to analyze the cooperation between the selected literature in the Web of Science database at home and abroad, and the results are shown in Figure 3. As can be seen from the figure, China has the highest intensity of cooperation with other countries, followed by the United States and the United Kingdom, and the global cooperative relationship has formed a multipolar pattern centered on China, the United States, the United Kingdom and Italy, and the rest of the countries are mainly distributed in Oceania, Europe and Southwest Asia.

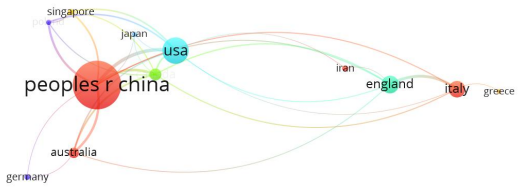

Figure 3. Map of Country Cooperation

4. Research Hotspot Analysis

The keywords of the eaasy can highly indicate the subject matter and centre idea of the literature, so the research status of the field can be analyzed according to the keywords that appear frequently in a certain field. In this paper, "Keyword" is used as the graph analysis node in VOSviewer to construct the knowledge graph of research hotspots in CNKI

database, and the top 15 keywords with the highest frequency are sorted out, as shown in Table 3. On the basis of the table 3, cloud model is widely used in construction risk assessment, and is used in the construction risk assessment of prefabricated buildings, tunnel construction and deep foundation pit construction. For example, in order to reduce the risk of shield tunnel construction, Huang established a cloud model, then determined the weight and language evaluation of the index through the discussion of the expert group. In the end, he used the calculation method of cloud theory to compute the construction risk level of shield tunnel [7]. In the process of risk assessment using cloud models, they are often used in conjunction with other methods, such as rough set theory and D-S evidence theory, and usually use combination weights for evaluation. He constructs a large deformation risk evaluation index system of soft rock tunnel system, combines the standardization process and the G1-CRITIC method, and proposes a new cloud model comprehensive risk assessment method through the subjective and objective weights obtained by game theory optimization, which offers a novel concept for the numerical assessment of the stability of the surrounding rock in soft rock tunnels. [8] Yao believes that the high-speed overpass bridge project is the throat of highway construction, and its construction risk must be reduced. The method of operation decomposition structure combined with risk breakdown structure matrix was employed to formulate the risk breakdown matrix. The principle of rough set theory was applied to ascertain the weight of risks associated with each fundamental work package, and ultimately, the risk level of each operational unit during the construction phase was categorized based on these weight values. [9]

Table 3. CNKI Keyword

Keyword	Occurrences	Total Link Strength
Cloud model	84	70
Risk assessment	37	34
Prefabricated buildings	14	19
Safety Engineering	11	18
2D cloud model	10	7
Construction safety	8	18
Combinatorial empowerment	8	17
Entropy weight method	7	16
Shield tunnels	7	13
Tunneling works	7	8
Game theory	6	11
Extensible cloud model	5	6
Deep foundation pits	5	11
Comprehensive evaluation	5	6
D-S Theory of Evidence	4	6

Due to the complexity of lexical analysis in the Web of Science database, the keywords of the Web of Science database should be further clustered and analyzed to obtain Figure 4. The modularity Q (Q>0.3) and the weighted mean silhouette (S>0.7) reflect the clarity and cluster size of the keyword clustering boundary, respectively [10]. The 672 clustering nodes in Figure 4 were analyzed, and Q=0.6415 and S=0.8644 were obtained, all of which passed the clustering test, indicating that the clustering structure was significant. On the basis of the clustering results of the English literature, the content of the literature was sorted out in more detail, and five types of topics were summarized with risk assesement, tunnel construction, buildings, highway bridge, and analytic hierarchy process as the central keywords.

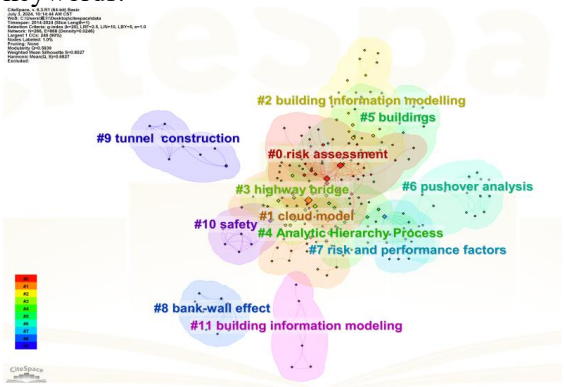

Figure 4. Keyword Clustering Results of Web of Science

4. Conclusion

With the help of CiteSpace V. software, this paper draws a knowledge graph, takes the relevant article in the field of cloud models in CNKI database and Web of Science database as data sources, analyzes the application of

cloud model in construction risk assessment from three aspects: knowledge base, cooperation strength and research hotspots, and primarily derives the subsequent conclusions and suggestions:

(1) The quantity of papers published in the field of risk assessment of cloud models at home and abroad shows a fluctuating growth trend, declaring that the study in this domain is still in a period of fast development and has not yet entered a steady stage.

(2) Most of the authors of domestic and foreign literature publish articles in teams, and the team led by Chen Guoming, Li Xiao and Galasso has published the most articles in the Web of Science database, and the cooperation relationship is the closest. However, judging from the overall trend of publishing, there is still more cooperation within each team, and I hope that communication with the team can be strengthened in the future.

(3) Based on the co-occurrence cluster analysis of keywords, it is found that the differences in research content at home and abroad are reflected in the method research and practical research. The concern about domestic research is on the study of methods, while foreign research focuses more on practical research. Intelligent and information-based building model and simulation technology are the common research directions at home and abroad in the future.

Based on the above conclusions, the author believes that the research on cloud models should focus on the combination of emerging research hotspots, carry out interdisciplinary cooperation, and cultivate new forces in the research field. In future research, the academic community will continue to break through geographical limitations, broaden the path of cooperation, and promote the integration of theory and practice. The use of cloud models in conjunction with other methods can also be studied in depth.

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