Research Hotspots and Trend Outlook of Hydraulic and Hydropower Construction Safety—Knowledge Graph Analysis Based on CiteSpace

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Abstract. As a representative of China's energy transformation, water conservancy and hydropower development play an essential role in China's realization of the dual carbon goal. Under the background of attaching great importance to safe production, the issue of safe production in the construction of water conservancy and hydropower projects is the focus of current attention. To study the safety of construction in water conservancy and the Hydropower industry, 490 research papers on production in the construction of water conservancy and hydropower systems published by CNKI in the past 20 years are retrieved in this paper. Using CiteSpace visual metrology software, keyword co-occurrence and cluster analysis are carried out on safety production problems of hydraulic and hydropower project construction, and a knowledge map is constructed. It is found that "safety management," "emergency plan," and "safety supervision" are hot topics in the research of safety production construction in the process of water conservancy and Hydropower construction. Future research trends include "Safety production responsibility system," "information management platform," and "emergency management system."

Keywords: Hydraulic and Hydropower construction · CiteSpace · Safety production responsibility system · Safe production · Emergency Plan

1 Introduction

Under "double carbon," China's energy and power industry is facing transformation and development. With the increase in the demand and scope of power consumption, many new energy power plants have been put into production and construction. The

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construction of a new power system is an inevitable requirement for transforming and developing China's energy and power under "double carbon." It is an essential practice for the energy and power industry to implement the new energy security strategy of "four revolutions and one cooperation" and promote the clean and low-carbon transformation of energy. It is an essential practice for the energy and power industry to implement the new energy security strategy of "four revolutions and one cooperation" and promote the clean and low-carbon transformation of energy, which is the necessary way to build a modern energy system and build a strong energy country and has an important guiding significance for the transformation development of energy and power in China [1].

Most energy projects, such as hydropower, are located in high mountain valley areas with rapid water flow. Risk factors such as geology, climate, and natural disasters have caused significant technical troubles in design, construction, and other safe production work. Since the 18th Party Congress, the Party Central Committee, with Comrade Xi Jinping as the core, has attached great importance to production safety. Since the 18th CPC National Congress, the CPC Central Committee has attached great importance to production safety. The chairman of China personally commands and makes arrangements, stressing that we should firmly establish the concept of safe development, adhere to the people's interests first, always put production safety first, and earnestly safeguard the security of people's lives and property. Therefore, water conservancy and hydropower construction safety work is particularly important. This paper searches the literature about water conservancy and hydropower construction safety. The CiteSpace visualization tool is used to systematically analyze the hot issues of safety products in the past 20 years and summarize the layout of safety products in the future general trend.

2 Data Sources and Research Methods

2.1 Source

In this paper, China Knowledge Network (CNKI) was selected as the database to retrieve literature on safety production in water conservancy and hydropower engineering construction, and 490 articles were retrieved by removing invalid data such as the call for papers, information, revelation, and notification. The specific data collection method was as follows: select "advanced search" in the search interface, set the search topic keywords as hydropower AND construction, development AND safety production; hydropower AND construction, development AND responsibility system; pumped storage AND construction, development AND safety production; pumped storage AND construction, development AND responsibility system. The retrieved articles are filtered and exported in RefWorks format and finally imported into CiteSpace software for analysis.

2.2 Methodology

Each document in China Knowledge Network (CNKI) contains a large amount of information, such as year of publication, author, author institution, title, abstract, keywords, published journals, references, and so on. CiteSpace [2], as a visualization tool, systematically integrates and outputs the document information to generate a visualization

map, which shows the network, structure, interaction, intersection, evolution between knowledge units, knowledge clusters or derivation, and many other implicit complex relationships [3], through which knowledge can be related and then emerging knowledge can be mined. This paper mainly uses keyword co-occurrence analysis and keyword timeline clustering analysis in CiteSpace.

3 Hot Issues of the Research

3.1 Keyword Co-occurrence Analysis

Keyword co-occurrence analysis is one of the most effective methods to uncover the current status of a field and its trends. Keyword co-occurrence analysis is a systematic integration of keywords provided by authors in the data to find the research hotspots in different periods. In the keyword co-occurrence network, the larger the label of the keyword node, the more frequently it appears, which indicates the higher research hotness. The lines between different nodes indicate the association between the keywords, and the color shades of the nodes indicate the time when the paper was published. In contrast, the darker color indicates that the keyword has been studied more extensively. In this paper, by retrieving the literature data on safety production in water conservancy and hydropower construction, the keyword co-occurrence analysis is shown in Fig. 1, and the corresponding hot keywords are shown in Table 1. We can get "safety management," "water conservancy and hydropower," "countermeasures," "safety production," "safety control," "construction management," "engineering construction," "construction technology," "safety supervision," and so on appear more frequently, indicating that their research situation is mature in the past water conservancy and hydropower construction.

According to Fig. 1, the keyword "safety management" has received much attention. Zhou Dabing [4] proposed early that the construction process of the power system should follow the principles of "constantly improving the awareness of leaders at all levels about the importance of safety production" and "establishing and improving the safety management system based on the project legal person." "establish and improve the power construction management system with the project legal person responsibility system as the core, and promote the improvement of the safety management level," "strict management and implementation of the system centered on the safety production responsibility system" of the safety development concept. And deepen the reform of safety products in the process of power construction From the owner's responsibility system to the whole staff's responsibility system for safety production, the concept of a responsibility system has been accompanied by water conservancy and hydropower infrastructure construction. With the introduction of the new product safety law, the implementation of the entire production safety responsibility system has become the focus of the current stage of production safety construction, and how to implement the production safety responsibility system in the process of hydropower infrastructure is a problem we need to study at this stage. Wang Shengjiang and Ji Yongjin [5] pointed out that the enterprise's production safety responsibility system is the most basic safety management system. A proven production safety responsibility system should establish both the operator (decision-making, management, and supervision responsibilities), managers, technical staff, and all staff safety responsibility system, forming a production

safety responsibility system and ensuring the implementation of the production safety responsibility system through inspection, supervision, rewards, and punishments The system of responsibility for safety products should be implemented through inspection, supervision, rewards, and punishments. In recent years, to achieve the goal of "double carbon," the construction of pumped storage power stations has become the leading force in constructing electric power systems. The problem of safety management in the infrastructure construction process has been approaching the source. The concept of "essential safety" has become more and more critical to the public. The concept of "intrinsic safety" is getting more and more attention from the public, and safety management measures in the infrastructure construction process are continuously being promoted.

Figure 1 also shows that the keyword "emergency planning" has been a critical area of concern in the hydropower infrastructure process in recent years. The recently introduced "14th Five-Year Plan" national emergency system plan insists on "people first and life first". It takes "promoting high-quality development" its theme and "preventing and resolving major security risks" as its main line. "It is committed to promoting emergency management system from seven aspects: sound emergency management command system, emergency management rule of law system, hidden danger investigation and safety prevention and control system, natural disaster prevention and control capability system, emergency rescue force system, emergency material guarantee system, science and technology, and talent support guarantee system. The modernization of emergency management system and capacity. Jiang Xin, Sun Zhengxi et al. [6] evaluated the vulnerability of the emergency management system in the construction phase of hydropower projects, effectively assessed the emergency response capability of emergency management system in the construction phase of hydropower projects, and found the weak links in the system, and proposed a vulnerability evaluation method for the emergency management system. Jiang Benhong, Peng Huimin, et al. [7] pointed out that the primary responsibility of emergency plan management for production safety accidents of water conservancy and hydropower construction enterprises should be compacted in the management of emergency plan for production safety accidents of water conservancy and hydropower construction enterprises based on the management of emergency plan preparation and drill; Strengthen the systematic construction of enterprise emergency plans; Strengthen accident risk identification, assessment and emergency resource investigation; Pay attention to the demonstration (review), filing and drilling of the emergency plan.

In summary, the research hotspots of water conservancy and hydropower construction safety mainly focus on several aspects; one is safety production, safety management, emergency management, and other safety foundation work; the second is construction site management, engineering construction, construction conditions, construction technology, and other engineering construction issues; the third is the project unit management of participating units, safety supervision, subcontracting units and engineering systems.

3.2 Keyword Timeline Clustering Analysis

The keyword timeline clustering graph can help us better understand the keywords and keyword clustering that focus on different research periods in a particular field.

Table 1. Keyword frequency table

Number	Key words	frequency	Number	Key words	frequency
1	Safety management	108	8	Safety	23
2	Management	56	9	safety control	18
3	Water Resources and Hydropower	56	10	Construction management	18
4	Hydroelectric Engineering	54	11	engineering construction	17
5	construction	36	12	construction technique	17
6	Safety production	35	13	engineering development	16
7	countermeasure	25	14	Safety supervision	12

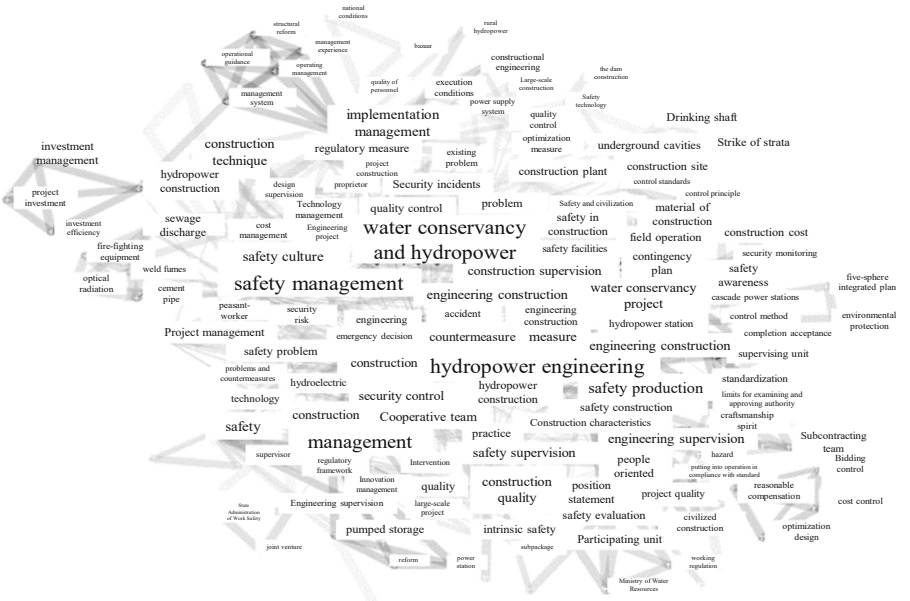

Fig. 1. Keyword co-occurrence analysis

The citation chronology in the graph represents an article's citation history, and the chronology's size reflects the number of citations in the paper. The color of the wheel corresponds to the time of the citation, and the color of different wheels is positively correlated with the number of citations of the cited papers. The lines of different keywords represent the association between them. According to the retrieved data, a timeline cluster

analysis was performed, as shown in Fig. 2. A total of nine clusters were obtained as #0 construction, #1 engineering construction, #2 control, #3 safety production, #4 emergency planning, #5 hydropower engineering, #6 subcontracting team, #7 safety management, # and #8 water conservancy and hydropower. The cluster size, the average year of publication, and the main keywords of each cluster were counted to generate a keyword clustering table, as shown in Table 2.

In cluster 0 "construction", most of the articles published in the field of water conservancy and hydropower construction are mainly about building a perfect construction management system, strengthening safety monitoring and control at this stage, and building a safety risk management system and safety prevention mechanism in the construction process. According to previous experience, Wang Jigang, Tang Guoqing [8], and others pointed out that the introduction of a professional safety monitoring management mechanism, the establishment of a perfect monitoring management system, the separate standard for monitoring project characteristics, organic combination of safety monitoring and engineering construction, development of easy-to-operate monitoring information management platform, and early construction of automated monitoring system are specific measures and typical practices. With the advent of the era of big data, engineering construction is gradually combined with Internet technology, and "intelligent control" monitoring platforms, such as digital site control, can achieve full coverage of the construction area and play a supervisory and deterrent role in the construction process [9].

In cluster 1, "engineering construction", keywords such as control practice, construction technology, and construction conditions appear. It is worth noting that the construction workload of water conservancy and hydropower projects is large, diverse, and complex, so the pre-construction preparations should be made in advance. Wei Linliang and Li Zixiang [10] pointed out that the management and control at different construction stages must be clearly defined. Construction enterprises should make a technical submission before construction to make construction requirements and technical requirements clear to constructors and operate strictly by technical standards for foundation treatment of hydraulic and Hydropower projects. Employees with poor technical levels should use the period with less engineering volume for technical training, which can ensure humans' essential safety in the project's construction and reduce the incidence of safety production accidents.

Cluster 2 "control", water conservancy, and hydropower construction process always adhere to the "human-centered" view of safety, with hidden danger investigation and management as an efficient means of safety control. Fan Qixiang [11] et al. analyzed the characteristics of hidden dangers and causes of accidents, summarized a set of intelligent measures for hidden danger investigation and safety risk control of modern hydropower projects, and applied Wesafety [12] platform to initially realize intelligent flat-closed-loop management of hydropower project safety, and committed to essentially realize the dual prevention mechanism of safety risk grading control and real-time efficient, hidden danger investigation and management. Wang Junsong, Duan Bin [13], and others further combined new generation information technology and technology such as the Internet of Things, artificial intelligence, big data, and cloud computing based on project management informatization and engineering digitalization of Jinchuan hydropower

station to drive the triadic integration and collaborative operation of "human-machine-loop", to build a platform for prediction, monitoring, early warning, evolution, and control. Monitoring, early warning, evolution, and control of a comprehensive safety operation platform.

In Cluster 3, "Safety Production", the main keywords are safety supervision, employee benefits, safety protection, and safety system. The safety production situation is complicated and changeable in the new development stage. The construction of water conservancy and hydropower also involves a large number of personal control and mobilization, so the safety supervision work is facing significant challenges. Song Sixin and Zhao Yunsheng [14] pointed out that it is necessary to establish information-based countermeasures for safety production management in supervision enterprises so that the leaders pay attention to supervision work, implement supervision planning step by step, and build supervision platform and information-based supervision system in modules. At the same time, water conservancy and hydropower construction are difficult and dangerous compared with other construction, so the role of safety protection devices should be strengthened in the construction process.

The keywords in cluster 4, "emergency planning," and cluster 5, "hydropower engineering," involves emergency response several times. Li Yuqin [15] et al. provided safety emergency solutions. They established a safety emergency cloud platform, taking into account the emergencies in water conservancy and hydropower construction and the problems of most emergency industries in terms of technology, business knowledge, and supporting equipment.

The keywords in Cluster 6, "subcontracting team," are construction site, hazard sources, risk factors, supervision, management measures, and safety education. Nowadays, subcontracting has become a kind of basic engineering construction scheme. The subcontractors should pay attention to the safety production standards and norms of the construction site, the dangerous sources, and dangerous and harmful factors of the construction site. Jiang Xiuhui and Zhu Yanyue [16] analyzed the application of different hazard source evaluation methods by combining the actual situation of water conservancy and hydropower projects. They pointed out that the determination of significant hazard sources (processes) of construction projects by the LEC method realized the transformation from qualitative to quantitative and constructed a significant hazard source assessment factor applicable to building construction projects by using the safety production assessment factor of building construction enterprises as a hazard offsetting factor. By using the safety assessment factors of construction enterprises as risk offsetting factors, a method of assessing significant hazards for construction projects is constructed, and quantitative calculations of significant hazards (processes) for the project are carried out according to the specific construction situation, to achieve control and management of significant hazards.

In Cluster 7, "Safety Management", it is necessary to implement safety management during the construction process to ensure the safety of hydropower construction. Hydropower construction is a long, large scale, and difficult to manage, so it is challenging to implement safety management in detail. Safety management of teamwork is the basis and key to water conservancy and hydropower construction projects [17]. In the construction of team safety management, it is necessary to realize that the team

leader is the leader of safety management. It is necessary to assess the team leader regularly and simultaneously, clarify the list of responsibility systems of each participant in construction and implement the safety production responsibility system for the whole staff.

In Cluster 8, "water conservancy and hydropower", China faces energy system reform. Pumped storage station construction has become the mainstream of hydropower construction due to the unique characteristics of the pumped storage power station. Its construction is relatively more complex than traditional hydropower station construction, so all aspects should focus on strengthening the internal management system construction.

Table 2. Keyword clustering table

Cluster	Size	Keywords
#0 Construction	24	Construction management, management system, safety monitoring, hydropower construction, safety prevention
#1 Engineering construction	17	Control practice, construction technology, construction conditions and construction process
#2 Control	19	People-oriented, construction quality, engineering construction, accident potential and construction difficulties
#3 Safety production	16	Intrinsic safety, safety supervision, employee benefits, safety protection, safety system, construction control
#4 Emergency plan	11	Emergency management, safety awareness, emergency response, safety planning, corporate culture
#5 Water and electricity engineering	14	Hydropower engineering, craftsman spirit, emergency capability, grey fuzziness, safety appraisal
#6 Subcontracting team	12	Construction site, hazard sources, hazard factors, supervision work, governance measures, safety education
#7 Safety management	10	Safety management, factor identification, safety inspection, large equipment, simulation research
#8 Water conservancy and hydropower	16	Water conservancy and hydropower, construction management, control management, quality management and safety measures

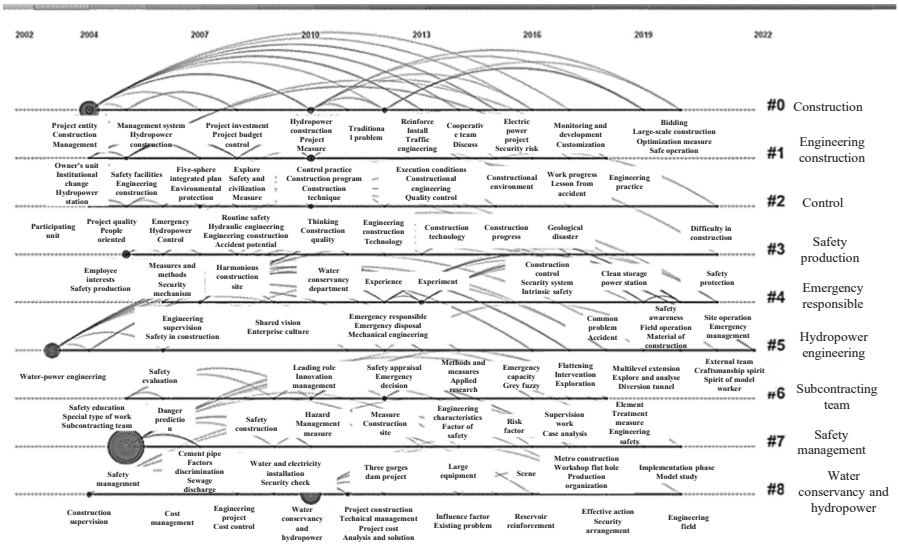

Fig. 2. Keyword co-occurrence analysis

4 Conclusion

For the analysis of the above co-existence, it is concluded that the future development direction of water conservancy and hydropower construction safety research is mainly focused on the following aspects:

(1) Improve the production safety responsibility system

As early as 1963, the State Council promulgated the "State Council on strengthening the safety of enterprise production in several provisions" put forward "the concept of production safety responsibility system"; in 2002, the promulgation of the "production safety law" put forward: "production and operation units must establish and improve the production safety responsibility system "In the past 20 years, the concept of responsibility system has been deepened, and the latest "14th Five-Year Plan" National Safety Production Plan points out the need to establish a comprehensive system of responsibility for production safety. The latest "14th Five-Year Plan" points out the need to establish a tightly woven network of risk prevention and control responsibilities, to effectively deepen the reform of the regulatory system, to compact the leadership of the party and government, to consolidate the departmental supervision responsibilities, strengthen the primary responsibility of enterprises, serious target responsibility assessment.

In water conservancy and hydropower construction, there are unclear responsibilities, management loopholes, the existing responsibility system not being implemented, and other issues. Combined with national policies and regulations, improve the all-round, multi-level, broad field of water conservancy and hydropower construction process of production safety responsibility system, consolidate the responsibility system of each department assessment and supervision mechanism, coordinate and coordinate all parties to strengthen the responsibility system, the responsibility system list to become the goal of future research.

(2) Build an information safety management system

Water conservancy and hydropower construction and management of such large projects are more complicated, need to coordinate all parties need to strengthen the project construction management. Nowadays is the era of big Internet data, and how to build and improve the information technology management system has become the subject of today's research. At present, Wesafety [12] platform can efficiently realize risk control and hidden danger investigation and management, and the "intelligent control" monitoring platform can realize the monitoring and supervision of each construction area. Various information software programs combined with safety to build a comprehensive "smart safety" system will become a significant future development trend. Green, sustainable development is the goal of the digital transformation of water conservancy and hydropower construction to minimize the impact on the surrounding environment so that it is genuinely a modern transformation.

(3) Sound all-round emergency concept

During the "14th Five-Year Plan" period, China's emergency development is still in a significant strategic opportunity period. To comprehensively improve the ability of public security, improve the level of safety production, improve the national emergency management system and another comprehensive deployment, solve the long-standing problems of emergency management, to promote the modernization of emergency management system and capacity provides a significant opportunity. The construction of large water conservancy and hydropower projects must comprehensively enhance emergency awareness, strengthen the construction of emergency plans, and build a safety and emergency cloud platform. Using information technology to realize the emergency disposal, command, and mobilization of large hydropower projects during construction is a subject we need to focus on.

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