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Review

Megaproject Governance Research in China: A Review and Visual Analysis from the Whole Life Cycle Perspective

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Abstract: At present, the number of megaprojects in China is rapidly increasing, with multiple projects ranked as the world's highest. To showcase the theoretical and practical achievements of China's megaprojects to the world, a visual analysis was carried out using CiteSpace software based on data from 520 pieces of core literature related to megaproject governance in the CNKI database from 2001 to 2023. Our findings indicate that: the number of publications has significantly increased since 2016, with a core group of researchers significantly contributing to this field, while team collaboration needs to be strengthened; the research hotspots include social stability risks, transaction governance, and innovation in megaprojects; the research can be divided into three stages, starting with early macro-studies, gradually forming clear and hierarchical research branches, and beginning to develop in the direction of Chinese characteristics and innovative deepening in recent years; research on the megaproject governance system is becoming gradually more enriched, but there is a lack of research at the levels of top-level governance and operational governance. Finally, in order to advance the study of megaproject governance in China, future research directions are suggested.

Keywords: megaproject; project governance; research progress; bibliometrics; whole life cycle; CiteSpace; China; CNKI

Citation: Ding, J.; Zhang, G.; Sun, M. Megaproject Governance Research in China: A Review and Visual Analysis from the Whole Life Cycle Perspective. *Buildings* **2023**, *13*, 1443. https://doi.org/10.3390/buildings13061443

Academic Editors: Saeed Banihashemi and Maxim A. Dulebenets

Received: 29 March 2023
Revised: 17 May 2023
Accepted: 30 May 2023
Published: 31 May 2023

1. Introduction

Megaprojects include mega national defense projects, mega scientific and technological projects, and mega infrastructure projects [1]. The mega infrastructure projects that the government invests in or participates in to provide fundamental services for people's lives with a long-term influence are the subject of this study, such as the South-to-North Water Diversion Project, the Three Gorges Project, the Hong Kong–Zhuhai–Macao Bridge Project, the Qinghai–Tibet Railway Project, etc. The "trillion-dollar age" of global megaprojects has now begun. With the deepening of reform and opening up, the construction quantity and investment amount in megaprojects in China have been increasing year by year. Megaprojects frequently exhibit large investment scales, broad spheres of influence, and numerous interested parties when compared to typical projects. The decision-making, management/governance, and execution of project organizations are greatly hindered by the complexity of megaprojects, which can result in issues such as cost overrun or delivery delays in megaproject practices [2,3].

In terms of complexity and advances, China's megaproject management practices are currently among the best in the world. A significant research field in project management, the governance of megaprojects, has gained worldwide attention over the past 10 years from academics and industry professionals. However, review literature on megaproject governance is mostly focused on one side. For example, Li Y.K. et al., established a theoretical framework for major engineering OB through bibliometric analysis and a comprehensive review [4]; Derakhshan R. et al., conducted a comprehensive analysis of project governance literature, identified the roles and relationships of stakeholders within and outside the organization, and opened up new avenues for stakeholder research

on project governance [5]; Wang T. et al., reviewed research on the success criteria and critical success factors (CSFs) for large-scale infrastructure projects [6]; and Yang D.L. et al., used CiteSpace and bibliometric methods to analyze the research hotspots, trend evolution, and thematic evolution trends in the field of social responsibility in megaprojects [7]. These studies can help us understand certain specific aspects of megaproject governance, but they do not provide readers with a comprehensive, quantitative, or systematic analysis of the current research status of megaproject governance in China.

To showcase the current development status of China's megaprojects to the world, we used CiteSpace software to conduct visual analysis based on 520 relevant pieces of literature with the theme of "megaproject governance" in the China National Knowledge Infrastructure (CNKI) database from 2001 to 2023. By analyzing the number of literature publications, author networks, cooperative institution networks, keyword co-occurrence, prominence, and time trend graphs, as well as reading and summarizing the original literature, this paper sorts out, categorizes, summarizes, and compares the research progress and hotspots regarding megaproject governance in China, providing a reference for further research. This study aims to address three key research questions (RQ) in the context of China:

RQ1. How extensive is the growth of published research articles on megaproject governance over time in China?

RQ2. Who are the major contributors (authors and institutions) to megaproject governance research in China?

RQ3. What are the research hotspots and advances in megaproject governance in China?

We believe that our research results are beneficial for the engineering industry and can help global construction industry practitioners understand the latest developments in the theory and practice of megaproject governance in China, thereby helping them determine the best strategy for the governance of new megaprojects, ensuring project management performance and achieving project goals, and enabling the successful delivery of megaprojects.

2. Data and Methodology

2.1. Data Source

To study the current development status of megaprojects in China, this article selects the China National Knowledge Infrastructure (CNKI) as the database, which is currently the world's largest continuously updated full-text database of Chinese academic journals. It is the most authoritative literature retrieval tool and online publishing platform for Chinese academic journals, and can basically and completely collect all the content of academic journals in China, and thus, can comprehensively reflect the current research status of megaproject governance in China.

Therefore, in this paper, we used "theme = megaprojects" or "theme = mega construction projects" or "theme = mega public projects" and "theme = project governance" as the search formula. At the same time, the megaproject governance research project approved by NSFC (the National Natural Science Foundation) and NSSFC (the National Social Science Foundation) was used as the carrier. It also selected typical projects, such as the South-to-North Water Diversion Project, the Three Gorges Project, the Hong Kong–Zhuhai–Macao Bridge, the Shanghai World Expo, the Beijing–Shanghai High-speed Railway, and the West–East Gas Pipeline, which have attracted much attention from the academic community in China. Based on this, the CNKI database was searched, and the published time range of the literature began on 1 January 2001, and ended on 31 March 2023. The retrieval results were de-duplicated and sorted, the low-level papers were removed, and 520 related documents were finally obtained.

2.2. Methodology

In order to present the development and structure relationship of scientific knowledge in the field of megaproject governance and to reflect the numerous complex relationships between knowledge groups [8], the bibliometric method and CiteSpace visual analysis software were used in this study. However, it is worth noting that the CNKI database is unable to conduct journal co-citation analysis compared to the WOS database. Based on the above analysis, from the standpoint of the entire life cycle, this study evaluated the existing research hotspots in China's megaproject governance area and identified a development direction for future research. The research framework is shown in Figure 1.

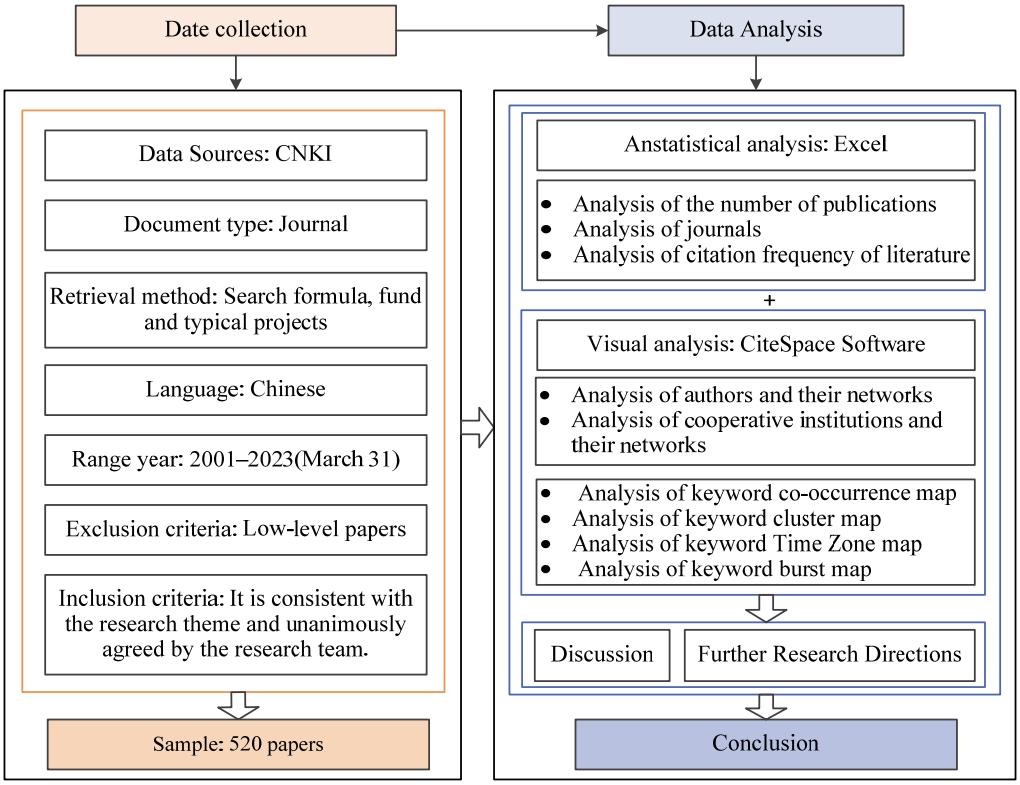

Figure 1. Research framework.

3. The Temporal Distribution of Publications on Megaproject Governance Research in China

3.1. Analysis of the Number of Publications

Figure 2 shows the number of documents issued for megaproject governance research in China from 2001 to 2023 (as of 30 March). It can be seen from Figure 2 that the number of papers on the governance of megaprojects in China has increased in the past 20 years, from 2 in 2001 to 52 in 2023. The research was divided into three stages: the embryonic stage (before 2006), the exploration stage (from 2006 to 2015), and the rapid development stage (after 2016).

In the embryonic stage (before 2006), the relevant literature paid less attention to megaprojects, and research on megaproject governance in China was in its infancy. Since 2006, the number of documents issued for the treatment of megaprojects in China has increased.

In the exploration stage (from 2006 to 2012), there were an average of 12 documents issued annually. This number increased, but at a relatively slow rate, and was still in the low output stage. From 2013 to 2015, there were an average of 31 papers issued annually, a significant increase over the 12-document average from 2006 to 2012. At this point, China's policy progressively shifted its attention to megaprojects, and academics intensified their research efforts in response. The majority of Chinese academics' research on megaproject governance was in the exploratory phase between 2006 and 2015.

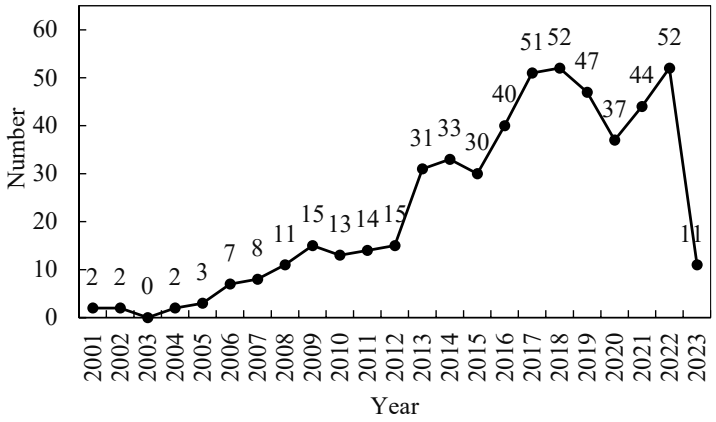

Figure 2. Number of publications related to megaproject governance in China between 2001 and 2023 (as of 31 March).

In the rapid development stage (since 2016), Chinese academics once more dramatically increased their research on megaproject governance, with an average of 46 publications being published annually. This shows that China's research on megaproject governance has advanced quickly, but it is also clear that fewer relevant papers were published in 2020 than in 2019, which indicates that the worldwide COVID-19 pandemic could have had a significant influence.

3.2. Analysis of Journals

The sample documents for this study were taken from 209 journals, of which 8 included more than 10 papers each, including *Management World* and the *Journal of System Management*, which have an important influence in China. The volume of papers published by major journals is depicted in Figure 3. Figure 3 shows that, with a total of 40 articles (9.5%), the *Journal of Engineering Management* is the journal with the most megaproject publications in China, followed by *Construction Economics* (8.1%) and *Project Management Technology* (5.7%).

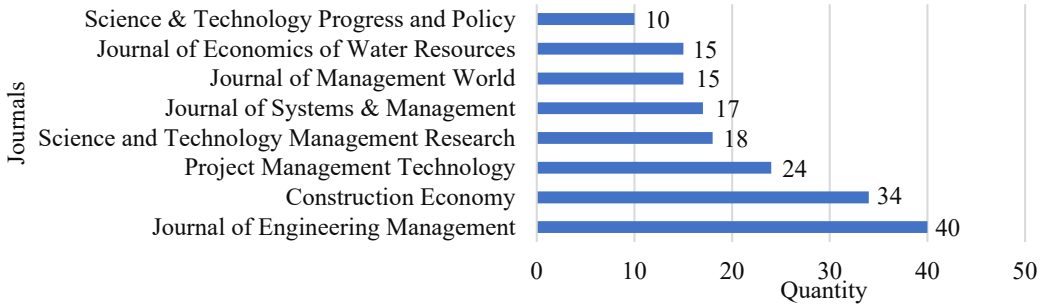

Figure 3. Number of related publications of major journals in China.

3.3. Analysis of Citation Frequency of Literature

The frequency of citations can serve as a side-by-side indicator of an article's academic worth. Highly cited literature suggests that it has resolved some significant scientific existential questions and even spawned new areas and lines of inquiry. Table 1 lists the Chinese publications, and the periodicals that served as their sources, that were cited more than 70 times in the sample publications, three of which were cited over 100 times; they are the foundation for conducting megaproject governance research. Table 1 shows that the majority of the material that has been cited the most in China was written before 2014, and it can be seen that relevant research has opened up some new directions for megaproject governance research.

Table 1. Highly cited papers and their sources.

Year	Source	Article	TC	Ref.
2004	*China Soft Science*	"Introduction about Project Governance Structure"	193	[9]
2010	*China Soft Science*	"The study on project governance based on social network analysis—an example of large construction project supervision"	178	[10]
2010	*Science Technology and Management*	"Study on social risk indicator system for large project"	118	[11]
2014	*Management World*	"Construction of the whole process management system for major engineering projects"	104	[12]
2018	*Journal of Systems & Management*	"Evolutionary game analysis of risk management behavior in major infrastructure projects based on prospect theory"	101	[13]
2013	*Statistics & Decisions*	"Social risk assessment of major engineering projects based on fuzzy comprehensive evaluation method"	94	[14]
2016	*Soft Science*	"Progress risk analysis of large-scale complex engineering project groups based on Bayesian network"	93	[15]
2006	*Construction Economy*	"Discussion on the implementation mode of integrated risk management for large construction projects"	91	[16]
2008	*Science & Technology Progress and Policy*	"Methods and methods of large-scale complex engineering management: comprehensive integrated management—Take Sutong Bridge as an example"	90	[17]
2018	*Journal of Systems & Management*	"Research on engineering risk management based on bayesian network—taking the design risk of main works of Hong Kong Zhuhai Macao Bridge as an example"	85	[18]
2019	*Management World*	"Constructing a major engineering management theoretical system and discourse system with Chinese characteristics"	71	[19]

4. Major Contributors to Megaproject Governance in China

4.1. Analysis of Authors and Their Networks

The cohesiveness effect of relevant research orientations in the study field might be shown via an analysis of researchers' collaborative relationships [20]. This study uses the research author as the node and CiteSpace software to conduct a visual analysis of the sample literature's research authors and their cooperative networks in order to assess the core researchers and their cooperative relationships regarding megaproject governance in China. Figure 4 displays the analysis findings.

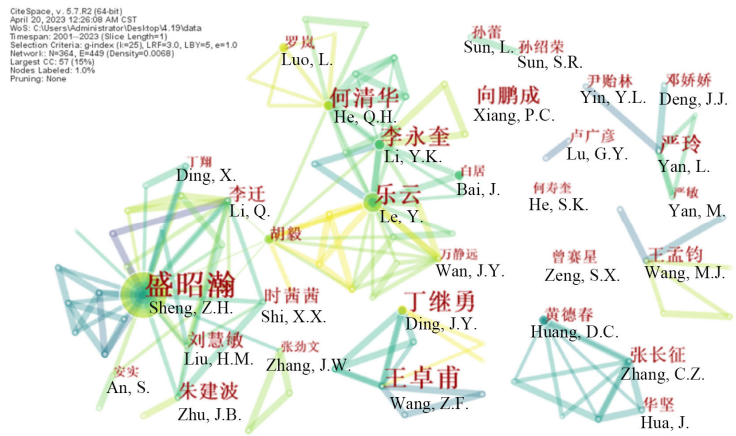

Figure 4. Authors and their cooperation networks (note: the authors added English translations corresponding to the original Chinese to aid understanding).

There are a total of 364 institution nodes (N = 364) and 449 network connections (E = 449) in Figure 4, with a density of 0.0068. The larger the node, the more articles the author has published. The connections between nodes represent the cooperation between different authors in publishing, and the thickness of the connections indicates the degree of cooperation between authors.

Figure 4 demonstrates that Sheng Z.H. is the most prolific author, accounting for 42 articles (8.8%) in total. Due to the mutual exchange and cooperation of scholars, a number of sub-networks of research authors have emerged in the maps, the most prominent of which is the team led by Sheng Z.H., which has formed a cooperation network with Li Q., Zhu J.B., and others. The second team is represented by Le Y., He Q.H., Li Y.K., and other scholars who are part of the collaboration network, followed by Wang Z.F.'s team. At the same time, there are also teams with fewer connections, such as Xiang P.C., Yan L., Yin Y.L., He S.K., Wang M.J., Zeng, S.X., etc. This demonstrates that scholars in the field of megaproject governance in China are relatively concentrated, the core academic group has made significant contributions, and cooperation among research team members is relatively close, but cooperation between teams needs to be strengthened.

4.2. Analysis of Cooperative Institutions and Their Networks

In order to further investigate the scientific research institutions and their cooperation in the field of the governance of megaprojects in China, this paper takes the research institutions as a node and uses CiteSpace software to conduct a visual analysis of the sample literature research institutions and their cooperation networks. Figure 5 displays the findings of the examination of research institutions and their networks of collaboration.

Figure 5. Research institutions and their cooperation networks (note: the authors added English translations corresponding to the original Chinese to aid understanding).

There are a total of 242 institution nodes (N = 242) and 174 network connections (E = 174) in Figure 5, with a density of 0.006. The larger the node, the more papers the research institution has published. The connections between nodes represent the cooperation between different research institutions in publishing papers, and the thickness of the connections indicates the degree of cooperation between research institutions.

Figure 5 shows that, with a total of 57 papers (13.6%), Nanjing University has the most publications, followed by Tongji University, Hohai University, Tianjin University of Technology, Tianjin University, Harbin Institute of Technology, etc. Many sub-networks of research institutions have developed in the atlas as a result of the institutions' mutual communication and cooperation. More remarkable is the network of collaboration that Nanjing University has formed with Tongji University, Shanghai Jiao Tong University,

Nanchang University, and other universities. On the one hand, there is cooperation among active research authors, indicating that these universities have relatively concentrated research on the governance of megaprojects. On the other hand, due to industry–university cooperation, such as the research network formed by the Hong Kong–Zhuhai–Macao Bridge Authority with Nanjing University, the Harbin Institute of Technology, and Shanghai Jiaotong University, the industry–university cooperation network can promote research in this field to a certain extent. At the same time, it can be seen that universities have formed obvious local cooperative network relationships due to regional relationships, such as Tianjin University and Tianjin University of Technology. Yet, it is also obvious that there is less cooperation across research institutions and that the connections between the institutions that cooperate, as shown in Figure 5, are not very strong.

5. Analysis of Keyword Knowledge Map

5.1. Analysis of Keyword Co-Occurrence Map

In order to identify important research topics on megaproject governance in China, this article conducted a keyword co-occurrence analysis. CiteSpace software was used to draw a keyword co-occurrence graph for megaproject governance research in China, in order to analyze the research hotspots in this field. The results are shown in Figure 6.

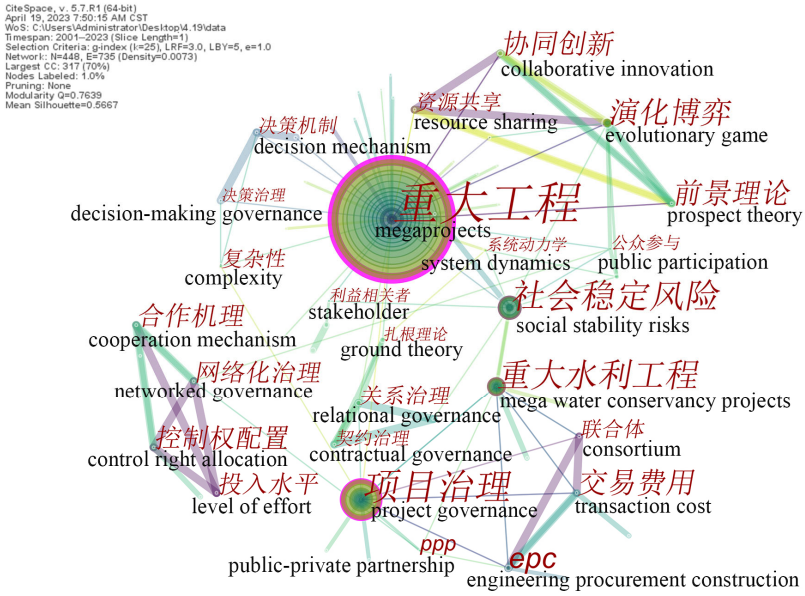

Figure 6. The keyword co-occurrence map for the field of megaproject governance from 2001 to 2023 (as of 31 March) in China (note: the authors added English translations corresponding to the original Chinese to aid understanding).

There are a total of 448 keyword nodes (N = 448) and 735 network connections (E = 735) in Figure 6, with a density of 0.0073. The larger the node, the higher the frequency of keyword occurrence. It can be seen in Figure 6 that the circle of "megaprojects" keyword nodes is the largest, while the circle of other keyword nodes is relatively small, indicating that "megaprojects" has the highest influence in the research field. The more connections there are, the more co-occurrence between two keywords. The thicker the connection, the stronger the connection, indicating wider research coverage in this field.

The frequency and centrality of the top 10 keywords are shown in Table 2. The keywords with higher centrality are more significant, and the research field of megaproject governance has greater importance.

Table 2. Top 10 keywords in the field of megaproject governance in China.

Rank	Keyword	Frequency	Centrality	Year
1	megaprojects	211	0.69	2001
2	project governance	70	0.30	2001
3	social stability risks	50	0.16	2008
4	mega water conservancy projects	45	0.12	2006
5	evolutionary game	29	0.05	2008
6	EPC	27	0.02	2007
7	transaction cost	25	0.01	2001
8	prospect theory	24	/	2008
9	collaborative innovation	23	0.02	2003
10	control right allocation	19	0.01	2002

Among the top 10 keywords, "megaprojects" has the highest frequency of occurrence, ranking first because it is a search term in our research. At the same time, "project governance" has the second highest frequency of occurrence, and is also a search term that we studied. Therefore, there is no need to consider them. Due to the fact that mega water conservancy engineering is a type of megaproject, an EPC project is one of the modes of a megaproject, and the centrality of a megaproject is much higher than that of mega water conservancy engineering and EPC, mega water conservancy engineering and EPC were not considered research hotspots in the analysis. Based on the above analysis, taking into account frequency and centrality, we identified the following six research hotspots: social stability risk, evolutionary game, transaction costs, prospect theory, collaborative innovation, and control allocation. Below, we will discuss these six research hotspots based on representative literature in the field of megaproject governance in China.

In terms of social stability risks, the research hotspots mainly focus on the evolution mechanism of social stability risks, the construction of evaluation index systems, and the study of evaluation methods. Li F. et al., used social combustion theory to construct a risk evolution analysis framework, revealing the generation and evolution mechanism of social stability risks in major railway projects [21]. On the construction of the evaluation index system, it is mainly launched from three aspects: risk source, logical structure, and evaluation theory. In terms of evaluation methods, there are currently three main methods in China: qualitative analysis, quantitative analysis, and comprehensive evaluation [22].

In terms of evolutionary games, the research mainly focuses on game analysis of the organizational behavior of key stakeholders of megaprojects, including owners, contractors, consultants, etc., focusing on risk management behavior, innovation behavior, social responsibility performance, and other issues. Zhao Z.B. et al., constructed a game model to analyze the risk management behavior of the public and private sectors in megaprojects [13]. Based on the evolutionary perspective, Zhu J.B. et al., explored the cooperation and innovation issues between the general contractor and subcontractors under the general contracting mode (DB) for megaproject design and construction [23].

In terms of transaction costs, the research mainly discusses how to design a reasonable project transaction governance structure to reduce project transaction costs. Ma T.Y. et al., used the correlation matching relationship between transaction and governance structure to derive the basic positioning of engineering project governance structure, which is the mixed trilateral governance model [24]. Yang Y.Y. et al., studied the impact path of construction project transaction costs and pointed out that the certainty of owner behavior can reduce the final engineering transaction costs [25].

In terms of prospect theory, game analysis is mainly based on this. For example, He S.K. et al., introduced prospect theory into megaprojects and constructed a three-party perceived benefit matrix for government, social capital, and the public. Through analysis

and simulation, they proposed that the government establish reasonable incentive and constraint mechanisms, enhance reward and punishment efforts, and enhance public participation awareness, in order to ensure that all parties align with the expected and ultimate goals of the project [26].

In terms of collaborative innovation, the main research focuses on the behavioral evolution, key influencing factors, and design of incentive mechanisms for collaborative innovation. He H.Y. et al., explored the evolutionary law of innovation behavior of megaproject innovation teams under deep uncertainty [27]. Xue F. et al., designed incentive contracts for the collaborative innovation of megaprojects under bilateral moral hazard [28].

In terms of the allocation of control rights, scholars mainly explore the reasonable allocation of control rights. For example, Zhai W.J. et al., pointed out through research that the allocation of the control rights of project legal persons has an "inverted U-shaped" relationship with the network governance benefits of major water transfer projects, and the investment level of the government and the public has an "umbrella shaped" relationship with the governance benefits [29].

5.2. Analysis of Keyword Cluster Map

We used CiteSpace software to draw a keyword clustering graph for governance research on megaprojects in China, as shown in Figure 7. Figure 7 shows a total of 10 larger clusters. According to the clustering graph standard, the more connections between keywords, the greater the Q value (graph information modularity), indicating better clustering performance. When Q > 0.3, the modularity of graph information is significant; when S (the graph contour coefficient) is greater than 0.5, the clustering effect is more reasonable.

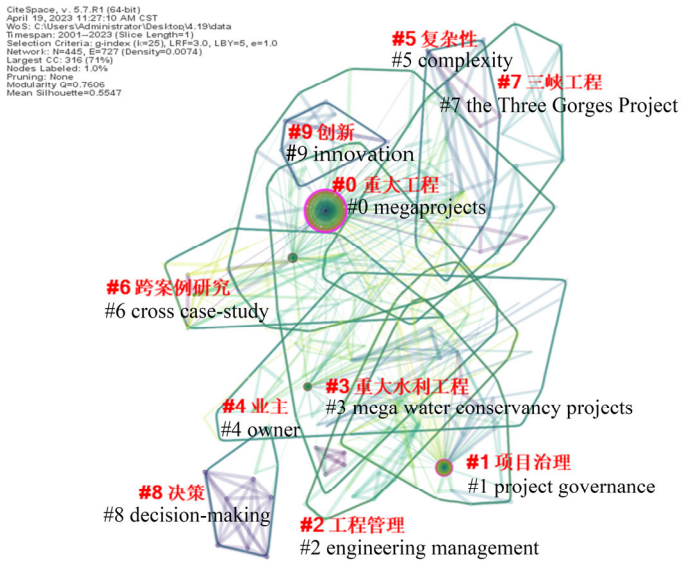

Figure 7. The keyword cluster map for the field of megaproject governance from 2001 to 2023 (as of 31 March) in China (note: the authors added English translations corresponding to the original Chinese to aid understanding).

From Figure 7, it can be seen that Q = 0.7606 and S = 0.5547, indicating a good clustering effect and reasonable clustering results, which can roughly reflect the overall situation of the research field. The silhouette reflects the degree of closeness between categories. If it is greater than 0.7, it indicates a strong degree of closeness. The year represents the year of concentration in which the category of research appeared.

Table 3 shows the top 10 clusters and their silhouette values. From Table 3, it can be seen that the keyword size and silhouette in the top 10 clusters far exceed the evaluation criteria, indicating that the relationships between categories are relatively close and the clustering effect is good. Among them, the silhouette of #5 (complexity) is 1, with the highest silhouette value among the 10 clusters.

Table 3. Top 10 keyword clusters in the field of megaproject governance in China.

Cluster ID	Size	Silhouette	Cluster	Mean (Year)
#0	73	0.95	megaprojects	2013
#1	43	0.87	project governance	2015
#2	42	0.95	engineering management	2008
#3	35	0.94	mega water conservancy projects	2012
#4	33	0.92	owner	2016
#5	26	1	complexity	2015
#6	24	0.87	cross-case studies	2019
#7	22	0.96	Three Gorges Project	2008
#8	19	0.95	decision-making	2007
#9	16	0.98	innovation	2010

From Table 3, it can be seen that the keyword size and silhouette value in the top 10 clusters far exceed the evaluation criteria, indicating that the relationships between categories are relatively close and the clustering effect is good. Using "megaproject" and "project governance" as search terms, megaprojects, project governance, engineering management and mega water conservancy projects occupy a central position in the graph. Keywords such as "owner", "decision-making", "complexity", and "innovation" are key subjects and research issues in megaproject governance, all of which are indispensable concepts in megaproject governance research. At the same time, due to the one-time and individual nature of megaprojects, no megaproject is completely the same. Conducting cross-case studies can better summarize the management experience of megaprojects and promote the construction of a governance system for megaprojects.

5.3. Analysis of Keyword Time Zone Map

This research uses the keywords as a node to illustrate development trends in the field of megaproject governance and conducts time series visual analysis of the keywords in the sample literature using CiteSpace software [30]. According to the "Time zone", a keyword map was created, and the results are displayed in Figure 8. The results of extracting the related high-frequency keywords are displayed in Table 4. Three steps make up the study method for megaproject governance in China, which is based on keyword information and its co-occurrence features.

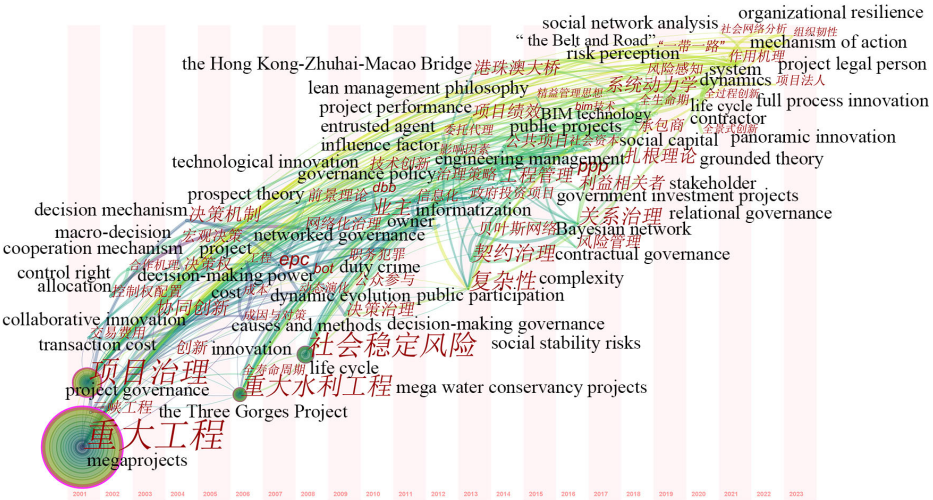

Figure 8. Keyword time zone network diagram (note: the authors added English translations corresponding to the original Chinese to aid understanding).

Table 4. Time sequence distribution of high-frequency keywords.

Year		Keywords
2001~2005 (infant period)		megaprojects, project governance, the Three Gorges Project, decision-making power, innovation, macro-decision; control right allocation
2006~2015 (exploration period)	2006~2012 (early stage)	mega water conservancy projects, decision governance, DBB, EPC, BOT, principal-agent, cost, life cycle, owners, information, public participation, networked governance, dynamic evolution, social stability risk
	2013~2015 (later stage)	the Hong Kong–Zhuhai–Macao Bridge, contractual governance, social capital, project performance, public projects, government investment projects, lean management idea, BIM technology, Bayesian network
2016~present (rapid development period)		stakeholders, contractor, "the Belt and Road", system dynamics, grounded theory, typical cases, institutional environment, Chinese characteristics, panoramic innovation, full process innovation, project legal entity, organizational resilience, social network analysis

The first stage, during which megaproject governance was in its infant stage, lasted from 2001 to 2005. During this stage, most relevant research was conducted from a macro-perspective. Megaprojects were expensive, took a long time to build, and had a broad range of effects. Correct project decision-making was based on scientific demonstration. The design of decision-making mechanisms and the distribution of decision-making power were the main topics of pertinent research. Moreover, China's management system, management mode, management standards, etc., also faced additional issues as a result of its WTO membership. One of the key research hotspots was how to integrate project information management and improve China's project management in accordance with international standards.

The second stage ran from 2006 to 2015 and was the megaproject governance exploration phase. Although the research generally stayed in the qualitative stage of theoretical description, the research material primarily focused on the common issues of project governance. The studies were still carried out from a macro-perspective in the early phases of this stage (2006–2012), but they initially demonstrated an exploration trend of various project types and research methodologies. For instance, pay attention to how megaprojects in the sectors of transportation, nuclear energy, and water conservation were managed. These studies assessed particular forms of governance, such as decision-making governance. The governance of megaprojects under various procurement modes, such as EPC, BOT and DBB, also started to attract the interest of scholars with the innovation of the project transaction model. One of the areas of research focus was the governance among the key parties involved in megaprojects, such as the owner and the general public. Evolutionary games, simulation analysis, and other methodologies were usually utilized. With the frequent occurrence of corruption issues in megaproject construction, duty crimes were also one of the key research directions at this stage.

The later stage of the exploration phase (2013–2015) was conducted primarily from a micro-perspective due to the investigation's depth. The project governance of the Hong Kong–Zhuhai–Macao Bridge project became a hot research topic at this stage, while also focusing on contractual governance and relationship governance among megaproject stakeholders, exploring the impact of governance elements on project governance. With the implementation of megaprojects, the complexity of megaprojects became a focus of scholars' attention, and project value-added, benefit distribution, etc., also became a focus of research at this stage. Lean management concepts and BIM technologies were used for megaproject management as a result of the rapid growth of information technology.

The third stage runs from 2016 to the present. This stage represents the rapid development of megaproject governance. Pertinent research frequently focuses on management innovation with Chinese characteristics. The research on megaprojects has advanced quickly in recent years, as evidenced by the 165 megaprojects that were specifically implemented during the 13th Five Year Plan, the 102 megaprojects that were promoted during the 14th Five Year Plan, and the proposal of the Belt and Road Initiative. The modernization of megaproject governance became a key priority in the field of project governance at the same time as the 19th CPC Central Committee's fourth plenary session proposed the overall goal of supporting the modernization of the national governance system and governance capability.

In the third stage, the megaproject construction has formed the fundamental institutional framework of the "government leading + market mechanism" under the institutional framework of socialism with Chinese characteristics. Scholars have carried out research on the institutional environment, management innovation, and other aspects, among which comprehensive, panoramic, and all-subject megaproject innovation research has also become one of the research hotspots. At this stage of the research, attention has gradually switched from qualitative to quantitative methods, and rooted theory, typical instances, and other methodologies are widely utilized. Megaproject governance has also been studied using the collaborative governance theory, life cycle theory, and network governance theory. In addition, with the research on organizational behavior and organizational models, building a resilient organization for megaprojects has become an important governance goal, and related research has also been gradually launched.

5.4. Analysis of Keyword Burst Map

Keyword burst analysis can identify keywords at the forefront of research in this field, and refers to a sudden change in the number of keywords in a short period of time [31]. A keyword burst includes two dimensions: burst intensity and burst time. Keywords with high burst intensity can be identified as prominent research topics, and the burst time can divide the research process. Based on CiteSpace software, the top 15 high-strength keywords in this field were obtained, as shown in Figure 9. From Figure 9, it can be seen that the strength values are all greater than one, with a maximum of 4.2094.

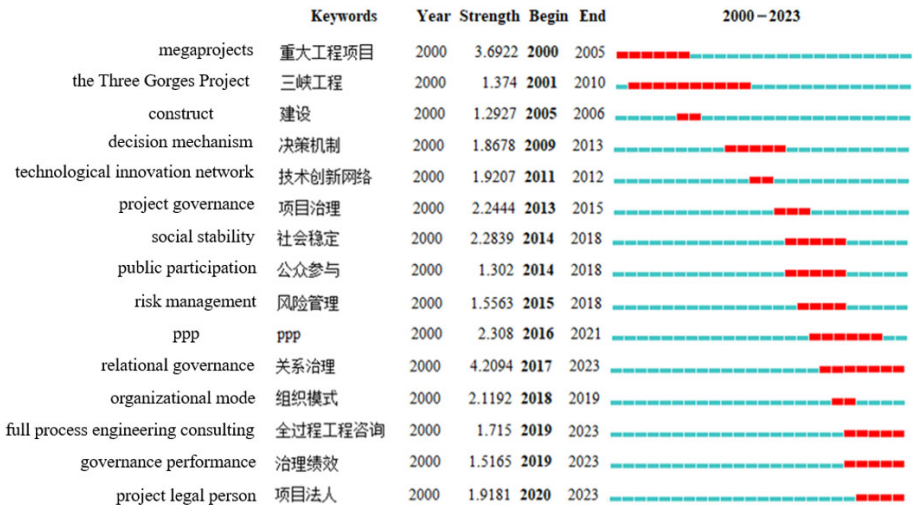

Figure 9. The keyword burst map of megaproject governance research in China from 2001 to 2023 (as of 31 March) (note: red represents the period of detected term burst, while blue represents the time. The authors added English translations corresponding to the original Chinese to aid understanding).

From 2001 to 2005, there were three burst words during this stage, including "megaprojects", "the Three Gorges Project", and "construct". Among them, the most intense keyword was "megaprojects" at 3.6922, which corresponds to the embryonic stage of research and

development. This corresponds to the previous results of keyword clustering co-occurrence and keyword clustering. During this period, megaprojects were a new research subject, and scholars conducted preliminary explorations, mainly focusing on the Three Gorges Project. Meanwhile, in 2004, Yang F.X.'s article "Introduction about project governance structure" received the highest citation frequency and opened up a research direction for megaprojects [9]. From 2001 to 2005, it promoted scholars' research interest in megaproject governance.

From 2006 to 2016, there were a total of seven burst words during this stage, including "decision-making mechanism", "technological innovation network", "project governance", "social stability", "public participation", "risk management", and "PPP". Among them, the burst intensity of "social stability is the highest", at 2.2839, which corresponds to the exploration stage of research and development. This corresponds to the high citation of the paper "Social risk assessment of major engineering projects based on fuzzy comprehensive evaluation method" published in *Statistics & Decisions* in 2013 [14]. At this stage, due to China's economic development and social progress, multiple megaprojects have been approved for construction. Although the investment in and construction of megaprojects have greatly improved people's living standards, the scale of investment is large, the scope of influence is wide, and there are many stakeholders involved. The complexity of these megaprojects is high, and they also causes crises. Some project planning is unreasonable, or the environmental pollution and benefit distribution issues caused by the project cannot be effectively solved, which can cause dissatisfaction among the public and breed potential social stability risks. If these risks are ignored or not properly handled, potential risks will surface, social conflicts will be exacerbated, leading to social unrest, and there will be adverse social and political impacts. Therefore, the social stability risks of megaprojects have also become a research hotspot.

From 2016 to the present, there are a total of five burst words during this stage, including "relationship governance", "organizational model", "whole process engineering consulting", "project performance", and "project legal entity". Among them, the burst intensity of "relationship governance" is the highest, at 4.2094, which corresponds to the rapid development period of research and development. Relationship governance is an important component of governance mechanisms, and the reasonable design of governance mechanisms plays a significant role in improving project performance. At this stage, the governance mechanisms of megaprojects based on the Chinese context have been widely studied. For example, Luo L. et al., pointed out that the megaproject governance mechanisms include government governance, relationship governance, and contract governance [32]. Empirical research has shown that the use of risk sharing, relationship maintenance, government supervision, and government coordination in megaproject governance can significantly improve project governance performance. It can be seen that the government research on megaprojects at this stage has shifted from focusing on external decision-making and risks to focusing on internal governance mechanisms, and the research has developed in depth. Project performance, project legal representation, and other issues have gradually become research hotspots.

6. Discussion and Further Research Directions

Through the above analysis, we have gained a certain understanding of the research on megaproject governance in China. Based on the research results, we will further discuss and analyze future research directions.

6.1. Discussion

Megaproject governance is the key to improving project performance and ensuring successful project delivery. The research on megaproject governance in China has undergone several stages between 2001 and 2023, including the infant stage, the exploration stage, and the rapid development stage, and has generated a variety of outcomes. Here, we will discuss megaproject governance-related research in more detail.

Megaproject construction should go through the project approval, project execution, and project operation processes or stages when the project is finished, similarly to general construction projects. Throughout these procedures or stages, there are challenges with governance. The megaproject governance system can be broken down into decision-making governance, top-level governance, transaction governance, and operation governance from the perspective of the whole life cycle. There are problems with governance structure and mechanism regardless of the process or stage of governance. Intelligent platforms have been developed as an element of megaproject governance with the development of contemporary technology. Based on this, a megaproject governance system can be built, as shown in Figure 10.

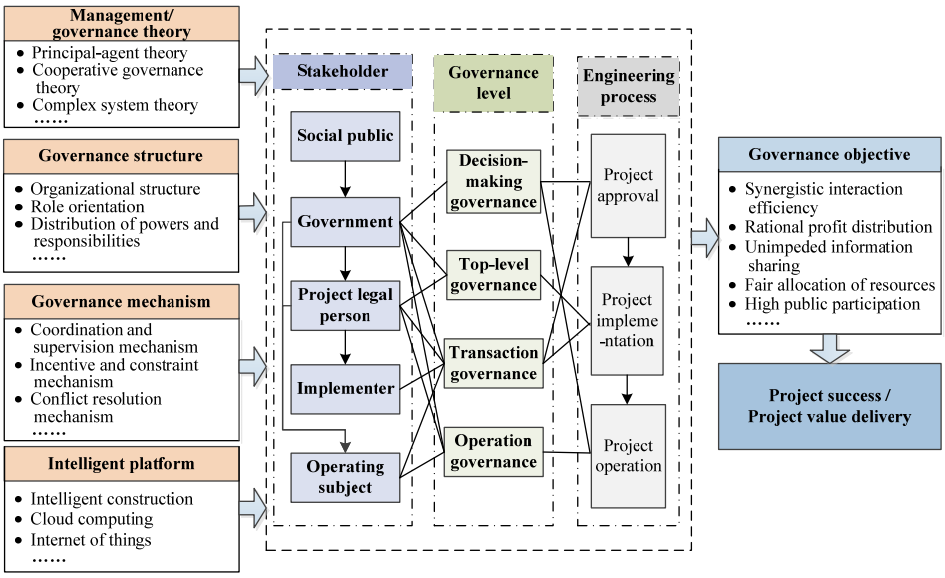

Figure 10. Megaproject governance system.

6.1.1. Megaproject Decision-Making Governance

The scientific allocation and balance of the decision-making subject's decision-making power, governance capacity, and executive power comprise megaproject decision-making governance. Studies were mainly carried out by Professor Sheng Z.H. and his research team, who undertook numerous NSFC projects such as Research on the Theory, Method and Application Innovation of China's Major Infrastructure Project Management (71390520), Research on the Decision Analysis and Decision Management of Major Infrastructure Projects (71390521), etc. These authors have attained an affluence of study results, developed and refined a number of megaproject management fundamental concepts, including "government" principal-agent [33], complexity degradation [34], meta-synthesis management, and adaptive selection [35], designed a theoretical model and discourse system for megaproject management with Chinese characteristics, proposed a new megaproject management model called complex system management [36], and studied the "governance of China" [37].

In addition, considering the complexity of megaproject decision-making, relevant literature has involved research on the features of decision-making complexity of megaprojects [38], decision-making complexity degradation [34,39], and ethical issues in the decision-making process. The quality of the decision-making process [40], the quality of the decision-making scheme [41], and decision-making objectives [42] were investigated in terms of the decision-making quality and decision-making evaluation of megaprojects. Other studies have proposed mechanisms, such as risk assessment and early warning of large project decision-making [43], expert selection [44], and information transfer [45], to ensure the science of decision-making. Regarding the study of the decision-making and governance systems of megaprojects, Li Q. et al. [46] used the Hong Kong–Zhuhai–Macao Bridge as

an example to build a decision-making and governance system of a megaprojects; moreover, Hu Y. established a maturity model of decision-making and governance capability for megaprojects, which provides theoretical support and a basis for the standardized management of the decision-making and governance of megaprojects.

Megaproject governance decision-making starts from the basic theory of government-style hierarchical principal-agent relationships in the market environment of megaproject decision-making. Megaproject decision-making is highly complex due to the multi-level and dynamic nature of the hierarchical agent chain, as well as the interdisciplinary and integrative nature of the decision-making issues. The four levels of governance, however, are interdependent. For instance, top-level governance, transaction governance, and practical governance are all influenced by decision-making governance. In order to modernize the capacity for decision-making governance of significant projects in the future, this study will focus on the internal relationships between the four governance levels. Therefore, exploring the internal relationships of the four governance levels could represent a research direction for the modernization of the decision-making governance capacity of megaprojects in the future.

6.1.2. Megaproject Top-Level Governance

The rational and scientific distribution of responsibilities and power between the government and a project's legal entity is called megaproject top-level governance. It is the core of the whole project governance system and has an impact on the governance of various megaproject transactions. Megaproject top-level governance is currently the focus of relatively few systematic research findings. Hu Yi and others proposed that the top-level governance function be strengthened at the headquarters of megaproject construction on the basis of the twin roles of "government + market" [47]. Some scholars have carried out research on megaproject top-level governance from the aspects of organizational models and behavior, top-level governance structure, top-level governance mechanisms, etc.

In terms of organizational models and organizational behavior, researchers have studied the evolution of organizational models, the diversity of organizational models [48], organizational citizenship behavior [49], tunnel behavior [50], etc. In studies of top-level governance structure, scholars have discussed the establishment of major water conservancy project legal persons [51], proposed the "government-contract-relationship" three-dimensional project governance structure [52,53], and carried out research on the optimization of the top-level governance structure of major water conservancy PPP projects [54]. In a study of top-level governance mechanisms, scholars considered the intermediary role of organizational situations and psychological state on governance performance [55], and built a megaproject top-level governance model based on housekeeper–agent theory.

The key to the entire megaproject governance system is megaproject top-level governance, and although the majority of the current study is conducted from one aspect, there is not much focused research on megaproject top-level governance. The theoretical study findings on megaproject top-level governance are generally weak and do not indicate the importance of this aspect of project implementation. In order to create a structured research framework, it will be important to conduct more focused research on megaproject top-level governance in the future.

6.1.3. Megaproject Transaction Governance

Megaproject transaction governance is guided by the realization of the objectives of megaprojects, and has always been the most widely concerned field. In a limited sense, megaproject transaction governance can be equated to megaproject governance. It aims to coordinate and balance various interest relationships between the project legal person and different market transaction entities, with a focus on the project legal entity. Currently, there are a considerable number of studies on megaproject transaction governance, mostly focused on the core elements of project transaction governance, such as the structure and mechanism of transaction governance.

On one hand, governance structure has a significant impact on the project's success, and several researchers have conducted relevant research based on various situations [56,57], such as nuclear power projects, large-scale public projects, water conservancy infrastructure PPP projects, highway PPP projects, etc. On the other hand, numerous studies on general project transaction modes have been conducted by Wang Z.F. and other practitioners, including transaction mode [58], transaction governance organization mode [51], transaction subject selection method [59], and contract type [60].

Several levels and different types of project transaction have diversified interest relationships among their transaction subjects in the governance of megaproject transactions, resulting in a diversified state of governance mechanism. On one hand, scholars define the framework of the governance mechanism for megaproject transactions as contract governance and relationship governance; on the other hand, some scholars discuss the impact of the bidding mechanism, income distribution mechanism, conflict resolution mechanism, and incentive and restraint mechanism on the success of the project [61–63]. Wang Z.F. and Ding J.Y. proposed a design theory and method for a megaproject transaction governance mechanism from the aspects of megaproject consulting project transaction governance and megaproject contracting project transaction governance [64].

In the research on megaproject transaction governance, the empirical research on megaproject transaction governance is still insufficient, the empirical research methods used have been relatively simple, and the data have primarily been obtained through questionnaire surveys, which can result in deviation; moreover, in the context of digital construction, the transaction element of the digital construction platform has been added to the transaction. Future studies will focus on how to create a rational and scientific management approach around the digital construction platform to effectively accomplish management goals and support project delivery success.

6.1.4. Megaproject Operation Governance

The operation phase is long and complicated after megaprojects are finished. The key to operation governance during the operating period is the coordination of the interests of relevant parties within the project's influence zone. Megaproject operation governance research is still comparably under-studied. It focuses primarily on PPP projects, on the one hand, and on megaprojects that have been completed, on the other.

Regarding the operation governance of PPP projects [65–67], researchers have looked at the investment return mechanism during the operation period of water conservancy PPP projects, risk management behavior during the operation period of PPP projects, renegotiation initiators' motivations and the renegotiation bargaining process during renegotiation during the operation period, and the exit decision of social capital of PPP projects.

Some papers have also researched the operation of megaprojects that have already been finished, such as the South-to-North Water Diversion Project and the Hong Kong–Zhuhai–Macao Bridge. For example, for the South-to-North Water Diversion Project [68–70], scholars have discussed the conflict between ecosystem services and compensation, the water pricing mechanism, the operation management mechanism, the income distribution mechanism, the water-saving mechanism, and other relevant issues. For the Hong Kong–Zhuhai–Macao Bridge project, some scholars put forward the operation management concept and strategy of "institutionalized management, intelligent operation and maintenance, market-oriented operation, and professional service" [71], and built a proprietary cloud platform for the Hong Kong–Zhuhai–Macao Bridge [72].

Decision-making governance and top-level governance have an impact on the governance optimization of the megaproject operation process from the viewpoint of the entire life cycle. It can be expected that project operation governance will soon become a study hotspot due to the gradual completion of megaprojects and the gradual attention of all parties paid to the project operation stage. The refined operation of megaprojects and the data governance of intelligent operation and maintenance platforms will become an important research direction for megaproject operation governance in the future.

6.2. Further Research Directions

Through quantitative analysis of the documents related to the megaproject governance published by domestic scholars in the past 20 years, it can be seen that this field is in an ascendant stage. In combination with social development and the changing trends of domestic and foreign situations, and looking forward to the future, the research on megaproject governance in China can be further expanded and deepened from the following aspects:

(1) Research on the construction of megaproject governance theoretical systems with Chinese characteristics. In the international academic and engineering communities, megaproject management and governance has emerged as a study hotspot. However, the current research perspectives are divergent, the scope of research is broad, and the research is in a "fragmented" condition. It is challenging to conduct an in-depth study, develop a theoretical framework, and provide a direction for the execution of megaprojects. The public project governance theory serves as the theoretical foundation for the current study of megaproject governance, and incorporates transaction cost theory, principal-agent theory, corporate governance theory, and collaborative governance theory [73]. At the same time, decision-making governance, top-level governance, operational governance, and transaction governance are interconnected rather than distinct from one another. Each governance level can be regarded as a subsystem. For example, the design of the transaction governance mechanism should be carefully thought out because it will influence the top-level governance structure and even the operational governance model.

Therefore, under the institutional framework of "government leading + market mechanism" in China, one of the development paths of megaproject governance in the future is to actively innovate megaproject management/governance theory [74], build a modern, systematic, and localized megaproject governance theoretical system, and explore the interrelationships of the four governance levels.

(2) Research on megaproject top-level governance structure optimization. Megaproject governance structure has a significant impact on megaproject success. However, the research on governance structure focuses more on the transaction governance level, whereas the present research on megaproject governance focuses more on the governance mechanism. The top-level governance of projects has become the primary focus of the megaproject governance system due to the uniqueness of China's system and mechanism, which has a significant effect on megaproject governance activities. Megaprojects differ from general projects in that they have a large and complicated structure and involve numerous stakeholders. It is easy to delay decision-making and reactions when faced with a complex and dynamic internal and external environment. From an organizational standpoint, megaproject organizations lack resilience to a certain extent, which is closely linked to how megaproject top-level governance structures are designed [75]. At the same time, at each stage of the life cycle of a megaproject, different participants will intervene or withdraw, and they will assume different responsibilities and have a constantly changing relationship with each other [76], which means the top-level governance structure of the project differs between life cycle stages and needs dynamic adjustment and optimization.

Therefore, from the top-level perspective, based on the particularity of China's system, carrying out dynamic optimization design research on megaproject governance structure, making the organization of megaprojects more resilient, and finally, realizing the value delivery of megaprojects are some of the core research focuses of megaproject governance in the future.

(3) Quantitative design research on the megaproject transaction governance mechanism. The current relevant study results broadly define the framework of the megaproject governance mechanism as contract governance and relationship governance, and it is generally thought that there is a complementary link between the two [55]. The megaproject governance mechanism is an addition to governance structure, and its

research is more complex. This is because megaprojects are implemented in stages, the situation of governance objects at each stage is different, and the governance mechanism also needs to change. For instance, when a megaproject legal person chooses a specific organizational structure, or governance structure, at the edge of the project, different governance mechanisms are objectively needed at different stages of the project due to variations in the project's external boundaries, such as the policy and regulatory environment. The majority of current studies, however, are conducted from an interpretive research perspective and mostly rely on questionnaires to collect data, which can lead to mistakes. The reference and use of quantitative and standardized research methods are of great significance to the study of megaproject governance. For the design of megaproject transaction governance mechanisms, we can explore the use of operational research methods to build a mechanism design model, analyze the mechanism-influencing factors and relevant parameters, and carry out solution analysis.

Therefore, combined with the megaproject transaction governance structure, carrying out research on the formulation of a quantitative portfolio matching the designs of the megaproject governance mechanism from the perspective of scenario embedding is an important direction of future research on megaproject governance.

(4) Research on smart platform governance of megaprojects. The traditional construction process and megaproject construction approach have been altered by intelligent construction technology based on BIM [77]. This has an effect on megaprojects during both the project's construction and operating phases. As a result, the widespread adoption of intelligent construction technology and platforms is a necessary development direction. In megaproject transactions, an intelligent construction platform is crucial. All parties participating in project transactions make decisions regarding project planning, control, and management here, as well as the storage, transmission, and application of information related to megaproject transactions. In addition, it alters each transaction subject's behavior in the conventional project transaction and enhances the observability and symmetry of the information in the process [78,79]. On the other hand, intelligent construction platforms have been incorporated into transactions in the framework of intelligent construction. Building and managing an intelligent construction platform have a significant impact on the role of the intelligent construction platform and improving megaproject performance. On the other hand, the primary suppliers of data information in the project implementation process are the project consultant and the project contractor, so a new "information asymmetry" problem has emerged. An important concern in the operation and control of intelligent construction platforms for megaprojects is encouraging them to actively and promptly give objective project data information [80].

Therefore, in the context of intelligent construction, it is worth carrying out research on the logic of governance reforms of megaproject transactions, and exploring the optimization of management modes of intelligent construction platforms, incentives of project data information supply, income distribution, data governance, etc., and analyzing the behavioral evolution of each transaction subject in megaproject transactions in the future.

7. Theoretical and Practical Contributions

Based on the above analysis, the contributions of this paper can be concluded as follows:

First, this review provides a comprehensive, quantitative, and systematic visual analysis of megaproject governance in China. Based on CiteSpace software, various research sub-domains in this field are plotted, and the main content of the research is analyzed and focused on.

Second, a megaproject governance system in China is studied and constructed, and we analyze the four levels of decision-making governance, top-level governance, transaction governance, and operation governance throughout the project life cycle. This helps scholars

clarify the basic content of the megaproject governance system and helps them to carry out targeted governance theoretical research.

Third, research has shown that with the development of society and the economy, megaproject governance has become a research hotspot. This review paper can help us better understand the current development status of megaproject governance, and apply systematic literature review analysis methods to provide guidance for future scholars' research.

Fourth, this study points out insufficient research in this field, as well as gaps and deficiencies in the existing literature. Due to the gap and inconsistency between theory and practice, research can make significant contributions to the governance development of future megaprojects. This article provides a more comprehensive understanding of megaproject governance and promotes further theoretical and practical development.

Fifth, by drawing a knowledge graph and constructing a megaproject governance system, valuable practical guidance can be provided for construction practitioners. With the transformation and upgrading of industry, intelligent construction platforms have become a key governance element in project transaction governance, which helps senior managers carry out top-level design research.

Lastly, our research provides a complete theoretical framework for governments, project entities, and others, which can ensure high project management performance and the attainment of project objectives, and enable the successful delivery of megaprojects.

8. Limitations

Although this research focuses on "megaprojects", "mega construction projects", "mega public projects", and "project governance" as keywords, uses NSFC and NSSFC initiation projects as carriers, and selects typical engineering cases that have received much attention from the academic community for literature screening, the data source is mainly Chinese core literature; thus, the study lacks a comparative analysis of English literature and ordinary journal literature. Therefore, our research has limitations such as incomplete data information and incomplete literature mining. In future research, consideration will be given to expanding the scope of the literature analysis to better grasp the progress and trends of megaproject governance research. At the same time, in future research, we will consider using data technology to export references from CNKI through the use of crawler software, and conduct literature co-citation analysis to further determine the research foundation for megaproject governance.

9. Conclusions

Currently, the number of megaprojects in China is rapidly increasing, with a relatively large number worldwide. To our knowledge, this article is the first study to systematically and comprehensively analyze megaproject governance in China over the past 20 years using bibliometric methods, showcasing the current research status of China's megaproject governance theory and practice to the world. Therefore, this article analyzed the basic situation of megaproject governance research in China, including the number of publications, published journals, and highly cited pieces of literature; identified the contributions of research authors and institutions by analyzing collaborative networks; and explored the research progress and advances in this field by analyzing a keyword knowledge graph. The main conclusions are as follows:

(1) Over the past two decades, research related to megaproject governance in China has developed rapidly, and the number of research papers has increased year by year since 2005. The research results are mainly published in professional journals in the field of engineering management or important journals with high recognition in the field of management and economics.

(2) The core academic group of megaproject governance in China has made great contributions to areas such as megaproject decision-making governance, mainly studied by Sheng Z.H.'s team, organizational models and organizational behavior, mainly investigated by Le Y.'s team, and megaproject top-level governance, studied by Wang

Z.F.'s team. However, cooperation between teams needs to be strengthened, and cooperation between high-yield research institutions is also scarce.

(3) The research hotspots include social stability risks, transaction governance, and innovation in megaprojects. China's megaproject governance research has gone through three stages of development, from a relative macro-level focus on the innovation of the management system to a micro-level focus on project governance structure, the project governance mechanism, project performance, project value-added, etc. At present, megaproject governance has begun to integrate new governance elements, such as BIM and intelligent construction, showing Chinese characteristics and deepening the trend of innovation.

(4) Megaproject governance can be divided into decision-making governance, top-level governance, transaction governance, and operation governance according to the project implementation process. Among them, compared with decision-making governance and transaction governance, the research on top-level governance and operational governance is obviously insufficient. Studies on engineering practice and related research [53,81] show that in-depth research on the optimization of the top-level governance system and the improvement of megaproject governance capacity are of great significance to promote megaproject construction levels or the improvement of project performance. At the same time, with the gradual completion of megaprojects, it is expected that project operation governance will become a research hotspot in the future.

This review utilized bibliometric methods to comprehensively, quantitatively, and systematically analyze the current status of governance research on megaprojects in China, including publications, major contributors, and keyword knowledge maps. Based on the analysis results, a discussion in conducted and future research directions are suggested. On the one hand, research can provide a foundation for future scholars' theoretical research in this field, and on the other hand, it can provide valuable practical guidance for construction practitioners.

Through the above analysis, we propose several future research directions. Firstly, we propose the construction of a theoretical system for megaproject governance with Chinese characteristics, exploring the interrelationships between the four governance levels. Secondly, we propose conducting dynamic optimization design research on megaproject governance structure, in order to make megaproject organization more resilient. Thirdly, based on the governance structure of megaproject transactions, we propose conducting research on the development of quantitative combination matching design for megaproject governance mechanisms from the perspective of scenario embedding. Fourthly, in the context of intelligent construction, we propose conducting research on the logic of governance transformation for megaproject transactions and exploring the governance of intelligent construction platforms. Last, but not least, we propose expanding the scope of literature analysis and comparing megaproject governance databases in different countries, in order to better grasp the research status of megaproject governance around the world.

Author Contributions: Conceptualization, J.D. and G.Z.; software, G.Z.; formal analysis, J.D., G.Z. and M.S.; data curation, J.D., G.Z. and M.S.; writing—original draft preparation, J.D., G.Z. and M.S.; writing—review and editing, J.D., G.Z. and M.S.; supervision, J.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the National Social Science Foundation of China (Grant No: 19FJYB004), the Postgraduate Research and Practice Innovation Program of Jiangsu Province, China (Grant No: KYCX22_0701), and the Anhui Natural Science Foundation, China (2208085US19).

Data Availability Statement: Not applicable.

Acknowledgments: We would like to thank the anonymous reviewers for their valuable comments and suggestions for improving this paper.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

PPP	Public–private partnership
EPC	Engineering procurement construction
BOT	Build–operate–transfer
DBB	Design–bid–build
BIM	Building information modeling
NSFC	National Natural Science Foundation
NSSFC	National Social Science Foundation

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