

A Review of Research Trends in Public-Private Partnership based on CiteSpace: Bibliometrics and Visualization

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Abstract: Applying the Public-Private Partnership (PPP) model is indispensable in creating new economic growth points in the public service sector. However, there is still a lack of research on mapping the application of the PPP model in the new era and context. Therefore, based on reviewing the characteristics and development concepts of the PPP model, this paper uses CiteSpace software to analyze the sample authors, journals, and regions in the Scopus database. This paper aims to explore the current development status, research paradigms, and research gap as well as future trends of the PPP model. The results show that (1) The focus of PPP research has shifted from traditional models such as Build-Operate-Transfer (BOT) and Private Finance Initiatives (PFI) to contemporary themes such as risk management, policy analysis, and project governance. Subsequent research (2014–2018) has emphasized the importance of governance and regulatory frameworks to improve PPP outcomes. (2) The growing academic interest in PPP development in China accounts for 28.78% of the total publications. This surge reflects China's rapid economic growth and highlights the interplay between government regulation and private financing. Key research themes include risk management, performance evaluation, contractual flexibility, and financing mechanisms, particularly concerning the BOT model. (3) Effective risk management, relationship dynamics, and innovative financing strategies are key components of a strong PPP knowledge framework. Collaborative risk sharing and strong relationships between public and private entities are key to project success, and strategic financing partnerships are necessary to cope with the complexity of large infrastructure projects.

Keywords: CiteSpace; Public-Private Partnership (PPP); Bibliometrics and visualization

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1. Introduction

As early as the 17th century, the United Kingdom began utilizing the Public-Private Partnership (PPP) model for public projects, effectively addressing funding shortages and inefficiencies while enhancing the overall benefits of infrastructure development. The completion of the Shenzhen Shajiao B power plant in 1984, executed under the

Build-Operate-Transfer (BOT) model, marked a significant milestone in China's adoption of the PPP framework for infrastructure initiatives. Recently, there has been a growing emphasis on the PPP model across various sectors, attracting increasing academic interest and yielding valuable research contributions. In the realm of statistical analysis of the PPP model, scholars such as Al Sharif, Ke, Dimas, and Tang have primarily concentrated on author distribution and research trajectories^[1-4]. Their findings regarding the volume of publications, regional distribution, and highly cited literature predominantly highlight external project development aspects and the internal knowledge structure characteristics inherent to PPP projects. Furthermore, the majority of empirical studies have examined issues related to project risk, public-private relationships, and project financing. In contrast, non-empirical research has largely focused on project financing, critical success factors, project risk, and concession agreements.

The PPP model, characterized by its collaborative dynamics, benefit-sharing, and risk-sharing attributes, has emerged as a pivotal reform initiative aimed at fostering new avenues for economic growth. This model facilitates the efficient allocation of resources, encourages innovation, and enhances the quality of public services through the strategic involvement of both public and private sectors. Recent research on the PPP model has produced significant findings, contributing to its evolution into a well-established domain within management science. Scholars have explored various facets of the PPP framework, including its operational mechanisms, effectiveness in different sectors, and its role in achieving sustainable development goals. Despite these advancements, a comprehensive review of the existing literature reveals a predominant reliance on qualitative inductive analyses. This methodological bias highlights a notable scarcity of quantitative approaches and visual analyses, which can provide deeper insights into the dynamics and performance of PPP projects. Moreover, there is a dearth of studies that critically examine citation patterns, which are essential for understanding the intellectual structure and influence of research within this field. To address these gaps and to gain a more holistic understanding of the current landscape and future trends of the PPP model, it is imperative to adopt a multifaceted research approach. This approach should prioritize quantitative methodologies while integrating qualitative analyses to enrich the findings. Additionally, employing visualization techniques will facilitate a clearer interpretation of complex data and enhance the overall understanding of the interactions and outcomes associated with the PPP model. By embracing a comprehensive research framework, scholars can not only advance the theoretical foundations of the PPP model but also provide practical insights that inform policy decisions and implementation strategies in various contexts.

To address the identified research gaps, this study employs bibliometric analysis as the primary analytical method, utilizing CiteSpace software to visualize and analyze sample data while clarifying the characteristics and concepts of the PPP model. The study encompasses various elements, including sample data, relevant journals, authors' geographical regions, institutional affiliations, and citation references. Based on the findings, this research provides a comprehensive overview of the current state of PPP model development and anticipates future research priorities and trends. Firstly, in contrast to purely textual theoretical research, this study aims to present the current status and future directions of PPP model development through data visualization, charts, and other illustrative forms, thereby offering scholars a more intuitive understanding of the subject. Secondly, the application of CiteSpace software facilitates visual analysis that not only organizes and summarizes fundamental information from the publications within the sample data sources but also employs co-citation analysis to examine the relationships among authors, institutions, geographical regions, and references. This approach culminates in a comprehensive and systematic perspective of the research landscape. Finally, this study explores the future developmental trends of the PPP model from an all-encompassing and multi-faceted standpoint, aiming to provide researchers across various fields with a clearer understanding of the PPP model and its implications. By integrating quantitative analysis with qualitative insights, this research contributes to the advancement of knowledge in the

field and informs practical applications in PPP initiatives.

2. Characteristics of the PPP model

To enhance the practical application of the Public-Private Partnership (PPP) model in engineering projects, both domestic and international experts and scholars have conducted extensive studies on its definition, leading to a preliminary consensus. However, the unique economic conditions, policy contexts, and operational focuses of different countries and regions, along with the varying priorities of industries, financial institutions, and regulatory committees, contribute to a diverse theoretical framework surrounding the PPP model in practice. The characteristics and definitions of the PPP model are presented in **Table 1**.

Table 1. Characteristics and definitions of PPP

Institutions	Definition
United Nations Development Program	A cooperative relationship between a government, a for-profit enterprise, and a nonprofit organization based on a project.
World Bank	Long-term contracts between the private sector and government agencies for the provision of public assets or services, in which the private sector bears significant risk and management responsibility for projects and is paid for performance.
Asian Development Bank	A range of possible partnerships between public and private sector entities for infrastructure and other services.
The Canadian Council for Public-Private Partnerships	A business relationship established by the public and private sectors based on their respective professional work experience to meet public needs through appropriate resource allocation, risk sharing, and benefit sharing.
PPP National Committee of the United States	A contractual arrangement between a public sector agency and a for-profit private sector developer in which resources and risks are used to provide public services or develop public infrastructure.
Hong Kong Efficiency Unit	The provision of public services or the implementation of projects by the public and private sectors, with varying degrees of involvement and commitment depending on their respective professional expertise.
European Commission	A partnership between the public and private sectors in which both parties share risks and responsibilities based on their respective strengths and weaknesses to provide public services for which the public sector is responsible.

Savas, in *Privatization and Public-Private Partnerships*, defines “Public-Private Partnership” as a type of action that relies primarily on non-governmental organizations (NGOs) to meet people’s needs ^[5]. The PPP model relies less on government action than formal projects and also points out that the key to success is competition among private institutions. Based on the perspective of the relationship between public and private define, Sagalyn from all the involved departments of PPP projects in different periods of work ^[6], its development process is divided into three stages: in the first stage, because of the lack of work experience, can be drawn lessons from mature division of labor unclear boundaries between public, private and consultant, in the process of project implementation cope with many problems of unknown; In the second stage, to improve the professionalism of PPP project implementation, professional planners are often employed to assist in the implementation of PPP projects; In the third stage, relevant theories and policies have achieved initial results. The implementation of PPP projects is mostly carried out by taking the initiative to seek the way of the private sector. Public and private sectors give full play to the advantages of each department in terms of working resources and environment to provide coordinated and optimized convenience for the efficient operation of projects. The commercialization concept of the worldwide revolution in infrastructure provision and project finance, which was written in *Public Private Partnerships* by Grimsey ^[7], made an important contribution to the privatization of infrastructure in Australia. The

book not only discussed the essence of the PPP model and its transformative impact on infrastructure construction but also profoundly analyzed the key points for the successful implementation of the PPP model with the help of abundant cases.

The implementation of the PPP mode not only requires the public and private to make full use of their respective advantages in resources and environment but also requires them to bear corresponding risks within their respective capabilities, to achieve the goal of saving resources while completing projects with high quality and efficiency^[8-10]. The active participation of private entities not only gives full play to their professional skills in the process of project implementation, experience, technology, and innovation advantage but also to their own working experience in advance forecast project development prospects in the market. At the same time, the positive interaction of public and private enlarged the public understanding of the project, based on the public focus on its own core competency^[11] supported project on the policies and procedures^[12]. As a result, the coordination and cooperation between public and private will greatly improve the output quality of public facilities and services and deliver satisfactory work results to owners^[13].

3. Method and data

The specific process of this study is illustrated in **Figure 1**. Bibliometrics, which emerged in the early 20th century, has gained popularity in academic research due to its capacity for quantitatively analyzing publications within specialized fields and presenting the results visually. This methodology allows researchers to analyze key aspects such as literature content, keywords, reference documents, journals, geographical distribution, institutions, and trends within a particular area. In contrast to traditional qualitative research methods, bibliometrics, grounded in the principles of total lead analysis and visualization, offers a more detailed and comprehensive understanding of a field. It not only aids researchers in identifying the latest developments but also helps predict future directions within the discipline.

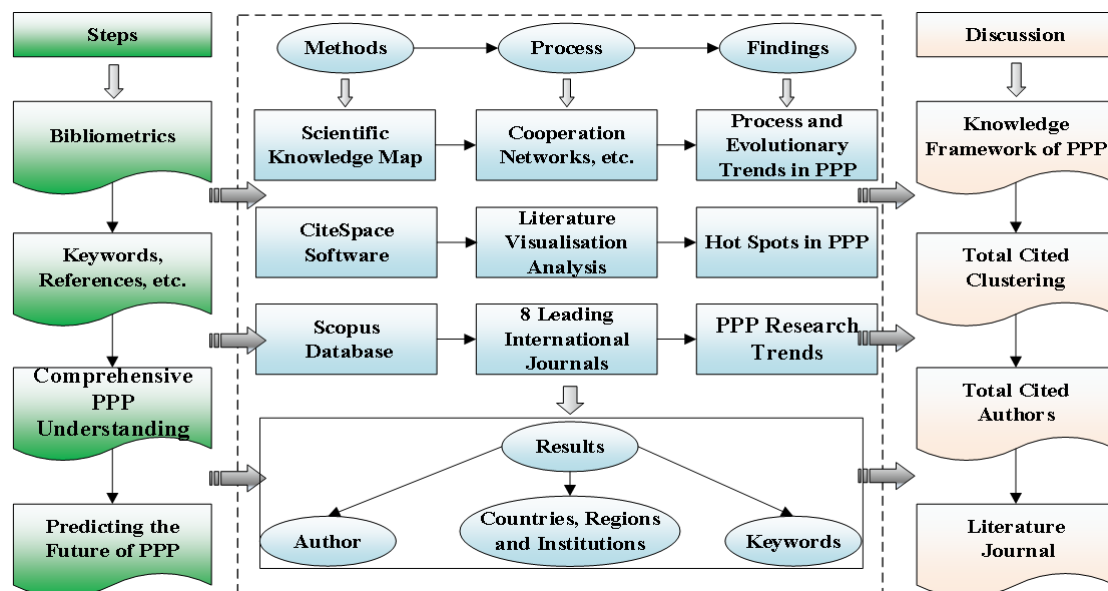


Figure 1. Study framework

Scientific knowledge mapping is a visual tool that employs various analytical methods, including citation analysis, co-occurrence analysis, clustering analysis, frequency analysis, social network analysis, and multidimensional scaling. This approach is essential for literature data analysis, producing knowledge maps that

include cooperation networks, co-occurrence networks, citation networks, and cited networks. Such quantitative analyses and visualizations intuitively reflect the processes and evolutionary trends in the development of disciplinary knowledge. CiteSpace is an advanced information visualization software developed by Professor Chen's research team at Drexel University in the United States. It is recognized as a leading tool among similar open-access software for identifying and displaying emerging trends and developments in scientific literature. CiteSpace generates network visualizations based on knowledge structures, subjects, periods, and the evolutionary trends of various information. It offers different analytical views, including cluster views, timelines, and time zones, enabling researchers to quickly identify subject areas, locate reference hotspots, and discern collaborative geographical patterns and unique collaborative domains. In this study, CiteSpace software was employed to conduct a visualization analysis of literature sourced from the Scopus database. By analyzing the results from cluster views, timelines, and time zone analyses, the research aims to highlight hotspots in PPP studies. The findings are expected to assist researchers in expanding both the scope and depth of PPP research in China, fostering a more profound integration of PPP theory and practice.

The accuracy of the dataset, which plays an important role in literature analysis, is contingent upon the selection of academic databases and the design of search strategies. Scopus, developed by Elsevier, is the world's largest database of abstracts and citations. This comprehensive database not only includes citation information for collected articles but also integrates network and patent retrieval data within a user-friendly interface, offering researchers a convenient one-stop resource for accessing scientific and technological literature. To ensure that the collected literature is of high quality and influence within the professional field, this study utilized the Scopus database as the primary data source. It employed specific criteria based on source journals, keywords, and document types, conducting keyword searches across eight leading international journals in the selected field (see **Table 2** for search information). The analysis focused on research trends related to the PPP model, utilizing all papers published in the Web of Science (WOS) Core Collection database from 1999 to 2018, spanning approximately 20 years, as input data for CiteSpace. All keywords utilized in the search strategy were compared with related terms, leading to the adoption of a broad definition of PPP, with a focus on the construction sector. This process yielded a total of 1,494 citations, in contrast to 34,696 citations across all identified documents.

Table 2. Summary of search details

Labels	Contents	Labels	Contents
Visual analysis software	CiteSpace	keywords	“PPP”
Literature database	Scopus	Number of citations	1,494
Time range	1999–2018(20 years)	Number of cited references	34,696
Professional field	Construction Management		

4. Results and discussion of citation analysis

This section could provide a concise and precise description of the citation analysis results, their interpretation, as well as the analysis conclusions that can be drawn.

4.1. Author analysis

This study is limited to journal articles published in English. The eight international top journals selected are: the International Journal of Project Management, Journal of Construction Engineering and Management, Construction Management and Economics, Journal of Management in Engineering, Engineering Construction and Architectural

Management, Construction Innovation, Automation in Construction, and the Tumu Gongcheng Xuebao China Civil Engineering Journal. By analyzing the authorship information obtained from the dataset, it is possible to scientifically reveal and identify the main researchers, institutions, and countries of the PPP research. By analyzing the co-authors, a network of co-authors and a network of institutions and countries of co-authors were generated as described below. According to the statistical results of CiteSpace on the authors of 1,494 papers (1999–2018), 203 authors contributed more than two papers per capita. Among them, the top 30 authors with five or more papers contributed are listed in **Table 3**. The top 30 authors from the data are ranked based on their contribution amount and their collaborative relationships, as illustrated in **Figure 2**. In this figure, the curve represents the author, the edges between nodes represent collaborations, and the node size reflects the author’s contribution to the papers. Among these, there are seven representative collaborative groups. The top three authors with the highest contribution amounts are Chan APC, Yuan JF, and Marques RC, who serve as central nodes in the collaboration network. Additionally, several independent collaborations are distributed around these core contributors.

Table 3. The top 30 authors and their contribution

Author	Contribution	Author	Contribution	Author	Contribution
Chan APC	42	Chen C	9	Smith J	6
Yuan JF	19	Cheung E	9	Petersen OH	6
Marques RC	17	Song JB	9	Jin XH	6
Zhang XQ	14	Chou JS	8	Van Den Hurk M	5
Skibniewski MJ	14	Girmscheid G	7	Regan M	5
Li QM	14	Yeung JFY	7	Hellowell M	5
Xiong W	12	Lam PTI	7	Verhoest K	5
Ke YJ	12	Osei-kyei R	7	Wang Y	5
Wang SQ	11	Xu YL	7	Deng XP	5
Cruz CO	10	Carpintero S	6	Feng Z	5

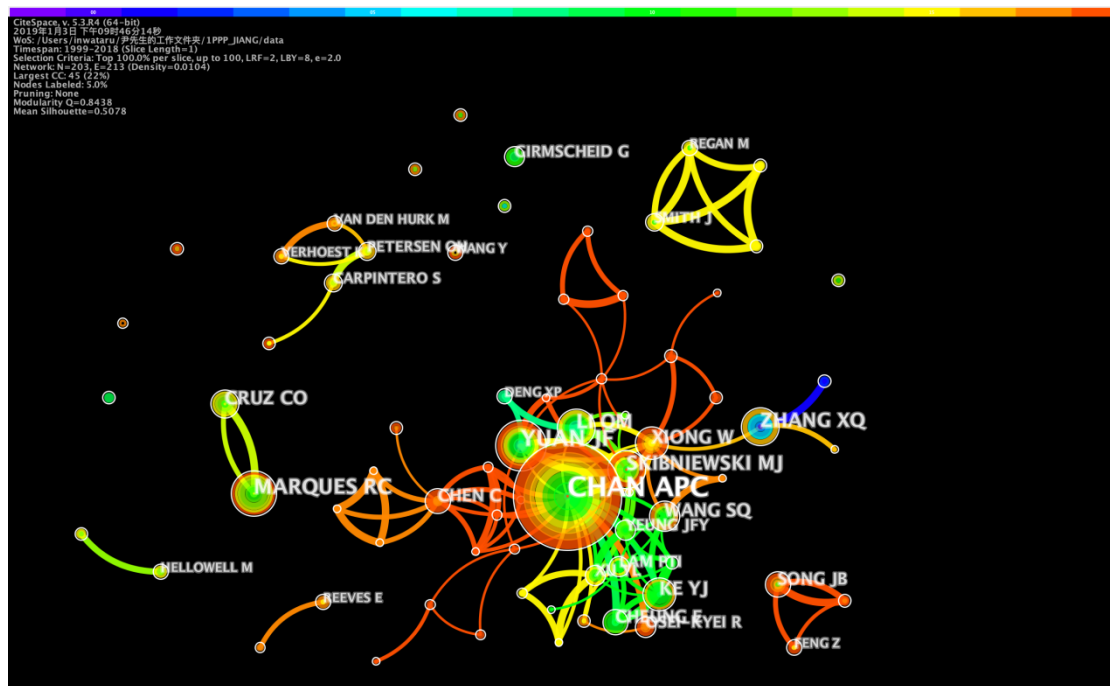


Figure 2. Paper contributing author between network diagram

Statistics show that more and more researchers' attention is graduating to the development of China's PPP, combined with the author's collaboration network diagram there are a large number of independent cooperation networks to forecast, the future there will be a lot for China's situation and the independent existence of subject research trend of combination, such as the Chinese government regulations and private financing analysis of PPP. Since 2009, Chan APC as the main author cooperation team has done key research on the risk allocation of PPP, covered the project potential elements ^[14], China's PPP risk sharing model ^[15], the PPP success factors ^[16], etc. In addition, some partners also separately studied the project satisfaction ^[17,18], a renegotiation ^[19,20]. The cooperative network of Smith J and Regan M focuses on performance evaluation from the perspective of the whole life cycle ^[21-23]. Cooperation network between Song JB and Feng Z, BOT mode in PPP ^[24-27]. To study the restraining factors and government support of various PPP projects, Petersen OH et al. made a comparative analysis of PPP in several countries ^[28-30]. Cruz CO author cooperation network, such as more focus on the problem of flexibility of the PPP contract, emphasizing the capital value of flexible implementation projects to maximize ^[31,32]. The cooperative network of Hellowell M analyzes the role of government decision-making in PPP and the purpose of private investment, especially in hospital projects ^[33-35]. Reeves E et al. paid more attention to the private financing methods of PPP ^[36,37].

4.2. Countries, regions, and institutions analysis

To further investigate the contributions of different regions to research on the Public-Private Partnership (PPP) model, this study compiles statistics on the geographical distribution of published papers, as presented in **Table 4**. The contributions from these countries and regions account for 75.10% of the total number of papers. Notably, the leading contributor is the People's Republic of China, which accounts for 28.78% of the total publications, representing nearly one-third of the overall output. Although the origin of the PPP model is not China, the steady increase in the country's economic growth rate since 1990 and the rapid development of its infrastructure have positioned China at the forefront of global infrastructure initiatives ^[38]. Consequently, the demands of China's economic and infrastructural development have significantly accelerated domestic scholarly research on PPP in a relatively short timeframe. Furthermore, the statistical results underscore the critical role of policy orientation in advancing PPP development. For instance, the introduction of related planning for new-type urbanization utilizing the PPP model by the Chinese government from 2013 to 2017 has catalyzed a research boom, making new-type urbanization a prominent topic within the field.

Table 4. Countries and regions with the top 10 paper contributions

Region	Contribution	Region	Contribution
People's Republic of China	430	Germany	39
United States of America (U.S.A.)	206	Spain	38
England	158	Netherlands	37
Australia	104	Taiwan	35
Italy	41	India	34

The contributions of the top 10 regions are illustrated in conjunction with the cooperative relationships among countries and regions, as depicted in the network diagram in **Figure 3**. In this diagram, the curves represent collaborative ties between countries and regions, while the nodes signify the literature associated with each location. Nodes of the same color indicate that they belong to the same cluster, highlighting a specific or primary research focus. If a state within a cluster is connected to another cluster, it suggests that the country is also engaged

in additional research areas. The analysis primarily highlights the core contributions from China, the U.S.A., and England, which are central to the diffusion of research. This is accompanied by various independent collaborations among other countries and regions. Notably, the relationships illustrated by the curves indicate that almost all countries and regions maintain cooperative ties with China, suggesting that there is considerable global interest in the development of the PPP model in China. Currently, China's PPP market development, along with its policy and institutional framework, is regarded as leading globally. China has emerged as the largest PPP market in the world, contributing significantly to the evolution of global PPP practices^[39]. This development enhances the ability of countries along the Belt and Road Initiative to effectively implement PPP projects, and it reflects the inevitable outcomes of China's rapid economic growth and infrastructure expansion.

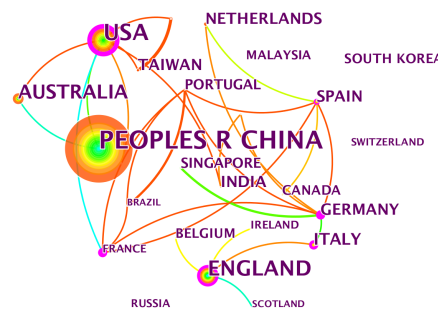


Figure 3. Network diagram of countries and regions contributing papers

The distribution of research organizations affiliated with the PPP-related papers collected in this study is illustrated in **Figure 4**. The analysis indicates that institutions from China occupy a central position within the institutional cooperation network. The network diagram reveals that Hong Kong Polytechnic University serves as the hub, with numerous organizations interconnected, highlighting its pivotal role in collaborative efforts. **Table 5** presents the top 10 research institutions based on paper contributions. Among these, six institutions are from China, while the remaining four are from Belgium, Singapore, the U.S.A., and Portugal, respectively. Notably, the top three contributing institutions are all Chinese: Hong Kong Polytechnic University, with 56 papers; Southeast University, with 23 papers; and Tsinghua University, with 16 papers. This indicates that the research outputs from China's PPP institutions hold significant value on a global scale.

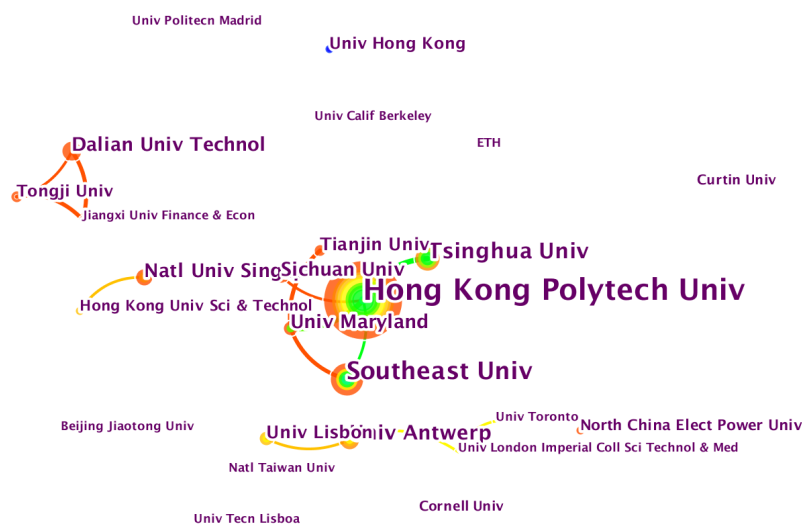


Figure 4. Network diagram of the institutions contributing papers

Table 5. Paper contribution amount in the top 10 research institutions

Institution	Contribution	Institution	Contribution
Hong Kong Polytech University	56	Dalian University Technology	12
Southeast University	23	University of Maryland	10
Tsinghua University	16	Sichuan University	10
University of Antwerp	13	University of Lisbon	9
National University of Singapore	12	Tianjin University	9

4.3. Keywords analysis

This study employs quantitative visual analysis of keywords to explore the distribution of research hotspots in the field of PPP, with the results presented in **Figure 5**. After excluding the keywords “PPP” and “public-private partnership” the leading keywords in the statistical ranking are “management,” “China,” and “performance.” The quantitative visualization analysis conducted on 1,494 papers from 1999 to 2018, using CiteSpace software, reveals these prominent keywords. In addition to the top keywords, over nearly two decades of research, other frequently used terms include “infrastructure,” “partnership,” “risk allocation,” “model,” “BOT,” and “policy.” A classification and analysis of these keywords indicate that the types of projects involved in infrastructure research predominantly encompass highway projects ^[40], water treatment projects ^[41], waste recycling projects ^[42], and urban transportation projects ^[43]. Research about PPP models primarily includes the revenue-sharing model ^[44], price model ^[45], value-for-money (VFM) model ^[46], risk management model ^[47], and cooperative game model ^[48]. Additionally, significant areas of inquiry involve risk sharing between partners ^[49], government policy guidance ^[50], and the BOT model ^[51].



Figure 5. Network diagram of keywords in the paper

To comprehensively and clearly observe the evolving trends in PPP research, this study divides the period from 1999 to 2018 into three distinct phases: the first phase from 1999 to 2008, the second from 2009 to 2013, and the third from 2014 to 2018.

4.3.1. Session 1: 1999–2008

According to the results of quantitative visualization analysis of keywords by CiteSpace from 1999 to 2008 (as shown in **Figure 6** and **Table 6**), PPP research focuses on topics related to BOT mode, private financing institutions, project management, and risk management during this period. Among them, the hot research on BOT mode mainly involves the analysis of the BOT procurement mode ^[52], the setting of cooperation terms in BOT

contracts ^[53], and the success factors in the construction and operation stage ^[54]. The hot spots of private financing institutions mainly involve performance supervision of Private Finance Initiative (PFI) implementation ^[55], key success factors of PFI project implementation ^[56], and relationship management of PFI partnership ^[57].

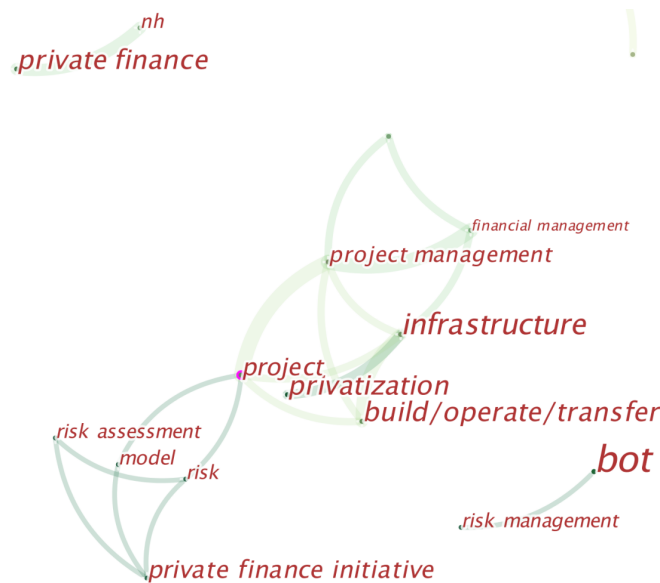


Figure 6. Keyword network diagram from 1999 to 2008

Table 6. The top 20 keywords between 1999 and 2008

Keywords	Contribution	Centrality	Keywords	Contribution	Centrality
Bot	26	0.00	Risk management	3	0.09
Infrastructure	7	0.10	Risk	3	0.06
PFI	11	0.00	Trust	3	0.00
Private finance	6	0.00	Model	3	0.01
Privatization	6	0.09	Risk assessment	3	0.02
Project	5	0.25	Game theory	2	0.00
Project Management	4	0.10	Financial management	2	0.01

4.3.2. Session 2: 2009–2013

Many hotspots involved in PPP policy analysis include the effectiveness and risk of policy implementation. The quantitative visualization analysis of keywords performed by CiteSpace for the period from 2009 to 2013 (as shown in **Table 7** and **Figure 7**) indicates that the research scope of PPP hotspots is gradually expanding. The focus is no longer limited to traditional frameworks such as the Private Finance Initiative (PFI) and the Build-Operate-Transfer (BOT) model. Instead, there is a noticeable increase in studies addressing risk sharing, risk management, modeling, and policy-related issues. Specifically, the pathway for PPP risk management typically involves two key components: risk identification and risk assessment ^[58]. Moreover, several significant research hotspots during this period have centered on the analysis of PPP policies, particularly regarding the effectiveness and risks associated with policy implementation ^[59].

Table 7. The Top 20 keywords between 2009 and 2013

Keywords	Contribution	Centrality	Keywords	Contribution	Centrality
Infrastructure	39	0.12	Policy	18	0.04
Management	32	0.07	Construction	18	0.04
Performance	28	0.09	Project	16	0.04
Partnership	26	0.10	Service	16	0.04
China	25	0.10	Private finance initiative	15	0.14
Risk allocation	24	0.05	Governance	14	0.05
Model	24	0.10	Infrastructure project	14	0.04
Risk management	22	0.06	Critical success factor	14	0.04
Bot	21	0.01	Procurement	13	0.03
Risk	20	0.04	Network	12	0.05

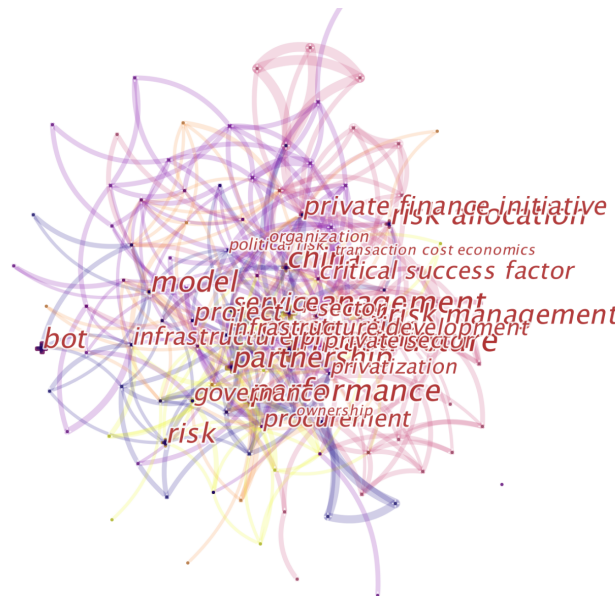


Figure 7. Keyword network diagram from 2009 to 2013

4.3.3. Session 3: 2014–2018

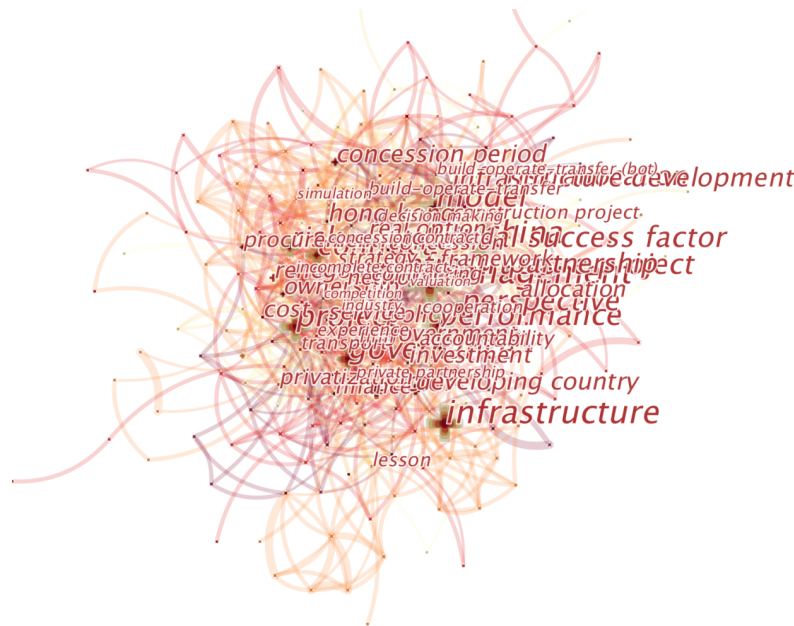
The keywords visualization analysis conducted by CiteSpace for the period from 2014 to 2018 (as illustrated in **Table 8** and **Figure 8**) indicates a more diversified trend in research topics. In addition to key themes such as project management, project performance, success factors, and risk management, the issue of project governance has garnered significant attention during this period. Among the primary topics within project governance are government regulation^[60] and the legal framework governing contracts^[61].

Table 8. The Top 20 keywords between 2014 and 2018

Keywords	Contribution	Centrality	Keywords	Contribution	Centrality
Management	83	0.03	Risk	43	0.02
Infrastructure	77	0.02	Perspective	42	0.07
China	73	0.04	Risk Allocation	35	0.02
Performance	59	0.03	Partnership	35	0.04

Table 8 (Continued)

Keywords	Contribution	Centrality	Keywords	Contribution	Centrality
Project	59	0.07	Sector	34	0.01
Model	57	0.01	System	29	0.02
Governance	50	0.05	Infrastructure Development	29	0.02
Infrastructure Project	47	0.04	Developing Country	27	0.02
Contract	46	0.01	Hong Kong	27	0.10
Critical Success Factor	45	0.06	Concession Period	24	0.05

**Figure 8.** Keyword network diagram from 2014 to 2018

5. Discussion

5.1. Knowledge framework of PPP

Through the analysis of data sources using CiteSpace, a total of approximately 34,696 references were identified across 1,494 papers published from 1999 to 2018. The top 10 references ranked by citation frequency are presented in **Table 9**. The most frequently cited work by Ke YJ examines reasonable risk-sharing methods in China’s PPP projects, while the second most cited reference focuses on the key factors contributing to the success of these projects. The third significant reference addresses risk assessment practices within China’s PPP framework.

These findings suggest that the context of the PPP model, particularly about China, is a primary focus for researchers in the field. Moreover, the areas of risk assessment, risk sharing, financing methods, foundational frameworks, key success factors, and overall project viability represent the fundamental themes of discussion in PPP research. This underscores the importance of understanding how these elements interact within the Chinese context, providing valuable insights for practitioners and policymakers involved in the implementation of PPP projects. As the field continues to evolve, addressing these core areas will be crucial for enhancing the effectiveness and sustainability of PPP initiatives both in China and globally.

The analysis of highly cited references from a co-citation perspective reveals a diverse methodological landscape within the field of PPP research. Some of these references are based on empirical research, while others

adopt a non-empirical approach. Despite this methodological diversity, the predominant themes across these studies consistently center on three key areas: risk management, relational dynamics, and financing strategies. This indicates that, regardless of the research approach employed, scholars are primarily focused on understanding how these elements interact within the PPP framework. The emphasis on risk underscores its critical role in project success and sustainability, while the exploration of relationships highlights the importance of collaboration between public and private entities. Additionally, financing remains a pivotal concern, as securing adequate funding is essential for the effective implementation of PPP projects. Overall, these findings suggest that further exploration of these interconnected themes is vital for advancing knowledge in the field and enhancing the practical application of the PPP model.

Table 9. Information of references in the top 10 cited frequency statistics

Author	Year	Frequency	Literature resources	Research perspectives
Ke YJ ^[62]	2010	62	INT J PROJ MANAG	China's PPP projects and reasonable risk-sharing
Chan APC ^[63]	2010	54	J CONSTR ENG M	China perspective, key success factors
Tang LY ^[64]	2010	53	INT J PROJ MANAG	Risk, financing, contract agreement
Chan APC	2011	47	J MANAGE ENG	China's PPP projects, risk assessment, and risk sharing
Hodge GA	2007	45	PUBLIC ADMIN REV	The performance evaluation
Xu YL	2010	43	AUTOMAT CONSTR	The risk assessment
Yescombe ER	2007	43	PUBLIC PRIVATE PARTN	Policy, financing
Kwak YH	2009	42	CALIF MANAGE REV	Development framework
Hwang BG	2013	39	INT J PROJ MANAG	Key factors, risks
Marques RC	2011	35	J CONSTR ENG M ASCE	Risks, contracts

5.1.1. Risk management

Risk management in Public-Private Partnership (PPP) projects encompasses several critical components, including risk factor identification, risk assessment, and the analysis of risk-sharing frameworks. For instance, Bing et al. utilized the value judgment method to analyze the risks associated with the entire life cycle of PPP projects ^[65]. They highlighted the significance of recognizing various risk factors and categorized them into three levels: micro risks, medium risks, and macro risks. This classification aids in developing targeted risk management strategies appropriate for different scales and contexts. Grimsey and Lewis contributed to this discourse by evaluating risk factors specifically within the context of infrastructure projects employing the PPP model ^[7]. They proposed a comprehensive risk assessment framework that facilitates systematic analysis and understanding of the inherent risks involved in such partnerships. Building on this foundational work, Ke et al. employed the Delphi survey method to analyze risk preferences associated with PPP projects in China ^[66]. Their findings revealed that government entities identified 12 specific risks, including “levy and nationalization” risks, while the private sector recognized 10 risks. Notably, there were 12 risks deemed to be shared among stakeholders, illustrating the collaborative nature of risk management in PPP projects. These studies collectively underscore the complexity of risk management in PPP, emphasizing the need for robust frameworks that accommodate the diverse interests of stakeholders. Moreover, the emphasis on collaboration in risk-sharing highlights the importance of effective communication and negotiation between public and private entities. Future research should further explore the dynamics of risk perception among different stakeholders, as well as the effectiveness of various risk-sharing mechanisms in enhancing project outcomes. By advancing this understanding, researchers can contribute to the

development of more resilient and successful PPP models.

5.1.2. Relational dynamics

The organizational relationship between the public and private sectors is a critical determinant of the success of Public-Private Partnership (PPP) projects. Ineffective relationships can lead to misunderstandings, conflicts, and ultimately project failure. Research on relationships within PPP projects primarily focuses on topics such as relationship improvement, relationship management, and relationship contracts. For instance, Iossa and Martimort examined the impact of the relationship between the public sector and private capital from a micro-economic perspective ^[67]. Their analysis highlights the significance of incentive structures and flexibility in PPP contracts, which can enhance organizational relationships and foster cooperation between stakeholders. Soomro and Zhang (2015) evaluated the key factors contributing to relationship failures in 35 PPP projects, identifying critical issues such as communication breakdowns and misaligned objectives ^[68]. They proposed an improvement mechanism for partnerships that emphasizes the importance of establishing clear communication channels and aligning the interests of both parties. Liu et al. utilized principal-agent theory to analyze the relationship dynamics within PPP contracts, specifically focusing on incentive mechanisms designed to reduce opportunistic behavior ^[69]. Their findings suggest that well-structured incentive mechanisms are essential for minimizing conflicts of interest and ensuring that both parties remain committed to the project's success. Overall, these studies collectively highlight the complexity of organizational relationships in PPP projects and the necessity of adopting a multifaceted approach to relationship management. Future research should further explore the interplay between relationship quality and project outcomes, investigating how different management strategies can enhance collaboration and reduce the risk of conflicts.

5.1.3. Financing strategies

Research on financing within the PPP framework encompasses several key areas, including financing sources, financing strategies, and financing risk assessments. Wang et al. investigated the primary financing sources utilized in the construction of sponge city projects in China, highlighting the importance of innovative financing mechanisms that leverage both public and private resources ^[70]. The findings illustrate how local governments can collaborate with private entities to secure funding, which is crucial for the successful implementation of large-scale infrastructure projects. Liu and Wilkinson conducted a comparative analysis of PPP projects in Hong Kong and New Zealand, identifying effective financing strategies that include robust business development, streamlined financing arrangements, comprehensive tender documentation, and an effective governance structure for PPP consortia ^[71]. This comparative approach provides valuable insights into how different regulatory environments and market conditions influence financing strategies, ultimately impacting the success of PPP projects. Additionally, Li et al. analyzed the risk implications associated with various parameters in PPP project financing, including capital structure, asset income, and volatility ^[72]. The study emphasizes the critical need for thorough risk assessments to understand how these factors can affect the overall financial viability of PPP initiatives. In summary, the evolving landscape of PPP financing underscores the importance of strategic collaboration between public and private sectors. Future research should focus on further delineating the relationships between financing strategies and project outcomes, as well as exploring the effectiveness of different risk assessment methodologies. By advancing this understanding, stakeholders can better navigate the complexities of financing within PPP frameworks, ultimately leading to more successful project delivery.

5.2. Discussion of total cited clustering

Using CiteSpace, we conduct a comprehensive analysis of copolymerization types within the Web of Science

(WOS) core journals, focusing on 1,494 published papers from 1999 to 2018. The analysis employs a time slice of one year, with three key thresholds set at default values: reference frequency (c) at 2, resonant frequency (cc) at 2, and coefficient (CCV) set at 20 for the initial period, (5, 4, 20) for the second, and (4, 3, 20) for the third. The results, illustrated in the timeline view shown in **Figure 9** and **Table 10**, reveal that nodes #0, #2, and #3 represent the three core matrices within the field of PPP research, demonstrating sustained relevance over time. These matrices encapsulate critical areas of inquiry and persist throughout the analysis period. Given their prominence, this study focuses on the research content associated with these three matrices.

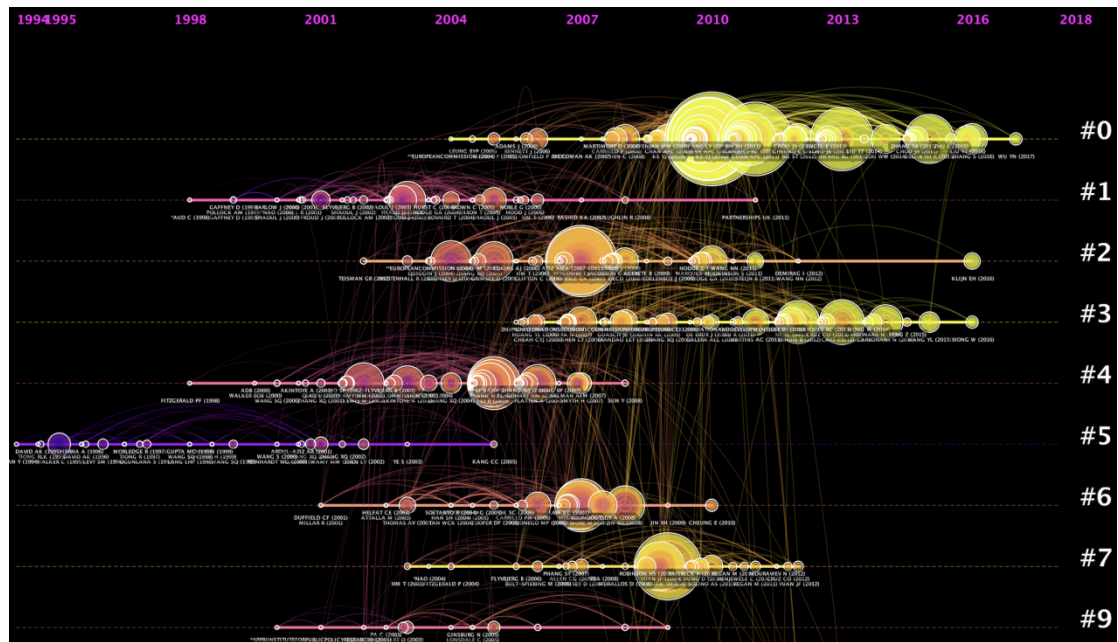


Figure 9. References cited clustering analysis the time line of the view

Table 10. Co-cited clustering matrix analysis of references

Cluster ID	Document	Silhouette value
0	Public-private partnership	0.719
1	Pfi process	0.819
2	Harnessing market competition	0.767
3	PPP toll road	0.796
4	Construction industry	0.7
5	Public-private partnered project	0.956
6	Efficient risk allocation	0.831
7	Capital market collapse	0.864
9	Private finance initiative	0.942
10	Slow adoption	0.87
11	PFI project	0.991
12	UK private finance initiative	0.994
13	Operate-transfer scheme	0.996
14	Facing management choice	0.993
18	Ria model	0.99

5.2.1. #0 successful factors of PPP

The clustering theme #0 centers on analyzing key factors and identifying risks associated with the success of Public-Private Partnership (PPP) projects. This analysis employs principal-agent theory to examine the relationships among PPP project partners, incorporating case studies that assess social capital capabilities and financial evaluations. These evaluations form the foundation for risk sharing within the PPP contract structure. Additionally, the client's contract framework serves as a critical basis for leveraging social capital in executing PPP projects ^[73]. Building on this foundation, some scholars explore the role of Special Purpose Entities (SPEs) utilized in PPP arrangements for mega projects. The integration of law, finance, and project management constitutes the fundamental elements of the contract framework in constructing SPEs ^[74]. Furthermore, research on project success and risk factor identification predominantly focuses on infrastructure projects related to energy, transportation, water conservancy, and healthcare. Among these, five critical success factors emerge: project feasibility, project environment, project company, project contractor, and project suppliers ^[14]. In energy projects, the most significant success factors include the necessity of the project, the expected debt repayment capacity, the competency of personnel from the developer, the financial capacity of the contractor, and the level of project financing management ^[75]. Conversely, the risks impacting PPP projects encompass various dimensions, with critical factors identified as political risk, legal risk, government credit risk, market demand fluctuations, inflation risk, and product price risk ^[76]. It is important to note that the risks associated with different types of projects may vary. For instance, quasi-revenue projects are exposed to additional risks such as nationalization/default, lack of supporting infrastructure, and public opposition ^[77]. This body of research often employs case study methodologies to provide in-depth insights into these complex dynamics ^[15]. By systematically identifying and analyzing these factors, researchers contribute to a more nuanced understanding of the determinants of success and the associated risks in PPP projects.

5.2.2. #2 financing proposal for PPP

The focal point of cluster #2 is the financing theory surrounding PPP. This encompasses a thorough examination of financing methods, risk analysis, practical evaluations of financing plans, and feasibility assessments of business investments. Such research often draws on existing PPP case studies, integrating comparable instances to analyze practical outcomes. In their analysis of social capital's role in financing, Silvestre and De Araujo compared two types of PPP projects in Portugal—highway and water supply projects—highlighting the varying degrees of enthusiasm and resistance toward social capital participation in these contexts ^[78]. Practical analyses of Private Finance Initiatives (PFI) frequently involve comparisons between healthcare and transportation projects. Henjewe et al. argued that the expertise of the private sector can enhance cost, time, and risk performance in public projects, although they also emphasize the persistent financing challenges faced by these initiatives ^[79]. Wang et al. utilized a Generalized Linear Model (GLM) to explore the impact of competitive bidding, transaction costs, contract types, and deadlines on private investment levels in PPPs ^[80]. The findings indicated that higher levels of asset specificity and greater surplus control rights for private investors correlate positively with the likelihood of private investment, particularly in the context of competitive bidding. Pantelias and Zhang contributed to this discourse by proposing a financing analysis framework that employs various sensitivity and scenario analyses to assess the feasibility of project financial evaluations ^[81]. Moreover, this body of research often investigates the financing dynamics between social capital and governmental entities. Consequently, the matrix incorporates extensive studies on the relationships inherent in PPPs. For instance, Warsen et al. conducted a multi-level analysis using survey data from 144 stakeholders involved in Dutch PPP projects, revealing that trust and effective management are closely linked to project cooperation ^[82]. Additionally, the matrix engages in a complex analysis of relationship governance,

recognizing the inherent challenges within PPP structures. Relevant studies highlight that PPPs represent intricate infrastructure projects characterized by ambiguous responsibilities between public and private partners, leading to a complex governance framework^[83]. Such insights underscore the necessity for robust governance structures to facilitate collaboration and mitigate risks within PPP projects.

5.2.3. #3 franchise period

The inherent characteristics of long cycles, irreversibility, and high uncertainty in PPP projects often lead to the undervaluation of concessions in project evaluations. Consequently, cluster #3 aggregates studies that analyze the value generated during the concession period. This includes discussions on the optimal duration of the concession, flow forecasts during this period, cooperative optimization strategies, and revenue equivalence. Lv et al. proposed an alternative model designed to address the inflexibility of traditional Net Present Value (NPV) management, enabling a more effective determination of the optimal concession period for Build-Operate-Transfer (BOT) transportation projects^[84]. Another significant challenge is the accurate measurement of the concession period, particularly in forecasting traffic volumes. Phong et al. utilized the Geometric Brownian Motion (GBM) process to estimate traffic volume for transportation projects, employing a Monte Carlo simulation technique to analyze various scenarios^[85]. This stochastic approach allows for a systematic examination of traffic volume fluctuations, providing more reliable estimates for PPP projects. In addition to traffic forecasting, the analysis of revenue equivalence is critical for transportation projects. Repolho et al. constructed a cooperative optimization model aimed at ensuring profit for social capital while maximizing social welfare^[86]. Furthermore, analyses related to the concession period also explore strategies to enhance the likelihood of social capital involvement through government decision-making, promoted the innovative capabilities of social capital via competitive gaming, and ensured long-term stability in the concession period through renegotiation mechanisms^[87]. Most studies investigating the concession period of PPPs employ mathematical modeling paradigms, incorporating methods such as Bayesian analysis, Brownian motion, Monte Carlo simulations, and Nash equilibrium. These analytical frameworks provide robust tools for assessing the complexities associated with the concession period and optimizing project outcomes.

5.3. Discussion of total cited authors and literature journal

5.3.1. Discussion of total cited authors

The analysis of total citations indicates that there are 29,938 referenced works, with the top 10 cited authors highlighted for their influence and frequency, as presented in **Table 11**. Among these, Zhang XQ from the Hong Kong University of Science and Technology emerges as the most prominent author, recognized for their pivotal contributions in identifying key success factors for the PPP model within infrastructure projects^[88]. The study delineated five critical dimensions: economic viability, appropriate risk allocation through reliable contractual arrangements, sound financial packages, favorable investment environments, and the importance of a reliable concessionaire consortium with robust technical capabilities. While Zhang's classification method has provided significant insights, it has also influenced how subsequent studies categorize factors affecting PPP project performance, risk management, and regulatory challenges. Notably, recent scholarly attention has shifted towards understanding the factors that contribute to the early termination of PPP contracts. Scholars have suggested that accurately determining compensation mechanisms can mitigate the risks associated with early contract termination^[89]. The second most-cited author, Li B has also made substantial contributions to the field, though his specific contributions warrant further exploration^[90]. Following him, Grimsey D stands out for establishing methodologies related to PPP risk assessment and the valuation of project finance, as detailed in his seminal works^[91,92]. This evolving discourse around PPP highlights the importance of adaptive frameworks that

can account for the complexities of risk, performance, and contractual obligations. Further investigation into the interplay between these factors will enhance the understanding of PPP dynamics and inform best practices in project management.

Table 11. Influence of the top 10 co-cited authors and frequency

Author	Centrality	Year	Frequency
Zhang XQ	0.06	2002	241
Li B	0.15	2006	195
Grimsey D	0.15	2006	179
Hodge GA	0.05	2007	158
Chan APC	0.04	2010	143
World B	0.01	2006	138
Akintoye A	0.06	2005	134
Lewis M	0.12	2006	124
Ke YJ	0.01	2010	121
Hm T	0.06	2003	116

Table 12. Literature publications top 10

Journals	Count
Journal of Management in Engineering	52
International Journal of Project Management	51
Journal of Construction Engineering and Management	43
Journal of Construction Engineering and Management ASCE	38
Transportation Research Record	31
Public Money Management	30
Sustainability	27
Journal of Infrastructure Systems	23
International Journal of Strategic Property Management	18
Public Management Review	18

5.3.2. Discussion of literature journal analysis

Table 12 presents the top 10 journals ranked by their contributions to the literature on PPP. The Journal of Management in Engineering holds the top position, emphasizing contemporary issues in civil engineering management through case studies, technical descriptions, and engineering practices. The journal’s focus on PPP hotspots is primarily manifested through empirical case studies and practical engineering applications. Recent publications have highlighted critical topics such as PPP relationship governance^[93], risk perception in PPP contexts^[94], and specific case studies centered on PPP implementations in China^[95–97]. Ranking second, the International Journal of Project Management concentrates on softer scientific issues within the realm of project management. The journal frequently addresses vital topics relevant to PPP, including risk management, project success factors, and the incentives that drive participant engagement. This emphasis reflects a growing recognition of the intricate dynamics influencing PPP outcomes. In addition to these leading journals, Transportation Research

Record, Public Money Management, and Public Money Management also demonstrate a keen interest in PPP research outside the primary domain of project management. Transportation Research Record specifically targets PPP research related to transportation projects, providing valuable insights into the unique challenges and solutions within this sector. Public Management Review explores financing issues pertinent to public management projects, while Public Money Management focuses on governmental decision-making processes, underscoring the critical role of policy frameworks in facilitating successful PPP implementations. Collectively, these journals contribute to a comprehensive understanding of the diverse aspects of PPP, ranging from theoretical explorations to practical applications, and highlight the multifaceted nature of collaboration between public and private entities.

6. Conclusion

In this study, based on reviewing the basic concepts of PPP, CiteSpace software is used to quantitatively visualize and analyze the papers dealing with PPP research in the selected journals during the last 20 years from 1999 to 2018, which mainly include authors, journals, countries, regions, institutions, keywords, and references. The conclusions are obtained as follows.

Firstly, the focus of research on PPP has evolved significantly from 1999 to 2018. While early studies focused on traditional models such as Build-Operate-Transfer (BOT) and Private Finance Initiative (PFI), later studies show an expansion into different areas such as risk management, policy analysis, and project governance. This transformation reflects the growing complexity and multifaceted nature of PPP projects in contemporary research. The main themes of PPP-related infrastructure research cover a wide range of projects, including road construction, water treatment, waste recycling, and urban transport. In addition, key models such as revenue sharing and risk management are at the center of the discussion. The later phase of the study (2014–2018) in particular highlights the growing emphasis on the role of project governance and government regulation in PPP, with a focus on the effectiveness of legal frameworks governing contracts and policy implementation, suggesting that governance challenges are becoming a central concern for researchers, a trend that underscores the importance of understanding the regulatory and institutional contexts that influence the outcomes of PPP.

Secondly, there is a growing academic interest in the development of PPP in China and a significant transformation in the interest in understanding the unique regulatory and financing environment that affects PPP projects, with future research increasingly exploring the interplay between government regulations and private financing in the context of China. The diversity of PPP research themes reveals a variety of key research topics within the PPP framework, including risk management, performance evaluation, contractual flexibility, and government decision-making. Notably, studies on BOT models and private financing mechanisms are prevalent, indicating that researchers are actively addressing the theoretical and practical challenges associated with the implementation of PPP in different sectors. Chinese academia is the major contributor to PPP research, accounting for 28.78% of total publications. This remarkable output reflects China's rapid economic growth and infrastructural development, which have made the country a central player in the development of PPP practice globally, and underscores the critical role of policy orientation in promoting PPP research and implementation. Between 2013 and 2017, the Chinese government's new urbanization planning and other initiatives stimulated a significant increase in academic activity, making this topic a prominent focus of the PPP field.

Finally, the PPP knowledge framework highlights the interrelated themes of risk management, relationship dynamics, and financing strategies, further reflecting the complexity and multifaceted nature of PPP projects. Effective risk management becomes the cornerstone of successful PPP implementation, but also an important process that influences the outcome of the project. Collaborative risk-sharing mechanisms are essential to enhance

project sustainability and stakeholder confidence. Relationship dynamics within the PPP knowledge framework as key determinants reveal that the quality of the relationship between public and private entities is critical to the success of a PPP project. Effective communication, aligned goals, and well-designed incentives are necessary to promote trust and cooperation. Financing strategies within the PPP knowledge framework are evolving, with increasing emphasis on innovative financing mechanisms that utilize public and private resources. Comparative analyses demonstrate how different regulatory environments affect the relevant strategies, highlighting the need for robust risk assessments to measure their impact on project viability. The emphasis on strategic partnerships in financing highlights the importance of cooperation in addressing the complexity of large infrastructure projects.

7. Limitation

Although this study provides some guidance for future research on PPP to some extent, some objective factors in the research process may mislead future research. Therefore, to avoid this problem, here is an overview of three main constraints: first, the finiteness of data sources. Although our data cover the most important ones in the PPP field, the data source of this study firstly locates eight restricted journals in Scopus data, and some important journals may not be taken into account, resulting in a small number for research and analysis. Secondly, the limitation of software function. CiteSpace cannot directly process the content of citations, so it needs to manually analyze and explain the details of important articles. This process is time-consuming and relatively prone to errors. Finally, the limitations of information transmission. Since the information provided by the analysis results of data sources and CiteSpace is only a brief introduction to the paper, compared with obtaining all the information through full-text reading, this analysis method may cause the loss of key details in the full text. Therefore, the above three limitations remain to be further studied and solved.

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