

A Review of Urban Rail Transit PPP Research

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Abstract. To relieve the pressure of government investment and high-cost operation in major infrastructure projects, the PPP (Public-Private Partnership) is widely used in transportation engineering projects, especially urban rail projects. In this paper, we use Excel and Citespace software to categorize the research hotspots and analyze the trend changes to visualize the cooperation network analysis by searching 217 academic papers in core journals of Zhiwang, CSI, EI, CSSCI, and CSCD by keywords "PPP and transportation". Nowadays, the research of PPP-Transportation Engineering mainly focuses on the construction of risk management systems, performance evaluation systems, subsidy scheme decision systems, and operation mode selection methods for the whole life cycle of urban rail projects. This paper also analyzes the one-sidedness and research blind spots in the field of PPP_transportation, and provides research ideas for building a complete knowledge system and application development in the field of PPP-transportation in the future.

Keywords: PPP; traffic engineering; Citespace; analysis of current research status; hot spot prediction.

1. Introduction

To meet the accelerating urbanization in China, the construction of transportation infrastructure is increasingly important. However, the construction of such large-scale facilities requires huge construction funds and high operation and maintenance costs, which are prone to the shortage of funds, prominent debt crisis, and poor operation and management of local governments. The PPP (Public-Private Partnership) introduces social capital into the construction of public projects and becomes an emerging investment and financing method, which is conducive to the formation of deep cooperation between the government and the private sector. In addition to relieving the government's financial constraints and promoting diversified investment, the PPP model is also promoting the transformation of government functions from investors and builders to participants and supervisors of the whole process of investment, operation, and management, and realizing "risk sharing and benefit sharing" with the private sector. This paper thus summarizes the current status of research on transportation PPP projects, visualizes and analyzes this using cite space software, and predicts and suggests future research trends.

2. Data sources and research methods

In this paper, 232 papers were retrieved from databases CNKI-SCI source journal, EI source journal, core journals, CSSCI, and CSCD on May 9, 2021, for "Topic: PPP and Topic: Transportation;". The remaining 217 papers were analyzed by citing space software for visualization, summarization, hotspot overview, and prediction of research trends.

3. Data analysis

3.1 Overall trend analysis

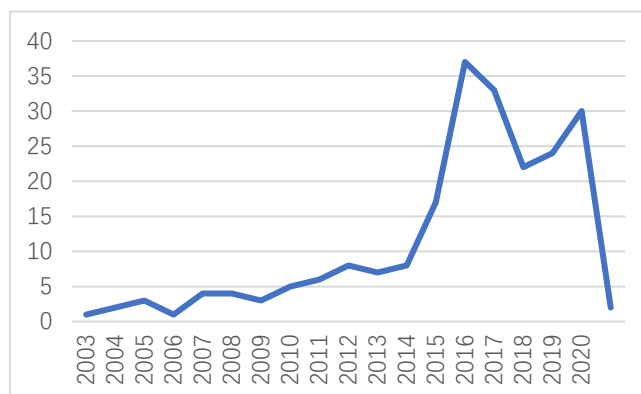


Figure 1 PPP+ traffic posting volume line graph

Through Table 1, we can see the research trend about PPP+transportation. The number of PPP projects exceeded 700 in 2014. During this period, the number of projects and the number of papers published increased but very slowly because the research on PPP development just started and was constrained by the global financial crisis in 2008. 2014-2017, as China's economic growth, accelerated, PPP projects became more standardized, the market development became more mature, the industry distribution of projects became more extensive, and the number of projects also showed a steep increase in the growth rate. In 2017, the number of papers issued increased steeply and the speed of issuing papers became significantly faster. In this period of 2017-2020, the development of PPP projects enters a bottleneck period due to the increased difficulty of PPP project accession and landing, poor policy continuity, unscientific performance assessment, etc. The volume of issuance in this period also appears to fall back and then rise, and the overall trend is more volatile and tortuous.

Table 1 Main contents and trends of research in each stage

Year	Phase	Characteristics
2003-2014	Phase I	Slow rise, research related to PPP+transportation gradually started
2014-2016	Phase II	Gradual rise, scholars' attention to PPP+transportation continues to increase
2016-2020	Phase III	Zigzag development, the number of articles fluctuates, and related research moves forward slowly
2020-2021	Phase IV	Rapid development, more attention will be paid to related aspects in the future

Through the analysis, it is found that the papers retrieved in the year 2021 to the first half of the year, and the related articles may not be fully shown until the end of 2021, but the authors of this paper predict that the volume of publications will continue to increase in 2021. Because, firstly, the policy support is continuing and the relevant legal documents introduced about PPP projects are perfect. Secondly, the research of relevant scholars is richer and more detailed, which gradually forms a complete cooperation network and promotes the realization of PPP projects, which is beneficial to the medium and long-term development of the projects.

3.2 Analysis of Researchers' Cooperation

From the researcher cooperation network diagram, each researcher conducts scattered and independent research among themselves and has not yet formed a complete cooperation network; there are two main cooperation blocks: Wang Jianbo, You Weibao, Zhang Wei, Zhang Shuai, Peng Longdart, and Liu Fangmeng as block one, and Sun Jie, Li Xiuting, Dong Jichang, Jia Kang, Lou

Yanni, and Chai Jian as block two. Within these two distinctions, the authors are more closely associated with each other in terms of cooperation.

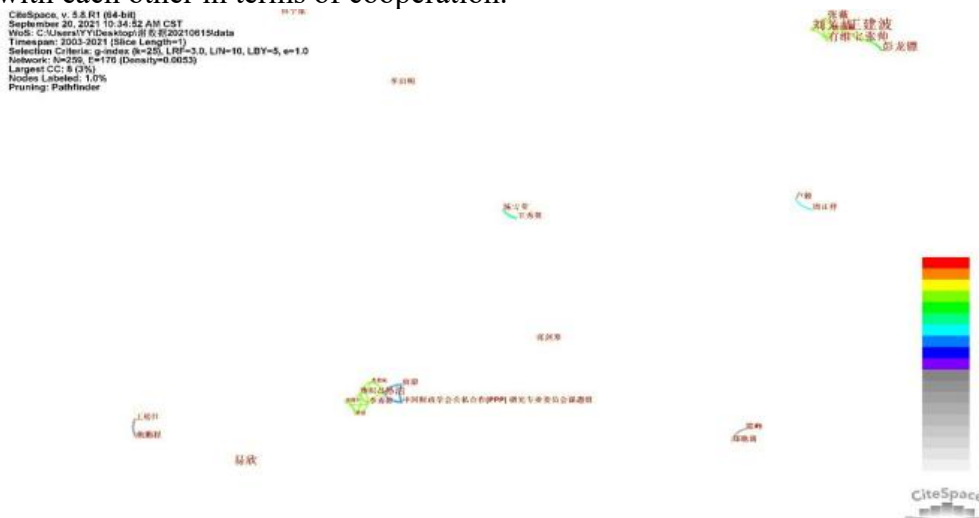


Figure 2 Researcher collaboration network diagram

Table 2 Frequency of researcher's cooperative publications

Frequency	Year	Name
7	2011	Wang Jianbo
5	2017	Liu Fangmeng
4	2017	Zhang Shuai
4	2017	Peng Longbiao
4	2015	Yi Xin
4	2018	You Weibao
4	2013	Li Mingyang
4	2013	Xing Yanting
3	2013	Liu Liqin
3	2019	Liu Hua
3	2014	Sun Jie
3	2017	Zhang Wei
3	2015	Xu Xingbo
3	2015	Hu Fangjun
3	2012	Hao Weiya
3	2015	Chen Jianjun

From the table of posting frequency, the main focus is on researchers with posting frequency ≥ 3 . Overall, the greater the posting frequency, the earlier their posting starting year and the longer the research period. Wang Jianbo has published 7 articles since 2011, the largest number, 6 of which are completed in cooperation with Youwibao, Liu Fangmeng, Peng Longdart, Li Na, Zhang Shuai, and Zhang Wei, concentrated in 2017 and 2018, which can represent the research frontier of PPP transportation industry. The research of Sun Jie, Li Mingyang, Xing Yanting, Hao Weiya, and Liu Liqin started earlier, from 2012-2014, but the cooperation network formed by them is not as close as that of Wang Jianbo's team, mainly between Li Mingyang, Xing Yanting, and Liu Liqin.

In the future, if the researchers with high publication frequency form a closer cooperation network, it will be more conducive to the in-depth and systematic research on transportation PPP projects.

3.3 Analysis of research institutions

Table 3 Research frequency of research institutions

Frequency	Year	Agency
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6	2011	Qingdao University of Technology School of Management
5	2010	Beijing Jiaotong University School of Economics and Management
5	2009	Chang'an University School of Economics and Management
4	2019	School of Management, Xi'an University of Architecture and Technology
4	2016	Beijing Urban Construction Design and Development Group Co.
3	2015	Academy of Science, Ministry of Transport Henan University, School of Economics
3	2016	College of Civil Engineering, Southeast University
3	2009	School of Civil Engineering, Beijing Jiaotong University
3	2015	College of Civil Engineering and Construction, East China Jiaotong University
3	2016	Beijing Jiaotong University

A visual analysis of research institutions by cite space revealed that a total of 10 institutions had a posting frequency of 3 or more. The higher the frequency, the earlier the year the research started. Among them, the School of Management of the Qingdao University of Technology has the highest frequency of 6 times, the School of Economics and Management of Beijing Jiaotong University and the School of Economics and Management of Chang'an University have 5 times each, and the School of Economics and Management of Chang'an University and School of Management of Xi'an University of Architecture and Technology have 4 times each. It can be seen that the visualization results of the institutions at the forefront of research and the institutions where the scholars at the forefront of research are trying to match, and it further shows that the use of cite space to analyze the current state of research on transportation PPP projects has a high degree of accuracy.

Currently, there is also no collaborative network between institutions and they are more fragmented. In the future, research cooperation between institutions should also be strengthened to complement each other's strengths and jointly promote good cooperation in the field of PPP research.

3.4 Keyword analysis

3.4.1 Keyword word frequency analysis

Table 4 Keyword frequency table

Frequency	Intermediary centrality	Year	Keywords
66	0.64	2003	PPP
57	0.49	2004	Urban rail transit
32	0.31	2005	PPP model
29	0.15	2011	PPP projects
27	0.39	2008	Rail transit
9	0.06	2010	Transportation infrastructure
7	0.19	2008	Public-private partnership
7	0.12	2005	Investment and financing
7	0.05	2013	Transport economy
6	0.07	2013	Investment and financing models
6	0.06	2017	Urban rail transit PPP projects
6	0.08	2018	Performance evaluation
6	0.19	2018	Risk evaluation
5	0	2017	Infrastructure
5	0.14	2013	Beijing Metro
4	0.26	2007	Concession period
4	0.17	2009	Public-private partnership

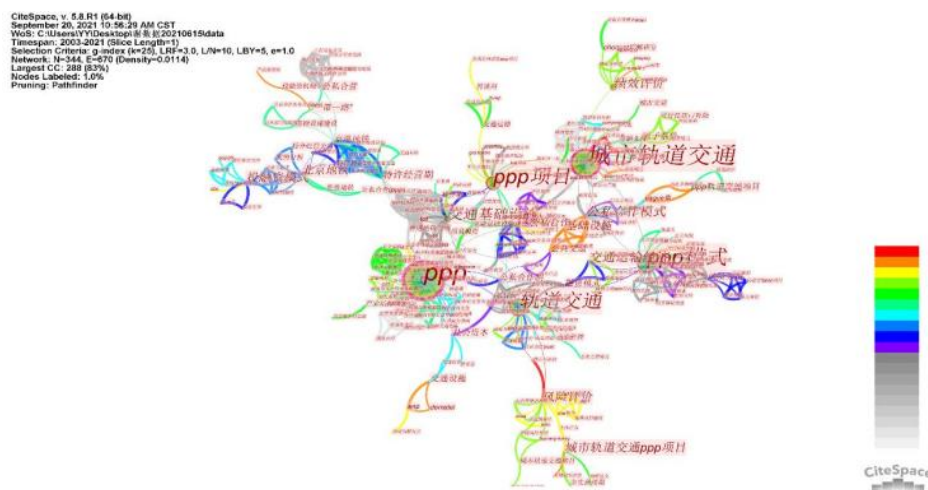


Figure 3 Keyword word frequency network diagram

The keyword word frequency, intermediary centrality, and year of the first occurrence of 217 articles were analyzed by using cite space, from which keywords with frequency ≥ 4 were sorted out, and these 13 keywords were used as clustering tags to cluster the 217 articles. Overall, the higher the frequency, the stronger the intermediary centrality, and the earlier the year of keyword appearance, indicating that the year of keyword appearance can reflect its importance. Obviously, "PPP" has the highest frequency and intermediary centrality, and the year of appearance is 2003, which is consistent with the theme of this study. The frequency and intermediary centrality of "urban rail transit" are also high, indicating that PPP projects in the transportation field are mainly implemented in urban rail transit projects. In addition, the PPP model, company cooperation model, investment and financing, risk evaluation, and performance evaluation are all hot spots of research, and the PPP model, company cooperation model, and investment and financing model were mainly studied at the early stage of PPP development (2003-2007); from 2014, PPP entered a period of rapid development and reached a peak in 2017. At this time, the research hotspots also gradually changed to the construction of scientific performance evaluation system, risk evaluation, and investment and financing models, which coincided with the emergence of problems such as ineffective supervision, hollow performance evaluation, unclear accountability of risk sharing, and backward risk warning in the actual implementation of PPP in this stage.

3.4.2 Keyword clustering analysis

Table 5 15 clustered keywords

Clustering	Size	Clustering mean contour value	Year	Clustering labels (LLR algorithm)
0	46	0.995	2012	PPP
1	35	0.977	2012	Urban rail transit
2	27	1	2012	PPP model
3	22	0.994	2018	Risk evaluation
4	20	0.945	2014	Rail transit
5	19	0.893	2008	Transportation infrastructure
6	18	0.883	2016	PPP projects
7	18	0.971	2014	Public-private partnership model
8	16	0.984	2014	Investment and financing model
9	16	0.953	2014	Transportation economy
10	13	1	2011	Public-private partnerships
11	11	0.931	2013	Concession period

12	10	0.93	2012	Investment and financing
13	9	0.996	2018	Performance evaluation
14	8	0.992	2017	Shared mobility



Figure 4 Clustered keyword labels

Next, the LLR natural log rate algorithm built into cite space was used to cluster the keywords, and a total of 15 clusters were obtained. The cluster size reflects the number of articles in each cluster, the average profile value of the clusters is an important indicator of the reliability of the clusters, and the "year" reflects the year of publication of the articles contained in each cluster. All contour values in the table are greater than 0.7, indicating a good clustering effect. Among them, clusters 2, 5, 10, and 12 are early, indicating that the research on the PPP model, transportation infrastructure, public-private partnership, and investment and financing are the research directions that emerged early and have existed in PPP projects; after 2017, performance evaluation, risk management, and shared mobility have become hot keywords, contributing to the improvement and medium- and long-term development of the completed PPP projects. In terms of cluster size, "PPP", "urban rail transportation" and "PPP mode" are in the top three. This indicates that these three keywords have dominated the research of all transportation PPP projects and become a fundamental research direction in the long term.

3.4.3 Timeline analysis of keyword clustering labels

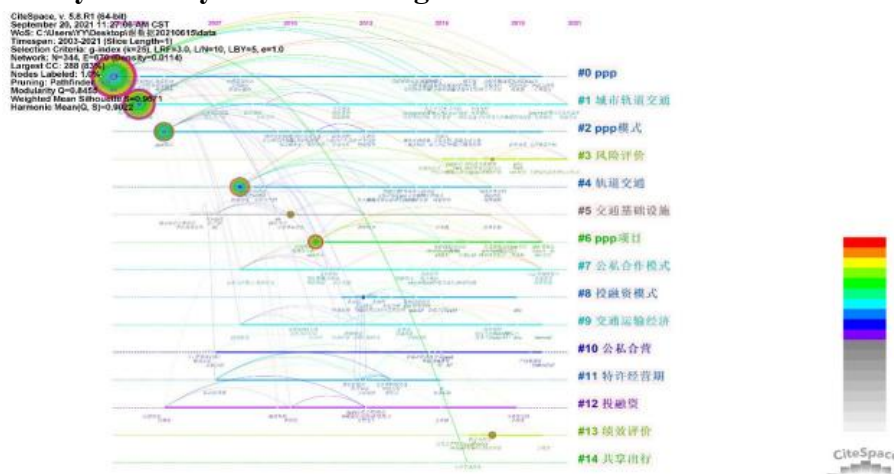


Figure 5 Timeline of clustering labels

Similar to the cluster size in the previous section, the earlier the cluster tag appears, the more linear connecting lines with the later tags are located, indicating that this keyword cluster tag overlaps

almost all studies of transportation PPP projects and becomes a long-term and basic general research direction. The circles and connecting lines show that the latest emerged keyword clustering tags such as investment and financing model, risk evaluation, performance evaluation, and shared mobility are based on the very early emerged "Urban Rail Transit", "PPP", and "PPP Model". In addition, this table shows in detail the start and end of the study for each cluster label, e.g., the concession period was no longer studied as early as 2016. By 2021, urban rail transit and risk evaluation are still continuously studied, so it can be predicted that the risk evaluation of urban rail PPP projects is still a hot topic of research.

3.5 Keyword emergence analysis

The keywords were analyzed for emergence, and the top 10 keywords in terms of emergence intensity were compiled, and the table shows when they first appeared and when they last appeared as of 2021. In the range of 2008-2012, "public-private partnership model", "financing model", "financing model", "corporate partnership" and "risk sharing" are the hot spot of research, and from 2017 to the present, the hot spot of research mainly focuses on "Urban rail transit PPP projects", "Performance evaluation" and "Risk evaluation", which can also reflect the development history of PPP project development from quantitative change to qualitative change.

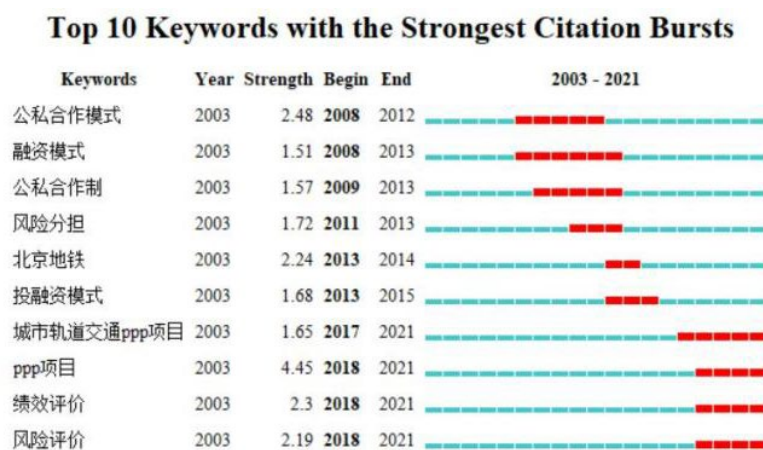


Figure 6 Top 10 keyword emergence intensity

4. Research conclusions

Throughout the 217 articles, it is found that macroscopically, the research mainly focuses on promoting the marketization of the PPP model in the field of rail transportation; the method of determining the specific selection model of PPP (BOT, TOT, DBFO, etc.). From risk identification and classification, risk index system construction and grading, the method of determining the weight occupied by the index, evaluation model, etc., the early warning, avoidance, management, and undertaking mechanism of risks are constructed, and suggestions are made for the countermeasures. On the micro side, the research focuses on the study of the capital subsidy decision model of PPP projects, the optimization way of price design, the construction of the whole life cycle performance evaluation system of PPP projects, the analysis of investment and financing scheme and the study of distribution decision of excess returns, the identification of success factors and multi-level project management and supervision mechanism; some scholars also study the typical cases of PPP at home and abroad and draw inspiration. However, there is less research on PPP projects based on industry characteristics, even in the transportation field, the research on PPP projects is only limited to urban rail transportation, and there is a lack of research on airport construction and highway construction; the number of literature reviews is extremely small, the content is vague, and there is no collection of industry characteristics for a personalized analysis.

4.1 Risk management system construction

In terms of risk management principles of urban rail PPP, Liu Yongquan [1] proposed that the risk-sharing mechanism should also follow the principle of "complementary advantages and strengths" by depicting the transaction structure of Beijing Metro Line 4, and the risk should be borne by the party with the most control and the lowest control cost.

In terms of the risk avoidance mechanism for urban rail transit PPP projects, Li Qidong [2] designed the risk avoidance mechanism by improving the performance appraisal system and derived the optimal appraisal coefficient for the government according to the genetic algorithm model. Tao Siping [3], Sheng Xueyan [4], and others proposed the dynamic mechanism of risk sharing, the basic principles, and specific processes of risk sharing from the mechanism of risk sharing. Shao Jianming, Zhou Hua & Zhang Shengjia [5] analyzed the necessity and design of risk sharing, sharing principles, and risk division with Hangzhou Metro Line 5, and concluded that risk sharing should match with control power and revenue. Zhu Xiangdong, Xiao Xiang, and Zheng Na [6] break the tradition of risk sharing between two parties and study the risk-taking game mechanism of multiple parties instead.

Risk early warning plays an important role in risk avoidance, but this aspect has only been studied by very few scholars at present. Mao Tengfei and Pan Yan [7] constructed a risk warning index system for toll expressway PPP projects based on literature research and questionnaire survey and designed a set of risk warning models based on variable-weighted topological elements and evidence theory. In the future, how to overcome the bias brought by the expert scoring method will become a hot spot in risk early warning research.

In terms of risk index analysis, Wang [8] et al. screened the risk points of rail transit PPP projects through telephone interviews and email interviews and constructed a material element topoable risk evaluation model to propose a reference for risk management and evaluation. Lu-Ping Che [9] not only established the risk points of PPP projects, but also focused on the internal connection and interaction between risk evaluation indicators, constructed an ANP model based on causality, and analyzed risk indicators from macro and micro perspectives, and calculated their weights. Li Yang and Ren Xu [10] focused on the risks of urban rail PPP projects during the operation period, constructed a system dynamics model of risk evolution, and analyzed the trend of the entropy value of each risk indicator in the operation phase of PPP projects through simulation, and concluded that each risk factor of PPP projects not only forms a causal path between them but also is a dynamic system that changes from time to time. Han Hongxia, Liu Song, and Cui Wuwen [11], based on Li Yang and Ren Xu's research, quantitatively analyzed the risk-return of the operation period and constructed the internal rate of return analysis and the Monte-Carlo algorithm-based investment risk assessment analysis model. Lou Yanni [12] et al. did risk transmission analysis from the functional perspective of stakeholders, aiming to study the risk framework, risk contagion mechanism, and characteristics of stakeholder partnership in the deterministic scope of the PPP model in the transportation field, and to construct a stakeholder risk contagion network and formulate risk contagion prevention and control strategies through social network analysis (SNA). Zhao [13] constructed the corresponding evaluation index system through the gray correlation analysis method, graded and weighted the risk indicators, and considered financing, construction, and operation as the main sources of risk.

Throughout all risk management-related papers, researchers have a deep understanding of risk management principles; risk factor classification and risk evaluation are also hot spots of academic research, but few scholars have screened the advantages and disadvantages of various classification methods; few scholars have ventured into risk early warning. Therefore, it is predicted that how improving the accuracy of risk warnings and how to choose an efficient evaluation method will become a hot spot for academic research in the future.

4.2 Performance evaluation

Ke Hong and Wei Ke believe that the existing research related to the regulatory performance of PPP projects mainly focuses on the research of regulatory performance improvement methods,

regulatory performance influencing factors, and regulatory performance evaluation system and few studies have conducted in-depth qualitative analysis for regulatory performance. They analyze the literature based on four dimensions: job performance, stakeholders, internal management, and learning and growth, summarize the evaluation indexes and propose corresponding quantitative or qualitative measurement methods based on policy documents, and finally integrate them to form a regulatory performance measurement system for rail transit PPP projects and make suggestions for government departments to improve regulatory performance. Its innovation lies in the revision of the BSC system from the perspectives of stakeholders, internal management, and work performance difficulty. This author has more research results on the three selection mechanisms of transportation PPP project partners and dynamic benchmark return rate.

4.3 Investment and financing model

For the investment and financing model, Wu Xianguo et al. described the current situation of China's urban rail financing model, i.e., the government's non-repayable input funds or government debt type is the main one, and the diversified market financing model is initially formed but not widely applied. On this basis, Liu Liqin and Ma Ming summarized the three major financing difficulties of PPP: large financing demand, long financing period, and diversified financing, and elaborated on the different funding sources, respective characteristics, and models of government-led market-based financing and government-led debt-based financing.

For financing stage risk management, Zhao Hui screens out different kinds of risks by defining different PPP operation modes and different project types. Li Mingyang et al. conducted a systematic study on the selection and application of the urban rail transit PPP model from the determination of the scope of investment and financing, the operation revenue and the way of risk sharing, and the return rate of social investors.

For financing guidelines and influencing factors, Sheng Lei discusses the key points of the path to optimizing the government-social capital cooperation system from three dimensions of optimal financing, management, and governance, and believes that financing should promote the matching of price, return and risk for PPP projects of transportation infrastructure construction. Li Chao summarizes the factors influencing the capital structure of rail transit PPP projects from three perspectives: political and economic system, industry environment, and project characteristics, and identifies six key factors using Matlab software and fuzzy DEMATEL method to explore financing efficiency evaluation methods, and also suggests the development model of land use (transportation + property) along the route.

Throughout all the literature on investment and financing, the combing of financing characteristics of different modes has been exhaustive, but a systematic research network has not been formed for the mode selection and specific implementation process of different projects, as well as the mode selection methods for each stage of the same project.

4.4 Distribution of PPP projects in the transportation industry

At this stage, the research on PPP+transportation-related projects mainly focuses on urban rail transportation projects, partly related to highways and civil airport facilities, and hardly involves the research on water transportation, civil aviation, and pipeline transportation.

In terms of highways, Wang Gu believes that the PPP model for highway construction projects has no precedent in China and is an emerging investment model in foreign countries, and that highway PPP projects involve issues related to toll pricing, road upgrading, adaptation of land use and economic development, adaptation of road service level and actual capacity, and risk management strategies. How to plan and design, construction, maintenance, operation and management, road renovation and upgrading, and other aspects of the implementation of continuous optimization, requires long-term survey data and predictive analysis as the basis to ensure the realization of public benefits, the implementation of a greater degree of difficulty. The only road PPP research at this stage is mainly focused on the issue of highway tolls. Based on the sensitivity of road users to PPP highway

toll prices, Xiong Yupu explored the linkage mechanism of pricing and diversion rate during the concession period and established an optimal model of comprehensive benefits of PPP highway projects.

In summary, although scholars have identified and analyzed the success factors of urban rail PPP projects in detail, there are few analyses of the shortcomings arising from the cases, and few studies have been conducted on whether highway and civil aviation PPP projects can learn from the model of urban rail PPP. Therefore, in the future, for other transportation modes with large investment volume, such as intercity high-speed rail, highways, and civil aviation, it is worthwhile to further study whether the PPP model can be adopted to reduce the government's investment, construction, and operation pressure, achieve reasonable risk sharing and improve the service efficiency and profitability of the projects.

5. Research Outlook

At present, the research on PPP+transportation should consider whether the introduced social capital has professional advantages in the relevant public service fields and standardize the development of PPP mode in China from the perspective of improving policies and regulations.

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