RESEARCH OF PPP PROJECT GOVERNANCE IN CHINA FROM THE PERSPECTIVE OF SOCIAL NETWORK THEORY: BASED ON BIG DATA ANALYSIS

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Abstract:

Relevant researches have shown that PPP project is a long-term network organization. From the perspective of social network theory, PPP project has its unique network structure in each stage, and the complex network relationships among all participants in the PPP project network will affect the project management mode, contract structure, relationship governance, risk sharing scheme, performance, etc. In this study, Web Crawler Search will be used to analyze and classify data by taking PPP projects of China's urban underground pipeline corridor as an example. Then the Social Network Analysis method is used to explore the different network density, structure hole, centrality and other characteristics of Chinese PPP projects at different development stages. Specifically, this study will analyze the social networks in different stages, so as to get the relative relations among the project participants in different stages. Will be clarify China on the basis of the PPP projects of urban underground pipeline corridor of the network characteristics, in order to different countries or companies involved in the PPP projects in China to provide a clear and concise analysis perspective, and project participants can according to the different PPP project social network structure, to determine the optimal contract governance structure and relations, in order to further enhance the performance of the PPP project.

Keywords: PPP Project, Project Governance, Social Network Theory, Web Crawler Search

1. INTRODUCTION

As a pipeline corridor for centralized management of municipal infrastructure and pipelines, the urban underground pipeline corridor can simultaneously accommodate municipal water supply, sewage, reclaimed water, natural gas, power supply, heating and communication lines.It can effectively solve many urban diseases such as frequent excavation of pipeline overhaul, interference of urban traffic jam and pollution of urban environment caused by traditional isolated pipeline laying mode. It is a key project of municipal infrastructure to ensure the normal operation of the city, and has been paid attention to and applied in many countries all over the world.Since 2013, the Chinese government has gradually begun to attach importance to the development of urban underground pipeline corridor. After that, several policy guidance documents have been issued successively, vigorously promoting the introduction of public-private partnership (PPP) model in the construction and operation of comprehensive pipeline corridors.

In view of the long construction and operation cycle involved in the PPP project of urban underground pipeline corridor, the large number of stakeholders involved in the project, and the previous experience of the government parties in various Chinese cities in implementing the project of urban underground pipeline corridor is insufficient. Previous studies show that in the process of PPP project, if private sectors than the public sectors in the information and resource advantage, is in response to private sectors of opportunistic behavior, improve project risk management performance, etc., the relationship between the project stakeholders governance than project contract management more effective. Based on this, this study will comb the present Chinese urban underground pipeline corridor PPP project implementation present situation, and from the perspective of social network analysis

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(SNA) to analyze the interaction between the various stakeholders, in order to in the relations of the embedded type under the background of Chinese social reality, combing the PPP projects of urban underground pipeline corridor network structure characteristics between in different stages of PPP project, and provide suggestions for China's PPP project relationship management.

Specifically, the PPP project management database published on the website of the public and private partnership center of the ministry of finance of China is used as the data source for the analysis of the application status of PPP projects in the urban underground comprehensive tunnel.

By the end of May 2019, 243 PPP projects have been included in the PPP project management database of the public and private partnership center of the ministry of finance of China. In order to more representative, this study by China's ministry of finance of national demonstration project for benchmarking, use "Octopus" software data fetching technology screening get 60 details of the project, and from the project amount, the private sectors structure, operation mode, reward system, regional distribution, social capital attribute of current situation of the PPP projects, a total of six aspects combing; On this basis, the method of SNA is adopted to depict and analyze the stakeholder relationship network of PPP projects in the three stages of procurement, construction and operation, and to summarize the relationship network structure characteristics and key points of relationship governance of PPP projects.

2. CURRENT APPLICATION STATUS OF PPP PROJECTS IN URBAN UNDERGROUND COMPREHENSIVE PIPE CORRIDORS IN CHINA

2.1 Project quantity analysis

According to the data by the end of May 2019, 26% of China's urban underground pipeline corridor PPP projects are below 1 billion yuan (all over 100 million yuan), and 74% of the projects above 1 billion yuan. Among them, projects of 1 billion yuan to 3 billion yuan, 3 billion yuan to 5 billion yuan and above account for 47%, 12% and 15% respectively. The minimum investment amount is 160 million yuan and the maximum is 15 billion yuan. It can be seen from the above data that the PPP project of urban underground pipeline corridor in China has a high investment. Generally speaking, the larger the total investment amount of the project is, the more necessary it is for all stakeholders with different advantages such as investment, construction and design to cooperate together to deal with technical, legal, capital and other risks in the whole life cycle of the PPP project.

2.2 Private sectors structure analysis

According to the data by the end of May 2019, 40 of the 60 projects were won in the form of consortium, accounting for 66.67%, while only 20 projects were won in the form of non-consortium, accounting for 33.33%. In the non-consortium projects, the proportion of state-owned enterprises with strong comprehensive strength, such as engineering construction, investment and financing capacity, is as high as 88%, while pure private enterprises account for only 12%. The above data reflects the large number of participants in China's PPP projects, mainly state-owned enterprises, as shown in figure 1.

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Bidding situation of PPP project of
urban underground pipeline colligate alure

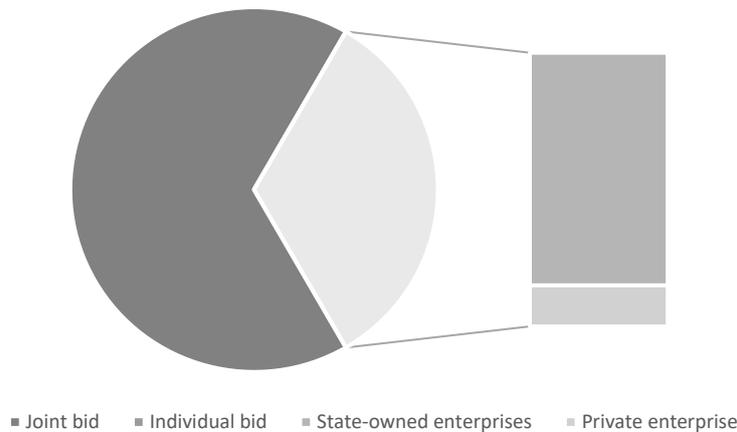■ Joint bid   ■ Individual bid   ■ State-owned enterprises   ■ Private enterprise

Fig.1 Bidding situation of PPP project of urban underground pipeline colligate alure in China

2.3 Project operation mode and rewarding system analysis

BOT mode as the mainstream of underground pipeline corridor PPP project operation mode, the proportion of total 88%, at the same time DBFOT model has been applied gradually in some projects, the project design, construction, financing, operation and transfer to implement integration to the private sectors, can give full play to the social capital management advantages of capital and technology, more in line with the connotation of the characteristics of PPP. The details are shown in figure 2 below.
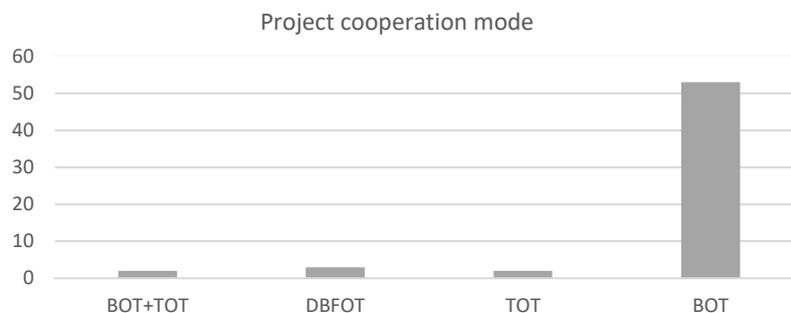

Fig.2 Underground pipeline colligate alure PPP Project cooperation mode

In the current operation mode of underground pipeline corridor PPP project, the most common rewarding system is the combination form of "user payment + government subsidy", which is consistent with the quasi-public product property of underground pipeline corridor. Because the underground pipeline corridor has great positive external benefits, but the investment and construction cost is high, only relying on the single user fee or government subsidy is not conducive to the promotion and sustainable development of the pipeline corridor.

2.4 Area distribution

Based on the analysis of the regional distribution of 60 projects, it is found that the PPP projects of

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China's underground comprehensive pipeline corridor are involved in all seven regions, and have the characteristics of wide distribution and full coverage. However, there are differences in the number of projects distributed in different regions. Southwest region has the most significant number of projects with a greater degree of attention, followed by northeast region and east China region with a larger number of projects and south China region with the least distribution. The details are shown in figure 3.
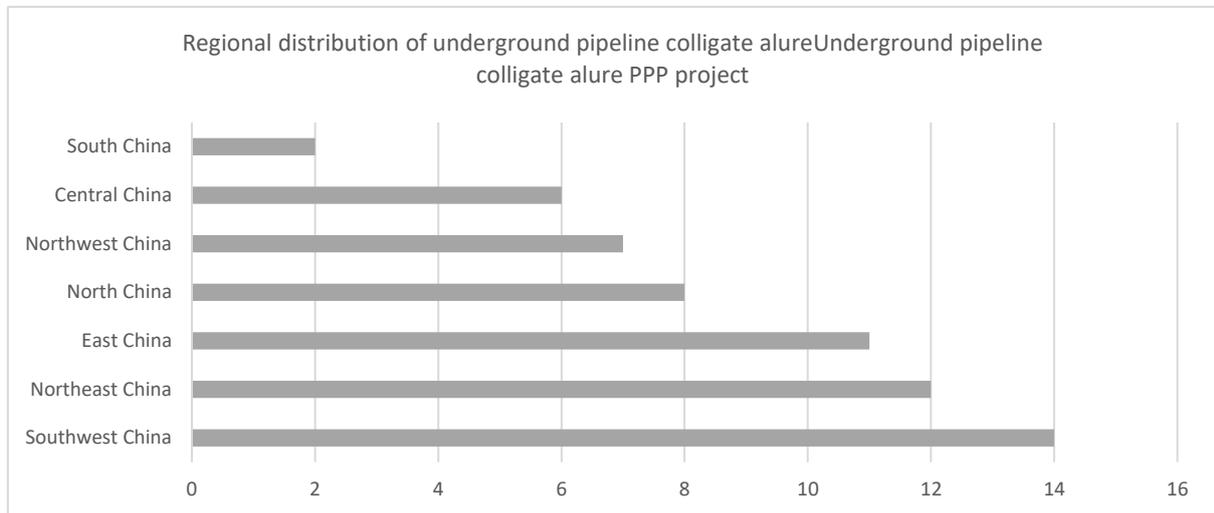

Fig.3 Regional distribution of underground pipeline colligate alure PPP project

2.5 Analysis of consortium leading units

For the PPP project of the underground pipeline corridor, the private sectors winning the bid of the consortium shall participate in the bidding of the consortium mainly including financial institutions, infrastructure industrial investment institutions, project construction units, design units, consulting units, infrastructure construction and operation management units, equipment and technology companies, etc. According to data statistics, the leading unit of the consortium is analyzed, mainly involving state-owned enterprises and their subordinate units, private enterprises, mixed ownership enterprises and other enterprises, as shown in figure 4.

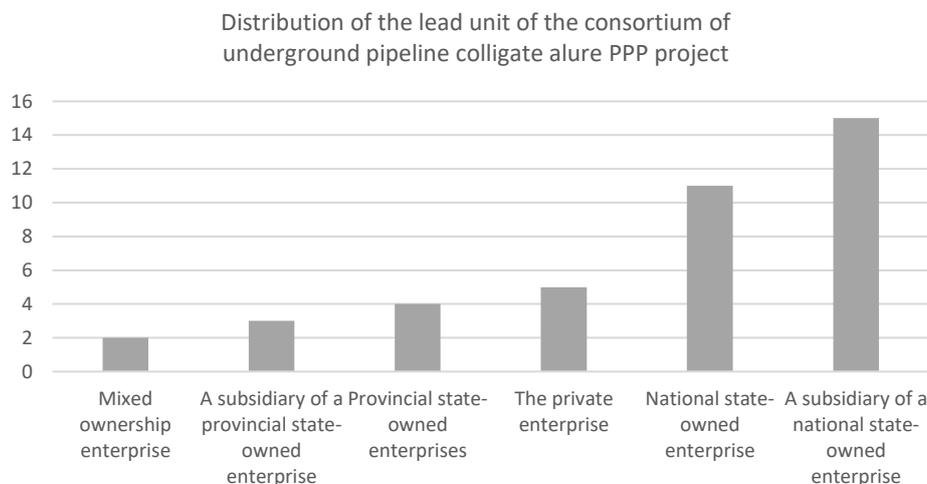Fig.4 Distribution of the lead unit of the consortium of Underground pipeline colligate alure PPP project

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It can be seen that the leading unit of the consortium of underground pipeline corridor PPP project is mainly large state-owned enterprises and their wholly-owned subsidiaries. These enterprises have a close relationship with the government, which lays a good foundation for research and data collection.

3. PPP PROJECT STAKEHOLDER SOCIAL NETWORK ANALYSIS FOR CHINA'S URBAN UNDERGROUND PIPELINE CORRIDOR

In the research of social network, node represents stakeholders of PPP project, and connection line represents the relationship between stakeholders. In China's PPP projects, there are many stakeholders with different forms in different project stages. Generally speaking, the stakeholders of the PPP project include finance bureau, development and reform commission, housing and construction authority, urban construction investment company, private sectors, project design unit, geological exploration enterprise, consulting enterprise, construction contractor, material supplier, financing institution, special purpose vehicle(SPV) and the public.

On the other hand, the connecting lines between nodes represent the strength of the relationship between stakeholders. Specifically, some scholars measure the relationship strength from the four dimensions of communication frequency, closeness, trust and relationship persistence (Marsden and Campell, 1984). Some studies measure the relationship strength from the two dimensions of communication frequency and closeness (Levin and Cross, 2003). Other studies also measure the relationship strength from six dimensions of interaction frequency, mutual trust, continuity, reciprocity and control (Nooteboome and Gisling, 2004). This study takes into account the function and characteristics of the social network in the PPP project of urban underground pipeline corridor, from the aspects of trust and cooperation (Zhang L. Y. et al., 2013), trading and regulation (Solis F. et al., 2013), contact time (Pryke S. D. et al., 2005) to measure the relationship strength. Refer to the measures of trust, cooperation, and contact(Pryke S．D．et al., 2006，Chinowsky P．et al., 2008，Sheikha A．E．et al., 2010) form the stakeholder relationship intensity measurement index of the PPP project of the urban underground pipeline corridor, as shown in table 1.

Tab. 1 measurement indexes of stakeholder relationship strength for PPP projects of underground pipeline corridor in China

measurement dimension		Index	Guidelines
Relationship strength	Trust	A1	We believe that the stakeholders have the ability to achieve the objectives of the plan on time, quality and quantity
		A2	It is believed that the stakeholders will fully consider the overall interests of the project
		A3	It is believed that the stakeholder will not make decisions at the expense of others
	Contract and supervision	B1	A contractual relationship with the stakeholder
		B2	A regulatory relationship with the stakeholder
	Cooperation	C1	Strong task dependency with the stakeholder
		C2	There is a strong resource dependence relationship with the stakeholder
	Communication time	D1	Frequent formal communication with the stakeholder
		D2	Frequent informal communication with this stakeholder

According to the relationship strength indicators determined in table 1, a questionnaire was prepared for investigation. The research conducted a survey on the participants of the PPP project of the urban underground pipeline corridor without project restrictions, and scored on the measurement dimensions of the trust, transaction and regulation, cooperation and contact time among stakeholders. The total number of respondents was 97, including all types of stakeholders involved in different project stages. Network - based analytic hierarchy process (AHP) is used in data processing, determine the weight of trust, cooperation, contact time, and the magnitude scale method is adopted, express the description and the actual situation in line with the degree of measurement, {5,4,3,2,1}

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indicates degree from high to low. Then, the scores of 97 questionnaires were averaged, and the relationship between the upper and lower levels of stakeholders in the business was taken into account. Finally, the relationship matrix and social network structure chart of stakeholders in the PPP project of the underground pipeline corridor were established in stages.
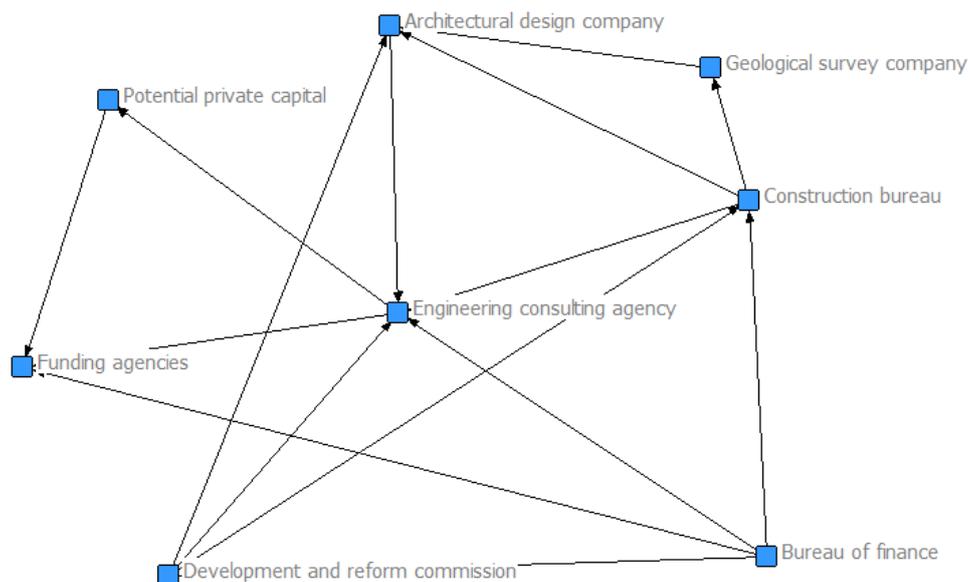
3.1 Bidding and procurement stage

Through sorting out the questionnaire information, the relationship strength among stakeholders in the bidding and procurement stage of PPP projects is calculated, and the relationship matrix is formed as shown in table 2.

Tab. 2 relationship matrix of bidding and procurement stage

Stakeholder	Bureau of finance	Development and reform commission	Construction bureau	Geological survey company	Architectural design company	Engineering consulting agency	Potential private capital	Funding agencies
Bureau of finance	0	4	4	2	2	4	1	3
Development and reform commission		0	5	2	4	3	1	2
Construction bureau			0	4	4	4	1	1
Geological survey company				0	4	2	1	1
Architectural design company					0	4	2	2
Engineering consulting agency						0	3	3
Potential private capital							0	5
Funding agencies								0

This relation matrix was input into UCINET software for calculation. Meanwhile, NETDRAW software was used to draw the network structure. As shown in figure 5, the stakeholder network relation diagram of the procurement bidding stage of the PPP project of the urban underground pipeline

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corridor was obtained.

Fig. 5   stakeholder relationship network in bidding and procurement stage

The density of the above networks is analyzed by UCINET software, which is 53.57%， and the calculated results of network centrality index are shown in table 3.

Tab. 3 network centrality index of bidding and procurement stage

Stakeholder	Degree centrality	Closeness centrality		Betweenness centrality
		inCloseness	outCloseness	
Construction bureau	23.000	16.667	33.333	2.500
Engineering consulting agency	23.000	33.333	16.667	9.000
Architectural design company	22.000	25.000	20.000	3.000
Development and reform commission	21.000	14.286	50.000	0.000
Bureau of finance	20.000	12.500	100.000	0.000
Funding agencies	17.000	100.000	12.500	0.000
Geological survey company	16.000	20.000	25.000	0.000
Potential private capital	14.000	50.000	14.286	0.000
Other data	（Degree）Network Centralization = 13.33% （Betweenness）Network Centralization Index = 19.39%			

3.2 Construction stage

Through sorting out the questionnaire information, the relationship strength among stakeholders in the construction stage of PPP project is calculated, and the relationship matrix is formed as shown in table 4.

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Tab. 4 relationship matrix of project construction stage

Stakeholder	Bureau of finance	Development and reform commission	Construction bureau	Urban construction investment corporation	Geological survey company	Architectural design company	Engineering consulting agency	Potential private capital	Funding agencies	SPV	Government regulator	Material supplier	Construction contractor	Social public
Bureau of finance	0	2	3	3	1	2	3	3	5	4	4	1	1	2
Development and reform commission		0	4	3	1	2	3	2	2	3	4	2	1	3
Construction bureau			0	5	3	4	4	4	3	3	3	3	3	2
Urban construction investment corporation				0	2	4	4	4	4	4	4	4	4	4
Geological survey company					0	3	2	1	1	1	3	1	2	1
Architectural design company						0	4	4	2	3	2	3	4	1
Engineering consulting agency							0	5	4	5	4	2	3	3
Private capital								0	5	5	4	4	5	4
Funding agencies									0	5	3	2	2	2
SPV										0	4	4	4	4
Government regulator											0	3	3	3
Material supplier												0	4	2
Construction contractor													0	2
Social public														0

The relation matrix was recorded into UCINET software for calculation, and NETDRAW software was used to draw the network structure. As shown in figure 6, the stakeholder network relation diagram of the PPP project construction phase of the urban underground comprehensive pipe corridor can be obtained.
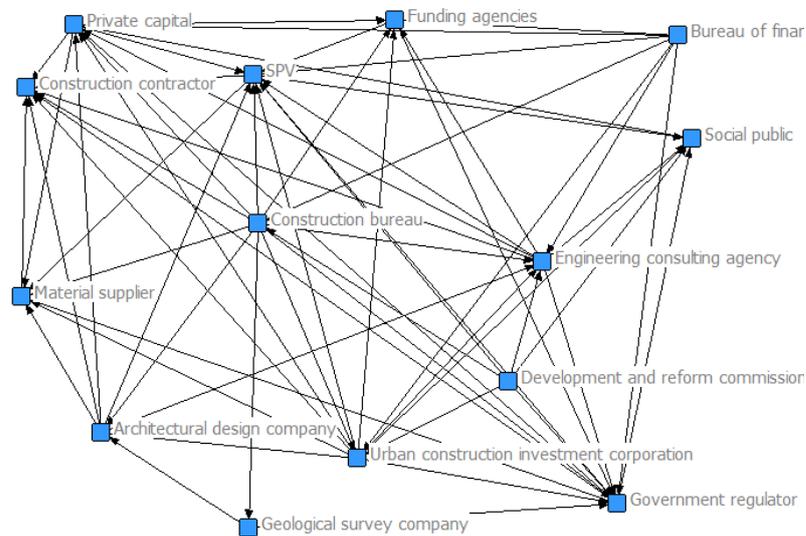

Fig. 6   stakeholder relationship network in project construction stage

The density of the above networks is analyzed by UCINET software, which is 67.03%， and the calculated results of network centrality index are shown in table 5.

Tab. 5 network centrality index of project construction stage

Stakeholder	Degree centrality	Closeness centrality		Betweenness centrality
		inCloseness	outCloseness	
Private capital	50.000	14.286	12.500	2.767
SPV	49.000	20.000	10.000	3.717
Urban construction investment corporation	49.000	9.091	25.000	2.883
Engineering consulting agency	46.000	12.500	14.286	3.100
Government regulator	44.000	25.000	9.091	5.050
Construction bureau	44.000	8.333	33.333	4.483
Funding agencies	40.000	16.667	11.111	0.000
Architectural design company	38.000	11.111	16.667	5.000
Construction contractor	38.000	50.000	7.692	0.000
Material supplier	35.000	33.333	8.333	0.000
Bureau of finance	34.000	7.143	100.000	0.000
Social public	33.000	100.000	7.143	0.000
Development and reform commission	32.000	7.692	50.000	0.000
Geological survey company	22.000	10.000	20.000	0.000
Other data	（Degree）Network Centralization = 18.72% （Betweenness）Network Centralization Index = 2.15%			

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3.3 Operation stage

Through sorting out the questionnaire information, the relationship strength among stakeholders in the operation stage of PPP project is calculated, and the relationship matrix is formed as shown in table 6.

Tab. 6 relationship matrix of Project operation stage

Stakeholder	Bureau of finance	Construction bureau	Urban construction investment corporation	Potential private capital	Funding agencies	SPV	Government regulator	Social public	Pipeline supervisor
Bureau of finance	0	3	3	3	4	3	4	2	3
Construction bureau		0	4	4	3	4	3	2	5
Urban construction investment corporation			0	4	4	4	3	2	5
Potential private capital				0	5	5	4	3	5
Funding agencies					0	5	3	2	2
SPV						0	4	4	5
Government regulator							0	2	2
Social public								0	2
Pipeline supervisor									0

The relation matrix was recorded into UCINET software for calculation, and NETDRAW software was used to draw the network structure. As shown in figure 7, the stakeholder network relation diagram of the PPP project construction phase of the urban underground comprehensive pipe corridor can be obtained.
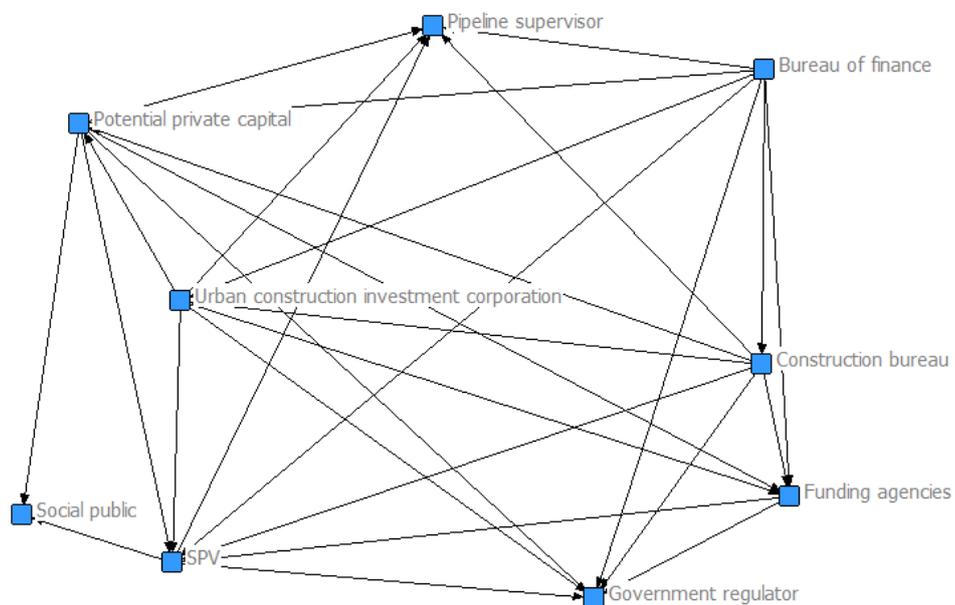

Fig. 7   stakeholder relationship network in Project operation stage

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The density of the above networks is analyzed by UCINET software, which is 77.78%， and the calculated results of network centrality index are shown in table 7.

Tab. 7 network centrality index of project construction stage

Stakeholder	Degree centrality	Closeness centrality		Betweenness centrality
		inCloseness	outCloseness	
SPV	34.000	25.000	16.667	3.500
Potential private capital	33.000	16.667	25.000	1.500
Pipeline supervisor	29.000	100.000	11.111	0.000
Urban construction investment corporation	29.000	14.286	33.333	0.000
Funding agencies	28.000	20.000	20.000	0.000
Construction bureau	28.000	12.500	50.000	0.000
Government regulator	25.000	33.333	14.286	0.000
Bureau of finance	25.000	11.111	100.000	0.000
Social public	19.000	50.000	12.500	0.000
Other data		（Degree）Network Centralization = 20.00%（Betweenness）Network Centralization Index = 5.92%		

4. RELATIONAL NETWORKS STRUCTURAL ANALYSIS

For a more accurate expression of China's PPP projects of urban underground pipeline corridor of each stage of the relationship between stakeholders, realize the overall relationship between the state of the network description, the recognition of core subjects, as well as the optimization of network structure, etc., whole network density, centricity, central potential index to calc ulate and analysis.

4.1 Stakeholder network density

Network density reflects the closeness of the relationship among stakeholders in the network. In a high-density network, the communication between nodes is very frequent and the exchange of resources and information is relatively close. The research shows that the higher the network density, the stronger the integrity of the network, and the higher the collectivization degree of the actors in the network. That is, if the overall network density is large, then the network will have a greater possibility to influence the attitude and behavior of each stakeholder. It can be seen that network density in social network can be used to evaluate two aspects:
● the network density can reflect the propagation speed of information, knowledge and resources in the network. The higher the network density is, the stronger the communication and coordination ability is.
● network density can reflect the limiting ability of the whole network to actors in the network. The higher the network density is, the more consistent the behaviors of actors are.

Specifically, in this study, the relational network density of China's urban underground pipeline corridor PPP project is 53.57% in the bidding and procurement stage, 67.03% in the construction stage, and 77.78% in the operation stage. The data results show that the relational network in the operation stage has a strong integrity and each stakeholder has a high degree of collectivization. This is consistent with the practice, that is, it indicates that the relationship between stakeholders in the operation stage has become stable, and their interest demands tend to be consistent. In the context of this reality, network density of the lowest bidding procurement stage, reflecting the relations between the phase of the various stakeholders PPP projects tend to alienate, partly because of a shortage of initial trust between the various stakeholders, on the other hand is due to the phase of each stakeholder demands are not clear, and the larger project uncertainty. These aspects all lead to the need for a more clear list of project requirements at this stage, so as to improve the level of relations among the parties involved at this stage, which is embodied in enhancing mutual trust,

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strengthening communication, and refining the contract and regulatory content at this stage.

4.2 Centrality analysis of relational network

Network centrality degree is an index to measure individual actors in the network. According to different dimensions, network centrality degree can be divided into three categories: degree centrality, closeness centrality and betweenness centrality.

4.2.1 Degree centrality

Degree centrality is the number of relationships directly connected to a node in a network. The degree centrality reflects the degree of concentration of relationships and the communicative ability of actors in the network. If the degree centrality of a stakeholder is larger than that of other actors, it can be considered that it has stronger communication ability in the network and is easier to establish contact with other stakeholders. In the PPP project stakeholder relationship network, the degree centrality can reflect the ability of one stakeholder to establish communication relations with other stakeholders in the network.

In this study, the Construction bureau is the one with the highest degree centrality score in the bidding and procurement stage of China's urban underground pipeline corridor PPP project, the private sectors is the one with the highest degree centrality score in the Construction stage, and the SPV is the one with the highest degree centrality score in the operation stage. These institutions or companies have strong relational communication ability in different PPP project stages.

4.2.2 Closeness centrality

Closeness centrality reflects the degree of closeness between one actor and other actors. If an actor has a greater closeness centrality, it has a closer relationship with other actors and is less controlled by other actors. In the PPP project stakeholder relationship network, the degree of closeness centrality can reflect the degree of closeness between one stakeholder and other stakeholders. Specifically, stakeholders with higher closeness centrality have stronger ability to obtain information and resources from other stakeholders, and are less restricted by other stakeholders, and their behaviors will have greater impact on the whole network. There are absolute value and relative value of the degree of proximity to the center.

In this study, the funding agencies get the highest score of closeness centrality in the tendering and procurement stage, private sectors gets the highest score of closeness centrality in the construction stage, and pipeline supervisor gets the highest score of closeness centrality in the operation stage. These institutions or companies have strong information collection and control capabilities in different stages of PPP projects, and they also have a great impact on the whole relational network.

4.2.3 Betweenness centrality

The degree of betweenness centrality indicates how likely one actor is to be on the interconnected path of other actors in the network. Then, the degree of betweenness centrality reflects the ability of an actor to control resource sharing and information transmission of other actors. If the degree of betweenness centrality of an actor is large, we can consider that it plays a relatively large "intermediary" role In the relationship communication of other stakeholders. In the relationship network of stakeholders in PPP projects, the degree of betweenness centrality can be used to measure the ability of one stakeholder to control other stakeholders' behaviors of spreading information,

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transferring knowledge and sharing resources.

In this study, the highest betweenness centrality score of China's urban underground pipeline corridor PPP project in the tendering and procurement stage is the engineering consulting agency, the highest score in the construction stage is the government regulator, and the highest score of the operation stage is SPV. These data show that in different stages of PPP projects, there are different relationship communication "intermediaries", which control information transmission, knowledge transfer and resource sharing in different stages respectively.

4.3 Network Centralization Analysis

The network centralization reflects the power distribution of the whole network. Specifically, the network centralization is an indicator to describe the overall characteristics of the network, which is mainly used to describe the degree of power concentration in the network. The network centralization includes three types: degree centrality, closeness centrality and betweenness centrality. Among them, the higher the network centralization of degree centrality is, the higher the ability of some stakeholders in the network to develop relations is far beyond that of other relevant parties, and the concentration degree of network relations tends to be centralized. The higher the betweenness centrality of network centralization is, the more powerful the integration ability of network information is.

In this study, the highest degree centrality of network centralization of China's urban underground pipeline corridor PPP project is in the operation stage, which reaches 20%. The betweenness centrality of network centralization has the highest potential in the stage of bidding and procurement. It is noted that the highest score of degree centrality and betweenness centrality of network centralization in the operation stage is SPV, so the above data indicates that China's urban underground pipeline corridor PPP projects have an obvious centralization trend in the operation stage and are concentrated towards SPV, which is consistent with the practical experience of PPP projects. At the same time, the engineering consulting agency has the highest score of betweenness centrality of network centralization in the bidding and procurement stage of China's urban underground pipeline corridor PPP project. The above data indicates that the engineering consulting agency in the bidding and procurement stage has relatively strong knowledge integration ability, and it controls more resources and information at this stage.

5 GOVERNANCE RECOMMENDATIONS AND RESEARCH CONCLUSIONS

Research shows that the low relationship strength in PPP projects may lead to the wrong understanding of stakeholders' intentions, the formation of wrong expectations among stakeholders, and the unnecessary suspicion or opportunistic behavior, which will damage the value co-creation of the project. On the other hand, as there is only a low degree of trust among stakeholders, all parties tend to be risk averse and vigilant, and their willingness to share risks is reduced. That is to say, low relationship strength in PPP projects is not conducive to forming an effective risk sharing mechanism among stakeholders.

In traditional construction projects, the time limit for a project is relatively short, which leads to the changeable concomitant and cooperative relationship, making it difficult for both parties to form a high degree of trust and reciprocity relationship through limited trading history. However, the stakeholders of PPP projects have built a long-term cooperative relationship, which is at least 10 years under the current policies and regulations in China. In this process, trust, friendship, respect and reciprocity among stakeholders are crucial to risk sharing. In strong relation network, the PPP project

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stakeholders can be a good deal of interactive experience to form a high degree of trust, reciprocal relationship, this will help partners committed to more efficient allocation of resources, the transfer of tacit knowledge, willingness to share risks and improve the subject, which is beneficial to the PPP project various stakeholders to solve project risk.

Based on the above, in order to promote   strength of network, it is necessary to the diversity of the different stages of project implementation countermeasures, respectively from the perspective of degree centrality, closeness centrality and betweenness centrality and to guide the stakeholders, and will build a PPP project relationship network featuring open resources, open information and knowledge sharing. Create possibilities for risk sharing, value realization and performance improvement of PPP projects.

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