Research on the factors affecting the choice of private capital in PPP projects of urban underground comprehensive pipe gallery

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Abstract. In the practice of PPP projects, many projects failed due to the inability of private capital to meet the objectives of construction and operation. Therefore, choosing the right private capital is the prerequisite for the success of the PPP project. This paper takes the urban underground comprehensive pipe gallery PPP project as the research object, and proposes five factors that affect the choice of private capital. Through the structural equation model (SEM), the structural model of the influencing factors of private capital selection is constructed, and the influence of each variable on private capital choice and the interaction between variables are analysed. According to the calculation results of the model, corresponding suggestions are put forward, which aims to save time and effort in the process of purchasing social capital, so as to achieve a win-win situation for both government and private capital.

1. Introduction
With the rapid development of economic construction and the continuous expansion of the city scale, there are widespread problems such as dense telegraph poles and air lines in cities. In the process of expansion, renewal, renovation and maintenance of municipal pipelines, the road has been repeatedly dug and backfilled, and the problem of traditional direct buried pipelines has become increasingly prominent. In order to save road excavation and repair costs, avoid affecting urban traffic, and improve urban land utilization, the state vigorously promotes the construction of urban underground comprehensive pipe gallery. However, the construction, operation and maintenance phase of the comprehensive pipe gallery is costly, and it is difficult to meet the funding needs only through financial allocation. The introduction of the PPP mode in the construction of comprehensive pipe gallery not only reduces the government's financial burden, but also introduces advanced construction operation and maintenance experience to solve the problems of financing difficulties and management difficulties of comprehensive pipe gallery projects. However, the PPP project of the comprehensive pipe gallery has a long construction period and many uncertain factors. If the private capital is unable to meet the construction and operation objectives, it may lead to project failure. How to choose the appropriate private capital is still a difficult problem to be solved.

2. Research status and problems
The urban underground comprehensive pipe gallery originated in France. In 1833, France built the world's first comprehensive pipe gallery, which contains various municipal public pipes such as electricity, communication, tap water and compressed air. Since then, the comprehensive pipe gallery
has gradually emerged in the United Kingdom, Germany and other places, and its construction technology and related legal systems have also been upgraded and improved. At present, most of the domestic and international research on the comprehensive pipe gallery PPP project focuses on risk management, pricing and price adjustment, and the selection and application of financing modes. Little research has been done on the selection of private capital for the urban underground comprehensive pipe gallery PPP project.

Johnson studied the private capital selection method of PPP project on the basis of relationship theory and proposed a two-step method. The first step is the primary selection. The characteristics of each potential bidder are analyzed by constructing an evaluation system. The second step is the optimization, which is to quantitatively analyze the technical strength and financial status of the enterprise, and finally determine the optimal private capital. Li, J. et al. simulated the PPP project through a risk assessment model. The simulation results showed that the private capital candidate failed to be one of the major risks. Arata, M. et al. analyzed the issues related to the procurement phase of PPP projects, studied the highway engineering PPP project, and proposed appropriate private capital is the key to project success. Vinodh, Balagi, and Patil proposed to select private capital from the comprehensive evaluation of finance, technology, management, and industry credit. Based on this, the Dematel method was used to analyze the correlation between evaluation indicators to ensure the practicality of the indicator system. Xu, Y. et al. established a private capital selection procedure for multi-criteria evaluation based on fuzzy comprehensive evaluation, and used the questionnaire survey to study the key risks of PPP projects. Huang Yajiang identified 17 factors influencing the government's choice of private capital, and built a private sector selection evaluation model based on financial, technical, management and cooperation capabilities, and fully considered the interrelationship between indicators. By collecting 29 PPP projects that have been completed by bidding or in the pre-purchase stage, Liu Jiangfan analyzes the methods and procurement requirements adopted in the procurement process in each case, and concludes that the PPP mode for comprehensive governance of river should adopt competitive negotiation as procurement method and propose that the government should occupy a small amount of equity in the Special Purpose Vehicle (SPV), and its financing ability and professional level should be considered in the process of private capital selection. By summarizing the research results and practical experience of PPP project procurement, and drawing on the legal system of PPP project procurement in the UK and Japan, Zhan Yuxin proposed the concept of perfecting the government procurement legal system for PPP projects in China. Zhang Hongli analyzed the type of private capital and its responsibilities in the PPP project, and established a bid evaluation system from the aspects of bidding enterprises, bidding schemes and economic benefits, and determined the index weights through the triangular fuzzy analytic hierarchy process, so as to conduct comprehensive evaluation to select appropriate private capital.

In summary, many studies have shown that the choice of private capital has become the key to the success of PPP projects, but there are few studies on the factors influencing the selection of private capital for urban underground comprehensive pipe gallery PPP projects. Therefore, based on the existing research, this paper combines the survey data and the results of the questionnaire survey, combined with the characteristics of the underground comprehensive pipe gallery PPP project to analyze the factors that should be considered when choosing private capital. Through SEM, the structural model of private capital selection influencing factors is established, and the action path and degree of influence of each variable are simulated to provide a basis for scientific choice of private capital.

3. Establishment of structural model of influencing factors of private capital selection in PPP project of urban underground comprehensive pipe gallery

Firstly, through the analysis of the existing research, the factors affecting the choice of private capital are preliminarily determined. Combined with the characteristics of the underground comprehensive pipe gallery PPP project, the enterprise strength, bidding scheme, business indicators, economic
indicators and social indicators are initially identified as potential variables affecting the choice of private capital, and the content and impact path are expounded.

(1) Enterprise strength
The financial ability, technical strength, management ability, performance experience, credit level, and cooperation ability of the bidding enterprise are static indicators for selecting private capital. The focus of these indicators varies according to the responsibility of private capital. For example, when private capital is responsible for the construction, operation and maintenance of the project, due to the flexible design and professionalism of the comprehensive pipe gallery, it should mainly examine its qualifications, technology and management capabilities; When private capital is responsible for financing the project, it should mainly examine its financial capabilities and credit status. The above indicators will affect the performance of private capital performance contracts, and it is the key to ensuring the realization of bidding schemes, business indicators, economic indicators and social indicators. Therefore, the following hypothesis is proposed:

H1-1: The enterprise strength directly affects the choice of private capital;
H1-2: The enterprise strength indirectly affects the choice of private capital through bidding scheme;
H1-3: The enterprise strength indirectly affects the choice of private capital through business indicators;
H1-4: The enterprise strength indirectly affects the choice of private capital through economic indicators;
H1-5: The enterprise strength indirectly affects the choice of private capital through social indicators.

(2) Bidding scheme
The bidding scheme refers to the financing, design, construction, operation, management, handover scheme and SPV formation scheme for the specific urban underground comprehensive pipe gallery PPP project, involving the full life cycle of a specific project. Comprehensive evaluation of the investment and financing of the project, the organization and arrangement of the pipe gallery and pipeline, the quality and safety of the operation and maintenance phase, and the handover scheme of the project after the contract expires are conducive to saving project costs and maximizing benefits. In addition, the bidding scheme will affect the realization of business indicators, economic indicators and social indicators. Therefore, the following hypothesis is proposed:

H2-1: The bidding scheme directly affects the choice of private capital;
H2-2: The bidding scheme indirectly affects the choice of private capital through business indicators;
H2-3: The bidding scheme indirectly affects the choice of private capital through economic indicators;
H2-4: The bidding scheme indirectly affects the choice of private capital through social indicators.

(3) Business indicators
Business indicators include bidding quotations, financial analysis and insurance plans. Among them, the bidding quotations refers to the rationality and validity of the quotation, that is, the auditing of the rationality of the operating cost and the financial internal rate of return; Financial analysis refers to the accuracy and rationality of financial analysis and forecasting, fixed asset resetting and additional investment during project implementation; The insurance plan refers to the risk analysis and control measures proposed for specific projects, as well as the completeness and rationality of the types of insurance that the bidder plans to invest. It can be seen that business indicators can influence the choice of private capital by affecting the realization of economic indicators. Therefore, the following hypothesis is proposed:

H3-1: The business indicators directly affects the choice of private capital;
H3-2: The business indicators indirectly affects the choice of private capital through economic indicators.

(4) Economic indicators
Under normal circumstances, the comprehensive pipe gallery fees cannot meet the investment, and its investment recovery mainly depends on government subsidies. Therefore, the urban underground comprehensive pipe gallery PPP project has the characteristics of quasi-operability and stable income. The economic indicators of this paper include cost management scheme, pipe gallery charging scheme and investment recovery scheme. Among them, the cost management scheme is affected by factors such as the financial ability, technical level and financing scheme of the bidding enterprise; The pipe gallery charging plan and investment recovery scheme are affected by factors such as the management ability of the bidding enterprise. Therefore, the following hypothesis is proposed:

H4: The economic indicators directly affect the choice of private capital.

Social indicators can be analyzed from the perspective of social contribution, namely the rational use and development of resources in the project implementation process, the protection of the natural environment, and the plan of people-oriented and safe production. Compared with other projects, the urban underground comprehensive pipe gallery PPP project has strong social welfare, which is beneficial to improve the urban environment and save pipeline repair costs. Therefore, social indicators can be divided into resource allocation plan, environmental protection plan and safety production plan. And the following hypothesis is proposed:

H5: The social indicators directly affects the choice of private capital.

In summary, the selection of the private capital of the urban underground comprehensive pipe gallery PPP project will be affected by an exogenous latent variable (enterprise strength) and four endogenous latent variables (bidding scheme, business indicators, economic indicators, social indicators). The structural model is shown in Figure 1.

![Figure 1](image_url)

Figure 1 Structural model of factors influencing the selection of private capital for PPP projects in urban underground comprehensive pipe gallery

The SEM consists of a structural model and a measurement model. The structural model is used to describe the relationship between latent variables and can be represented by structural equations; The measurement model is used to describe the relationship between latent variables and observable variables, which can be expressed by the measurement equation. The structural equations and measurement equations for the selection of private capital of the urban underground comprehensive pipe gallery PPP project are shown in equations (1) and (2).
\[ Y = \Lambda_{y\eta} + \varepsilon \]
\[ X = \Lambda_{x\xi} + \sigma \]
\[ \eta = B\eta + \Gamma\xi + \zeta \]  \hspace{1cm} (1)

In equation (1), \( \xi \) represents the exogenous latent variable, \( X \) represents the observable variable of \( \xi \), \( \sigma \) represents the observable error of \( X \), \( \Lambda_x \) is a factor load matrix of \( X \) at \( \xi \); \( \eta \) represents the endogenous latent variable, \( Y \) represents the observable variable of \( \eta \), \( \varepsilon \) represents the observable error of \( Y \), \( \Lambda_y \) is a factor load matrix of \( Y \) at \( \eta \).

In equation (2), \( B \) represents the matrix describing the influence between the endogenous latent variables, \( \Gamma \) represents the matrix describing the influence of the exogenous latent variable on the endogenous latent variable, and \( \zeta \) represents the residual vector.

4. Model inspection and correction

4.1. Questionnaire design and data collection

This paper collects the initial data through questionnaire survey. Firstly, according to the relevant theoretical research, field research and expert interview results, the observable variables of each latent variable are determined, and the index system of private capital selection influencing factors of urban underground comprehensive pipe gallery PPP project is established. Secondly, based on the indicator system, the questionnaires for the influencing factors were designed. The questionnaire was designed using the Likert 5 scale, with a score range of 1-5. Finally, the questionnaire was distributed to 20 experts in relevant fields for trial research, and the questionnaire was revised and improved according to the results of expert feedback to form a formal questionnaire.

In order to improve the scientific and reliable results of the questionnaire, we surveyed several PPP projects of underground comprehensive pipe gallery in Beijing, Hubei, Guangdong and Shaanxi. A total of 240 questionnaires were distributed and 185 were returned, of which 163 were valid questionnaires. The valid questionnaires account for 88% of the returned questionnaires, 68% of the total number of questionnaires.

4.2. Data reliability and validity test

In this paper, the reliability of the questionnaire is tested by the Cronbach’\( \alpha \) coefficient from the internal consistency of the scale. The data was analyzed by SPSS, and the Cronbach’\( \alpha \) of each measured variable were all greater than 0.8. As shown in Table 1, it can be seen that the data used in this case has a high reliability. In addition, the validity of the data is tested by KMO value and factor analysis. The results of SPSS analysis are shown in Table 1. The KMO value of the observable variables is at least 0.629, which is greater than the criterion of 0.6, and the factor load of each observable variable to the latent variable is higher than 0.5, so the hypothesis model analysis can be performed.

| Latent variable | Observable variable | Factor load | Cronbach’\( \alpha \) | KMO |
|-----------------|---------------------|-------------|------------------|-----|
| Enterprise strength | Financial ability | 0.705 | 0.855 | 0.635 |
| | Technical strength | 0.715 | | |
| | Management ability | 0.657 | | |
| | Performance experience | 0.871 | | |
| | credit level | 0.836 | | |
| | cooperation ability | 0.865 | | |
| | Financing scheme | 0.681 | | |
| | Designs scheme | 0.549 | 0.910 | 0.709 |
4.3. Model inspection and correction

Figure 2 shows the modified model of the influencing factors of the private capital selection of the urban underground comprehensive pipe gallery PPP project after AMOS operation. According to the calculation result of the modified model, the relationship effect of each influencing factor can be obtained, as shown in Table 2.

| Business indicators | Construction scheme | 0.637 |
|                     | Operation scheme    | 0.586 |
|                     | Management scheme   | 0.719 |
|                     | Handover scheme     | 0.642 |
|                     | Bidding quotations  | 0.719 |
| Financial analysis  |                       | 0.853 |
| Insurance plans     |                       | 0.871 |
| Economic indicators | Cost management scheme | 0.763 |
|                     | Pipe gallery charging plan | 0.818 |
|                     | Investment recovery scheme | 0.635 |
|                     | Resource allocation plan | 0.859 |
|                     | Environmental protection plan | 0.504 |
|                     | Safety production plan | 0.566 |
|                     | Economic benefits   | 0.707 |
|                     | Social benefits     | 0.826 |
|                     | Input efficiency    | 0.756 |
|                     | Output effects      | 0.667 |

| Social indicators   | Environmental protection plan | 0.849 |
|                     | Safety production plan        | 0.721 |
| Private capital selection | Social benefits | 0.808 |
|                      | Input efficiency              | 0.715 |

Figure 2 Modified model of influencing factors of private capital selection in PPP project of urban underground comprehensive pipe gallery
Table 2: Effects of various factors on the private capital selection of urban underground comprehensive pipe gallery PPP project

| Enterprise strength | Bidding scheme | Business indicators | Economic indicators | Social indicators |
|---------------------|----------------|---------------------|---------------------|------------------|
| Direct effect       | Indirect effect| Total effect        | Direct effect       | Indirect effect  | Total effect        | Direct effect       | Indirect effect  | Total effect        | Direct effect       | Indirect effect  | Total effect        |
| Enterprise strength | ---            | ---                 | ---                 | ---              | ---              | ---                 | ---              | ---              | ---                 | ---              | ---              | ---                 |
| Bidding scheme      | 0.66           | 0.06                | 0.72               | ---              | ---              | ---                 | ---              | ---              | ---                 | ---              | ---              | ---                 |
| Business indicators | 0.13           | ---                 | 0.13               | ---              | ---              | ---                 | ---              | ---              | ---                 | ---              | ---              | ---                 |
| Economic indicators | 0.25           | 0.25                | 0.50               | 0.19             | 0.19             | 0.38               | 0.14             | 0.14             | 0.28               | ---              | ---              | ---                 |
| Social indicators   | 0.01           | 0.01                | 0.02               | 0.17             | 0.17             | 0.34               | ---              | ---              | ---                 | ---              | ---              | ---                 |
| Private capital selection | 0.32 | 0.3347              | 0.6547             | 0.33             | 0.1022           | 0.4322             | 0.21             | 0.049            | 0.259              | 0.35             | 0.35             | 0.21               |

4.4. Model result analysis

According to the relationship effect of Table 2, the total effect of each influencing factor on the private capital selection of urban underground comprehensive pipe gallery PPP project ranks from large to small: enterprise strength (0.6547) > bidding scheme (0.4322) > economic indicators (0.35) > business indicators (0.262) > social indicators (0.21).

(1) The enterprise strength has the greatest impact on the private capital selection of the urban underground comprehensive pipe gallery PPP project, with a total effect of 0.6547. Among them, the direct effect is 0.32 and the indirect effect is 0.3347. It shows that the enterprise strength has a direct impact on the private capital selection of the urban underground comprehensive pipe gallery PPP project, and its indirect effect of the bidding scheme, business indicators, economic indicators, social indicators also can’t be ignored. Therefore, in the bidding documents for the PPP project of the urban underground comprehensive pipe gallery, clear requirements should be made for the financial ability, technical strength, management level, performance experience, credit qualification and cooperation ability of the bidding enterprise, and relevant evaluation criteria should be set. Otherwise, if the private capital fails to fulfill the responsibilities and obligations stipulated in the contract, it will greatly affect the progress, quality and cost objectives of the project, and even lead to the failure of the project.

(2) The total effect of the bidding scheme on the private capital selection of the urban underground comprehensive pipe gallery PPP project is 0.4322, second only to the enterprise strength, of which the direct effect is 0.33 and the indirect effect is 0.1022. The purpose of evaluating the bidding scheme is to achieve the project objectives at the lowest cost, so as to maximize the project benefits. At this time, it is necessary for private capital to exert its own advantages and formulate financing, design, construction, operation, management and handover plans for specific projects to ensure that the goals and values of the various stages of the project can be realized. Therefore, in the process of selecting private capital for urban underground comprehensive pipe gallery, the bidding scheme should also be an important reference.

(3) The total effect of economic indicators on the private capital selection of the urban underground comprehensive pipe gallery PPP project is 0.35. From the aspects of economic benefits, input efficiency and output effects of the project, the project’s cost management scheme is an input-oriented indicator, which affects the final input efficiency of the project and can fully reflect the financing ability and construction technology of private capital; The pipe gallery charging scheme and investment recovery scheme are output-oriented indicators, which affect the economic benefits and output effects of the project, and indirectly reflect the management and operation capabilities of private capital. Only by selecting appropriate and excellent private capital can we control both the project cost and the project benefit. Therefore, the economic indicators should also be an important indicator for the private capital selection of the urban underground comprehensive pipe gallery PPP project.

(4) The total effect of business indicators on the private capital selection of urban underground comprehensive pipe gallery PPP project is 0.259, of which the direct effect is 0.21 and the indirect effect is 0.049. It is indicated that the business indicators should also be considered when selecting the
appropriate private capital for the urban underground comprehensive pipe gallery PPP project. Firstly, the government should evaluate whether the bidder has considered the risks that the project may face and developed a reasonable insurance plan. Secondly, the accuracy and rationality of the financial analysis of the bidder should be considered. Finally, whether the bidder has comprehensively considered the project type, payment method, and cooperation period to determine a reasonable bid price should also be taken into account.

(5) The total effect of social indicators on the private capital selection of urban underground comprehensive pipe gallery PPP project is the smallest, the total effect is 0.21, but it is also a point that cannot be ignored. Social indicators are closely related to the social benefits of PPP projects. At present, most PPP projects consider the social benefits of the project in the process of assessment and evaluation, such as whether the project meets urban planning requirements, drives urban economic development, and effectively allocates resources. Through the measurement of social indicators of private capital, the realization of social benefits of the project can be guaranteed.

5. Conclusion

There are many influencing factors involved in the private capital selection of the urban underground comprehensive pipe gallery PPP project, and there are interactions between the factors. In-depth analysis of the impact of various factors on the choice of private capital is conducive to the selection of appropriate private capital, so as to ensure the smooth implementation of the project. This paper constructs a structural model of the factors affecting the private capital selection of urban underground comprehensive pipe gallery PPP project, and empirically analyzes the SEM model, analyzes the path and effect of each influencing factor, and proposes the optimization strategy of private capital selection. The research results of this paper have certain reference and reference value for the scientific selection of private capital of similar PPP projects.

References

[1] JOHNSON 2014 Success and failure factors of housing public private partnership in Malaysia Habitat International pp 150-157
[2] Li X 2016 Research on Project Financing Modes of BOT and PPP Based on Case Studies. Journal of Construction Engineering & Management pp 88-92
[3] Arata M., Petrangeli M. and Longo F.2016 Innovative approaches to implement road infrastructure concession through Public-Private Partnership (PPP) initiatives: a case study. Transportation Research Procedia pp 56-63
[4] VINODH S, BALAGI T S and PATIL A.2016 A hybrid MCDM Approach for agile concept selection using fuzzy DEMATEL, Fuzzy ANP and Fuzzy TOPSIS. International Journal of Advanced Manufacturing Technology, pp 15-18
[5] Xu Y., Chan A. P. C. and Yeung J. F. Y. 2010 Developing a Fuzzy Risk Allocation Model for PPP Projects in China JOURNAL OF CONSTRUCTION ENGINEERING AND MANAGEMENT-ASCE pp 894-903
[6] Huang Yajiang and Zhang Shuibo.2012 Study on Private Sector Selection of PPP Project Based on ANP Theory. Project Management Technology pp 46-51
[7] Liu Jiangfan and Xue Xiongzh 2016 The Government Selects Social Capital Mode and Requirements for PPP Projects in River Basin Comprehensive Management. Building Economy pp 54-57
[8] Zhan Yuxin 2018 Research on the legal system of government procurement in PPP project (Anhui University of Finance and Economics)
[9] Zhang Hongli 2018 Research on Social Capital Choice of Railway PPP Project (Shijiazhuang Railway University)