Risk Assessment of PPP Model Based on Fault Tree Model for Urban Underground Utility Tunnel

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Abstract. The application of PPP mode in urban underground utility tunnel project has been vigorously promoted and popularized in China. However, the degree of project promotion varies greatly in different regions, and the enthusiasm of social capital to participate in projects varies. In essence, the impact of project risks cannot be ignored. Using the fault tree model to analyze the factors that affect the risk of PPP mode in the urban underground utility tunnel project, and obtains five factors which have great influence on the risk of the project, such as the demand for corridor entrance, revenue, financial capacity, imperfect legal system, land expropriation and historical legacy. Considering the different economic development strengths of different regions, the adaptability of PPP projects is different. Through the empirical analysis of improving the correlation degree, the conclusion is drawn that the application of PPP model in underground comprehensive pipeline corridor is more suitable for developed areas.

Introduction

As an important part of municipal infrastructure construction, urban underground utility tunnel has been strongly supported and promoted by the state and is an important measure to promote economic and social development. It can effectively improve the urban environment and change the phenomenon of “horizontal zipper”, “air spiderweb” and “manhole cover to eat people”. In the long run, the economic value brought by the traditional direct burial method is considerable. However, due to the high construction cost in the early stage, the large volume of the project and the long construction period, the comprehensive pipe corridor project, which is a billion or even billions of projects, has brought considerable pressure on the local finance. Since 2014, the country has successively introduced one. The series of policies began to vigorously promote the Public and Private Partnership (PPP) model to encourage and support the participation of social capital in the field of infrastructure construction, thereby alleviating the financial pressure of central and local governments and reducing local debt risks, revitalizing stock assets, increasing the effective supply of public services in infrastructure and public utilities, broadening financing channels for infrastructure construction and bringing more effective management experience. As an integral part of the infrastructure sector, the utility tunnel has set off a nationwide wave of application of the PPP model to build a comprehensive pipe gallery. However, as the utility tunnel is in its infancy in China, the growth of its PPP model is applied, some problems have also appeared in the development. If the PPP model is applied to the long-term healthy growth of the current integrated corridor project, the risk prevention and control and response are imminent.

As an important part of the preliminary preparation of the project's life cycle, fully identifying the project risks is conducive to objective evaluation and effective management of risks \cite{1}, adequate assessment of risks to help stakeholders plan effective risk allocation and mitigation and to ensure the success of business and projects is critical \cite{2}. Mehdi Tavakolan, M.ASCE, Hannaneh, and Etemadinia proposed a risk interaction network in the construction project. The MICMAC analysis
shows that the contract abnormality has the greatest impact on other risks of specific projects [3]. Khwaja et al. proposed a multi-attribute risk assessment model, which provides insightful countermeasures and recommendations for risk analysis of stakeholders and stakeholders. [2] Bing determines priority risk allocation in the UK PPP/PFI project. The aim is to prepare a practical risk allocation framework and matrix for public sector clients for use in tender documents, thereby saving time in negotiations and contract transactions [4]. Bing Li uses Bayesian update technology to provide a new approach to risk allocation, with a focus on how to assign risk management responsibilities between public and private contractors [5]. Akintoye records the risk management of local authority PFI development based on a questionnaire survey of 55 local authorities (LA) Private Financing Program (PFI) in Los Angeles. The main impact of the survey is that there are two aspects: First, the need for public sector risk Relevant training in the subject areas of the assessment, followed by the development of an appropriate and agreed risk assessment and management framework for the PFI programme [6]. Badi S examines the impact of risk allocation on sustainable energy innovation in the context of PFI project delivery models, emphasizing the importance of appropriate risk allocation for PFI projects. Attention to the perceived harmful effects of capital cost risk as a major inhibitor of innovation highlights the need for a clear reflection of sustainable energy demand in the public sector comparison value (PSC) [7].

Analyze the operation of the PPP model in the current urban underground utility tunnel. Throughout the whole process of the project, including the pre-project, implementation and post-project risks and foreseeable and unforeseen risks to the project stakeholders and projects, Risk management lays a good foundation for the previous period, and further promotes the PPP model to be applied to the standardized and orderly development of utility tunnel projects. Zhao Dan and Zhao Yanchao used the entropy method to evaluate the financing risk of the actual project from the perspective of social capital and verified the rationality of the evaluation method [8]. From the perspective of investors' risk management, Guo Qi uses the combination of RBS and investment work breakdown structure to systematically analyze the investment risk factors that may be faced in each stage of hydropower BOT projects and construct a risk identification matrix [9]. Zhang Jun took the LPS comprehensive pipe corridor project as an example to analyze the current situation and effectiveness of the project PPP risk management, and proposed a project risk management framework for the utility tunnel from the perspective of social capital parties [10]. Xiang Pengcheng and Song Xianping identified risk factors from the perspective of financing parties, established a dynamic model of urban infrastructure construction financing risk system, conducted simulation analysis with the case and made a systematic evaluation of financing risks [11]. Based on the theoretical basis of the PPP model, Gu Yu analyzed and analyzed the factors affecting the financing risk of the Changchun underground utility tunnel project, and proposed corresponding solutions to the main risk factors [12]. From the perspective of social capital, Wang Ting relied on the analysis of risk preference game model and identified 10 risk factors that need to be shared by project participants [13]. Qi Xia et al. analyzed 16 failed or problematic PPP project case studies to summarize the main risk influencing factors and proposed corresponding measures and recommendations [14]. Zhao Jia constructed a PPP model financing risk management model adapted to the utility tunnel, and proposed risk sharing measures using game theory [15]. At present, the research on the risk of PPP projects is mostly concentrated in the fields of municipal roads and old-age services. There are few risks research on integrated corridor projects. This paper will combine a large number of existing project cases and expert interviews, based on the fault tree approach to China. The risk of the PPP model applied to the only underground pilot project of the underground comprehensive pipe gallery project in Jilin Province was analyzed, and the key factors were identified to promote the healthy development of the PPP model in the Jilin Province utility tunnel line Project.

Utility Tunnel Application PPP Mode Risk Identification

The project risk is a common problem in the PPP project across the country. The pre-financing is not in place[16,17], and the post-work will not be promoted. The whole process will be
triggered[18], and the problems such as the end of the project and the termination of the contract are not uncommon. Therefore, it is the key to the early stage[19,20]. In the first step, we must firmly grasp the risk issues and lay a solid foundation for the project to promote the smooth development of the project[21]. According to the case of applying the PPP model in the urban underground comprehensive pipe gallery project of the Ministry of Finance and the Development and Reform Commission's PPP project library, combined with the provincial construction department and the provincial authorities[22], law firms and other related investigations and interviews, analyze and summarize the PPP impact at various stages of the project[23,24]. The risk factors for the application of the model in the utility tunnel project (Table 1).

Table 1. Risk factors affecting the application of PPP mode in utility tunnel engineering at different stages.

<table>
<thead>
<tr>
<th>Stage of project</th>
<th>Specific risk factors and risk points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project approval stage</td>
<td>The project has not passed the examination and approval; due to the government's work efficiency problems, the construction approval is slow or stagnant, the construction land is difficult to implement, the supporting facilities are not in place; the construction preparation formalities and the completion acceptance work result in the approval risk.</td>
</tr>
<tr>
<td>Design phase</td>
<td>The government department requested to change the functional requirements of the project; when the contract was implemented, the project company proposed a more economical construction or operation plan to change the functional requirements of the project; the design of the project was flawed.</td>
</tr>
<tr>
<td>Investment stage</td>
<td>The preliminary funds were not put in place in time; the budget approval of the National People's Congress did not pass the government's reasons and the risk caused by the increase in the cost of the project company caused by the government's request for the construction period.</td>
</tr>
<tr>
<td>Construction stage</td>
<td>Financing risks include fluctuations in market interest rates, insufficient financing amounts, uncertainties in refinancing, and fluctuations in the financial environment during the construction period; land includes land demolition and compensation, historical issues, land and underground space use rights, etc.; improper design, design The cost caused by the change exceeds the budget or the construction period is prolonged; the construction technology is improper, the engineering quality technology is inferior; the subcontractor and the supplier default; the construction period is delayed; the construction site is safe; the labor dispute, the strike; the labor health and safety; the environmental damage; the discovery of historical relics Increased cost or delay in completion due to protection; geological conditions, etc.</td>
</tr>
<tr>
<td>Operational stage</td>
<td>Over-expenditure of operating costs; management company's management level and capacity defects lead to impaired operating capacity and income; poor quality of operation services of project companies; damage to facilities; inadequate violations; environmental damage; It is expected that the proportion of the entrance to the corridor will result in insufficient operating expenses; excess returns; multilateral revenue competition; fee price or adjustment restrictions; government subsidies; project company bankruptcy;</td>
</tr>
<tr>
<td>Transition phase</td>
<td>After the expiration of the concession, the new social or market requirements cannot be met; asset expropriation; facilities are defective at the time of project handover, over payment of overdraft costs, etc.</td>
</tr>
<tr>
<td>Law and policy</td>
<td>Violation of financing contracts, guarantees or mortgages for implementation or entry into force; legal changes and policy changes beyond the control of the government; legal changes that can be controlled by the government; low efficiency of government decision-making; changes in tax policies.</td>
</tr>
</tbody>
</table>

In addition, the economic risks brought about by interest rate changes, inflation and tax adjustment, social capital, government[25,26], third-party credit risk, natural force majeure and political force majeure are also risk factors that must be considered when applying the PPP model to an utility tunnel[27].
Utility Tunnel Application PPP Mode Risk Division

According to the risks identified above and the expert survey questionnaire, the risk points that have little impact on the application of the PPP model to the integrated corridor project are filtered out[28,29], and the main risk points affecting the application of the PPP model to the integrated corridor project are classified according to the reasons for the occurrence. Further analysis of the risk factors with deeper impact (Table 2).

Table 2. Risk Division of PPP Mode in utility tunnel engineering.

<table>
<thead>
<tr>
<th>Source of risk</th>
<th>Risk type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Political risk</td>
<td>Political decision-making mistakes, political opposition</td>
</tr>
<tr>
<td>Economic risk</td>
<td>Interest rates, inflation, tax adjustments, demand and income in the corridor, financing risks, local government financial capacity</td>
</tr>
<tr>
<td>Market risk</td>
<td>Project uniqueness (multilateral revenue competition), pipe gallery market is not mature</td>
</tr>
<tr>
<td>Legal policy risk</td>
<td>Legal changes, legal system is not sound</td>
</tr>
<tr>
<td>Credit risk</td>
<td>Government credit, social capital credit, third-party credit</td>
</tr>
<tr>
<td>Force majeure</td>
<td>Natural force majeure, political force majeure</td>
</tr>
<tr>
<td>Project risk</td>
<td>Incomplete technology (design and construction defects), delay in construction, cost overrun</td>
</tr>
<tr>
<td>Other</td>
<td>Land demolition, asset expropriation</td>
</tr>
</tbody>
</table>

Political risk: mainly includes political decision-making and political opposition. During the project approval stage[30], the government does not understand the relevant policies of the corridor project, and lacks relevant engineering practice management experience[31,32], which may lead to the approval of some pipe gallery projects that are not suitable for PPP mode; in some areas due to the public's comprehensive project of the corridors Insufficient recognition may cause public dissatisfaction and opposition in the early stage of project construction.

Economic risk: In the context of continuous economic development, the cooperation period of the utility tunnel PPP project is 10 to 30 years, generally not less than 25 years. In such a long period of time, interest rate changes, inflation, and tax adjustments Such may happen at any time, with a high or low impact on the cost of social investment. In terms of pipeline entrance and charging, the willingness of the pipeline unit to enter the corridor is not strong, resulting in a large gap between the actual income of the project and the budgetary revenue. Eventually, the government will bear a large part of the cost subsidy expenditure, when the government bears the expenses beyond the public of the year. The fiscal expenditure budget will not only bring financial pressure to the government, but also cause project income to be difficult to offset, increase the difficulty of project implementation, and lead to unsustainable projects[33].

Market risk[34,35]: The uniqueness of the project in the contract is a guarantee for the PPP project including the pipe gallery project to obtain the benefits normally. Secondly, although the development of the utility tunnel project is very mature abroad, at home, In particular, the utility tunnel project under the PPP mode has not yet matured practical experience, and at the same time, due to the differences in the economic development of the provinces, there is a lack of relevant practice in Jilin Province. Not mature enough, therefore, the application of the PPP model to build a comprehensive pipe gallery in Jilin Province is also in the process of exploration.

Legal policy risks[36]: At present, there is no legal policy on the mandatory importation of pipelines in Jilin Province, lack of the charging mechanism system for the integration of PPP projects and maintenance of operating fees, so that SPV companies have no reference for collecting fees from pipeline units. Based on this, it may cause related series of disputes.

Credit risk[37]: Both parties should implement the contract according to the contract. The credibility and credibility of the parties to the cooperation are, to a certain extent, the key
influencing factors for the success of the integrated corridor project [16,38], based on the relevant credibility evaluation indicators, A comprehensive credit assessment provides a reliable credit basis for the smooth operation of the project. Project risks [39]: Incomplete technology (design and construction defects), delays in construction period, cost overruns lead to insufficient cash flow for project operation, gaps or breaks in project funds, and failure to repay project loan capital, interest and operating costs in full and on time.

In addition, natural force majeure, political force majeure, land demolition problems, asset expropriation and other risks are also risks that Jilin Province must take into account in the construction of urban underground utility tunnel projects under the PPP model.

Risk Analysis of PPP Mode Based on Fault Tree-based Utility Tunnel Application

Fault Tree Construction

Fault Tree Analysis (FTA) can predict the reliability of the system by analyzing the logical relationship of the system. FTA can not only perform qualitative analysis, but also quantitative analysis, find in the logical relationship from top to bottom. All factors affecting the top event (denoted as T) are analyzed, and the cut sets are analyzed by probability and key importance to find the minimum cut set. This method can analyze the underlying causes of failure [17]-[18]. Based on the identified risk points affecting the PPP model of the utility tunnel, the fault tree model is used to evaluate and analyze the key risk points according to the importance of the project promotion impact, in preparation for the next risk response. The fault tree is constructed as shown in Figure 1.

![Fault Tree for risk in PPP mode using utility tunnel Project.](image)

**Fault Tree Analysis**

**Determination of the Correlation between Basic Events and Risks.** According to the degree of correlation between the basic events affecting the top event and the degree of influence of these basic events on the top event, the minimum cut set is obtained. In the PPP mode risk fault tree model of the utility tunnel project, it is assumed that there is a common fault tree. n basic events, where the minimum number of cut sets is m, and any minimum cut set \( L \) represents the i data consisting of \( n \) basic events, and the feature matrix is established according to the basic event of the risk:

\[
X_L = \begin{bmatrix}
X_{l1} \\
X_{l2} \\
\vdots \\
X_{ln}
\end{bmatrix} = \begin{bmatrix}
X_{11} & X_{12} & \cdots & X_{1n} \\
X_{21} & X_{22} & \cdots & X_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
X_{m1} & X_{m2} & \cdots & X_{mn}
\end{bmatrix}
\]  

(1)
The mode vector $X_T$ to be tested is established according to the degree of influence of each basic event [19]:

$$X_T = \{X_T(1), X_T(2), \ldots, X_T(n)\}$$

Correlative degree calculation is performed on the typical fault feature matrix $\{X_i\} (i = 1, 2, \ldots, m)$ and the mode vector $\{X_T(j)\} (j = 1, 2, \ldots, n)$ to be detected. In the obtained correlation degree, firstly, according to the degree of relevance, the basic event with a large degree of relevance is the primary risk considered in the PPP mode of the utility tunnel engineering application.

**Model Solving.** (1) Determine the probability of occurrence of basic events:

For the determination of the probability of occurrence of the basic event, the expert library may be used to evaluate the probability of causing the PPP mode to be applied to the basic event of the underground utility tunnel engineering, and calculate the probability of the basic event according to $P = 0.5 \times (a_i + b_i) (i = 1, 2, \ldots, 22)$. The probability of a basic event is shown in Table 3:

<table>
<thead>
<tr>
<th>Number</th>
<th>Basic event reason</th>
<th>Probability</th>
<th>Number</th>
<th>Basic event reason</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$</td>
<td>Project uniqueness</td>
<td>0.4</td>
<td>$X_{12}$</td>
<td>The legal system is not sound</td>
<td>0.65</td>
</tr>
<tr>
<td>$X_2$</td>
<td>The pipe gallery market is not mature</td>
<td>0.35</td>
<td>$X_{13}$</td>
<td>Government credit</td>
<td>0.4</td>
</tr>
<tr>
<td>$X_3$</td>
<td>The mistakes of political decision</td>
<td>0.4</td>
<td>$X_{14}$</td>
<td>Social capital credit</td>
<td>0.45</td>
</tr>
<tr>
<td>$X_4$</td>
<td>Political opposition</td>
<td>0.35</td>
<td>$X_{15}$</td>
<td>Third party credit</td>
<td>0.4</td>
</tr>
<tr>
<td>$X_5$</td>
<td>Interest rate</td>
<td>0.59</td>
<td>$X_{16}$</td>
<td>Immature technology</td>
<td>0.3</td>
</tr>
<tr>
<td>$X_6$</td>
<td>Inflation</td>
<td>0.35</td>
<td>$X_{17}$</td>
<td>Delay in construction</td>
<td>0.35</td>
</tr>
<tr>
<td>$X_7$</td>
<td>Tax adjustment</td>
<td>0.4</td>
<td>$X_{18}$</td>
<td>Cost overrun</td>
<td>0.45</td>
</tr>
<tr>
<td>$X_8$</td>
<td>Demand and income into the gallery</td>
<td>0.65</td>
<td>$X_{19}$</td>
<td>Asset expropriation</td>
<td>0.4</td>
</tr>
<tr>
<td>$X_9$</td>
<td>Financing risk</td>
<td>0.45</td>
<td>$X_{20}$</td>
<td>The issue of land expropriation</td>
<td>0.65</td>
</tr>
<tr>
<td>$X_{10}$</td>
<td>Local government financial capacity</td>
<td>0.65</td>
<td>$X_{21}$</td>
<td>Ownership of underground space</td>
<td>0.3</td>
</tr>
<tr>
<td>$X_{11}$</td>
<td>Legal changes</td>
<td>0.3</td>
<td>$X_{22}$</td>
<td>Historical issues</td>
<td>0.65</td>
</tr>
</tbody>
</table>

In grey theory, the structure function can be expressed as:

$$\varphi(x) = x_1 + x_2 + \cdots + x_n$$

The structural function of the PPP model applied to the integrated pipe gallery project:

$$\phi(x) = M_1 + M_2 + M_3 + M_4 + M_5 + M_6 + M_7 + M_8$$

In the PPP mode fault tree model applied to the utility tunnel project, it is assumed that the minimum cut set can be composed of any one of the basic events. In the constructed feature matrix, the value of the basic event that occurs in the minimum cut set is set to "1", and the value of the remaining basic events that have not occurred is set to "0", then the identity matrix can be expressed as:

$$X_L = E$$
(2) Solution of the pending mode vector

According to the conditions defined above, any basic event that is applied to the risk fault tree of the underground utility tunnel project in the PPP mode can be regarded as the minimum cut set, and the probability of occurrence of any basic event is independent of each other and does not affect each other. The probability of occurrence of a top even in the model can be found:

\[
P = \begin{cases} 
1 - \prod_{i=1}^{n}(1 - P_i) & \text{when} \varphi(x) = \bigcup_{i=1}^{n} x_i, \\
\prod_{i=1}^{n} P_i & \text{when} \varphi(x) = \bigcap_{i=1}^{n} x_i.
\end{cases}
\]

When there are more than 1 basic event occurrences, the contribution of any basic event to the whole system and the contribution of any basic event are required:

\[
t_i = \sum_{j=1}^{n} \frac{P_j}{P_i}
\]

Normalization of \( \{ x_i(j) \} \) yields matrix \( X_j \).

(3) Calculate the difference between the two poles

The maximum difference and the minimum difference are obtained based on the sequence difference:

\[
\Delta_{\text{max}} = 1; \Delta_{\text{min}} = 0
\]

(4) Calculate the correlation coefficient

At \( \rho = 0.5 \), the correlation coefficient:

\[
\rho_{ij}(K) = \frac{\Delta_{\text{min}} + \rho \Delta_{\text{max}}}{\Delta_{\text{max}}(K) + \rho \Delta_{\text{max}}}
\]

(5) Calculating the degree of relevance

Calculate the relevance of the basic event according to the formula: \( r_i = \frac{1}{N} \sum_{j=1}^{N} \rho_{ij}(L) \) sort the degree of association. According to the calculation results, it is inferred that the PPP mode needs to be highly valued in the application of underground integrated pipe corridor engineering risk.

Application Case Analysis

In April 2015, Jilin Province was identified as the “utility tunnel line Pilot Province” and is currently the only integrated pilot province in China. Based on the above model, the PPP model risk analysis is applied to the utility tunnel, based on the Jilin Province T[47]. An underground utility tunnel project in the city applied the PPP model case for empirical analysis.

Project Overview

The project belongs to the municipal engineering public service field project, and the industry belongs to the underground utility tunnel industry. The project is located in the T city of Jilin Province. The proposed pipe gallery is located in the road where the key municipal pipelines are located in the downtown area and the Chenggang Economic Belt included in the planned expansion and construction. The cooperation period is 30 years, of which the construction period is 5 years. The main construction and operation of the project is divided into three parts: (1) Newly built and operated underground utility tunnel 80.96 km (excluding pipelines). (2) Renovate and restore and operate 50.6 kilometers of municipal roads along with the corridors (including roads, roadways, sidewalks, landscapes of greening facilities on the ground, signage lines, street lamps, etc.). (3) Newly built and operated municipal roads with a capacity of 21.85 kilometers (including roads, roadways, sidewalks, ground greening facilities, signage markings, street lights). The total investment of the project is 6.5 billion yuan, and the return mechanism of the feasibility gap subsidy is adopted. The project is currently in the implementation phase and has not yet entered the operational period.
Project Investment and Financing Structure and Risk Evaluation

The capital of the project is not less than 20% of the total investment of the project, about 1.5 billion yuan. The remaining funds required for project investment are solved by the project company through bank loans, etc., about 6 billion yuan. The capital and loan ratio of the project is approximately 2:8. The project capital is partially paid by the selected social capital and the government-funded representative according to the share ratio in the project company. In the project company, the proportion of the shares of the government and the social capital is 20% and 80% respectively. The remaining funds required for the investment of the project shall be solved by the project company through bank loans. Under the premise of obtaining the consent of the implementing agency, the project company can obtain funds by means of charging rights pledge and asset collateral, and use relevant income as the source of repayment. According to the needs of the project company financing, if the shareholder guarantee is required, it will be provided by social capital, and the government will not provide guarantee. The registered capital of the project company is tentatively set at 1.5 billion yuan, and the amount of payment for the first year of the project construction period is not less than 100 million yuan. In the project company, the proportion of shares held by the government and the social capital side is 20% and 80% respectively. The risk categories of the project are divided as shown in Table 4:

<table>
<thead>
<tr>
<th>Source of risk</th>
<th>Risk type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Political risk</td>
<td>Political decision-making mistakes</td>
</tr>
<tr>
<td>Economic risk</td>
<td>Demand and income in the corridor, financing risks, local government financial capacity</td>
</tr>
<tr>
<td>Market risk</td>
<td>Project uniqueness (multilateral revenue competition), pipe gallery market is not mature</td>
</tr>
<tr>
<td>Legal policy risk</td>
<td>Legal changes</td>
</tr>
<tr>
<td>Credit risk</td>
<td>Government credit, social capital credit</td>
</tr>
<tr>
<td>Force majeure</td>
<td>Political force majeure</td>
</tr>
<tr>
<td>Project risk</td>
<td>Incomplete technology (design and construction defects), construction delay, cost overrun</td>
</tr>
<tr>
<td>Other</td>
<td>Land demolition, asset expropriation</td>
</tr>
</tbody>
</table>

The probability of a basic event is shown in Table 5:

<table>
<thead>
<tr>
<th>Number</th>
<th>Basic event reason</th>
<th>Probability</th>
<th>Number</th>
<th>Basic event reason</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$</td>
<td>The mistakes of political decision</td>
<td>0.4</td>
<td>$X_9$</td>
<td>Political force majeure</td>
<td>0.35</td>
</tr>
<tr>
<td>$X_2$</td>
<td>Demand and income into the gallery</td>
<td>0.67</td>
<td>$X_{10}$</td>
<td>Immature technology</td>
<td>0.66</td>
</tr>
<tr>
<td>$X_3$</td>
<td>Financing risk</td>
<td>0.64</td>
<td>$X_{11}$</td>
<td>Delay in construction</td>
<td>0.35</td>
</tr>
<tr>
<td>$X_4$</td>
<td>Local government financial capacity</td>
<td>0.65</td>
<td>$X_{12}$</td>
<td>Cost overrun</td>
<td>0.45</td>
</tr>
<tr>
<td>$X_5$</td>
<td>Project uniqueness</td>
<td>0.4</td>
<td>$X_{13}$</td>
<td>land acquisition and demolition issues</td>
<td>0.67</td>
</tr>
<tr>
<td>$X_6$</td>
<td>The pipe gallery market is not mature</td>
<td>0.35</td>
<td>$X_{14}$</td>
<td>Asset expropriation</td>
<td>0.4</td>
</tr>
<tr>
<td>$X_7$</td>
<td>The legal system is not sound</td>
<td>0.66</td>
<td>$X_{15}$</td>
<td>Government credit</td>
<td>0.66</td>
</tr>
<tr>
<td>$X_8$</td>
<td>Social capital credit</td>
<td>0.45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The solution to the contribution of the basic event of the PPP mode risk fault tree to the T-city utility tunnel is shown in Table 6:

Table 6. Contribution of any basic event.

<table>
<thead>
<tr>
<th>Number</th>
<th>Contribution</th>
<th>Number</th>
<th>Contribution</th>
<th>Number</th>
<th>Contribution</th>
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According to the above model, the contribution of the PPP model risk to the top event can be obtained from the urban underground utility tunnel[40,41]. However, the PPP mode promotion intensity and the market acceptance degree of the utility tunnel are different due to different regions, which reflects the integration of different regions. The ability to use the PPP mode of the pipe gallery is somewhat helpless[42,43,44].

Different regions and PPP models carry out different depths and qualifications. Developers deepen the design level of PPP mode in the utility tunnel application, which will change the results of model analysis. In particular, different regions have different degrees of promotion and understanding of the PPP model for utility tunnel. At present, each region is basically constructing underground utility tunnel, and the weight coefficient can more accurately reflect the application of underground utility tunnel. The comprehensive level of risk of PPP mode entering the market[45,46].

\[
r^*_ij = \sum_{l=1}^{22} A_i \cdot \sum_{j=1}^{15} d_{lj} \cdot C_{ij} 
\]  

(9)

\( r_{ij} \) is the weighted degree of association coefficient, \( A_i \) is the object weight distribution of the PPP mode of the utility tunnel application, \( d_{lj} \) is the weight distribution of each risk in different areas, and \( C_{ij} \) is the grade of different risk types.

According to the improved relevance: (9) sort the degree of relevance. It can be concluded that \( X_2 \) (Demand and income into the gallery), \( X_4 \) (financing risk), \( X_5 \) (local government financial capacity), \( X_7 \) (The legal system is not sound), \( X_{10} \) (Immature technology), \( X_{13} \) (land acquisition and demolition issues), \( X_{15} \) (government credit) are required Issues of importance.

Conclusion

(1) For the risk identified by the PPP model applied in all stages of the utility tunnel project, the fundamental analysis of the risk from the perspective of the project risk is to summarize 22 risks, based on the risk tree correlation and event probability. The final analysis of the main risks affecting the top event.

(2) Taking a comprehensive pipe corridor project in T City as an example, systematically analyze the risk of applying the PPP model to the utility tunnel project, and obtain a risk identification matrix containing 15 risks, and improve the correlation degree through the weight coefficient to make the model analysis more suitable. In fact, the final conclusions are that the demand and income of the corridor, the financing risk, the local government's financial capacity, the unsound
legal system, the incomplete technology, the land acquisition and the government credit, etc., need to attach great importance to the application of the PPP model for the integrated corridor project.

(3) Through analysis and verification, it can be seen that the application of the utility tunnel to the PPP mode is more suitable for the developed regions. The economic strength of the developed regions is relatively strong. With strong financial capabilities and advanced management tools, the PPP model of the utility tunnel can be better. Application and promotion. Relatively speaking, it is more difficult to use the PPP model to construct underground utility tunnel in underdeveloped areas or poverty-stricken areas. In addition to the pilot cities and pilot projects, the application of the PPP model in the general integrated corridor project, due to lack of financial support, and the lack of local financial capacity, it is difficult to ensure the normal income of the corridor project, which makes it more difficult to attract social capital to participate. In addition, the problem of land acquisition and demolition has always been a major problem. At the same time, due to the lack of drawings, many areas lack clear control over underground embedding, which makes the project unsustainable. Therefore, compared with the underdeveloped areas or poverty-stricken areas, there are many problems to be considered and solved in the application of PPP mode to construct underground utility tunnel.

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