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Risk Analysis of Integrated Pipe Gallery PPP Project Based on the Analytic Hierarchy Process

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Abstract

As a public infrastructure for integrated construction, the integrated pipe corridor can extend the service life of the road and save the urban ground space [1]. Rational distribution of integrated pipe corridors provides a strong guarantee for the sustainable development of the city [2]. In recent years, the integrated management of the corridor government and social capital cooperation (PPP) has been widely used in China, in the integrated pipe gallery PPP project, high-speed under the development situation, problems such as out-of-control design in the early stage and loss of trust during the construction period are frequent. Contractual disputes caused by these problems, government repurchase, project suspension and other risks damage the project benefits, which seriously violate the original intention of the project [3]. PPP projects are characterised by long-term, variability and complexity. Risks are more difficult to control than conventional projects. It is a need for a dynamic risk management system that can effectively prevent and control the occurrence of risks, accurately assess risk factors and ensure the protection of risk management.

Subject Areas

Risk Management

Keywords

Risk Analysis, PPP Project, Analytic Hierarchy Process

1. Introduction

As a public infrastructure for integrated construction, the integrated pipe corridor can extend the service life of the road and save the urban ground space [1]. Rational distribution of integrated pipe corridors provides a strong guarantee for the sustainable development of the city [2]. In recent years, the integrated management of the corridor government and social capital cooperation (PPP) has been widely used in China, in the integrated pipe gallery PPP project, high-speed under the development situation, problems such as out-of-control design in the early stage and loss of trust during the construction period are frequent. Contractual disputes caused by these problems, government repurchase, project suspension and other risks damage the project benefits, which seriously violate the original intention of the project [3]. PPP projects are characterized by long-term, variability and complexity. Risks are more difficult to control than conventional projects. It is a need for a dynamic risk management system that can effectively prevent and control the occurrence of risks, accurately assess risk factors and ensure the protection of risk management.

2. PPP Project Overview

PPP (Public-Private-Partnerships) is a cooperative model formed by government and social capital through the establishment of formal contracts. Broad PPP refers to the long-term cooperation between the government and enterprises to provide public goods or services; narrowly defined PPP refers to a series of long-term cooperation between the public sector and the private sector based on project financing, providing public goods or services [4] [5]. The risk of PPP project goes through the whole life cycle, and the PPP project has a longer construction period, a larger investment amount, and more stakeholders involved, resulting in poor predictability of risks. Therefore, risk management during project implementation. It has become ever more important.

3. PPP Mode Risk Analysis

3.1. PPP Project Risk Identification

Risk management of PPP projects is very complex, including risk identification, risk assessment, risk monitoring and risk response. Risk identification is the foundation for risk management of PPP projects. By collecting a large amount of project data, one or more combinations are used to determine the relevant sources and characteristics of the project [6]. It is necessary to establish a dynamic and complete risk identification system within the project cycle, analyze the risks existing in the project by using certain risk identification methods, analyze the causes and processes of the risks, and evaluate the probability of occurrence of risks and the impact on the project.

3.2. PPP Project Risk Classifications

Through the summary of the literature, the risk can be classified in the following ways: According to the risk factors, the risk is divided into systemic risk and non-system risk. According to the risk taker, the risk is split into the risk assumed by the government and the risk assumed by the investor. The risk assumed by the construction party; the risk can also be divided into three levels: macro level risk, metro level risk and micro level risk; the risk is divided into three levels: national risk, market risk and project risk [7]. In this paper, by referring to the literature and analyzing the PPP project case, the risk factors of a PPP project are divided into four risk categories: pre-project, the project construction period, project operation period and project full-cycle. These four risks also include risk factors within their respective scope.

4. Risk Analysis of PPP Project Based on AHP

4.1. Construction of Investment Risk Index System for Integrated Pipe Corridor PPP Project

The article first constructs an index system for comprehensive PPP project risk, and then determines the risk size and impact on the project based on the constructed risk factor indicators. Depending on the above classification and classification of risks, this paper establishes a three-level indicator system, namely the target layer, the criterion layer and the indicator layer. The criterion layer has 4 indicators and the indicator layer has 20 indicators, as showed in **Table 1**.

Table 1. Risk indicator system of integrated pipe gallery PPP project.

Target layer	Criteria layer	Indicator layer
Integrated pipe gallery PPP project risk U	Pre-risk U_1	Procurement risk U_{11}
		Financing risk U_{12}
		Approval risk U_{13}
	Construction period risk U_2	Land acquisition risk U_{21}
		Financial risk U_{22}
		Engineering change risk U_{23}
		Security risk U_{24}
		Construction risk U_{25}
		Supply risk U_{26}
		Technical risk U_{27}
		Design risk U_{28}
		Geological risk U_{29}
	Operational risk U_3	Income price adjustment U_{31}
		Entrance risk U_{32}
		Increased operating costs U_{33}
	Full cycle risk U_4	Government decision risk U_{41}
		Inadequate regulatory or legal system U_{42}
		Inflation U_{43}
		Government credit U_{44}
		Contract, contract risk U_{45}

4.2. AHP-Based Decision Results

Analytic Hierarchy Process (AHP) is a multi-criteria decision-making method that combines qualitative and quantitative analysis. The AHP method is used to decompose the relevant elements of the PPP project risk problem into the target layer, the criterion layer and the indicator layer, and then subjectively The judgment is objectively quantified, and finally the problem is reduced to the problem of determining the relative importance weight of the lowest level relative to the highest level [8]. The AHP method is used to analyze the various factors of the risk of the PPP project of the integrated pipe gallery, and the steps to obtain the decisive results of all levels of factors are as follows:

Step 1 construct a judgment matrix.

Each element of each layer in the comprehensive risk indicator system of the PPP project is compared with each other to obtain a judgment matrix of two layers of elements. The 1-9 scale method is used to quantify the decision judgment, and the experts analyze and determine two kinds of numerical judgment matrices: 1) the judgment matrix of the criterion layer for the target layer; 2) the judgment matrix of the index layer for the criterion layer U -U_i, among them, $i = \{1, 2, 3, 4, 5\}$ (**Table 2**).

Step 2 consistency tests.

In order to prevent the determination of the relative importance of each indicator, there will be uncoordinated or even contradictory results, and a consistency check is required. According to the relationship between the matrix and the corresponding eigenvalues in the matrix theory, the characteristics of the eigenvalue can largely reflect the characteristics of the matrix to which it belongs. Therefore, the indicator that the measurement matrix deviates from the consistency is represented by the eigenvalue (n = matrix order)

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{1}$$

The larger the value of CI, the worse the consistency test result of the matrix is, and the more uncoordinated between the indicators; on the contrary, the better the consistency test and the coordination of the indicators.

$$CR = \frac{CI}{RI} \tag{2}$$

As shown in Equation (2), in order to characterize the matrix random consistency ratio, the ratio of CI to RI (mean random consistency index) is selected to determine and denoted as CR. Wherein, the value of RI is obtained from **Table 3** according to the order of the matrix.

With 0.1 as the limit, the meaning of the CR value can be divided into two cases:

$$\begin{cases} (\text{I})\, CR < 0.1, \text{The matrix has satisfactory consistency} \\ (\text{II})\, CR \geq 0.1, \text{Make adjustments until satisfaction} \end{cases} \tag{3}$$

Step 3 Hierarchical single sorting.

Table 2. Judges the relative importance and meaning of the matrix.

Scaling	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very Strong or demonstrated importance
9	Extreme importance
2, 4, 6, 8	Median value of adjacent judgment

Table 3. RI (Average Random Consistency Indicator) value table.

Order	1	2	3	4	5	6	7
R value	0	0	0.58	0.88	1.12	0.24	0.32

The weighting information of each element of the hierarchy relative to the previous layer is obtained by the judgment matrix, that is, the order of the hierarchical order of the solving system is transformed into the largest eigenvalue and the corresponding eigenvector of the solving matrix. In this paper, the least eigen method is used to solve the maximum eigenvalue $\lambda_{\max}$ and the weight vector of the matrix W_i, $i = \{1, 2, 3, 4, 5\}$, and the evaluation results of the consistency test are obtained by Equations (1) and (2).

Step 4 levels total sorting.

The total hierarchical ranking calculation calculates the PPP project risk index system hierarchically from top to bottom along the ladder level, and obtains the weight share of all the index factors at the lowest level of the highest target layer.

5. Example Analysis

A-city new integrated and operated pipeline corridor in the new district of a city is a PPP project of cooperation between the government and social capital. The corridor is about 13 km long, 3 m high and 5 m wide, including weak electric pipelines, high-pressure pipelines, communication pipelines, and water pipelines. Pipeline. It was made available for operation in early 2015 and has now entered the operation period. The project cooperation period is 27 (including the 2a construction period), and the project has not been handed over.

On the basis of data review and field investigation, a risk index system was established according to the characteristics of the project, and the stakeholders involved in the government agencies, contractors, investors and other projects were investigated through questionnaire survey, and then according to the above introduction. The method is analyzed.

The judgment matrix is established according to the above risk hierarchy diagram, the weight of each level is calculated, and the total weight is sorted. The scoring results of the questionnaire were analyzed to obtain a judgment matrix (**Tables 4-8**).

Table 4. Judgment matrix U.

U	U_1	U_2	U_3	U_4	W
U_1	1	1/2	1	1/2	0.1622
U_2	2	1	3	2	0.4226
U_3	1	1/3	1	1/2	0.1443
U_4	2	1/2	2	1	0.2708

$CC\ \lambda_{max} = 4.0458$, $CR = 0.0170 < 0.1$.

Table 5. Judgment matrix U_1.

U_1	U_{11}	U_{12}	U_{13}	W_1
U_{11}	1	3	2	0.2395
U_{12}	1/3	1	4	0.6232
U_{13}	1/2	1/4	1	0.1373

$CC\ \lambda_{max} = 3.0183$, $CR = 0.0176 < 0.1$.

Table 6. Judgment matrix U_2.

U_2	U_{21}	U_{22}	U_{23}	U_{24}	U_{25}	U_{26}	U_{27}	U_{28}	U_{29}	W_2
U_{21}	1	1/3	1/7	5	1/9	3	1/5	2	4	0.0562
U_{22}	3	1	1/5	6	1/5	4	1/3	3	5	0.0951
U_{23}	7	5	1	8	1/2	6	1/2	5	7	0.2396
U_{24}	1/5	1/6	1/8	1	1/9	1/3	1/7	1/4	1/2	0.0171
U_{25}	9	5	2	9	1	7	3	6	8	0.3210
U_{26}	1/3	1/4	1/6	3	1/7	1	1/5	1/2	2	0.0335
U_{27}	5	3	1/2	7	1/3	5	1	4	6	0.1655
U_{28}	1/2	1/3	1/5	4	1/6	2	1/4	1	3	0.0485
U_{29}	1/4	1/5	1/7	2	1/8	1/2	1/6	1/3	1	0.0235

$CC\ \lambda_{max} = 9.7092$, $CR = 0.0607 < 0.1$.

Table 7. Judgment matrix U_3.

U_3	U_{31}	U_{32}	U_{33}	W_3
U_{31}	1	1	3	0.4160
U_{32}	1	1	4	0.4577
U_{33}	1/3	1/4	1	0.1263

$CC\ \lambda_{max} = 3.0092$, $CR = 0.0089 < 0.1$.

Table 8. Judgment matrix U_4.

U_4	U_{41}	U_{42}	U_{43}	U_{44}	U_{45}	W_4
U_{41}	1	1/3	1/2	1/2	1/4	0.0794
U_{42}	3	1	3	2	2	0.2442
U_{43}	2	1/2	1	1	1/3	0.1373
U_{44}	2	1/2	1	1	1/3	0.1373
U_{45}	4	2	3	3	1	0.4017

$CC\ \lambda_{max} = 5.0331$, $CR = 0.0074 < 0.1$.

According to the calculation results of the above-mentioned criteria layer and the weight of the measure layer, the weight of each layer of the PPP project of the A-site integrated pipe gallery is finally obtained, as showed in Table 9:

It can be seen from Table 9:

1) The risk of financing risk, engineering change risk, construction risk and contract and contract risk are more than 10%, which are a major risk factor for this project. Unreasonable handling can lead to grave consequences, even project failure, so project managers must attach great importance to these risk factors.

2) The nominal risk, the entrance risk, the income price and the imperfect supervision or legal system are between 5% and 10%, which is a huge risk factor for this project. It also needs to pay sufficient attention during the implementation of the project.

3) The remaining risk weight is all below 5%, which are general and routine risks. Such risks are more common, and the research on response measures is more comprehensive. It can handle reasonably according to the situation during project implementation.

Table 9. Judgment matrix U_4.

Risk factor	Pre-risk U_1	Construction period risk U_2	Operational risk U_3	Full cycle risk U_4	Total weight
Item weight	16.22%	42.26%	14.44%	27.08%	
Procurement risk U_{11}	23.95%				3.88%
Financing risk U_{12}	62.32%				10.10%
Approval risk U_{13}	13.73%				2.22%
Land acquisition risk U_{21}		5.62%			2.38%
Financial risk U_{22}		9.51%			4.02%
Engineering change risk U_{23}		23.96%			10.13%
Security risk U_{24}		1.71%			0.72%
Construction risk U_{25}		32.10%			13.57%
Supply risk U_{26}		3.35%			1.42%
Technical risk U_{27}		16.55%			6.99%
Design risk U_{28}		4.85%			2.05%
Geological risk U_{29}		2.35%			0.99%
Income price adjustment U_{31}			41.60%		6.01%
Entrance risk U_{32}			45.77%		6.61%
Increased operating costs U_{33}			12.63%		1.82%
Government decision risk U_{41}				7.94%	2.15%
Inadequate regulatory or legal system U_{42}				24.43%	6.62%
Inflation U_{43}				13.73%	3.72%
Government credit U_{44}				13.73%	3.72%
Contract, contract risk U_{45}				40.17%	10.88%
Total					100.00%

6. Integrated Pipe Gallery PPP Project Risk Response

6.1. AHP-Based Decision Results

1) Improve cognition and ability

Both the government and the social capital need to be aware of the PPP model so that the project does not lead astray.

2) Suggested financial product innovation

The economic and social benefits of the integrated pipe corridor are long, and it is recommended to innovate the medium and long-term financial instruments to solve the problem of maturity mismatch.

6.2. Project Construction Period Risk Responses

It is recommended that the PPP project of the A-city integrated pipe gallery adopts the method of using different design institutes for each project, and the design risks are decentralized by comparing the advantages and disadvantages of each design institute with the quality of design products and services.

Formulate management policies to form a normalized communication and rapid advancement mechanism for multiple entities. The responsible departments of each pilot project to implement a summary system to detect and solve problems in a timely manner.

6.3. Risk Responses during Project Operation Period

1) Optimize the timing and sequence of the corridor

Since the entrance hall will be influenced by the size and quantity of the hoisting port during the operation period, it will increase the difficulty of entering the corridor. Therefore, during the construction period of the pipe gallery, pipeline units are urged to follow the progress of the construction of the pipe gallery.

2) Using floating pricing

With the continuous development and changes of the integrated pipe gallery and pipeline market, the price of the entrance fee will also fluctuate. Therefore, the market should be fully considered in the formulation of the fee collection price, and a variable mechanism should be adopted in order to cater to the market law.

6.4. Project Full Cycle Risk Responses

1) Establish a technical standards system

The establishment of a series of technical standards system of national standards, industry standards and local standards is conducive to the formation of standardized integrated corridor design and construction, reducing engineering risks.

2) Establish appropriate financial subsidy policies

Unreasonable subsidies will become the government's financial burden. Therefore, the formulation of fiscal policies requires a keen sense of the market, and the establishment of appropriate financial subsidies to test the government's grasp of the market.

7. Conclusions

Under the current situation of the government's vigorous promotion of the PPP model, the integrated pipe corridor PPP project will be launched in major cities across the country as an emerging municipal infrastructure. Due to the large investment amount, difficult construction, long cycle time and many uncertain factors, the integrated pipe corridor project needs to conduct risk management research in the early stage of development and seek management mode and methods to avoid or reduce risks.

1) The article adopts the stage-oriented and divides the risk from the perspective of the whole life cycle theory, and divides the risk of the integrated pipe PPP project into the pre-project risk, the project construction period risk, the project operation period risk and the project full-cycle risk. The risk management objectives and management rights and responsibilities at each stage are clear, making the risks more systematic and controllable.

2) Identifying 20 risks factors for the project, the analytic hierarchy process is used to clarify that the PPP project of the integrated pipe gallery belongs to a more serious risk level, and identifies the important risk factors of the pipe gallery project, including financing risk, engineering change risk, construction risk and contract, contract risk, technical risk, and entrance. Risk, income price and regulatory or legal system are not perfect. Risk management is made more targeted and practical, and the results are more valuable.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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