Multidisciplinary Inclusive Education, Management and Legal Services (MIEMLS)

Journal Homepage: <https://topicsonsocialdevelop.com>

DOI: 10.26480/ismiemls.01.2018.47.50

ISBN : 978-1-948012-13-3

RISK MEASUREMENT OF RURAL INFRASTRUCTURE PPP PROJECT BASED ON FAHP

Feng Yiting¹, Ao Hui²

¹International Education department of Wuhan University of technology, Jinhua, Zhejiang, China

²Management department of Wuhan University of technology, Zhangshu, Jiangxi, China

*Corresponding Author Email: fengyi98@163.com; aohui69@aliyun.com

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ARTICLE DETAILS

Article History:

Received 26 June 2018

Accepted 2 July 2018

Available online 1 August 2018

ABSTRACT

The rural infrastructure is the sum of material base public service facilities to develop rural production and guarantee the livelihood of peasants, which is closely related to the development of rural economy. This paper analyzes the structure and connotation of rural infrastructure PPP project from the characteristics of PPP project, then carry on a rural infrastructure PPP project risk measurement by using analytic hierarchy process (AHP) to measure the weight of each risk factor and fuzzy analysis method to measure PPP project risk level.

KEYWORDS

Rural Infrastructure, PPP Project, Risk Measurement, FAHP.

1. INTRODUCTION

Since 2004, the issue of "agriculture, rural areas and farmers" has been placed in a prominent position in the overall work of the party and the country. It has been mentioned and emphasized successively in the Central Document No.1. The proposal and continuous promotion of the "socialist new rural construction" plan further highlight the necessity of rural infrastructure construction. Rural infrastructure in a broad sense covers various areas of rural production, life and ecology, which can be divided into productive, living, ecological environment construction and social development infrastructure. However, due to insufficient fiscal budget and industrial support, it is difficult for government to maintain long-term and stable development of rural infrastructure construction. Experience at home and abroad has shown that the public-private-partnership (PPP) is a reasonable and effective way to maximize the performance of both parties. It is a project operation mode of "sharing interests, sharing risks and cooperating all the way" between the government and the private sector to meet the needs of public infrastructure construction and development. Its application in rural infrastructure construction has clarified the public and private sector their respective advantages and attract private capital innovatively to make up for the government financing gap.

2. CHARACTERISTICS OF RURAL INFRASTRUCTURE PPP PROJECT

Using PPP mode can enhance the rural economic vitality and promote the development of rural infrastructure construction. The PPP project can make full use of the resources of rural and create maximum efficiency and benefit with minimum cost between the government and the private sector, so as to achieve the ideal state "pareto optimality". By the end of 2017, there were 7,137 projects registered in the China PPP information management database with an investment of 10.8 trillion yuan. Compared to the end of 2016, 2017 increased 2,684 projects registered in the PPP information management database with a net investment of 4.0 trillion yuan. However, relative to other PPP projects, PPP projects of rural infrastructure are restricted by the following factors, and construction lags behind relatively slowly.

2.1 Private capital participation enthusiasm is not high and the market exit mechanism is not sound

On the one hand, the low income of rural infrastructure PPP project is contrary to the pursuit of high profits by social capital. On the other hand,

the project requires huge investment capital and a long period (usually 20-30 years), which determines that it needs long-term stable financing. Private capital takes into account issues such as profitability, uncertainty and liquidity, and is not highly motivated to participate. In addition, at present, the withdrawal of PPP project investors in China must be approved by the government. However, relevant departments have not clearly defined the specific operation process of the withdrawal. The asset ownership of PPP project is not clear, and the exit mechanism is not perfect, so it is difficult to win the favor of the private sector.

2.2 Failed to establish a mature legal and regulatory system and perfect risk sharing mechanism

So far, Authoritative national PPP departments haven't issued unified laws and regulations with high legal effect. The existing legal effect of department rules and regulations, to some extent weaken the attraction of the PPP projects and increase the private sector costs in the project risk and transaction. In addition, the PPP project risks full of diversity and uncertainty, rural infrastructure PPP project risk sharing boundary is vague and lacks rational risk-sharing mechanism so that increases the difficulty of project's orderly operation.

2.3 Government and enterprises lack the spirit of credit contract

Many Chinese governments simply use PPP as a financing tool to transfer debt leverage and risks to private capital. The current government's debt pressure has been increasing, which results in its violation of the spirit of credit and contract. For example, when making relevant policies, some governments arbitrarily make unfair policies that are obviously not conducive to private capital rather than from the perspective of "benefit sharing".

3. RISK COMPOSITION OF RURAL INFRASTRUCTURE PPP PROJECT

PPP is a new project management and financing mode. It needs huge amount investment, long life cycle about 20 ~ 30 years and the financing structure is complex, main body and the environment characteristics full of uncertainty. All factors lead the PPP project especially rural infrastructure PPP project to the face of complex risks. Scholars at home and abroad combined with the specific cases from different angles and levels to explore the risk of PPP project: widely accepted in the academic circle, a scholar divided PPP risk factors into macro, middle and micro three levels of view; a group of scholars divided BOT risks into political,

market, financial, legal, operational and construction risks; other scholars divided the risks generated from the inside and outside of rural water conservancy PPP projects into external risks and internal risks; a previous researcher made analysis the risk of 16 Chinese PPP failure case; other researcher explored PPP project risks in the infrastructure field from the perspective of PPP whole life cycle theory. In conclusion, many literatures analyze from risk sources, risk management processes and risk levels [1-

5]. Based on the existing literature data and the actual situation of the rural infrastructure PPP project, compare to the various indicators of risk factors by screening and retaining the main factors, ignoring secondary factors [6]. Based on a study, rural infrastructure PPP project risk can be divided into system risk and non-system risk briefly [7]. Under this category further divided them in details, then establish the risk composition of rural infrastructure PPP project shown in table 1.

Table 1: Risk composition of rural infrastructure PPP project

System risk X_1	Political and legal risk X_{11}	Non-system risk X_2	Development and design risk X_{21}
	Financial risk X_{12}		Technical risk X_{22}
	Natural risk X_{13}		Construction and operational risk X_{23}
	Market risk X_{14}		Cooperation risks X_{24}

3.1 System risk (X_1)

System risk refers to the external risk caused by the overall political, economic, social and other external environmental factors, which exists in the whole life cycle of PPP projects [8]. It is non-dispersible, and the incentives are often outside the project rather than under control.

3.1.1 Political and legal risk (X_{11})

Political and legal risk include government intervention, legal changes, tax reform and other risks. China's PPP project is still in the primary stage and there is still a big gap between China and some European countries. What's worse, a complete legal and regulatory system has not been established. The government directly interferes in the operation process of PPP projects or even deprives the decision-making power of private enterprises, which will lead to the failure of normal operation of PPP projects. At the same time, changes in the external legal environment or the validity of contract agreements, such as changes in laws and taxes, will also have a direct impact on the expected benefits of PPP projects.

3.1.2 Financial risk (X_{12})

The financial risks of PPP infrastructure projects are mainly risk of interest rate, exchange rate and inflation. Because of the huge capital amount needed by PPP project, financial risks will generate problems like decreasing the purchasing power of money and so on. To a great extent, it leads to the increased cost of project operation and the damaged interests.

3.1.3 Natural risk (X_{13})

Natural risks are risks that harm PPP projects due to irregular changes in natural forces, mainly including environmental pollution, force majeure and climate risks [9]. They are often insurmountable and unavoidable. In severe cases will lead to project delays and failures.

3.1.4 Market risk (X_{14})

Market risk usually includes market demand risk and market supply shortage risk. Lack of market supply refers to the failure of completed projects to meet the expected targets or a sharp increase in market demand. Market demand risk refers to the change of market demand caused by environmental change. For example, after the completion of the project, the social demand for the product of the project changes and the income is lower than expected.

3.2 Non-system risk (X_2)

Compared with system risk, non-system risk is the risk caused by internal reasons such as complicated contract structure and uncertainty of subject. It comes from the micro-factors within the project and a certain subject or process. It's likely to generate errors and losses during the life cycle of projects.

3.2.1 Development and design risk (X_{21})

Development and design risks are mainly caused by challenges such as feasibility, limitation of scientific knowledge and contingency of bidding. It is constrained by technology, unpredictable competition and the objective environment, so that the original development design is proved wrong or out of date.

3.2.2 Technical risk (X_{22})

Technical risk, on the one hand, is the risk of project technology innovation and protection. On the other hand, including the risk of inaccurate technology market prediction. Late technical changes and is replaced easily may lead to increasing production costs or even fail to meet established project standards.

3.2.3 Construction and operational risk (X_{23})

Construction and operational risk refer to the risk of losing project profit due to limited environmental adaptability. It exists in project construction and operation of the project whole life cycle. For example, in the process of project construction, is likely to generate problem caused by a lack of financing channels, labor costs rise or the public demanded changes in the direction of energy, raw materials can't arrive on time.

3.2.4 Cooperation risks (X_{24})

Improper distribution of rights and responsibilities of both parties and uneven distribution of interests are usually the causes of cooperation risks. If the communication between the two sides is not smooth, the cooperation relationship is not coordinated, or the public sector and the private sector have different priorities, which will bring inevitable cooperation risks.

4. RISK MEASUREMENT OF RURAL INFRASTRUCTURE PPP PROJECT

After understanding and determining risks qualitatively, it is necessary to analyze and measure them on this basis. However, due to the complexity and diversity of PPP project risks, Analytic Hierarchy Process (AHP) lacks the ability to analyze and process fuzzy information [10]. Fuzzy analysis can deal with fuzzy and inaccurate data to a certain extent. Therefore, this paper uses Fuzzy Analytic Hierarchy Process to measure the risk level of PPP projects of rural infrastructure to overcome their respective disadvantages.

4.1 Determine the factor theoretic domain X of the evaluation object

Risk assessment of PPP projects of rural infrastructure is a complex problem, which needs to take into account different levels of influencing factors. According to the level of risk measurement index system has been established, determine the first level of evaluation factor $X = \{X_1, X_2\}$, the second level of evaluation factors for the $X_1 = \{X_{11}, X_{12}, X_{13}, X_{14}\}$, $X_2 = \{X_{21}, X_{22}, X_{23}, X_{24}\}$, and between each factor meet $X_i \cap X_j = \emptyset$ ($i \neq j$).

4.2 Determine the remark set V of the evaluation object

According to the hierarchical structure of AHP, the remark set $V = \{V_1, V_2, V_3, V_4, V_5\} = \{\text{high, relatively high, medium, relatively low, low}\} = \{0.9, 0.7, 0.5, 0.3, 0.1\}$.

4.3 Determine the weight vector ω of the evaluation factor

4.3.1 Build a judgment matrix.

Experts used 1-9 scale method to judge the relative importance of risk indicators at each level and determined the comparative judgment matrix as shown in table 2-4.

Table 2: Judgment matrix of the overall project risk level and the second layer of correlative factors A_1-X_i

A_1	X_1	X_2
X_1	1	11/2
X_2	2/11	1

Table 3: Judgment matrix of "system risk" and the third layer of correlative factors A_2-X_{1i}

A_2	X_{11}	X_{12}	X_{13}	X_{14}
X_{11}	1	3/2	4	3
X_{12}	2/3	1	11/2	5
X_{13}	1/4	2/11	1	1/3
X_{14}	1/3	1/5	3	1

Table 4: Judgment matrix of "non-system risk" and the third layer of correlative factors A_3-X_{2i}

A_3	X_{21}	X_{22}	X_{23}	X_{24}
X_{21}	1	3/4	2/3	1/2
X_{22}	4/3	1	1/3	1/4
X_{23}	3/2	3	1	1/3
X_{24}	2	4	3	1

4.3.2 Hierarchical single ordering and consistency check.

Calculate the maximum characteristic root from judgment matrix, then rank the importance of risk factors at the current level and check consistency, among them weight coefficient as a basis to obtain the optimal decision. In this paper, the weight and consistency test results are calculated with yaahp software, as shown in table 5-6.

Table 5: The risk evaluation index weight of rural infrastructure PPP project

Rural infrastructure PPP project risk A	System risk X_1 (0.8462)	Political and legal risk X_{11} (0.3975)
		Financial risk X_{12} (0.4042)
		Natural risk X_{13} (0.0678)
		Market risk X_{14} (0.1305)
	Non-system risk X_2 (0.1538)	Development and design risk X_{21} (0.1543)
		Technical risk X_{22} (0.1265)
		Construction and operational risk X_{23} (0.2403)
		Cooperation risks X_{24} (0.4789)

Notes: ($\omega = (0.8462, 0.1538)$), $\omega_1 = (0.3975, 0.4042, 0.0678, 0.1305)$, $\omega_2 = (0.1543, 0.1265, 0.2403, 0.4789)$

Table 6: Consistency check results of rural infrastructure PPP project judgment matrix

Judgment matrix	maximum characteristic root	CI	CR	consistency check
A_1-X_i	$\lambda_{\max}=2$	CI=0	CR=NAN	CR=NAN, CI=0, can be considered to pass consistency check
A_2-X_{1i}	$\lambda_{\max} (1) = 4.1924$	CI (1) =0.0641	CR (1) =0.0721	CR (1) <0.1, can be considered to pass consistency check
A_3-X_{2i}	$\lambda_{\max} (2) = 4.2060$	CI (2) =0.0687	CR (2) =0.0772	CR (2) <0.1, can be considered to pass consistency check

4.4 Establish fuzzy relation matrix R

Fuzzy relation matrix R_i can be regarded as a fuzzy membership relation between factor theoretic domain X and remark set V .

Each fuzzy matrix (R_1 and R_2 are represented as fuzzy matrices of factor set X_1, X_2 and remark set V respectively) is arranged as follows:

$$R_1 = \begin{bmatrix} 0.2 & 0.4 & 0.2 & 0.1 & 0.1 \\ 0.1 & 0.5 & 0.3 & 0.05 & 0.05 \\ 0.1 & 0.1 & 0.35 & 0.35 & 0.1 \\ 0.1 & 0.3 & 0.3 & 0.2 & 0.1 \end{bmatrix} \quad R_2 = \begin{bmatrix} 0.0 & 0.3 & 0.3 & 0.3 & 0.1 \\ 0.0 & 0.3 & 0.4 & 0.2 & 0.1 \\ 0.1 & 0.4 & 0.4 & 0.1 & 0.0 \\ 0.1 & 0.45 & 0.3 & 0.15 & 0.0 \end{bmatrix}$$

4.5 Conduct fuzzy comprehensive evaluation

In order to show the degree of membership of evaluated objects in the whole, perform the weight of risk evaluation factor and its fuzzy matrix R by fuzzy transformation and synthesis.

4.5.1 Conduct fuzzy evaluation from single factor

$$P_1 = \omega_1 R_1 = (0.3975, 0.4042, 0.0678, 0.1305)$$

$$\times \begin{bmatrix} 0.2 & 0.4 & 0.2 & 0.1 & 0.1 \\ 0.1 & 0.5 & 0.3 & 0.05 & 0.05 \\ 0.1 & 0.1 & 0.35 & 0.35 & 0.1 \\ 0.1 & 0.3 & 0.3 & 0.2 & 0.1 \end{bmatrix} = (0.13975, 0.40703, 0.26364, 0.10979, 0.07979)$$

$$P_2 = \omega_2 R_2 = (0.1543, 0.1265, 0.2403, 0.4789)$$

$$\times \begin{bmatrix} 0.0 & 0.3 & 0.3 & 0.3 & 0.1 \\ 0.0 & 0.3 & 0.4 & 0.2 & 0.1 \\ 0.1 & 0.4 & 0.4 & 0.1 & 0.0 \\ 0.1 & 0.45 & 0.3 & 0.15 & 0.0 \end{bmatrix} = (0.07192, 0.395865, 0.33668, 0.167455, 0.02808)$$

4.5.2 Multi-index comprehensive evaluation was carried out based on the calculation results of single factor fuzzy evaluation

$$P = (P_1, P_2) = \begin{pmatrix} 0.13975 & 0.40703 & 0.26364 & 0.10979 & 0.07979 \\ 0.07192 & 0.395865 & 0.33668 & 0.167455 & 0.02808 \end{pmatrix}$$

$$B = \omega P = (0.8462, 0.1538)$$

$$\times \begin{pmatrix} 0.13975 & 0.40703 & 0.26364 & 0.10979 & 0.07979 \\ 0.07192 & 0.395865 & 0.33668 & 0.167455 & 0.02808 \end{pmatrix} = (0.12932, 0.40531, 0.27487, 0.11866, 0.07184)$$

4.6 Analyze the results of fuzzy comprehensive evaluation

It can be seen from the calculation results of Analytic Hierarchy Process that system risk is an important aspect of rural infrastructure PPP project risk. Its weight value is 0.8462, far exceeding non-system risk. This indicates that as state-led PPP project, it's greatly affected by non-dispersible external system risks. Secondly, among the system risks, financial risks and political and legal risks have large weight (0.4042, 0.3975). Among non-system risks, cooperation risks and construction and operational risks have large weight (0.4789, 0.2403). These four are high risk factors in rural infrastructure projects. Both the public sector and the private sector should pay attention to and take measures to minimize the impact of these high-risk factors. Multi-index comprehensive evaluation results show that 12.93% of scholars believe that the overall risk of rural infrastructure PPP project is the high level, 40.53% think that is a relatively high level, 27.49% of medium level, 11.87% believe to be relatively low, 7.18% believe to be low. According to the principle of maximum membership, the measurement result of rural infrastructure PPP project risk level is 0.40531, which is a relatively high-risk level.

5. CONCLUSIONS

From the evaluation results, the overall risk of rural infrastructure PPP projects is relatively high, indicating that there are still some outstanding weak links in rural areas' PPP projects. The public and private sector managers should make timely and correct understanding of all kinds of existing or potential risks. On this basis, focus on prevention and control of important high-risk factors and take active and effective measures. Both public and private parties can establish a reasonable risk sharing mechanism to allow the most capable party to bear these risks, so as to maximize the benefits of the project and minimize the existing or potential risks. As a result, the government has achieved its goal of providing public infrastructure while the private sector has received the expected return. However, PPP, as a new financing model, is still in its infancy stage in the application of China rural infrastructure in China and lacks relevant experience. The authorities should strengthen the completion of legal system and combine the concrete situation of China rural to specialize risk management plan in order to make up the objective defects and boost the

vigorous development of rural infrastructure PPP project.

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