Construction and application of risk assessment system for environmental PPP projects

To cite this article: Junhui Yin *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **242** 052005

IOP Conf. Series: Earth and Environmental Science **242** (2019) 052005 doi:10.1088/1755-1315/242/5/052005

Construction and application of risk assessment system for environmental PPP projects

Junhui Yin, Xue Bai *and Meng Yuan

School of Business and Management, Tianjin University of Science and Technology, Tianjin, 300222, China

*Corresponding author's e-mail: 2323450921@qq.com

Abstract: In order to balance the urgent requirements of environmental protection and the huge financial pressure of the government, the PPP model has been promoted in the construction of environmental protection, and effective risk management is still the key to project success. Based on the expert scoring method, combined with the risk evaluation index system of environmental protection PPP project, this paper uses the analytic hierarchy process and the entropy weight fuzzy comprehensive evaluation method to construct the risk evaluation model of environmental protection PPP project. Taking PY County water environment treatment and ecological restoration project as an example, seven first-level risk factor indicators and 23 two-level risk factor index evaluation systems were constructed to conduct risk assessment and draw conclusions.

1. Introduction

During the "Thirteenth Five-Year Plan" period, China's new industrialization, informationization, urbanization, and agricultural modernization have developed in depth, and new growth drivers are being formed. However, the development mode is extensive, the imbalance, uncoordinated and unsustainable problems are still outstanding. The extensive economic growth mode of industrial civilization with high input, high consumption and high pollution leads to serious environmental pollution and ecosystem damage[1]. The construction of environmental protection facilities requires a large amount of investment. At present, China's economy is at an important stage of new normal development, economic growth is slowing down, downward pressure is increasing, and the contradiction between fiscal revenues and expenditures is more prominent.

In 2014, the Ministry of Finance issued the Notice on Issues Relating to the Promotion and Application of the Government-Social Capital Cooperation Model[2]. And because PPP model plays a key role in alleviating government financial pressure, broadening financing channels, breaking geographical constraints and so on, it has been widely used in transportation, residential construction, environmental protection, energy and other fields. Environmental comprehensive management PPP project has the characteristics of long life cycle, huge amount of financing and many participants. Because of the particularity of the project itself, each participant faces different internal and external risks in different stages of the project implementation. Risk assessment is still the key control point for the effective implementation of the project.

2. Construction of risk assessment model for environmental PPP projects

2.1. Applying AHP Method to Determine Index Weight

According to the principle of analytic hierarchy process (AHP), the environmental protection PPP project is analyzed, and $C = (C_1, C_2, \ldots, C_m)$ is set up as the first level risk indicator set of environmental protection PPP project; and $C_i = (C_{i1}, C_{i2} \ldots, C_{in})$ in is set up as a two level risk indicator set. Starting from the first-level risk indicators, for the factors belonging to the same higher-level indicators, the judgment matrix of the indicators is constructed by two-to-two comparison method. A judgment matrix is constructed for the relative importance of elements in the same level evaluation layer. The form is as follows:

$$X = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix}$$

Calculate the weights of each indicator and the consistency test according to the matrix. For the judgment matrix constructed according to practical problems, if the consistency is not satisfied, it will affect the effective decision-making. The random consistency ratio of the judgment matrix is CR, and the formula is $CR = \frac{C \cdot I}{R \cdot I}$. When $CR < 0.1$, the matrix satisfies the consistency requirement, otherwise the judgment matrix should be adjusted until the conditions are satisfied[3].

2.2. Constructing risk index evaluation set

After determining the risk factors, it is necessary to use fuzzy mathematics to construct risk evaluation set. Assessment set is a set of possible evaluations of risk factors, such as high risk, high risk, moderate risk, low risk and so on. The evaluation set is usually expressed in V, $V = \{v_1, v_2, \ldots, v_n\}$. Among them, $v_j (j = 1,2, \ldots, n)$represents the outcome of the *j* evaluation.

2.3. Fuzzy comprehensive evaluation based on entropy weight

In the evaluation, the fuzzy set of the two level risk indicators can be expressed as: $R_{i1} = (r_{i11}, r_{i12}, r_{i13}, \ldots, r_{i1n})(i = 1,2,\ldots,m)$. The fuzzy evaluation matrix can be expressed as: $R_i = \begin{bmatrix} R_{i1} & R_{i2} & \cdots & R_{im} \end{bmatrix}^T$. And then combined with the weight calculated in the first step to get $B_i = W_i \square R_i$.

According to the principle that the risk is smaller and the better, using formula $z_{ij} = \frac{b - \min b_{ij}}{\max b_{ij} - \min b_{ij}}$, the matrix $B = (B_1, B_2, \ldots, B_n)$ standardized processing.

The formula is $E_i = -k \sum_{j=1}^{n} p_{ij} \ln p_{ij}$, and the unknown value of the upper form are $k = \frac{1}{\ln n}$ and $p_{ij} = \frac{z_{ij}}{\sum_{j=1}^{n} z_{ij}}$. When $p_{ij} = 0$, set $p_{ij} \ln p_{ij} = 0$. Then according to formula $\lambda_i = \frac{1 - E_i}{m - \sum_{i=1}^{m} E_i}$, the entropy weight is calculated. Finally, according to formula $Y = \frac{w_i \lambda_i}{\sum_{i=1}^{m} w_i \lambda_i}$, the fuzzy comprehensive evaluation result of entropy weight is obtained[4].

3. Empirical analysis of an environmental protection PPP project

PY County water environment management and ecological restoration project is the fourth batch of national PPP demonstration projects. The project includes nine sub-projects, including river and lake water ecological restoration project, distributed ecological sewage treatment station project, sludge and construction waste recycling project, intelligent water ecological supervision project and so on. The franchise period is 20 years (including construction period of 1.5 years). There are three payment modes for PPP projects: user payment mode, government payment mode and feasibility gap subsidy mode. Due to the public welfare characteristics of environmental PPP project, user payment mode will make it difficult for social participants to obtain reasonable benefits, or even cannot cover the construction and operation costs of the project[5]. In order to make the environmental PPP project commercially viable, the project of PY County uses the feasibility gap subsidy mode.

3.1. Building a risk indicator system

By referring to relevant literature and combining with the characteristics of environmental protection PPP project[6], the risk index system of water environment treatment and ecological restoration project in PY County (as shown in Table 2) is obtained, which includes seven first-level risk factors index and 23 second-level risk factors index. This paper evaluates the risk factors of environmental PPP projects by means of expert scoring[7]. Questionnaires are sent out through the Internet. The participants are university PPP project researchers, government officials and social capitalists. According to the Richter subscale, the environmental PPP project risk was divided into five levels in the questionnaire: high, high, medium, low, very low.

Table 1. Environmental risk assessment indicators for PPP projects

First level index	Two level index	Index meaning
Political risk	Government credit risk	The government fails to fulfill its contractual obligations and responsibilities, such as not paying the fees on time and terminating the concession agreement.
	Government intervention risk	Owing to the government's strong leadership, frequent involvement in projects with decision-making power leads to increased costs or delays in the duration of projects.
	Approved risk	Government departments cannot approve projects in time, resulting in delay in project completion time.
	Public opinion risk	Residents around the project site reject the project.
Legal risk	Tax risk	Changes in related tax policies lead to increased taxes and increased costs.
	Policy and regulation risk	Changes in policies and regulations related to projects, especially environmental laws and regulations, etc.
Financial risk	Interest rate risk	The impact of market interest rates on project returns.
	Inflation risk	Inflation in the project life cycle leads to higher prices and higher costs.

Project preparation risk	Insufficient risk in bidding competition	Risks arising from inadequate competition and failure to select the most suitable bidder due to unreasonable bidding access rules or substandard bidding processes.
	Financing risk	The impact of investors' lack of financing ability, unreasonable financing structure, and changes in financing environment on projects.
	Contract risk	Defects in the terms of the franchise contract, such as unreasonable risk sharing among the participants, make the project difficult to carry out.
Project construction risk	Completion risk	Project delay project cannot be delivered on time.
	Construction cost overrun risk	Government intervention, expansion and other factors caused the construction cost exceeding the budget.
	Engineering quality risk	The construction quality of the project is not up to standard, resulting in the project being unable to be delivered.
	Financial risk	The government or investors cannot pay the cost on time.
	Technical risk	During the construction period, the subsequent operation difficulties caused by the immature technology or unsuitable reasons.
Operation and transfer risk	Project uniqueness	Similar projects appear in the same area, resulting in reduced project returns.
	Residual Value Risk	When the concession period expires, the excessive consumption of resources by the operator leads to serious depreciation of the equipment, and it is difficult to carry out subsequent operation after the transfer.
	Secondary pollution risk	Environmental secondary pollution due to excessive emission of pollutants because of technology and other factors.
	Risk of return and cost change	In operation, investment is not recoverable because of rising costs or reduced revenues.
	Lack of supporting facilities	Inadequate construction of supporting facilities of the project has led to increased construction costs or difficulties in project operation.
Force majeure risk	Natural disaster	Impact of natural disasters such as earthquakes and floods on projects

	Social stability risk	Unstable factors such as workers' strike and social unrest.

3.2. Calculation of risk indicator weights

Based on the above risk assessment model, the two-to-two comparison matrix of risk factors is constructed. The data obtained from the questionnaire are selected, the judgment matrix is listed, and the weight of each index is calculated (see Table 2).

Table 2. Risk index weight of environmental protection PPP project

First level indicators and weights	Secondary indicators and weights	Weight value	Sort
Political risk（C1） 0.2127	Government credit risk (X11)	0.1169	1
	Government intervention risk (X12)	0.0506	7
	Approved risk (X13)	0.0264	13
	Public opinion risk (X14)	0.0187	20
Legal risk（C2） 0.0907	Tax risk (X21)	0.0227	16
	Policy and regulation risk (X22)	0.0681	5
Financial risk（C3） 0.0627	Interest rate risk (X31)	0.0125	22
	Inflation risk (X32)	0.0501	8
Project preparation risk（C4） 0.1755	Insufficient risk in bidding competition (X41)	0.024	15
	Financing risk(X42)	0.1097	2
	Contract risk (X43)	0.0419	10
Project construction risk（C5） 0.1877	Completion risk (X51)	0.0736	4
	Construction cost overrun risk (X52)	0.0324	12
	Engineering quality risk (X53)	0.0428	9
	Financial risk (X54)	0.0143	21
	Technical risk (X55)	0.0246	14
Operation and transfer risk（C6） 0.2424	Project uniqueness (X61)	0.0199	18
	Residual Value Risk (X62)	0.0224	17
	Secondary pollution risk (X63)	0.0399	11
	Risk of return and cost change (X64)	0.1077	3
	Lack of supporting facilities (X65)	0.0526	6
Force majeure risk（C7） 0.0283	Natural disaster (X71)	0.0189	19
	Social stability risk (X72)	0.0094	23

Source: calculated based on the questionnaire data.

3.3. Entropy weight fuzzy comprehensive evaluation of risk

Set evaluation set $V=(0.1\quad 0.3\quad 0.5\quad 0.7\quad 0.9)$ means {very low, low, medium, high, very high}. Based on the evaluation scores of risk factors obtained in the questionnaire and the weights obtained in the previous step, the fuzzy comprehensive evaluation sets B_1, B_2, B_3, B_4, B_5, B_6, B_7 of the secondary risk factor layer are obtained. According to the principle of the minimum risk, after standardization, matrix Z is obtained.

$$Z=\begin{bmatrix} 0.91 & 0.72 & 0.34 & 0.25 & 0.85 \\ 0.86 & 0.57 & 0.08 & 0.57 & 1 \\ 0.81 & 0.38 & 0.08 & 0.81 & 1 \\ 0.93 & 0.28 & 0.11 & 0.76 & 1 \\ 0.94 & 0.49 & 0.21 & 0.57 & 0.87 \\ 0.88 & 0.81 & 0 & 0.49 & 0.91 \\ 0.23 & 0.23 & 0.74 & 0.87 & 1 \end{bmatrix}$$

Using the entropy weight fuzzy comprehensive evaluation model, fuzzy entropy is calculated:

$$E_i=(0.9359\quad 0.8971\quad 0.8811\quad 0.8747\quad 0.9358\quad 0.8455\quad 0.9034)$$

Further, the entropy weight of the secondary risk index is:

$$\lambda_i=(0.0882\quad 0.1417\quad 0.1637\quad 0.1725\quad 0.0883\quad 0.2127\quad 0.1329)$$

The weight of the second tier according to the second tier

$C=(0.2127\quad 0.0907\quad 0.0627\quad 0.1755\quad 0.1877\quad 0.2424\quad 0.0283)$, The final entropy weight fuzzy comprehensive evaluation results are:

$$Y=(0.1303\quad 0.0892\quad 0.0712\quad 0.2101\quad 0.1151\quad 0.3579\quad 0.0261)$$

4. Conclusions

Based on the above evaluation results, according to the principle of maximum membership degree, the risk grade of water environment treatment and ecological restoration project in PY country is medium, and the overall risk degree is relatively moderate. The risk factors of the PPP project range from large to small: operational and transfer risks, project preparation risks, political risks, project construction risks, legal risks, financial risks, and force majeure risks. Operational and transfer risks, project preparation risks and political risks, these three types of risks account for about 70% of the risk ratio, need to pay attention to and develop countermeasures.

Reference

[1] Zhang Y. Y., Fan X. Y.. (2011) Ecological Civilization Construction and Resource and Environment Carrying Capacity. China's land and resources economy, 24(04)：9-11+8+54.
[2] Li Y., Zhao L. . (2015) Construction of PPP project risk evaluation system under the background of new urbanization -- Taking Xinzhuang CCHP project in Shanghai as an example. Economic restructuring, 05:17-23.
[3] Ameyaw, Effah，Chan ,Albert. (2015) Evaluation and ranking of risk factors in public-private partnership water supply projects in developing countries using fuzzy synthetic evaluation approach. Expert Systems with Applications ,42: 5102-5116.
[4] Fan X. J., Wang F. H., Zhong G. Y. . (2004) Dynamic fuzzy evaluation of the financing risks of large scale infrastructure projects. Journal of Shanghai Jiao Tong University, 03:450-454.
[5] Pang H. T., Xue X. F., Zhai D. D., et al.(2017) Research on PPP Mode of Integrated Watershed Management. Environment and sustainable development, 42(01)：77-80.
[6] Ng A, Martin Loosemore. (2007) Risk Allocation in the Private Provision of Public Infrastructure. International Journal of Project Management, 25 (01):66-76.
[7] Li, B., Akintoye, A. . Edwards , PJ. , et al. (2005) The Allocation of Risk in PPP/PFl Construction Projects in the UK. International Journal of Project Management, 23(01):25-35.