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Research on Life Cycle Risk Assessment of Public-Private Partnerships Project Project of Comprehensive Environmental Governance Based on PCA

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Abstract

China's implementation of public-private partnerships projects has been quite effective, involving infrastructure and other livelihood projects, a total of 19 industries, and an investment of nearly 1.5 trillion yuan. The characteristics of PPP projects such as long construction period and large investment amount determine the risks of PPP projects are also great, and the PPP projects of comprehensive environmental governance are also the same. The government and social capital use the PPP model to cooperate, and use the principal component analysis method to assess the risks of the entire life cycle of the comprehensive environmental governance PPP project. Therefore, it plays an important role in ensuring the smooth implementation of projects and reducing the losses caused by risks. According to the risk factors of the whole life cycle of the comprehensive environmental governance PPP project, an indicator system of 5 first-level indicators, 18 second-level indicators, and 43 third-level indicators has been established. Principal component analysis is used to analyze the influence weight of risk factors at each stage. The analysis shows that among the four stages, environmental pollution risk, project approval delay risk, completion risk, interest rate and financial fluctuation risk, and franchise life risk are the most influential risks in the implementation of PPP projects. Therefore, suggestions are made through the risk factors of each stage in the comprehensive environmental governance PPP project. For example, strengthen the response to the external environment risks of the comprehensive environmental governance PPP project, standardize the bidding and procurement of the comprehensive environmental governance PPP project, and strengthen the subsequent management of the transfer of the comprehensive environmental governance PPP project. In this way, the ability to resist risks of comprehensive environmental governance PPP projects is improved; the smooth implementation of the project is guaranteed, and the long-term development of comprehensive environmental governance PPP projects is promoted.

Keywords Environment·Comprehensive treatmen·public-private partnerships (PPP)·Full life cycle·Risk assessment·Principal component analysis (PCA)

Introduction

PPP project is a cooperative mode between the government and social capital in the PPP mode. The government USES the capital advantage of social capital to alleviate and solve the problem of insufficient public goods. Since China started its PPP project in 2014, the cooperation between the government and social capital has reduced the government's financial pressure, improving the operation efficiency of public goods, and Sharing various risks. By the end of August 2020, 9,667 PPP projects in China had entered PPP project management centers, with a cumulative investment of 14.9583 trillion yuan, involving 19 industries. Among all the projects, municipal projects have the most PPP projects, reaching 3,936 with an investment of 4,345.3 billion yuan (2020). PPP projects for ecological construction and environmental protection rank the third in the number of projects in all industries, reaching 925, with an investment of 877.4 billion yuan (2020). With China's new urbanization and rural agricultural modernization and other vigorous development, it is bound to cause certain damage to the ecological

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environment. Therefore, the report of the 19th National Congress once again proposed to "accelerate the reform of ecological civilization system, and build an environmental governance system dominated by the government, dominated by enterprises, and jointly participated by social organizations and the public" (2017). Up to now, PPP projects of ecological construction and environmental protection have huge investment amount, numerous participants, complicated processes involved, and long construction and operation cycle, resulting in numerous and complex risks faced by PPP projects. Therefore, the PPP project of ecological construction and environmental protection needs to accurately predict and evaluate various potential risks to ensure the smooth implementation of the project.

Public-private partnership (PPP) is a mode of cooperation between the public sector and private enterprises. It uses funds and management experience of private enterprises to operate efficiently and provide the public with required products and services (Akintoye, 2000). The social capital party provides the government with operational management experience and advanced technology, as well as financing services for PPP projects (Zou, 2008). The PPP model solves the funding difficulties for the government, and at the same time shares the risks of the project by the social capital (Doloi, 2007). The method of PPP project risk assessment originated from abroad. Through the risk assessment of the Skye Bridge project in the United Kingdom, the risk of the construction period and operation period of the social capital party is judged, and further qualitative research is carried out (Pete Moles, 1995). The risk assessment model established by Cheng's team uses the Delphi method, fuzzy mathematics method, and AHP method to conduct risk assessment and applies it to Taiwan BOT projects (Cheng, 2001). PPP project risks exist both in the micro-environment of the project itself, and in the macro-environment (Martin Loosemore, 2007). There are many methods for evaluating PPP project risks, such as the fuzzy comprehensive evaluation method of PPP project risk assessment (Chen Jingwu et al., 2006), and the network analytic method of PPP project risk assessment (Zhang Wei et al., 2012), The grey correlation theory method of PPP project risk assessment has been researched (Jia Lili et al., 2014). Through the PCA method the risks of PPP projects was to studied by Lu who constructed the PCA method and empirically conducted 10 PPP projects in Zhejiang Province, and concluded that the predictions are consistent with actual risks (Lu Xiaoqin et al., 2017). Zhang combined with PCA Research on the risks of low-rent housing PPP projects and predict the risks (Zhang Guihua, 2016). Regarding the risk assessment of the entire life cycle, Huang builds a three-dimensional structural model of the risks generated during the entire life cycle of the PPP project, and dynamically analyzes the risks at each stage (Huang Ke, 2019). Throughout the literature, few experts and scholars at home and abroad apply the PCA method to the entire life cycle of PPP projects for risk assessment, especially for ecological construction and environmental protection PPP projects. In this paper, principal component analysis (PCA) is used to carry out risk assessment for each stage of the whole life cycle of PPP projects under comprehensive environmental governance, and the risk impact weight of each stage is evaluated. Focus on key risk factors in real time to minimize the losses caused by risks and ensure a successful completion of PPP projects under comprehensive environmental governance within the whole life cycle. Through the study on the risk assessment of the whole life cycle of THE PCA-based comprehensive environmental governance PPP project, the study on the risk assessment of the whole life cycle by using principal component analysis has played a theoretical and practical significance.

Materials and methods

Construct risk index system

Based on theoretical research and literature review, a risk index system for the full life cycle of PPP projects under comprehensive environmental governance is constructed. The full life cycle of PPP project of comprehensive environmental governance includes identification stage, implementation stage, franchise stage and non-franchise stage. In the PPP project of comprehensive environmental governance, some risks run through the whole project, and this paper sets such risks as the first-level index separately. Therefore, there are five first-level indicators, namely, whole-cycle stage risk, identification stage risk, implementation stage risk, franchise stage risk and non-franchise stage risk. The five first-level indicators contain 18 second-level indicators, and the second-level indicators are divided into 43 third-level indicators (Table 1).

Table 1 Full life cycle risk index system of PPP projects under comprehensive environmental governance

Primary index	Secondary index	Tertiary index	Variable

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Full cycle stage	Political risk	Government credit risk	X1
		Government intervention risk	X2
		Risk of approval and licensing errors	X3
		Corrupt government officials risk	X4
	legal risks	Legal change risk	X5
		Tax change risk	X6
		Industry policy change risk	X7
		Third party default risk	X8
	Environmental risk	Environmental pollution risk	X9
	Force majeure risk	Likelihood risk of natural disaster	X10
		Risk the possibility of policy changes	X11
Identification stage	Land acquisition risk	Resettlement of difficulty degree of risk	X12
		Inappropriate siting risk	X13
	Project approval delay risk	Project approval difficulty level risk	X14
		Functional department work efficiency risk	X15
		Project staff efficiency risk	X16
	Financing risk	Risk of access to funds	X17
		Project risk for private investment attractiveness	X18
		Cost overrun risk	X19
		Investment expected return risk	X20
Implementation stage	Financing risk	Risk of access to funds	X17
		Attraction risk of the project to private investment	X18
		Cost overrun risk	X19
		Investment expected return risk	X20
	Construction risk	Engineering quality risk	X21
		Completion risk	X22
		Project construction change risk	X23
	Supply risk	Supplier qualification requirements risk	X24
		Risk of procurement difficulty	X25
		Risk of perfecting quality inspection system	X26
	Technology risk	Design unit qualification risk	X27
		Design document technical requirements risk	X28
Franchise stage	Demand risk	Macroeconomic change risk	X29
		Demographic change risk	X30
		Competitive risk of similar projects	X31
	Operational risk	Operational management level risk	X32
		Operation and maintenance cost risk	X33
		Operational expected return risk	X34
	Financial risk	Financial management system risk	X35
		Financial expense control system risk	X36
	Foreign exchange and interest rate risk	Exchange rate fluctuation risk	X37
		Interest rate fluctuation risk	X38
	Inflation risk	Financial market stability risk	X39
		Inflation rate risk	X40

Non-franchising stage	Operational risk	Operational management level risk	X32
		Operation and maintenance cost risk	X33
		Operational expected return risk	X34
	Residual value risk	Franchise signing period risk	X41
		Operation management experience capability risk	X42
		Operation management system to improve risks	X43

Construction of principal component model

Principal component analysis (PCA) is to recombine a series of correlated data with uncorrelated data through dimensionality reduction, and replace the original data with these data to reflect the original indicators (Pang Xiaoning, Wang Liu, 2012). Through SPSS software dimensionality reduction, it is concluded that the variance in the linear combination is the largest, which means that the more information F1 contains, then F1 is called the first principal component. If the first principal component cannot reflect the information of all the original indicators, the second principal component needs to be selected to continue to reflect the original data information, and the second principal component is represented by F2. In order to ensure that the original information is not missing, if it still cannot fully reflect the original data information, the third, fourth, ..., P-th principal components will be extracted (Zhu Genhua,2015).

First, the data is reduced in dimensionality through the software of SPSS24.0, and then the linear equation of the principal components is obtained, as follows:

$$F_1=a_{11}X_1+a_{21}X_2......+a_{p1}X_p \quad (1)$$

$$F_2=a_{12}X_1+a_{22}X_2......+a_{p2}X_p \quad (2)$$

…

$$F_p=a_{1m}X_1+a_{2m}X_2+......+a_{pm}X_p \quad (3)$$

In the formula, a1i, a2i, … , api(i=1,……,m) are the eigenvectors corresponding to the eigenvalues of the covariance matrix of X, and X1, X2,…, Xp are the original variables.

Secondly, the ratio of the feature value corresponding to each principal component to the sum of the total feature value of the extracted principal components is used as the weight to calculate the principal component synthesis model:

$$\mathrm{F} = \frac{\lambda_1}{\lambda_1+\lambda_2+\cdots\lambda_p}F_1 + \frac{\lambda_2}{\lambda_1+\lambda_2+\cdots\lambda_p}F_2 + \cdots + \frac{\lambda_n}{\lambda_1+\lambda_2+\cdots\lambda_p}F_n \quad (4)$$

Result and discussion

Questionnaire design and descriptive statistics

The questionnaire was designed according to the 43 risk indicators in Table 1, and the Likert scale was used for assignment. The "lowest risk", "low risk", "medium risk", "high risk" and "highest risk" are assigned points 1, 2, 3, 4, and 5 respectively. The questionnaire was sent to PPP project companies, governments, consulting companies, and major teaching and scientific research units that have participated in PPP projects through electronic questionnaires, using the "snowball" method to expand the interview. The survey started in October 2019, and after 3 months, the questionnaire survey was implemented well.

A total of 110 questionnaires were returned, of which 1 questionnaire that was unqualified due to inconsistencies in the questionnaire responses was eliminated. A total of 109 valid questionnaires were obtained, with a response rate of 99%. Respondents in the sample have worked for an average of 8.2 years and have participated in a number of PPP projects, involving 19 industries, with a total of 168 frequent participations. Among the participating industries, municipal engineering participated in the most frequently, with a frequency of 17.86%, followed by the transportation industry, with only one person participating in forestry. It can be seen that the interviewees have rich experience in PPP projects to ensure the reliability of the data (Table 2).

Table 2 Respondents' participation in PPP projects involving industries

Industry	Quantity	Frequency	Industry	Quantity	Frequency
Municipal Engineering	30	17.86%	Affordable housing project	6	3.57%
Transportation	22	13.10%	Social Security	5	2.98%
Ecological construction and environmental protection	15	8.93%	Pension	4	2.38%
Government infrastructure	15	8.93%	Technology	3	1.79%
Education	12	7.14%	Energy	2	1.19%
Comprehensive Town Development	12	7.14%	Physical education	2	1.19%
Water conservancy construction	10	5.95%	Agriculture	2	1.19%
Medical hygiene	9	5.36%	Other	2	1.19%
Tourism	9	5.36%	Forestry	1	0.60%
Culture	7	4.17%	Total	168	100.00%

According to the reliability analysis of Cronbach's Alpha, the overall value of Cronbach's α is 0.934, which is greater than 0.9. Cronbach's α of "full cycle stage risk evaluation", "identification stage risk evaluation", "implementation stage risk assessment", "franchise stage risk assessment", and "non-franchise stage risk assessment" are all between 0.772 and 0.895, reaching A critical value of 0.7 indicates good reliability; the combined reliability CR value of the four variables is between 0.703 and 0.8016, exceeding the critical value 0.7, indicating good reliability; the average extracted variance AVE value of the four variables is 0.604 to 0.728 Time, exceeding the critical value of 0.5, indicating that the convergence validity of the four variables is better. In summary, the survey data is very reliable (Table 3).

Table 3 Reliability and validity test

Variable	Cronbach's α	CR	AVE
Overall questionnaire	0.934	0.872	0.604
Risk Assessment Questionnaire	0.772	0.706	0.654
Risk Assessment Questionnaire at the Identification Stage	0.787	0.715	0.658
Risk Assessment Questionnaire at the Implementation Stage	0.844	0.723	0.635
Risk Evaluation Questionnaire at Franchising Stage	0.895	0.801	0.725
Risk Evaluation Questionnaire at the Non-Franchise Stage	0.844	0.703	0.728

The reliability and validity of the questionnaire was tested by SPSS24.0. The independent variables are "Risk Evaluation in the Whole Cycle Stage", "Risk Evaluation in the Identification Stage", "Risk Evaluation in the Implementation Stage", "Risk Evaluation in the Franchise Stage", and "Risk in the Non-franchise Stage" Evaluation" five variables. Through KMO and Bartlett test, the KMO value is 0.891, and the significance test sig value is 0.000, indicating that the validity of the questionnaire is very high, and factor analysis is suitable. In the questionnaire with secondary indicators, the minimum KMO value is between 0.725 and 0.859, all exceeding the standard of 0.7, indicating that the questionnaire is valid (Table 4).

Table 4 KMO and Bartlett test

Variable	KMO	sig
Overall questionnaire	0.891	0.000
Risk Assessment Questionnaire	0.725	0.000
Risk Assessment Questionnaire at the Identification Stage	0.759	0.000
Risk Assessment Questionnaire at the Implementation Stage	0.756	0.000

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Risk Evaluation Questionnaire at Franchising Stage	0.859	0.000
Risk Evaluation Questionnaire at the Non-Franchise Stage	0.857	0.000

Analysis of the full-cycle risk assessment of PPP project of comprehensive environmental governance

The political risk, legal risk, environmental risk, and force majeure risk in the comprehensive environmental governance PPP project are risks throughout the entire project cycle, which have a great impact on the entire project. Therefore, a separate risk assessment is carried out. Through SPSS24.0 software the dimension of the data are to reduced, and a total of 9 components are obtained in all indicators, which can represent the value of the original data. Component values observed features, extracted four eigenvalues greater than 1 of the component, the cumulative contribution rate derived e. The cumulative contribution rate reaches 83.025%, and the contribution rate is greater than 80%. It has a high degree of reliability, indicating that these four components can already reflect the information of the data. Therefore, the first 4 components can be used as principal components to evaluate the risk of the whole cycle (Table 5). The four principal components were extracted as F1, F2, F3, F4, and their characteristic values were 3.676, 2.548, 1.906, and 1.003. The contribution rates are 33.422%, 23.161%, 17.327%, 9.115%, and the total contribution rate reaches 83.025%. Principal component analysis can be performed (Table 6).

Table 5 Total variance explained

Component	Initial Eigenvalues			Extract the sums of squared loadings			Rotate the sums of squared loadings		
	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %
1	3.676	33.422	33.422	3.676	33.422	33.422	2.79	28.36	33.422
2	2.548	23.161	56.583	2.548	23.161	56.583	2.135	26.413	56.583
3	1.906	17.327	73.91	1.906	17.327	73.91	1.45	16.181	73.91
4	1.003	9.115	83.025	1.003	9.115	83.025	1.238	12.071	83.025
5	0.624	5.676	88.701						
6	0.462	4.201	92.902						
7	0.336	3.057	95.959						
8	0.267	2.425	98.383						
9	0.178	1.617	100						

Table 6 Extracting principal components and eigenvalues

Component	F1	F2	F3	F4	Cumulative
Eigenvalues（λ）	3.676	2.548	1.906	1.003	
Cumulative （%）	33.422	23.161	17.327	9.115	83.025

The data is subjected to principal component loading matrix analysis (Table 7, "Principal component loading number"). X2, X3, X4, X5, X6, X7, X11 in F1 have extremely significant relationships, and the correlation is very strong, indicating these risks overlap in information. At the same time, the load numbers of these indicators are very high, indicating that the first principal component basically reflects the information of these indicators. In the same way, X8 and X9 in F2 can reflect indicator information. Both X10 in F3 and X1 in F4 can reflect indicator information.

There are three steps to calculate the weight of risk factors. The first step is to calculate the combination coefficient of the principal component, and divide the load number of the corresponding risk index by the square root of the characteristic value of the principal component, which can be seen in Table 7 "Combination coefficient of principal components". Then establish a principal component mathematical model based on the combination coefficient.

$$F1=0.167X1+0.351X2+0.380X3\ldots+0.247X9+0.168X10+0.312X11 \quad (5)$$

$$F2=-0.310X1-0127X2-0.256X3\ldots+0.324X9+0.184X10-0.249X11 \quad (6)$$

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F3=0.105X1+0.020X2-0.085X3…+0.287X9+0.565X10-0.153X11 （7）

F4=0.669X1-0.021X2+0.100X3…+0.399X9-0.147X10-0.322X11 （8）

$$\mathrm{F} = \frac{\upsilon_1}{\upsilon_1+\upsilon_2+\cdots\upsilon_n}F_1 + \frac{\upsilon_2}{\upsilon_1+\upsilon_2+\cdots\upsilon_n}F_2 + \cdots + \frac{\upsilon_n}{\upsilon_1+\upsilon_2+\cdots\upsilon_n}F_n \quad (9)$$

The second step is to calculate the comprehensive score for each risk factor. In the formula, υ_n(n=1,2,3…) represents the variance contribution rate of the extracted principal components. In this model, 4 principal components are extracted, namely n=4. Calculate the risk variables separately to get the comprehensive score of each indicator. Taking "X1" as an example, the comprehensive score = 33.422/83.025*0.167+23.161/83.025*(-0.310)+17.327/83.025*0.105+9.115/83.025*0.669=0.103. By analogy, a comprehensive score of all risk factors is obtained.

The third step is to normalize the weights of the comprehensive scores of all risk factors to obtain their respective weights. According to the data, the environmental pollution risk (X9) has the highest weight. Because China's requirements for environmental protection are becoming stricter, it is also necessary to pay attention to environmental protection when implementing PPP projects for comprehensive environmental governance. The second is the risk caused by natural disasters (X10), because once the risk of natural disasters occurs, the damage it would brings is unimaginable. The government corruption risk (X4) has the lowest weight, indicating that my country’s anti-corruption work has truly been implemented. When implementing the PPP project of comprehensive environmental governance, there is no need to worry too much about the risks of government officials’ corruption.

Table 7 Principal component loads, combination coefficients, comprehensive scores and risk weights in the full cycle stage

Variable	Principal component loadings				Principal component combination coefficient				Composite scores	Factor weight
	F1	F2	F3	F4	F1	F2	F3	F4		
X1	0.32	-0.494	0.145	0.67	0.167	-0.31	0.105	0.669	0.103	0.053
X2	0.674	-0.202	0.027	-0.021	0.351	-0.127	0.02	-0.021	0.136	0.074
X3	0.728	-0.408	-0.117	0.1	0.38	-0.256	-0.085	0.1	0.109	0.052
X4	0.594	-0.325	-0.226	-0.018	0.31	-0.204	-0.164	-0.018	0.058	0.022
X5	0.671	0.366	-0.048	0.004	0.35	0.229	-0.035	0.004	0.226	0.137
X6	0.738	0.032	-0.02	-0.47	0.385	0.02	-0.014	-0.469	0.127	0.073
X7	0.638	0.269	-0.311	0.188	0.333	0.168	-0.225	0.188	0.188	0.107
X8	0.389	0.674	-0.424	0.034	0.203	0.422	-0.307	0.034	0.159	0.096
X9	0.473	0.517	0.397	0.399	0.247	0.324	0.287	0.399	0.318	0.203
X10	0.323	0.293	0.78	-0.147	0.168	0.184	0.565	-0.147	0.224	0.152
X11	0.598	-0.429	0.211	-0.323	0.312	-0.269	0.153	-0.322	0.063	0.032

Risk assessment analysis of PPP project identification stage of comprehensive environmental governance

According to the risk analysis method of the whole cycle stage to analyze the risk in the identification stage, the SPSS24.0 software obtains 3 components with characteristic values greater than 1, which become the principal components. The three principal components were extracted as F1, F2, and F3, and their characteristic values were 3.414, 2.143, and 1.779. The contribution rates were 37.934, 23.900, and 19.673 respectively. The total contribution rate reached 81.507%, and the cumulative contribution rate exceeded 80%. The components can reflect the information of the indicators, and principal component analysis can be performed (Table 8).

Table 8 Extracting principal components and eigenvalues

Component	F1	F2	F3	Cumulative
Eigenvalues（λ）	3.414	2.143	1.779	
Cumulative （%）	37.934	23.900	19.673	81.507

According to the weight analysis method of the whole cycle, the risk weight of the identification stage is obtained (Table 9). In the identification stage of a comprehensive environmental governance PPP project, there are three main types of risks:

land acquisition, project approval delays, and financing. The highest risk weight is the difficulty of project approval (X14). Because the approval process is very complicated and involves a wide range of areas, this risk has the highest weight. The second is work efficiency risk (X16). If work efficiency is low, it will inevitably increase the risk of approval delays and affect each other. The risk of investment expected return (X17) has the lowest weight. The comprehensive environmental governance PPP project has conducted a lot of research and investigation and the calculation of investment income in the early stage, with all factors that affect investment income taken into account, so such risks have the lowest impact.

Table 9 Principal component loads, combination coefficients, comprehensive scores and risk weights in the full cycle stage

Variable	Principal component loadings			Principal component combination coefficient			Composite scores	Factor weight
	F1	F2	F3	F1	F2	F3		
X12	0.657	0.076	0.314	0.355	0.052	0.235	0.237	0.165
X13	0.559	-0.526	0.383	0.302	-0.359	0.287	0.105	0.073
X14	0.640	0.304	0.545	0.346	0.207	0.409	0.321	0.223
X15	0.380	0.788	0.002	0.206	0.538	0.002	0.254	0.177
X16	0.579	0.263	-0.381	0.313	0.179	-0.285	0.129	0.090
X17	0.758	0.084	-0.280	0.411	0.057	-0.210	0.157	0.109
X18	0.650	-0.057	-0.065	0.352	-0.039	-0.049	0.140	0.098
X19	0.656	-0.200	-0.335	0.355	-0.136	-0.251	0.065	0.045
X20	0.595	-0.499	-0.126	0.322	-0.341	-0.094	0.027	0.019

Analysis of Risk Assessment in the Implementation Phase of PPP Project of Comprehensive Environmental Treatment

According to the principal component analysis method to analyze the risks in the implementation stage, the SPSS24.0 software obtains 3 components with characteristic values greater than 1, which become the principal components. The three principal components are extracted as F1, F2, and F3, and their characteristic values are 5.451, 2.670, and 2.002 respectively. The contribution rates were 45.421, 22.247, 16.680, the total contribution rate reached 84.348%, and the cumulative contribution rate exceeded 80%. These principal components can reflect the information of the index, and principal component analysis can be performed (Table 10).

Table 10 Extracting principal components and eigenvalues

Component	F1	F2	F3	Cumulative
Eigenvalues（λ）	5.451	2.670	2.002	
Cumulative （%）	45.421	22.247	16.680	84.348

According to the principal component analysis method, the risk weights at the implementation stage are obtained (Table 11). In the implementation phase of the PPP project of comprehensive environmental governance, there are mainly four types of risks including financing, construction, supply, and technology. The highest risk weight is the completion risk (X22). Due to the long construction period and large variables, this risk has the highest weight. The second is engineering quality risk (X21). The design unit's qualification risk (X27) has the lowest weight, and the PPP project of comprehensive environmental governance generally selects design units with certain performance and experience for design. Therefore, such risks have the lowest impact.

Table 11 Principal component loads, combination coefficients, comprehensive scores and risk weights in the full cycle stage

Variable	Principal component loadings			Principal component combination coefficient			Composite scores	Factor weight
	F1	F2	F3	F1	F2	F3		
X17	0.390	0.720	-0.031	0.167	0.441	-0.022	0.202	0.115
X18	0.428	0.641	-0.276	0.183	0.392	-0.195	0.164	0.093
X19	0.692	0.166	-0.463	0.296	0.102	-0.327	0.122	0.070
X20	0.656	0.232	0.214	0.281	0.142	0.151	0.194	0.111

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X21	0.667	0.183	0.185	0.285	0.112	0.130	0.209	0.119
X22	0.524	0.244	0.490	0.224	0.150	0.347	0.229	0.131
X23	0.546	-0.452	0.417	0.234	-0.276	0.295	0.111	0.064
X24	0.798	-0.169	0.053	0.342	-0.103	0.038	0.164	0.094
X25	0.790	-0.071	-0.102	0.338	-0.043	-0.072	0.157	0.089
X26	0.661	-0.321	-0.551	0.283	-0.196	-0.389	0.024	0.014
X27	0.540	-0.595	-0.282	0.231	-0.364	-0.200	0.011	0.006
X28	0.585	-0.187	0.434	0.251	-0.114	0.307	0.165	0.094

Risk Assessment Analysis of PPP Project Concession Management Stage of Comprehensive Environmental Treatment

According to the principal component analysis method to analyze the risk in the franchise stage, the SPSS24.0 software obtains three components with characteristic values greater than 1, which become the principal components. The three principal components are extracted as F1, F2, and F3, and their characteristic values are 5.862, 2.280, 2.087 respectively. The contribution rates were 48.849, 18.996, and 17.392 respectively. The total contribution rate reached 85.237%, and the cumulative contribution rate exceeded 80%. These principal components can reflect the information of the index, and principal component analysis can be performed (Table 12).

Table 12 Extracting principal components and eigenvalues

Component	F1	F2	F3	Cumulative
Eigenvalues（λ）	5.862	2.280	2.087	
Cumulative （%）	48.849	18.996	17.392	85.237

According to the principal component analysis method, the risk weight of the franchise stage is obtained (Table 13). In the concession stage of the PPP project of comprehensive environmental governance, there are mainly five types of risks such as demand, operation, finance, interest rate, and inflation. The highest risk weight is the risk of interest rate fluctuations (X38). Due to the long operating period, generally a 30-year franchise period, the fluctuation of interest rates is relatively large, and the resulting benefits will also fluctuate. Therefore, Interest rate fluctuation risk has the highest weight; and the second is the financial market stability risk (X39). This category is also regulated by the state. It cannot be changed and can only be dealt with. All risks are also relatively large. Operation and maintenance cost risk (X33) has the lowest weight. The companies selected for the comprehensive environmental governance PPP project have a very complete operating system and a complete system, so the impact of such risks is the lowest.

Table 13 Principal component loads, combination coefficients, comprehensive scores and risk weights in the full cycle stage

Variable	Principal component loadings			Principal component combination coefficient			Composite scores	Factor weight
	F1	F2	F3	F1	F2	F3		
X29	0.446	0.551	-0.047	0.184	0.365	-0.033	0.180	0.088
X30	0.525	0.677	-0.224	0.217	0.448	-0.155	0.193	0.093
X31	0.720	0.024	0.255	0.297	0.016	0.177	0.210	0.102
X32	0.749	-0.470	0.249	0.309	-0.311	0.173	0.143	0.069
X33	0.754	-0.403	-0.372	0.311	-0.267	-0.258	0.066	0.032
X34	0.751	-0.290	0.029	0.310	-0.192	0.020	0.139	0.067
X35	0.785	-0.253	-0.379	0.324	-0.167	-0.262	0.095	0.046
X36	0.857	-0.109	-0.123	0.354	-0.072	-0.085	0.169	0.082
X37	0.700	0.329	-0.416	0.289	0.218	-0.288	0.156	0.075
X38	0.730	0.181	0.391	0.301	0.120	0.271	0.255	0.124
X39	0.812	0.185	0.191	0.336	0.123	0.132	0.247	0.120
X40	0.378	0.092	0.744	0.156	0.061	0.515	0.208	0.101

Risk Assessment and Analysis of the Non-concession Operation Phase of the PPP Project of Comprehensive Environmental Treatment

According to the principal component analysis method to analyze the risk in the franchise stage, the SPSS24.0 software obtains 2 components with characteristic values greater than 1, which become the principal components. The two principal components extracted are F1 and F2, and their characteristic values are 3.418 and 1.540 respectively. The contribution rates were 56.960 and 25.665, the total contribution rate reached 82.625%, and the cumulative contribution rate exceeded 80%. These principal components can reflect the information of the indicators, and principal component analysis can be performed (Table 14).

Table 14 Extracting principal components and eigenvalues

Component	F1	F2	F3	Cumulative
Eigenvalues （λ）	5.862	2.280	2.087	
Cumulative （%）	48.849	18.996	17.392	85.237

According to the principal component analysis method, the risk weight of the franchise stage is obtained (Table 15). In the non-concession stage of the comprehensive environmental governance PPP project, there are mainly two types of risks: operation and residual value. The highest risk weight is the franchise signing period risk (X41). Due to the long operating period, it is generally a 30-year franchise period and will be transferred after 30 years. Great changes have taken place in the policy environment and economic environment in the past 30 years. No experts and scholars can predict the future economic environment. Therefore, this risk has the highest weight; followed by the risk of operational management experience capability (X42), and the risk of expected operating returns has the lowest weight. The comprehensive environmental governance PPP project has considered a long-term benefit when designing the benefit, so this kind of risk has the lowest impact.

Table 15 Principal component loads, combination coefficients, comprehensive scores and risk weights in the full cycle stage

Variable	Principal component loadings		Principal component combination coefficient		Composite scores	Factor weight
	F1	F2	F1	F2		
X32	0.819	-0.022	0.443	-0.017	0.300	0.173
X33	0.825	-0.371	0.446	-0.299	0.215	0.123
X34	0.798	-0.363	0.432	-0.292	0.207	0.119
X41	0.577	0.669	0.312	0.539	0.383	0.220
X42	0.700	0.429	0.379	0.346	0.368	0.212
X43	0.779	-0.093	0.421	-0.075	0.267	0.153

Conclusion and recommendations

The four stages in the full life cycle of a comprehensive environmental governance PPP project have different risks, and some risks run through the entire project. By constructing an index system and using principal component analysis, the main risks of each stage are obtained, so as to facilitate avoidance and prevention.

The full-cycle risks of PPP projects for comprehensive environmental governance include political risks, legal risks, environmental risks, and force majeure risks, with a total of 11 risk indicators. With the help of SPSS24.0 software, the dimensionality reduction of 11 risk indicators is performed first, and then the principal component analysis is performed to obtain the weight of each indicator. It can be seen from the results that environmental pollution risks and force majeure analysis risks have the greatest impact, and government corruption analysis has the lowest impact.

The risks in the identification stage of a comprehensive environmental governance PPP project mainly include land acquisition risk, project approval delay risk, and financing risk. There are a total of 9 risk indicators. Through principal component analysis, the weight of each indicator is obtained, and it is found that the risk of project approval difficulty and the work efficiency risk of functional departments at this stage have the greatest impact, and the risk of investment income has the lowest impact.

The risks in the implementation stage of the comprehensive environmental governance PPP project mainly include financing risks, construction risks, supply risks, and technical risks, with a total of 12 risk indicators. Through principal component analysis, the weight of each indicator is obtained. It is found that the completion risk and project quality risk in this stage have the greatest impact, while the qualification risk of the design unit has the lowest impact.

The risks in the franchise stage of comprehensive environmental governance PPP projects mainly include demand risk, operational risk, financial risk, foreign exchange and interest rate risk, and inflation risk, with a total of 12 indicators. The weights are obtained through principal component analysis, and it is known that the risk of interest rate and financial fluctuation has the greatest impact, while the risk of operation and maintenance has the lowest impact.

The non-concession risk of comprehensive environmental governance PPP project mainly includes operation and residual value risk, and there are a total of 6 risk indicators. Through principal component analysis, the weights of six indicators are obtained. It is known that the franchise life and the operational capability risk after the transfer have the greatest impact, while the expected return has the lowest risk impact.

Based on the research conclusions, our research team made relevant recommendations. First of all, the external environmental risks of the PPP project of comprehensive environmental governance mainly focus on the environmental risks, policy risks, interest rate risks, financial fluctuation risks and force majeure risks of the project implementation. Only in the implementation of comprehensive environmental governance PPP projects, intensify in-depth research on the hazards caused by such risks, and prepare corresponding risk emergency plans to minimize losses when risks come. Secondly, before the identification stage of the comprehensive environmental governance PPP project, in conjunction with the specific situation of the comprehensive environmental governance PPP project, in conjunction with the specific situation of the comprehensive environmental governance PPP project, the drafted contracts are studied one by one to standardize the legal compliance of bidding and procurement. To stipulate the rights and obligations of the government, social capital and third parties, and incorporate all possible risks into the contract as much as possible. Ensure that prevarication occurs when risks occur, as well as incomplete contract performance and postponement due to unclear contract during implementation. Finally, most of the final use rights of the comprehensive environmental governance PPP project belong to the government. The project company operates during the cooperation period and needs to be transferred to the government after the cooperation period. Therefore, it is necessary to strengthen the subsequent management of the transfer of the comprehensive environmental governance PPP project, so that the comprehensive environmental governance PPP project can continue to operate, and provide various facilities and guarantees for the society.

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