Life Cycle Risk Assessment of Public-Private Partnership Project of Comprehensive Environmental Management Based on Principal Component Analysis

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ABSTRACT

Public-private partnership (PPP) projects remain one of the key initiatives of the Chinese government. The key characteristics of the PPP projects include the long construction period and large investment amount, while constant monitoring is required to determine the risks of the projects within a comprehensive environmental management framework. Over the years, the government has used the PPP model to implement various projects, capitalizing on a few methods to assess the riskiness of the entire life cycle of the comprehensive environmental PPP projects. However, we argue that the principal component analysis (PCA) can be used to determine the various factors that may have a high influence on the risk potential of PPP projects. In fact, it plays an important role in ensuring the smooth implementation of projects while reducing the losses caused by various risks. According to the risk factors of the whole life cycle of the comprehensive environmental governance PPP project, an indicator system of five first-level indicators, 18 second-level indicators, and 43 third-level indicators has been established. Principal component analysis is used to analyze the influence and 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 based on the risk factors at each stage of the comprehensive environmental management PPP project. Building on this, we argue that the ability to resist any PPP projects with higher risk can be improved, thus ensuring a smooth implementation of the project while promoting the long-term development of comprehensive environmental management PPP projects in the future.

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1. INTRODUCTION

A PPP project is a cooperative mode between the government and social capital initiatives. The government uses the capital advantage of social capital to alleviate and solve the problem of insufficient public goods (Puneet K., Piyush V., and Lalit A., 2021). Since China started its PPP project in 2014, cooperation between government and social capital initiatives has reduced the government's financial burden, improved the operational efficiency of public works, and shared, or attenuated, various risks (Shen, YC. 2016). By the end of June 2021, 10,126 PPP projects in China had entered PPP project management centers, with a cumulative investment of 15.9583 trillion yuan involving 19 industries. Among all of these projects, municipal PPP projects are the most common, totaling 4,138 with an investment of 4,545.3 billion yuan (Ministry of Finance, 2020). PPP projects for ecological construction and environmental protection rank third in terms of the number of projects in all industries, totaling 956 with an investment of 1,177.4 billion yuan (Ministry of Finance, 2021). Given China's new urbanization, rural agricultural modernization, and other vigorous development, it is bound to cause certain damage to the ecological environment. Therefore, the report of the 19th National Congress once again proposed to "accelerate the reform of the ecological civilization system and build an environmental governance system dominated by the government, dominated by enterprises, and jointly participated in by social organizations and the public" (Xi, JP,. 2017). Up until now, PPP projects in ecological construction and environmental protection have led to huge investments, numerous participants, complicated processes, and long construction and operation cycles, resulting in numerous and complex risks to these projects (Tan, LB., 2018). Therefore, a PPP project devoted to ecological construction and environmental protection needs to accurately predict and evaluate various potential risks to ensure the smooth implementation of the project. In this study, principal component analysis (PCA) is used to carry out a risk assessment for each stage of the entire life cycle of PPP projects under comprehensive environmental governance, and the risk impact weight of each stage is also evaluated. The focus is on key risk factors in real time to minimize the losses caused by risks and ensure the successful completion of PPP projects under comprehensive environmental governance throughout the life cycle. The study of the risk assessment of the entire life cycle of the PCA-based comprehensive environmental governance PPP project has both theoretical and practical implications.

A public-private partnership (PPP) is a mode of cooperation between the public sector and private enterprises. It uses the 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, PXW, 2008). The PPP model solves the funding difficulties for the government and, at the same time, shares the risks of the project with the social capital party (Doloi, 2007). The method of PPP project risk assessment originated abroad. Through the risk assessment of the Skye Bridge project in the United Kingdom, the risks of the construction and operational periods to the social capital party are judged, and further qualitative research is carried out (Pete Moles, 1995). The risk assessment model established by Cheng's team uses the Delphi method, the fuzzy mathematics method, and the AHP method to conduct a risk assessment and applies it to Taiwan's BOT projects (Cheng JH, 2001). PPP project risks exist both in the micro-environment of the project itself and in the macro-environment (Martin L, 2007). There are many methods for evaluating PPP project risks, such as the fuzzy comprehensive evaluation method of PPP project risk assessment (Chen JW, et al., 2006) and the network analytic method of PPP project risk assessment (Zhang W, et al., 2012). The gray correlation theory method of PPP project risk assessment has also been explored (Jia LL, et al., 2013). Using the PCA method, the risks of PPP projects were studied by Lu, who constructed the PCA method and empirically conducted 10 PPP projects in Zhejiang Province, concluding that the predictions are consistent with actual risks (Lu XQ, et al., 2017). Zhang combined this with PCA research on the risks of low-rent housing PPP projects, predicting the risks (Zhang GH, 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 K, 2019). Throughout the literature, few experts and scholars, both 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. This study will use the principal component analysis method to integrate the risks of the entire life cycle of the comprehensive environmental management PPP project and conduct a risk assessment of the entire process. In this way, the risk loss at each stage is minimized, and it also provides new ideas and methods for the risk assessment and management of the PPP project's comprehensive environmental management.

2. MATERIALS AND METHODS

2.1. CONSTRUCT RISK INDEX SYSTEM

Based on theoretical research and a 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 a PPP project with comprehensive environmental governance includes the identification stage, the implementation stage, the franchise stage, and the non-franchise stage (Zhang YT, Cai ZH, & Yao Y, 2020). In the PPP project for comprehensive environmental governance, some risks span the entire project, and this study separately sets such risks as the first-level index. Therefore, there are five first-level indicators: 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).

PRIMARY INDEX	SECONDARY INDEX	TERTIARY INDEX	VARIABLE
Full cycle stage	Political risks	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 risks	Environmental pollution risk	X9
	Force majeure risks	Likelihood risk of natural disaster	X10
		Risk the possibility of policy changes	X11
Identification stage	Land acquisition risks	Resettlement degree of difficulty risk	X12
		Inappropriate siting risk	X13
	Project approval delay risks	Project approval difficulty level risk	X14
		Functional department work efficiency risk	X15
		Project staff efficiency risk	X16
	Financing risks	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 risks	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 risks	Engineering quality risk	X21
		Completion risk	X22
		Project construction change risk	X23
	Supply risks	Supplier qualification requirements risk	X24
		Risk of procurement difficulty	X25
		Risk of perfecting quality inspection system	X26
	Technology risks	Design unit qualification risk	X27
		Design document technical requirements risk	X28

(Contd.)

PRIMARY INDEX	SECONDARY INDEX	TERTIARY INDEX	VARIABLE
Franchise stage	Demand risks	Macroeconomic change risk	X29
		Demographic change risk	X30
		Competitive risk of similar projects	X31
	Operational risks	Operational management level risk	X32
		Operation and maintenance cost risk	X33
		Operational expected return risk	X34
	Financial risks	Financial management system risk	X35
		Financial expense control system risk	X36
	Foreign exchange and interest rate risks	Exchange rate fluctuation risk	X37
		Interest rate fluctuation risk	X38
	Inflation risks	Financial market stability risk	X39
		Inflation rate risk	X40
Non-franchising stage	Operational risks	Operational management level risk	X32
		Operation and maintenance cost risk	X33
		Operational expected return risk	X34
	Residual value risks	Franchise signing period risk	X41
		Operation management experience capability risk	X42
		Operation management system to improve risks	X43

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

2.2. CONSTRUCTION OF PRINCIPAL COMPONENT MODEL

Principal component analysis (PCA) is undertaken 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 (Pan XN, Wang L, 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, the more F1 is considered the first principal component. If the first principal component cannot reflect the information from all of the original indicators, the second principal component must be selected to continue to reflect the original data information. 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,..., and P-th principal components will be extracted (Zhu GH, 2015).

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

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

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

...

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

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

Second, 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 by which to calculate the principal component synthesis model:

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

2.3. 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 (Zainudin A, Asyraf A & Mustafa M, 2016). 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 upon the interview. The survey began in October 2021, and after three months, the questionnaire survey had been widely implemented.

A total of 110 questionnaires were returned, of which one questionnaire was eliminated due to inconsistencies in the questionnaire responses. 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, for a total of 168 frequent participations. Among the participating industries, municipal engineering participated the most frequently, with a frequency rate of 17.86%, followed by the transportation industry. At the other end of the spectrum, only one person participated in forestry. It can be seen that the interviewees have rich experience in PPP projects, thereby ensuring the reliability of the data (Table 2).

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, which indicates strong reliability (Akinyi, OP, Rambo, CM, & Ndiritu, A. 2019). The combined reliability CR value of the four variables is between 0.703 and 0.8016, exceeding the critical value of 0.7 and indicating good reliability. The average extracted variance (AVE) value of the four variables is between 0.604 and 0.728, exceeding the critical value of 0.5, which indicated that the convergence validity of the four variables is stronger. In summary, the survey data is very reliable (Table 3).

The reliability and validity of the questionnaire were tested using SPSS 24.0. 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 Evaluation in the Non-franchise stage." In terms of the KMO and Bartlett tests, 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 (Akintayo O., Godwin O.J. 2017). In the questionnaire with secondary indicators, the minimum KMO value is between 0.725 and 0.859, which exceeds the standard of 0.7, indicating that the questionnaire is valid (Table 4).

3. RESULT AND DISCUSSION

3.1 ANALYSIS OF THE FULL-CYCLE RISK ASSESSMENT OF PPP PROJECT OF COMPREHENSIVE ENVIRONMENTAL MANAGEMENT

The political risk, legal risk, environmental risk, and force majeure risk in the comprehensive environmental

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%

Table 2 Respondents' participation in PPP projects involving industries.

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 the Franchising Stage	0.895	0.801	0.725
Risk Evaluation Questionnaire at the Non-Franchise Stage	0.844	0.703	0.728

Table 3 Reliability and validity test.

management PPP project are risks that are present throughout the entire project cycle. Thus, they have a greater impact on the entire project. Therefore, a separate risk assessment is carried out. Using SPSS24.0 software, the dimension of the data is reduced, and a total of nine components are obtained in all indicators, which can represent the value of the original data. Component values observed features and extracted four eigenvalues of the component greater than one. The cumulative contribution rate was also derived. The cumulative contribution rate reached 83.025%, and the contribution rate was greater than 80%. This represents a high degree of reliability, indicating that these four components can reflect the information in the data. Therefore, the first four components can be used as principal components to evaluate the risk of the entire cycle (Table 5). The four principal components were extracted as F1, F2, F3, and F4, and their characteristic values were 3.676, 2.548, 1.906, and 1.003. The contribution rates were 33.422%, 23.161%, 17.327%, and 9.115%, respectively, and the total contribution rate reached 83.025%. Principal component analysis can be performed (Table 6).

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

There are three steps to calculating the weight of risk factors. The first step is to calculate the combination coefficient of the principal component and divide the

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

Table 4 KMO and Bartlett test.

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 5 Total variance explained.

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

Table 6 Extracting principal components and eigenvalues.

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." We then establish a principal component mathematical model based on the combination coefficient.

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

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

$$F3 = 0.105X1 + 0.020X2 - 0.085X3 \ldots + 0.287X9 + 0.565X10 - 0.153X11 \quad (7)$$

$$F4 = 0.669X1 - 0.021X2 + 0.100X3 \ldots + 0.399X9 - 0.147X10 - 0.322X11 \quad (8)$$

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

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, four principal components are extracted: namely, n = 4. The risk variables are separately calculated to obtain 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 management. The second is the risk caused by natural disasters (X10), because once the risk of natural disasters is realized, the resulting damage is unimaginable. The government corruption risk (X4) has the lowest weight, indicating that China's anti-corruption work has truly been implemented. When implementing the PPP comprehensive environmental governance project, there is no need to worry too much about the risks of government officials' corruption.

3.2. RISK ASSESSMENT ANALYSIS OF PPP PROJECT IDENTIFICATION STAGE OF COMPREHENSIVE ENVIRONMENTAL MANAGEMENT

According to the risk analysis method of the entire cycle stage, to analyze the risk in the identification stage, the SPSS24.0 software obtains three components with characteristic values greater than one, 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 from the indicators, and principal component analysis can be performed (Table 8).

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

Table 8 Extracting principal components and eigenvalues.

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

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

According to the weight analysis method for the entire cycle, the risk weight of the identification stage is obtained (Table 9). In the identification stage of a comprehensive environmental management PPP project, there are three main types of risk: 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. The risk of expected investment return (X17) has the lowest weight. The comprehensive environmental governance PPP project has conducted a significant research and investigation, including the calculation of investment income in the early stages, with all factors that affect investment income taken into account, so such risks have the lowest impact.

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

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 for comprehensive environmental management, there are primarily four types of risk: financing, construction, supply, and technology. The highest risk weight is the completion risk (X22). Due to the long construction period and significant 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 comprehensive environmental management project generally selects design units with certain performance and experience measures in design. Therefore, such risks have the lowest impact.

3.4. 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 were extracted as F1, F2, and F3, and their characteristic values were 5.862, 2.280, and 2.087. 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 in the index, and principal component analysis can be performed (Table 12).

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

Table 10 Extracting principal components and eigenvalues.

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

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

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 for comprehensive environmental management, there are primarily five types of risk: demand, operations, finance, interest rates, 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 highest is financial market stability risk (X39). This category is also regulated by the state. It cannot be changed and can only be dealt with. All of the risks are also relatively large. Operational and maintenance cost risk (X33) has the lowest weight. The companies selected for the comprehensive environmental management PPP

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

Table 12 Extracting principal components and eigenvalues.

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
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

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		
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

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

project have a very complete operating system, so the impact of such risks is the lowest.

3.5. 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 two components with characteristic values greater than one, which become the principal components. The two principal components extracted were F1 and F2, and their characteristic values were 3.418 and 1.540. The contribution rates were 56.960 and 25.665, respectively. The total contribution rate reached 82.625%, and the cumulative contribution rate exceeded 80%. These principal components can reflect the information from the indicators, and principal component analysis can be performed (Table 14).

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 management PPP project, there are primarily two types of risk: operational 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 that will be transferred after 30 years. Great changes have taken place in the policy environment and the economic environment in the past 30 years. No experts or scholars can predict the future economic environment. Therefore, this risk has the highest weight, followed by the risk of operational management experience capability (X42). The risk of expected operating returns has the lowest weight. The comprehensive environmental management PPP project has considered a long-term benefit when designing the benefit, so this kind of risk has the lowest impact.

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

Table 14 Extracting principal components and eigenvalues.

4. CONCLUSION

The four stages in the full life cycle of a comprehensive environmental management PPP project have different risks, and some risks span throughout the entire project. By constructing an index system and using principal component analysis, the main risks of each stage are identified, thereby facilitating 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 SPSS 24.0 software, the dimensionality reduction of 11 risk indicators is first performed, followed by the principal component analysis to obtain the weight of each indicator. It can be seen from the results that environmental pollution risks and force majeure risks have the greatest impact, and government corruption risks have the lowest impact.

The risks in the identification stage of a comprehensive environmental management PPP project primarily include land acquisition risk, project approval delay risk, and financing risk. There are a total of nine 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, while the risk of investment income has the lowest impact.

The risks in the implementation stage of the comprehensive environmental management PPP project primarily 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 completion risk and project quality risk at this stage have the greatest impact, while the qualification risk of the design unit has the lowest impact.

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

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

The risks in the franchise stage of comprehensive environmental governance PPP projects primarily 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 found that the risk of interest rate and financial fluctuations has the greatest impact, while the risk of operations and maintenance has the lowest impact.

The non-concession risks of the comprehensive environmental management PPP project primarily include operations and residual value risk, with a total of six risk indicators. Through principal component analysis, the weights of the six indicators are obtained. It is found 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 primarily focus on the environmental risks, policy risks, interest rate risks, financial fluctuation risks, and force majeure risks surrounding the project's implementation. Only in the implementation of comprehensive environmental management PPP projects can we intensify our in-depth research on the hazards caused by such risks and prepare corresponding risk emergency plans to minimize losses when risks arise. Second, before the identification stage of the comprehensive environmental management PPP project, in conjunction with the specific situation of the comprehensive environmental management PPP project, the drafted contracts are studied one by one to standardize the legal compliance of bidding and procurement. This is undertaken to stipulate the rights and obligations of the government, social capital parties, and third parties and incorporate all possible risks into the contract as much as possible. It also ensures that prevarication occurs when risks occur, and that incomplete contract performance and postponement due to an unclear contract during implementation are avoided. Finally, most of the final use rights for the comprehensive environmental management PPP project belong to the government. The project company operates during the cooperation period, and its rights are then transferred to the government after the cooperation period.

FURTHER RESEARCH

This study proposes a risk assessment throughout the entire life cycle of environmental comprehensive governance PPP projects. Further research is needed to explore the most applicable risk assessment and application methods.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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