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PPP Project Life Cycle Risk Assessment Model and Its Application Based on AHP

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Abstract: The life cycle risk assessment model and its application of PPP project based on AHP (Analytic Hierarchy Process) were studied. From the whole life cycle point of view, the whole life period of PPP project was divided into the early stage of the project, the project implementation period, the franchise operation period, and the non-franchise period of the project. Moreover, the potential risk factors in each stage were identified and analyzed, and the detailed assignment rules of each risk factor and the PPP project whole life cycle risk assessment index system were set up. Then, by establishing the CIM (Controlled Interval and Memory Models) risk assessment model, the risk degree of the PPP project in each stage was calculated, and the comprehensive evaluation model of the PPP project risk was constructed combined with the analytic hierarchy process. Finally, taking the KH bridge as an example, the empirical simulation of the whole life cycle risk assessment model of the PPP project was carried out. The empirical results showed that the risk of KH bridge project was high, which was consistent with the actual situation of the project.
Keywords: Analytic hierarchy process (AHP), PPP project, risk assessment model, life cycle

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1. INTRODUCTION

In the era of economic globalization in twenty-first Century, in order to speed up the pace of construction of public infrastructure projects to meet the needs of economic construction and development, governments around the world change their own traditional ideas to invest in the construction of public infrastructure, but take into account the investment ability of private enterprises and make private enterprises invest in building the public infrastructure of the country, which can reduce government financial pressure to a certain extent (KRITTIYA SAKSRISATHAPORN et al., 2016). In 1980s, China began to push the construction of public infrastructure projects to social financing gradually. Although there are many kinds of project financing methods, the new project cooperation model of PPP project financing can effectively improve the efficiency and effect of public projects. It has been widely applied to rail transportation, sewage treatment bridge construction and many fields by many countries and its application in many parts of the world has become a trend (Reza, 2015).

The use of PPP project financing model to build public infrastructure projects can not only effectively reduce the financial pressure of the government, alleviate the state of the government's debt economy, adjust the industrial structure of foreign investment and promote the diversification of the investment subject and the reform of the investment system, but also can improve the probability of the success of the project construction and the efficiency of project operation and transfer and relieve the project construction risks (Chan et al., 2014). At the same time, the introduction of foreign investment and construction of public infrastructure projects, to a certain extent, can introduce foreign advanced technology and management experience, which is a great development opportunity for Chinese enterprises. For the Chinese government, it is conducive to the realization of the integration of the international economy (Tsang et al., 2016).

But the PPP project has many characteristics, including numerous participation, high cost of investment, high cost of financing, long construction period and so on. The potential risk factors of PPP project have the characteristics of diversity, phase, and complexity and so on (Reza et al., 2014). Therefore, how to identify, analyze and evaluate these complex and diverse risk factors has become a key issue in the theoretical research on PPP projects. However, the actual application of PPP project financing mode to public infrastructure construction in China is only decades, and the experience accumulated is not much, especially the research on PPP project risk assessment is very insufficient in theory or practice. This paper is based on this research background, trying to explore a kind of risk assessment model to assess the potential risks in the actual project. Through the results of risk assessment, we can determine the risk level of a project and how to effectively warn and prevent risk.

2. LITERATURE REVIEW

Since the British government put forward the concept of PPP project financing for the first time in 1992, many countries in the world have launched an exploration and research on the financing mode of PPP project. Because the PPP project financing mode has the characteristics of large investment scale, high financing structure leverage ratio, various participating parties, long period of investment project construction, extensive involved level and many complicated risk factors, the problem of PPP project risk management becomes the key problem to determine whether the project is built successfully (Petrillo et al., 2016). To this end, the foreign academic fields actively explore and widely study the problems involved in PPP project risk management. These studies mainly adopt the mode of empirical analysis, focusing on the risk assessment and risk sharing of the PPP project. In the aspect of risk assessment, many foreign scholars mainly use sensitivity analysis, Monte Carlo simulation, NPV at-risk (based on the risk value method) to calculate the impact of risk factors on the project target, and get the result of the final impact of various risks on the project (Soloukdar & Parpanchi, 2015). Ahmed and others applied the Value-at-risk method to the PPP project evaluation index NPV in its literature, and obtained the method of calculating the NPV value based on a certain confidence interval to evaluate the project risk - NPV at-risk method. That is, if the project NPV under the set letter level is greater than 0, the project is feasible (Ahmed et al., 2016). Zheng and so on divided the potential risk factors involved in the PPP project into nine categories. Taking the Scotland wastewater treatment plant as an example, the empirical analysis of the project risk assessment was carried out from the perspective of the project sponsors, the government departments and the loan banks by the sensitivity analysis method and Monte Carlo simulation method (Zheng et al., 2014).

The research and application of PPP project risk in China's academia started late. It probably started in the early part of this century and is still in the exploratory stage at present. The existing literature mainly focuses on the risk assessment of PPP projects and the development and application of PPP projects. In the aspect of risk assessment, China's academic circles mainly discuss the application of fuzzy comprehensive evaluation, analytic hierarchy process and Monte Carlo simulation in the project evaluation method in actual projects. Guo and others used Monte Carlo technology to establish a project IRR and NPV evaluation model with engineering investment, income and interest rate as the output variable (Guo et al., 2015). Wang and others introduced the analytic hierarchy process (AHP), established the risk assessment model and compiled the software, and quantitatively analyzed all kinds of risk influencing factors in drilling.

Based on the current research situation at home and abroad above, this paper mainly studies the whole life cycle risk assessment model and its application of PPP project based on AHP (Wang et al., 2014).

3. METHOD

3.1 The principle of setting up the risk assessment index system

Index is a concept that reflects the quantity characteristic of the whole. It only comprehensively reflects the quantity characteristic of the whole in a certain aspect. It can be both the absolute number, and the relative number or the average number. The index system is an organic index combination which is formed on the basis of multiple indicators in a certain application process. It can be more scientific and objective to reflect the overall quantitative characteristics in all aspects (Kull& Talluri, 2015). The risk factor index of PPP project is the specific object of evaluation in the risk assessment of projects. By establishing a set of scientific, objective, systematic and practical risk assessment index system for PPP projects, it can reflect the existing or potential risk factors of the project to a certain extent, so as to assess the risk level of the project and to avoid and prevent all kinds of risks in a reasonable way. To some extent, it can ensure the smooth construction and implementation of the project. According to the specific points of the PPP project, the following principles should be followed in the establishment of the PPP project risk assessment index system.

The principle of scientificalness: the design of the index system of the PPP project risk assessment should fully grasp and reflect the various risk factors that exist in the whole life cycle of the project or the potential risk factors. From the scientific point of view, the risk factors can be identified systematically and accurately. The risk factor index can also accurately reflect the difficulty in achieving the major targets of PPP project. The selected indicators must have clear meaning and clear purpose, so as to ensure the accuracy and objectivity of the evaluation results.

The principle of hierarchy and logic: the index system of PPP project risk assessment should grasp and reflect the hierarchy and logic between each index and it should be clear and logical. Only with distinct level and strong logic can the index system be more scientific and operable. Only such an index system has a greater practical value and the distribution of major and minor risks involved in the project can be clearly reflected. It is beneficial for the project managers to make the more scientific, accurate and reasonable evaluation results.

The principle of completeness and simplicity: the index system of PPP project risk assessment involves a wide range of choices, and it is easy to be influenced by various factors when selecting index factors. Therefore, we should not only ensure the completeness of the selected indicators, but also prevent the indicators from being too general and complicated. In order to ensure the comprehensiveness of the selected indicators, we should identify and analyze the risk factors that exist in the PPP project throughout the life span from a number of aspects, so as to ensure that the established index system covers the risk factors involved in the various stages of the PPP project. In the selection of the number of indicators, the number of indicators should not be too much or too little. If the index is too much, the meaning of each index is easy to produce intersection, which leads to the serious lack of the correlation of the index, and it also increases the difficulty of collecting and sorting out the data. If the index is too little, the system of risk assessment index is difficult to represent and it does not reflect all the risk factors involved in the life cycle of the PPP project.

The principle of dynamic and static: the risk assessment index system of PPP project is not constant. The risk involved in the PPP project runs through the whole life cycle of the project, and in every stage of the project, some risk factors may be added or reduced according to the characteristics and conditions of the project. This requires us to make concrete analysis of specific situations when we formulate the risk assessment index system. The combination of dynamic and static will help us to explore the changing laws of risks involved in PPP projects.

3.2 Construction of risk assessment index system

The potential risk factors at various stages of the PPP project can be classified into different directions in combination with different classification criteria. In this paper, combined with the whole life cycle theory, the potential risk factors are divided into four categories: early stage risk of project, project implementation period risk, project franchise period risk, and project non-franchise period risk, composing of the standard layer of the risk assessment index system. Each two-level index also includes several three-level index for the formation of a substandard layer, thus realizing the construction of risk assessment index system based on the whole life cycle of the PPP project, as shown in Table 1. The index system constructed belongs to a universal index system, which is suitable for all kinds of PPP projects.

Table 1. PPP project whole life cycle risk assessment index system

Standard layer (one-level indexes)	Substandard layer (two-level indexes)		
Early stage risk of project A1	Political and legal risk A11	Government credit risk A12	Market competitive risk A13
	Land acquisition risk A14	Public acceptance risk A15	Force majeure risk A16
	Environmental risk A17	Cost overspending risk A18	Financing risk A19
	Project approval delay risk A110	Private investors choice risk A111	Negotiation failure risk A112
Project implementation period risk A2	Political and legal risk A21	Government credit risk A22	Market competitive risk A23
	Public acceptance risk A24	Force majeure risk A25	Environmental risk A26
	Cost overspending risk A27	Completion risk A28	Engineering quality risk A29
	Unsuitable site selection risk A210	Technical risk A211	Organizational coordination risk A212
	Supply risk A213	Security risk A214	Financial riskA215
Project franchise period risk A3	Foreign exchange risk A31	Inflation risk A32	Interest rate risk A33
	Operational management risk A34	Demand risk A35	Political and legal risk A36
	Government credit risk A37	Market competitive risk A38	Public acceptance risk A39
	Maintenance cost risk A310	Force majeure risk A311	Environmental risk A312
	Engineering quality risk A313	Supply risk A314	Security risk A315
	Financial risk A316		
Project non-franchise period risk A4	Residual value risk A41	Force majeure risk A42	Environmental risk A43
	Security risk A44	Engineering quality risk A45	Maintenance cost risk A46

3.3 Determination of index weight by analytic hierarchy process

The analytic hierarchy process (AHP) is the evaluation method with the combination of qualitative analysis and quantitative analysis. It was first proposed by American mathematician T.L.Saaty in 1970s and now it has been widely used in economics and management.

Analytic hierarchy process (AHP) is flexible and easy to understand in engineering project risk analysis. It enables the project risk manager to fully understand the overall risk of the proposed project and calculate the comprehensive risk level of the project. The analytic hierarchy process (AHP) is an effective method to determine the weight value of each risk factor. The basic procedure for determining the weight value of the risk factors is that the complex problems are divided into various components, and these components are grouped into a clear and ordered hierarchical structure according to their domination relations, and then the relative importance degree of each component in the hierarchical structure is determined by the two-two comparison. Finally, the overall ranking of the relative importance of each component is determined by the subjective judgment of the human.

3.4 Determination of risk probability distribution by CIM model

The CIM model is the abbreviation of the control interval and memory model for the combination of probability distribution. It was proposed by English scholars C.B.Chapman and Professor D.F.Cooper in 1983. This method uses histogram instead of the probability distribution of variables and uses the sum to replace the integral of the probability function. Because the interval of histogram division has the characteristic of equal width, and the CIM model requires probability combination superposition to be established on the histogram of the same interval, the CIM model makes the combination superposition calculation of probability distribution more simple and general.

The CIM model is mainly used to evaluate the targets or objects with complex relationship between risk factors. First of all, the probability distribution of each risk factor is correspondingly treated with mathematical models, and then comprehensive evaluation and analysis is carried out. This model is a new model of risk management analysis, which has strong applicability and effectiveness in the analysis and quantitative analysis of complex risk factors. The model can handle the mutually independent risk factors. Even if the two factors are completely unrelated, the model can also be used to carry out comprehensive evaluation analysis.

The CIM model is generally divided into two forms of parallel response model and series response model. According to the physical relation between each variable, the probability distribution of the variable is combined and superimposed. The analysis principle is similar to the parallel and series connection methods of the circuit in physics, respectively. The combination or superposition of the probability distribution of random variables is one of the important early jobs of risk assessment and analysis. In our common applied mathematical analysis methods, it is assumed that each of the random variables is independent and there is no relationship. This paper is based on the assumption that each risk factor is independent of each other, to establish the parallel response model of CIM risk assessment model. For a basic activity, the potential risk factors will not appear one by one as expected or in a certain order, so for each risk factor, the time, place and impact that may occur are different. As shown in Figure 1, there are several risk factors u and the occurrence of any risk factor will affect the target A of the basic activity.

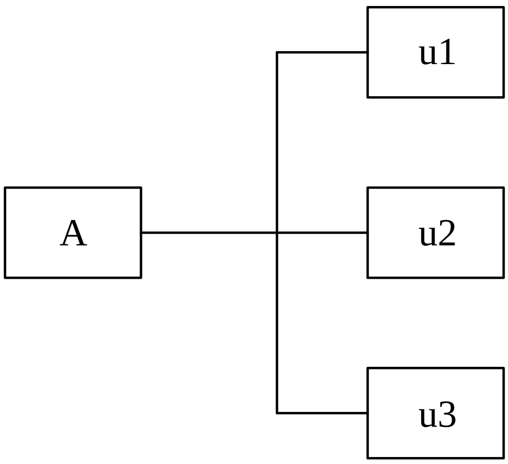

Figure 1. Parallel response model

From Figure 1, the probability combination superposition model of several risk factors is called the "parallel response model", and the curve between the probability combination and superposition is called "probability multiplication". The probability multiplication is usually a square method of a series of two-two probability distributions, that is, the probability of two risk factors is done with multiplication calculation firstly. Then, the result obtained is multiplicated with the third risk factors. By analogy, all the probability distribution combination and superposition figures of the project are finally obtained, as shown in Figure 2.

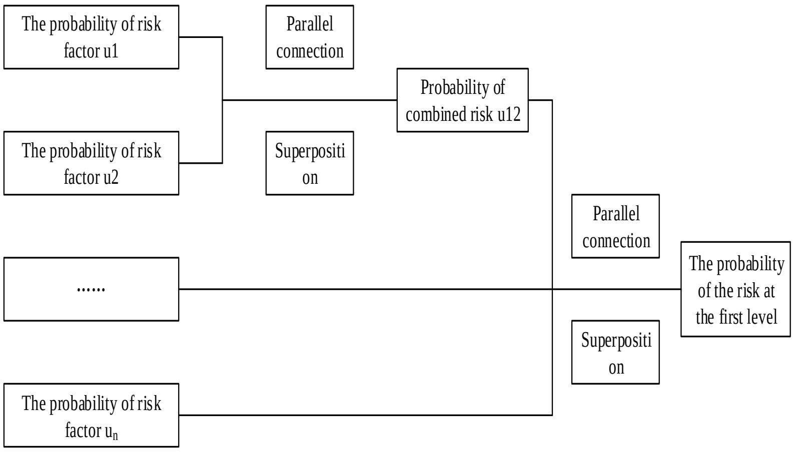

Figure 2. Parallel superposition diagram of risk factors

The formula for calculating the probability distribution of their combinations and overlapped effects is as follows:

$$P(U_x = u_x) = \sum_{i=1}^{u} P(U_1 = u_x, U_2 = u_i) + \sum_{i=1}^{u} P(U_1 = u_{i-1}, U_2 = u_x)(\mathrm{x} = 1, 2, \cdots, \mathrm{u}) \quad (1)$$

In the formula, UX represents the number of partitioned intervals. If the evaluation target contains more than two risk factors, first of all, the probability distribution of the first two risk factors is combined, then a new probability distribution is obtained and memorized, and then the probability distribution of the next risk factor is superimposed and analogous.

Supposing that a company's financial goals are influenced by two risk factors u1 and u2, the two risk factors are independent of each other and the probability distribution is shown in Table 2.

Table 2. Risk factor u1u2 probability distribution of independent influence on target

Financial risk u_x	Risk factor u_1	Risk factor u_2
-10%	0.05	0
-5%	0.16	0.27
0	0.41	0.20
5%	0.13	0.41
10%	0.25	0.12

The target combination and superposition influencing probability distribution is calculated by formula (1), and the results are shown in Table 3.

Table 3. Calculation of investment risk probability influenced by combination of risk factor u1 and risk factor u2

u_x	u_1	u_2	Combination influence
-10%	0.05	0	0.05* (0)=0
-5%	0.16	0.27	0.16*(0+0.27)+0.27*0.05=0.0567
0	0.41	0.20	0.41*(0+0.27+0.20)+0.20 *(0.16+0.05)=0.2347
5%	0.13	0.41	0.13 *(0.27+0.20+0.41)+0.41*(0.41+0.16+0.05)=0.3686
10%	0.25	0.12	0.25*(0.27+0.20+0.41+0.12)+0.12*(0.13+0.41+0.16+0.05)=0.34

Series response model: in the process of identifying and analyzing the risk factors of the project, the project activity can be decomposed by the work breakdown structure (WBS) method and decomposed into several sub activities. If the sub activities conform to the related characteristics of the series response model, the series response model can be used for the combination and superposition calculation of the probability distribution of each risk factor, so as to evaluate the probability of combination and superposition risk of an activity.

For example, for activity A, it can be decomposed into activity A1 and A2, and the probability of risk is P(A1) and P(A2), then the probability of activity A can be calculated by formula (2).

$$P(A=a)\sum_{i=1}^{k}\sum_{j=1}^{l}P(A_1=a_{1i},A_2=a_{2j})=\sum_{i=1}^{k}A(A_1=a_{1i})\sum_{j=1}^{l}A(A_2=a_{2j}) \tag{2}$$

For example, we know that a company's overall financial change A can be decomposed into two independent individual changes, A1 and A2, respectively. Assuming that their correlation is series connection, the probability distribution of risk is shown in Table 4. The probability distribution of financial risk after the combination and decomposition is calculated by formula (2) and the result is shown in Table 5.

Table 4. Change probability distribution of A1A2 two financial changes (unit: 10000 yuan)

A1	P(A1)	A2	P(A2)
-5	0.1	-8	0
-2	0.3	10	0.4
8	0.35	14	0.3
12	0.25	20	0.2

Table 5. The probability distribution of total financial risk under the impact of A1A2 independent combination (unit: 10000 yuan)

Finance	Probability	Finance	Probability	Finance	Probability	Finance	Probability
-13	0	-10	0	0	0	4	0
5	0.04	8	0.12	18	0.14	22	0.1
9	0.03	12	0.09	22	0.105	26	0.075
15	0.02	18	0.06	28	0.07	32	0.05

When we need to consider the correlation among random variables, we only assume that one of the random variables is independent. The expert questionnaire table of the conditional probability is used to obtain the conditional probability distribution of the relevant variables, and then according to the following formula, the probability distribution of financial change A2 can be calculated. Finally, the combination and decomposition of the probability distribution of A1 can be used to obtain the probability distribution of the total financial changes of the company. For a project composed of multiple sub activities, it can be analogical.

$$P(A_2)=\sum_{A_1}P(A_1)P(A_2/A_1) \tag{3}$$

4. RESULTS AND DISCUSSION

4.1 Construction of a comprehensive risk assessment model for PPP project

Because the risk factor index involved in the PPP project is characterized by randomness, fuzziness and uncertainty, the index of risk factors generally belongs to the qualitative index and it is difficult to quantify it. As a result, it is necessary to use the analytic hierarchy process (AHP) to determine the weight of the risk factors of each level firstly, and then apply the CIM model for the combination and superimposition of the probability distribution of the last layer risk factors. Finally, the fuzzy comprehensive evaluation method is applied to evaluate the risk level of the project. The main steps are as follows:

Step 1: the establishment of a set of risk factors. The risk factor set of PPP project is a set composed of various risk factors that affect the evaluation object, expressed in U.

$$U = \{u_1, u_2, \cdots u_m\} \tag{4}$$

In the above formula, U is a set of factors, and um represents a variety of risk factors.

Step 2: the establishment of the risk assessment set. The risk assessment set is a set composed of total evaluation results done by the risk judgers for all the judgment objects, expressed by V.

$$V = \{v_1, v_2, \cdots v_n\} \tag{5}$$

In (5), V is a judgment set, and vn represents all kinds of possible general judgment results.

Step 3: the establishment of factor weight set. In the risk factor set, each risk factor has different influence on the evaluation objects. In order to reflect the degree of influence of each risk factor, a corresponding weight ai is given to each risk factor ui. However, the set composed of corresponding weights of each risk factor is called risk factor weight set, expressed by A.

Step 4: the determination of the probability distribution of the two-level risk factor index. This article will use the expert questionnaire to obtain the relevant basic data to determine the probability distribution of the two-level risk factors, and to issue the risk rating scale of the PPP project risk factors to the expert group. It also requests each expert to judge the risk level of each PPP project risk factor and collect and collate each expert's assessment table, makes statistics of the number of experts for each risk factor corresponding to each risk level, and then determines the probability distribution of each two-level risk factor.

Step 5: the calculation of the probability distribution of the one-level risk factor index. After determining the probability distribution of the two-level risk factors, the parallel response model of CIM is used for the combination and superposition of them, and the probability distribution of each first class risk factor is obtained. Then, the probability distribution of each first level risk factor is used as the line of the matrix and the fuzzy matrix is constructed.

Step 6: the calculation of the fuzzy comprehensive evaluation set. The weight set of the first level risk factor is determined by step 3, and the weight set of the first level risk factor index and the fuzzy matrix constructed by step 5 are used as the matrix operation, and the PPP project is obtained.

Step 7: the processing of fuzzy comprehensive evaluation index. After obtaining the evaluation index and dealing with the evaluation indexes, we can get the final result of the evaluation target when considering the impact of all the risk factors.

4.2 Establishment of risk assessment index system for engineering cases

In this paper, the project case KH Bridge is selected as an example. The total length of the bridge is 36 km, including the bridge length of 35.8 kilometers, the total investment is about 10.8 billion yuan, and the design service life is more than 100 years. Two navigable holes are set up in the East and West of the KH Bridge. The East navigation port bridge is a single tower, single cable plane steel box girder cable-stayed bridge, and the navigation standard is 2000 tons. The West Tong Kong Bridge is a double cable plane steel box girder cable-stayed bridge in Twin Towers and the design standard is 30000 tons. The total length of the connecting lines between the two sides of the bridge is 74.4 km, with an investment of 4.21 billion yuan. Among them, the east coast connecting line is 24.1 kilometers, and the investment amount is 1.28 billion yuan; the West Coast connecting line is 50.3 kilometers, and the investment amount is 2.93 billion yuan. The total investment of bridges and cross-strait connections is about 13 billion yuan, and the actual construction period is 43 months.

The risk assessment index system for the KH Bridge is established. In this paper, 10 experts in the related fields are invited to make a discussion. According to the nature and characteristics of the KH bridge project, the importance of the risk factors of each layer in the universal index system is evaluated. Through many aspects of discussion and repeated evaluation, a consensus is reached, the results of evaluation are obtained, the judgment matrix is constructed, and then it is input in the calculation software of AHP to calculate. All the calculation results are collected and collated, the weight value of each risk factor index is obtained, and the ranking is carried out. Finally, some risk factor indexes of large weight value are selected, and the risk assessment index system of the KH Bridge is established.

4.3 Risk assessment and analysis of KH Bridge

Firstly, establish risk assessment set and determine the probability distribution of two-level risk factors. The two-level index of the risk assessment index system of the KH Bridge is evaluated by single factor. First of all, the evaluation set is set as {low risk, relatively low risk, medium risk, relatively high risk and high risk}, and the evaluation set assignment is {1, 2, 3, 4, 5}. And then a questionnaire aimed at the two-level indicators is issued to the expert group set up. Each expert gives a judgment on each two-level index, and the results of the evaluation are calculated. The probability distribution of each stage of the two-level risk factor is calculated, as shown in Table 6 to Table 9.

Table 6. Probability distribution of two-level risk factors in the early stage of the project

Risk factor	Risk level				
	Low risk	Relatively low risk	Medium risk	Relatively high risk	High risk
U11	1/10	4/10	3/10	1/10	1/10
U12	1/10	2/10	4/10	2/10	1/10
U13	3/10	4/10	2/10	1/10	0/10
U14	1/10	3/10	4/10	1/10	1/10
U15	1/10	1/10	2/10	4/10	2/10
U16	0/10	2/10	3/10	3/10	2/10
U17	1/10	1/10	4/10	1/10	0/10

Table 7. Probability distribution of two-level risk factors in project implementation phase

Risk factor	Risk level				
	Low risk	Relatively low risk	Medium risk	Relatively high risk	High risk
U21	2/10	4/10	1/10	2/10	1/10
U22	1/10	2/10	3/10	3/10	1/10
U23	0/10	1/10	3/10	4/10	2/10
U24	1/10	2/10	4/10	2/10	1/10
U25	1/10	1/10	2/10	3/10	3/10
U26	1/10	1/10	3/10	4/10	1/10
U27	1/10	3/10	3/10	2/10	1/10
U28	1/10	2/10	2/10	2/10	3/10
U29	2/10	1/10	2/10	4/10	1/10

Table 8. Probability distribution of two-level risk factors in project franchise stage

Risk factor	Risk level				
	Low risk	Relatively low risk	Medium risk	Relatively high risk	High risk
U31	2/10	3/10	3/10	1/10	1/10
U32	3/10	2/10	3/10	1/10	1/10
U33	0/10	2/10	2/10	4/10	2/10
U34	1/10	2/10	3/10	3/10	1/10
U35	3/10	4/10	1/10	1/10	1/10
U36	1/10	2/10	4/10	2/10	1/10
U37	2/10	4/10	2/10	1/10	1/10
U38	1/10	3/10	3/10	2/10	1/10
U39	1/10	1/10	3/10	3/10	2/10

Table 9. Probability distribution of two-level risk factors in project non-franchise stage

Risk factor	Risk level				
	Low risk	Relatively low risk	Medium risk	Relatively high risk	High risk
U41	1/10	3/10	3/10	2/10	1/10
U42	1/10	3/10	3/10	2/10	1/10
U43	1/10	4/10	3/10	1/10	1/10
U44	1/10	1/10	2/10	4/10	2/10

Secondly, the weight of the index is determined. The informal discussion is conducted by 10 experts and some technical backbone experts of the project construction unit, the item company, the construction unit, the design unit and the supervision unit. According to the feasibility study report of the KH Bridge project and the project design plan, the comparison is carried out for the first-level risk factor in the index system about the importance degree of the target layer. The scoring results are obtained by many aspects of discussion and repeated evaluation. Then, the scoring results are processed by analytic hierarchy process, and the weight value of the first level risk factor is obtained shown in Table 10.

Table 10. Calculation process and result of weight value of risk factors at each level

U	U1	U2	U3	U4
U1	1	1/4	1/3	2
U2	4	1	3	4
U3	3	1/3	1	3
U4	1/2	1/4	1/3	1
Weight value	0.1268	0.5222	0.2610	0.0895

Thirdly, using the parallel response model of the CIM model, the probability distribution of each level of risk factor index is combined to calculate the probability distribution of each level of risk factors. The probability distribution of the risk U-0 in the non-franchise period of the project is taken as an example, and the calculation process is as follows:

According to the parallel response model, we first of all calculate the probability distribution of risk factor index U41 and U42 combination and superposition risk, as shown in Table 11. Then, the probability distribution of the combination and superposition risk of U41, U42, U43 and U44 is calculated by using the parallel response model, namely the probability distribution of U4, which is not introduced in detail. Finally, we find out the probability distribution of other level risk factors, as shown in Table 12.

Table 11. Probability distribution calculation of U41U42 combination and superposition risk

Risks	Risk probability		Combination and superposition probability distribution
Levels	U41	U42	
Low	1/10	1/10	1/10*1/10=0.01
Relatively low	3/10	3/10	3/10* (1/10+3/10)+3/10*1/10=0.15
Medium	3/10	3/10	3/10*(1/10+3/10+3/10)+3/10*(1/10+3/10)=0.33
Relatively high	2/10	2/10	2/10*(1/10+3/10+3/10+2/10)+2/10*(1/10+3/10+3/10)=0.32
High	1/10	1/10	1/10*(1/10+3/10+3/10+2/14+1/10)+1/10*(1/10+3/10+3/10+2/10)=0.19

Table 12. The probability distribution of the first level risk factor index

Risks	Probability distribution			
Levels	U1	U2	U3	U4
Low	0	0	0	0.0001
Relatively low	0.0008	0	0.0001	0.0159
Medium	0.0717	0.0042	0.0217	0.1408
Relatively high	0.3940	0.2042	0.2617	0.4264
High	0.5334	0.7917	0.6566	0.4168

According to the calculation results in Table 12, the probability matrix of the risk factors of each level constructs the fuzzy matrix R for the row of matrix:

$$R=\begin{bmatrix} 0 & 0.0008 & 0.0717 & 0.3940 & 0.5334 \\ 0 & 0 & 0.0042 & 0.2042 & 0.7917 \\ 0 & 0.0001 & 0.0217 & 0.2617 & 0.6566 \\ 0.0001 & 0.0159 & 0.1408 & 0.4264 & 0.4168 \end{bmatrix} \tag{6}$$

Fourthly, the fuzzy comprehensive evaluation set is calculated. According to the weight value of each level risk factor in Table 10, the weight set A is set up:

$$A=\begin{bmatrix}0.1268 & 0.5222 & 0.2610 & 0.0895\end{bmatrix} \tag{7}$$

Then, fuzzy computation is carried out for the weight set A and fuzzy matrix constructed to get the fuzzy comprehensive evaluation set B:

$$B=A\bullet R=\begin{bmatrix}0.1268\\0.5222\\0.2610\\0.0895\end{bmatrix}^T \begin{bmatrix} 0 & 0.0008 & 0.0717 & 0.3940 & 0.5334 \\ 0 & 0 & 0.0042 & 0.2042 & 0.7917 \\ 0 & 0.0001 & 0.0217 & 0.2617 & 0.6566 \\ 0.0001 & 0.0159 & 0.1408 & 0.4264 & 0.4168 \end{bmatrix} \tag{8}$$

$$=\begin{bmatrix}0 & 0.0016 & 0.0296 & 0.2632 & 0.6901\end{bmatrix}$$

Fifthly, the evaluation index is dealt with. In this paper, the weighted average method is used to deal with the evaluation index, and the evaluation index bj of fuzzy comprehensive evaluation is weighted. The comprehensive risk degree of the project can be obtained after the weighted average of the evaluation results of the evaluation concentration (1, 2, 3, 4, 5), and the comprehensive risk degree of the project can be obtained as R. In addition, according to the probability distribution of U1, U2, U3 and U4 in Table 12, the initial risk degree R1 of the project, the risk degree R2 of the project implementation period, the risk degree R3 of the franchise operation period, and the non-franchise risk degree R4 of the project are calculated and the calculation process and results are shown in Table 13.

Table 13. The calculation process and result of risk degree at various stages

Risk degree	Calculation process and result
R	0*1+0.0016*2+0.0296*3+0.2632*4+0.6901*5=4.5953
R1	0*1+0.0008*2+0.0717*3+0.3940*4+0.5334*5=4.4597
R2	0*1+0*2+0.0042*3+0.2042*4+0.7917*5=4.7879
R3	0*1+0.0001*2+0.0217*3+0.2617*4+0.6566*5=4.3951
R4	0.0001*1+0.0159*2+0.1408*3+0.4264*4+0.4168*5=4.2439

4.4 Analysis of the results of risk assessment

Through the combination of the above CIM model and the fuzzy comprehensive evaluation model, we get the risk degree and the comprehensive risk degree of the project at each stage of the KH Bridge project, as shown in Table 13. It can be seen from the table that the overall risk degree of the project is 4.5953, which belongs to the interval of [4, 5], which belongs to the high risk interval, indicating that the KH Bridge project has a high risk on the whole. It can be seen from the table that the risk degree in the early stage of the project is 4.4597, the risk degree of the project implementation stage is 4.7879, the risk degree of the project franchise period is 4.3951, and the risk degree of the non-franchise period is 4.2439, all belonging to the interval of [4, 5], which all belong to the high risk interval, indicating that the risk of each stage is relatively high from the whole life cycle of the KH Bridge. In addition, it can be found that the risk degree of the KH Bridge project in the implementation stage is higher than that of the other three stages. It suggests that when the risk of each stage of the project is focused on, the focus should be placed in the prevention of risk in the phase of the project implementation period. The results obtained through the above comprehensive calculation are only an estimate of the possibility, but it is still worth the attention of the participants of the project, and a set of scientific and reasonable risk prevention measures can be set up, so as to reduce the impact of potential risk in each stage on the project and loss as much as possible.

5. CONCLUSION

This paper mainly studies the life cycle risk assessment model and its application of PPP project based on AHP. There are three main conclusions. Firstly, the whole life period of the project is divided into four stages, such as the early stage of the project, the stage of the project implementation period and so on. In addition, the identification and analysis of the potential risk factors in the four stages is carried out, the detailed rules of each risk factor are set up, and the risk assessment of the whole life cycle of the project is established. Secondly, the analytic hierarchy process (AHP) is used to determine the weight of the risk factor index, and the CIM parallel and series response model are introduced to determine the risk probability distribution. The fuzzy comprehensive evaluation method is applied to establish the comprehensive life cycle risk assessment model of the PPP project. Third, the whole life cycle risk assessment model of PPP project is applied to the engineering example, and the comprehensive risk degree of the project is 4.5953, which belongs to the high risk interval. It shows that the KH Bridge project has a high risk on the whole, which is in accordance with the actual situation of the project.

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