Journal of Social Sciences and Humanities
2018; 1(1): 20-26
http://www.aascit.org/journal/jssh

American Association for Science and Technology

Fuzzy Evaluation Method of Contract Risk in PPP Project and Its Application

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Citation

Shang Kejian, Feng Dongmei, Li Naiwen, Jia Chong. Fuzzy Evaluation Method of Contract Risk in PPP Project and Its Application. *Journal of Social Sciences and Humanities.* Vol. 1, No. 1, 2018, pp. 20-26.

Received: January 24, 2018; **Accepted**: February 18, 2018; **Published**: March 10, 2018

Abstract: The PPP mode is widely used in many infrastructure projects in China. However, due to the limited popularization of PPP mode in China, there are few researches on the contract risk evaluation, PPP contract risk evaluation system is lacked, evaluation value has the problem of information loss, and it is difficult to satisfy the independence hypothesis between the indexes of the evaluation model. In this paper, contract risk evaluation index system is established for PPP project. Then, based on the latest research results of fuzzy mathematics and multi-attribute decision-making model, contract risk evaluation method is proposed for PPP project in CMLN, so that information loss and the issue of independence hypothesis between indexes can be solved by rational use of intuitionistic fuzzy numbers and fuzzy measures. Finally, the applicability of index system and method is verified by applying the evaluation index system and evaluation method proposed in this paper to CMLN PPP project in Shanxi Province

Keywords: PPP Project, Risk Evaluation, Fuzzy Mathematics, Gas Pipeline Network

1. Introduction

PPP mode refers to the public-private-partnerships (hereinafter referred to as PPP mode). The contract is the basis to guarantee the smooth operation of PPP project and the government plays a strong role in PPP project. Therefore, for the construction and operation party - social capital in the PPP mode, it is necessary to evaluate contract risk of the PPP project, so that whether the PPP project is worthwhile can be judged. Reasonable risk evaluation requires two conditions, namely, a reasonable evaluation index system and supporting evaluation model. At present, contract risk evaluation mainly focuses on risk evaluation of project contract [1, 2, 3, 4], while the PPP project differs from contracting project, as it covers not only project construction stage, but also project operation stage. Therefore, the contract risk scope involves the whole life cycle of project. However, there are few researches on contract risk evaluation for PPP projects at present. In addition, it is the first time for Coal Bed Methane Line Network (CMLN) project to be operated in PPP mode in China. As a result, there are more scarce researches on the evaluation index of PPP project contract risk.

In the aspect of the contract risk evaluation model, the commonly used multi-attribute evaluation models mainly include analytic hierarchy process and TOPSIS method. For example, Guo, Li Fang [5] studied the risk of hospital EEB based on AHP method; Zhang and Hao Ran [6] studied risk evaluation of long-distance oil and gas pipelines based on TOPSIS method. Then, fuzzy mathematics is introduced into the evaluation model to ensure the accuracy of expert evaluation preference. For example, Guo, Zixue [7] studied the project risk evaluation based on triangular fuzzy number and TOPSIS method; Jiang, Feng [8] studied risk evaluation of offshore platforms based on triangular fuzzy number and AHP method. However, there are two problems in the application of the above models:

First, there is the problem of information loss, that is, experts cannot fully express their evaluation opinions. The main reason is that in the traditional multi-attribute group evaluation model and fuzzy evaluation model, experts can only express their opinion on the evaluated object with a real number or interval number. This method of expressing opinions fails to reflect the psychological fact that negative expression of language is not equal to the negation of logical expression. For example, when the public score 80 for the service satisfaction out of 100 full marks, then from the mathematical logic, the corresponding dissatisfaction should be 20 points. However, if the public score the service dissatisfaction separately, it may be 30 points or 40 points. That is, the sum of scored satisfaction and dissatisfaction is not 100;

The second is the issue of independence between evaluation indexes. The traditional multi-attribute decision-making method, such as the weighted sum method, is based on the additive conditions in the classical probability measure. The form of expression is:$\sum_{j=1}^{n} w_j=1$, where,w_j is the weight of the jth index. The linear additive hypothesis requires that the indexes in the evaluation index system corresponding to the decision-making method should be independent of each other. However, the complete independence between the indexes is basically impossible in reality, so the decision-making method based on assumption of linear additiveity has strong limitations.

According to the latest research in fuzzy mathematics, intuitionistic fuzzy numbers can effectively solve the problem of information loss because it contains two variables, satisfaction and dissatisfaction. The sum of satisfaction and dissatisfaction is not necessarily equal to 1. Hence, intuitionistic fuzzy number can evaluate things from two aspects, and reflect the uncertainty of the experts for the given evaluation value at the same time. For the independence between the evaluation indexes, independence hypothesis can be avoided by thought shift. For example, according to the related research results of multi-criteria evaluation, fuzzy measure is used instead of weight. The advantage of this method is that monotonicity replaces additivity, thus avoiding the requirement of index independence hypothesis.

Based on CMLN's own characteristics, this paper constructs the corresponding PPP project risk evaluation index system to fill the blank of contract risk evaluation research in CMLN PPP project. Then, using intuitionistic fuzzy set as the preferred expression of expert evaluation, weight is replaced by fuzzy measure to build an evaluation model suitable for the contract risk evaluation of CMLN PPP projects. Finally, based on the above contents, a contract scheme selection framework for CMLN PPP project is constructed, and the applicability of the proposed model is verified by examples.

2. CMLN PPP Project Contract Risk Evaluation Index System

In essence, the contract is a prior agreement between the parties to the contract on subject quality, price, quantity, performance deadline, place, manner and responsibility for breach of contract as well as consensus on rights and obligations of both parties to achieve a common target, which is an assumption of the problems and responsibilities that may arise in the future process of achieving the target. The contract risk is the possibility of economic disputes due to the existence of uncertainty in the contract signing or performance process. Based on the research on contract risk evaluation of urban gas pipe network [9, 10, 11] and PPP risk study [12, 13, 14], this paper classifies the contract risks of CMLN PPP projects into external project contract risk, internal project contract risk and project contract execution risk based on main body of the project.

External project contract risk mainly refers to external environment changes uncontrollable by project managers that indirectly affect CMLN project construction and operation, such as inflation, foreign exchange risk and so on. This type of risk is mainly due to changes in the international or domestic political environment. With a low probability, such risk carries serious harm, especially when the political situation in the area where the CMLN project is located is not very stable. It thus requires particular attention. The specific indexes are shown in Table 1.

Internal project contract risk mainly refers to internal risks controllable by project managers that directly affect the CMLN project construction and operation, such as geological conditions risk, hydrological and climate conditions risk. This type of risk is intentionally or unintentionally created by project participants, for instance increased investment in the CMLN project when the owner provides geological data of poor survey quality. Its specific indexes are shown in Table 1.

Contract execution risk refers to the project risks encountered in the contract execution in accordance with the requirements, such as financing risk, organization and coordination risk. With a big probability, such risk carries little harm. Therefore, main consideration should be given to whether there is a plan for the risk in the contract and the rationality of the plan. Its specific indexes are shown in Table 1.

It should be noted that the indexes in Table 1 are negative indexes, that is, the higher the index value is, and the greater the risk is.

Table 1. *CMLN PPP project contract risk evaluation index system.*

Indexes	Sub-indexes
(PC11) External project contract risk	(PC11-1) Inflation risk
	(PC11-2) Foreign exchange risk
	(PC11-3) Legal Change Risk
	(PC11-4) Market change risk
	(PC11-5) Government Credit Risk
	(PC11-6) Tax Policy Risk
(PC12) Internal project contract risk	(PC12-1) Geological Conditions Risk
	(PC12-2) Hydrological and climatic conditions risk
	(PC12-3) Material, equipment supply risk
	(PC12-4) Technical Specifications Risk
	(PC12-5) Risk of Force Majeure
	(PC12-6) Engineering / Operational Change Risk
(PC13) Project contract execution risk	(PC13-1) Financing Risk
	(PC13-2) Organization & coordination risk
	(PC13-3) Risk of overrun operation cost
	(PC13-4) Payment capacity risk
	(PC13-5) Residual value risk
	(PC13-6) Environmental protection risk
	(PC13-7) Public hindrance risk
	(PC13-8) Contract document conflict risk

3. CMLN PPP Project Contract Risk Evaluation Method

3.1. Related Definitions

3.1.1. Intuitionistic Fuzzy Related Definitions

In order to more accurately reflect uncertainty of things, people expand the fuzzy mathematics, and intuitionistic fuzzy number is a recent research result in the field of fuzzy mathematics, which is defined as follows:

Definition 1: Set X as domain. If the two mappings on X, $\mu_A(x)$: $X \to [0,1]$ and $\upsilon_A(x)$: $X \to [0,1]$ make $x \in X \mapsto \mu_A(x) \in [0,1]$, $x \in X \mapsto \upsilon_A(x) \in [0,1]$ satisfy the condition $0 \le \mu_A(x) + \upsilon_A(x) \le 1$ at the same time, then $\mu_A(x)$ and $\upsilon_A(x)$ constitute an intuitionistic fuzzy set A on the domain X, to be denoted as $A = \{\langle x, \mu_A(x), \upsilon_A(x)\rangle \mid x \in X\}$.

Where, $\mu_A(x)$ is called the true membership function to indicate membership lower bound that satisfies with $x \in A$; $\upsilon_A(x)$ is known as the false membership function to indicate the membership lower bound not satisfying $x \in A$. $\pi_A(x)$ is known as the degree of hesitation, which is a measure of unknown information. Where, $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$ and $0 \le \pi_A(x) \le 1$. The larger value of $\pi_A(x)$ indicates more unknown information of x for A.

Definition 2: set X as domain of non-empty set. If mapping of the two given interval values of X, $\mu_{\tilde{A}} : X \to I_{[0,1]}$ and $\upsilon_{\tilde{A}} : X \to I_{[0,1]}$, make $x \in X \mapsto \mu_{\tilde{A}}(x) \subseteq [0,1]$ and $x \in X \mapsto \upsilon_{\tilde{A}}(x) \subseteq [0,1]$ meet $0 \le \sup\{\mu_{\tilde{A}}(x)\} + \sup\{\upsilon_{\tilde{A}}(x)\} \le 1$ at the same time, then $\mu_{\tilde{A}}$ and $\upsilon_{\tilde{A}}$ determine an interval fuzzy intuitionistic set $\tilde{A}$ on the domain X, which can be abbreviated as:

$$A = \{< x, \mu_A(x), \upsilon_A(x) >| x \in X\}$$

$\mu_{\tilde{A}}(x)$ and $\upsilon_{\tilde{A}}(x)$ are known as membership function of interval value and non-membership function of interval value, respectively. $\mu_{\tilde{A}}(x)$ and $\upsilon_{\tilde{A}}(x)$ are membership degree of interval value and non-membership degree of interval value of x belonging to $\tilde{A}$ respectively. The upper and lower endpoint values of interval value membership degree $\mu_{\tilde{A}}(x)$ and interval value non-membership degree $\upsilon_{\tilde{A}}(x)$ are respectively denoted as $\mu_{\tilde{A}L}(x), \mu_{\tilde{A}U}(x)$ and $\upsilon_{\tilde{A}L}(x), \upsilon_{\tilde{A}U}(x)$. In this way, the interval intuitionistic fuzzy set $\tilde{A}$ is expressed as:

$$\tilde{A} = \left\{< x, \left[\mu_{\tilde{A}L}(x), \mu_{\tilde{A}U}(x)\right], \left[\upsilon_{\tilde{A}L}(x), \upsilon_{\tilde{A}U}(x)\right] >| x \in X\right\}$$

Where: $\mu_{\tilde{A}L}(x) \in [0,1]$; $\mu_{\tilde{A}U}(x) \in [0,1]$; $\upsilon_{\tilde{A}L}(x) \in [0,1]$; $\upsilon_{\tilde{A}U}(x) \in [0,1]$; $\mu_{\tilde{A}U}(x) + \upsilon_{\tilde{A}U}(x) \le 1$.

In addition, $\pi_{\tilde{A}}(x) = \left[1 - \mu_{\tilde{A}U}(x) - \upsilon_{\tilde{A}U}(x), 1 - \mu_{\tilde{A}L}(x) - \upsilon_{\tilde{A}L}(x)\right]$ is known as the interval value hesitancy degree of element xbelonging to the interval intuitionistic fuzzy set $\tilde{A}$. Obviously, if $\mu_{\tilde{A}L}(x) = \mu_{\tilde{A}U}(x)$ and $\upsilon_{\tilde{A}L}(x) = \upsilon_{\tilde{A}U}(x)$, the interval intuitionistic fuzzy set $\tilde{A}$ degenerates into an intuitionistic fuzzy set.

It can be seen from the definition that interval intuitionistic fuzzy numbers can better express expert opinion than intuitionistic fuzzy numbers. The relevant operational rules of intuitionistic fuzzy sets are as follows:

Definition 3 [15]: Suppose $\tilde{A} = \left\{< x, \left[\mu_{\tilde{A}L}(x), \mu_{\tilde{A}U}(x)\right], \left[\upsilon_{\tilde{A}L}(x), \upsilon_{\tilde{A}U}(x)\right] >| x \in X\right\}$ and $\tilde{B} = \left\{< x, \left[\mu_{\tilde{B}L}(x), \mu_{\tilde{B}U}(x)\right], \left[\upsilon_{\tilde{B}L}(x), \upsilon_{\tilde{B}U}(x)\right] >| x \in X\right\}$ are intuitionistic fuzzy sets of interval value, $\lambda > 0$ and λ is any real number, then the operation rule of interval intuitionistic fuzzy set is as follows:

a. $$\tilde{A} + \tilde{B} = \{< x, \left[\mu_{\tilde{A}L}(x) + \mu_{\tilde{B}L}(x) - \mu_{\tilde{A}L}(x)\mu_{\tilde{B}L}(x), \mu_{\tilde{A}U}(x) + \mu_{\tilde{B}U}(x) - \mu_{\tilde{A}U}(x)\mu_{\tilde{B}U}(x)\right], \left[\upsilon_{\tilde{A}L}(x)\upsilon_{\tilde{B}L}(x), \upsilon_{\tilde{A}U}(x)\upsilon_{\tilde{B}U}(x)\right] >| x \in X\}$$

b. $$\tilde{A}\tilde{B} = \{< x, [\mu_{\tilde{A}L}(x)\mu_{\tilde{B}L}(x), \mu_{\tilde{A}U}(x)\mu_{\tilde{B}U}(x)], [\upsilon_{\tilde{A}L}(x) + \upsilon_{\tilde{B}L}(x) - \upsilon_{\tilde{A}L}(x)\upsilon_{\tilde{B}L}(x), \upsilon_{\tilde{A}U}(x) + \upsilon_{\tilde{B}U}(x) - \upsilon_{\tilde{A}U}(x)\upsilon_{\tilde{B}U}(x)] >| x \in X\}$$

c. $$\lambda\tilde{A} = \left\{< x, \left[1 - (1 - \mu_{\tilde{A}L}(x))^\lambda, 1 - (1 - \mu_{\tilde{A}U}(x))^\lambda\right], \left[(\upsilon_{\tilde{A}L}(x))^\lambda, (\upsilon_{\tilde{A}U}(x))^\lambda\right] >| x \in X\right\}$$

d. $$\tilde{A}^\lambda = \left\{< x, \left[(\mu_{\tilde{A}L}(x))^\lambda, (\mu_{\tilde{A}U}(x))^\lambda\right], \left[1 - (1 - \upsilon_{\tilde{A}L}(x))^\lambda, 1 - (1 - \upsilon_{\tilde{A}U}(x))^\lambda\right] >| x \in X\right\}$$

e. $$\tilde{A}^c = \left\{< x, \left[\upsilon_{\tilde{A}L}(x), \upsilon_{\tilde{A}U}(x)\right], \left[\mu_{\tilde{A}L}(x), \mu_{\tilde{A}U}(x)\right] >| x \in X\right\}$$

Definition 6 [15]: Intervalvalue intuitionistic fuzzy sets are compared and sorted. By means of the scores and exact values of the interval intuitionistic fuzzy sets, (when the interval value intuitionistic fuzzy set $\tilde{A} = \left\{< x, \left[\mu_{\tilde{A}L}(x), \mu_{\tilde{A}U}(x)\right], \left[\upsilon_{\tilde{A}L}(x), \upsilon_{\tilde{A}U}(x)\right] >| x \in X\right\}$ has only one element x, it can be simplified as $\tilde{A} = \left\{< \left[\mu_{\tilde{A}L}(x), \mu_{\tilde{A}U}(x)\right], \left[\upsilon_{\tilde{A}L}(x), \upsilon_{\tilde{A}U}(x)\right] >\right\}$), the score and exact value of interval value intuitionistic fuzzy set can be defined as:

$$\begin{cases} M(A) = \dfrac{\mu_{AL} + \mu_{AU} - \upsilon_{AL} - \upsilon_{AU}}{2} \\ \Delta(A) = \dfrac{\mu_{AL} + \mu_{AU} + \upsilon_{AL} + \upsilon_{AU}}{2} \end{cases} \tag{1}$$

Obviously, $M(A) \in [-1,1]$, $\Delta(A) \in [-1,1]$. Thus, for the two interval intuitionistic fuzzy sets A_j and A_k, their size relation or ranking are stipulated as follows:

If $M(A_j) > M(A_k)$, then A_j is greater than A_k, which is denoted as $A_j > A_k$; if $M(A_j) = M(A_k)$, then: 1) If $\Delta(A_j) = \Delta(A_k)$, then A_j equals to A_k, which is denoted as $A_j = A_k$; 2) If $\Delta(A_j) < \Delta(A_k)$, then A_j is smaller than A_k, which is denoted as $A_j < A_k$; 3) If $\Delta(A_j) > \Delta(A_k)$, then A_j is greater than A_k, which is denoted as $A_j > A_k$.

3.1.2. Fuzzy Measure Related Definitions

In addition to increasing the accuracy of qualitative expression, the researchers also improved evaluation quality by amending the basic assumptions of the multi-criteria model, namely, indicating importance of indexes with fuzzy measures instead of weights. The concept of fuzzy measures is defined in Definition 5.

Definition 4: Suppose X as a non-empty classical set, $X = \{x_1, x_2, ..., x_m\}$, function μ as a mapping from the power set $P(X)$ of X to [0, 1]. If it satisfies

$$\mu(\varnothing) = 0, \mu(X) = 1;$$

$$\forall A, B \in P(X), A \subseteq B \text{ and } \mu(A) \le \mu(B)$$

Then, μ is called fuzzy measure on X. If X is infinite, continuity conditions should be added.

It can be seen from the definition that the fuzzy measure replaces the additivity with monotonicity and avoids the requirement of independence hypothesis so that the relevance in the real world can be better expressed. Therefore, the fuzzy measure has also been applied in decision research [16, 17].

Definition 5 [18] For A, B∈P (X), A∩B = ∅. If the fuzzy measure g satisfies the following conditions:

$$g(A \cup B) = g(A) + g(B) + \lambda g(A) g(B)$$

Where, $-1 < \lambda < \infty$. Then, g is called λ - fuzzy measure.

Through the parameter λ, the link between indexes can be indicated:

If $\lambda = 0$, there is no interaction between A and B;

If $\lambda > 0$, then $g(A \cup B) > g(A) + g(B)$, indicating a multiplication between A and B;

If $\lambda < 0$, then $g(A \cup B) < g(A) + g(B)$, indicating an alternative between A and B;

If X is a finite set, then $\bigcup_{i=1}^{n} x_i = X$ .. λ - the fuzzy measure g satisfies the formula Eq. (1).

$$g(X) = \begin{cases} \dfrac{1}{\lambda}\left(\prod_{i=1}^{n}[1 - \lambda g(x_i)] - 1\right) & \text{if } \lambda \ne 0 \\ \sum_{i=1}^{n} g(x_i) & \text{if } \lambda = 0 \end{cases} \tag{2}$$

Where $x_i \cap x_j = \phi$, $i, j = 1, 2, ..., n$, and $i \ne j$. For a single index $x_i \in X$, $g(x_i)$ is called the fuzzy density function of x_i. It indicates the degree of importance of the attribute, which can be abbreviated as $g_i = g(x_i)$.

It can be known from formula (1) that, for any $A \in P(X)$, there is

$$g(A) = \begin{cases} \dfrac{1}{\lambda}\left(\prod_{i \in A}[1 - \lambda g_i] - 1\right) & \text{if } \lambda \ne 0 \\ \sum_{i \in A} g_i & \text{if } \lambda = 0 \end{cases} \tag{3}$$

According to formula (1), when $g(X) = 1$, λ can be determined by formula (3).

$$\lambda + 1 = \prod_{i=1}^{n}(1 + \lambda g_i) \tag{4}$$

Based on the above, the chain addition of interval intuitionistic fuzzy numbers in the fuzzy measure environment can be defined as Definition 7.

Definition 6 [15]: The hypothesis is an interval intuitionistic fuzzy set about $A_j = (a_1, a_2, ..., a_n) = ([\mu_{jL}, \mu_{jU}], [\upsilon_{jL}, \upsilon_{jU}]), j = 1, 2, ..., n$, μ is fuzzy measure about $A = \{a_1, a_2, ..., a_n\}$, then the operator (*IVILCA*) of interval intuitionistic fuzzy Choquet set can also be defined as:

$$\begin{aligned} IVILCA_{\mu}(a_1, a_2, ..., a_n) &= a_{(1)}(\mu(A_{(1)}) - \mu(A_{(2)})) \oplus a_{(2)}(\mu(A_{(2)}) - \mu(A_{(3)})) \oplus ... \oplus a_{(n)}(\mu(A_{(n)}) - \mu(A_{(n+1)})) \\ &= \left(\left[1 - \prod_{i=1}^{n}(1 - u_l(a_{(i)}))^{\mu(A_i) - \mu(A_{i+1})}, 1 - \prod_{i=1}^{n}(1 - u_u(a_{(i)}))^{\mu(A_i) - \mu(A_{i+1})}\right], \left[\prod_{i=1}^{n} v_l(a_{(i)})^{\mu(A_i) - \mu(A_{i+1})}, \prod_{i=1}^{n} v_u(a_{(i)})^{\mu(A_i) - \mu(A_{i+1})}\right]\right) \end{aligned} \tag{5}$$

Where, $(\bullet)$ denotes a transpose on *A*, which renders $a_{(1)} \le a_{(2)} \le \cdots \le a_{(n)}$, $A_{(i)} = \{a_{(i)}, ..., a_{(n)}\}$, and at the same time, $A_{(n+1)} = \varnothing$.

3.2. CMLN PPP Project Contract Risk Evaluation Steps

The evaluation of the contract risks of CMLN PPP projects is divided into three steps, specifically as follows:

Step 1: Determine the evaluation index. After the contract scheme of CMLN PPP project is confirmed, the experts need to conduct a detailed inspection of the contract scheme and construction site of CMLN project, so as to obtain the first-hand information of the contract risk evaluation. The risk evaluation of CMLN PPP project contracts is mainly based on the index system of CMLN PPP project contract risk evaluation proposed in this paper. The indexes can be the same as the evaluation indexes proposed in this paper, or can be deleted based on the actual situation.

Step 2: Determine the fuzzy measure of the index. The purpose of this stage is to determine the significance of CMLN PPP project contract risk evaluation indexes and sub-indexes through fuzzy measures. First, the experts score the importance of evaluation indexes and sub-indexes according to the alternatives of PPP projects, with the scores in the range of 0-1. The importance of the evaluation attributes is determined by the project governing body, and the relationship between indexes are determined by experts; then, based on the importance value determined in the first step, λparameter of attributes, indexes and sub-indexes are determined by formula (4); afterwards, based on the interaction between the indexes, fuzzy measure of different index combinations are determined through formula (3).

Step 3: Assess the index value aggregation. First of all, the risk of CMLN PPP project contract is evaluated according to the evaluation index. The experts first determine the probability interval $[\mu^L, \mu^U]$ of occurrence of CMLN PPP project contract in the evaluation index by scoring between 0 and 10, and then evaluate the probability interval of non-occurrence from the interval $[0, 1-\mu^U]$. These two scores constitute the interval intuitionistic fuzzy risk evaluation value of CMLN PPP project contract in the evaluation index. Then, the intuitionistic fuzzy risk evaluation value and fuzzy measure of sub-index and index are aggregated through interval intuitionistic fuzzy Choquet aggregation operator (formula (5)) to obtain the comprehensive evaluation value of CMLN PPP project contract risk. Finally, risk degree is judged according to the comprehensive evaluation value. The judgment basis is shown in Table 2.

Table 2. *Risk level partition table.*

	low risk	score value	exact value
interval	([0.00, 0.00], [1.00, 1.00])	-1	1
	([0.30, 0.33], [0.67, 0.70])	-0.37	1
	medium risk		
interval	([0.31, 0.34], [0.66, 0.69])	-0.35	1
	([0.60, 0.66], [0.34, 0.40])	0.26	1
	high risk		
interval	([0.61, 0.67], [0.33, 0.39])	0.28	1
	([1.00, 1.00], [0.00, 0.00])	1	1

4. Study Case

CMLN project is needed somewhere in Shanxi Province of China. Due to the huge investment in the project and the lack of funds as well as corresponding management experience of the local government, PPP mode is adopted for the construction and operation of this project. After reaching an agreement with the government, the social capital partyformulates the corresponding contract scheme and carries out risk analysis on the contract scheme.

Based on the local political environment, cultural environment and natural environment, risk analysts select the CMLN PPP project risk evaluation index and evaluate the importance of each index. The evaluation results are shown in Table 3 and can serve as fuzzy measure of indexes.

Risk analysts then conduct a risk evaluation of the contract scheme for CMLN PPP projects based on the indexes, with the evaluation results shown in Table 4. Then, the risk evaluation values of each index and fuzzy measures of indexes and sub-indexes are aggregated according to formula (5). The score of the contract scheme on the index and the overall composite score are then obtained, as shown in Table 5.

Then according to the formula (1), the score value and exact value of the intuitionistic fuzzy risk evaluation are calculated, as shown in Table 5. The risk level of the contract scheme of CMLN PPP project is determined according to the contents in Table 2. The final evaluation result is that the CMLN PPP project contract scheme has a low external project contract risk, indicating low risk from political environment impact at home and abroad during project construction and operation; the contract scheme has medium internal projectcontract risk, indicating that risk management should be strengthened in terms of address survey, hydro-climatic conditions and supply of equipment and materials; expected risks should be written into the contractual documents to prevent future disputes with property owners; the contract scheme has medium contract execution risk, indicating unreasonable areas in plan for dealing with contract execution risk, and that comprehensive evaluation value needs improvement.

Table 3. *Fuzzy measure of indexes.*

Indexes	fuzzy measure	Sub-indexes	fuzzy measure
PC11	0.70	(PC11-1)	0.66
		(PC11-2)	0.41
		(PC11-3)	0.36
		(PC11-4)	0.45
		(PC11-5)	0.46
		(PC11-6)	0.60
PC12	0.50	(PC12-1)	0.20
		(PC12-2)	0.20
		(PC12-3)	0.60
		(PC12-4)	0.55
		(PC12-5)	0.50
		(PC12-6)	0.60
PC13	0.40	(PC13-1)	0.43
		(PC13-2)	0.44
		(PC13-3)	0.70
		(PC13-4)	0.80
		(PC13-5)	0.20
		(PC13-6)	0.70
		(PC13-7)	0.50
		(PC13-8)	0.50

Table 4. *Contract risk value.*

Sub-indexes	Contract risk value	Sub-indexes	Contract risk value
PC11-1	([0.15, 0.22], [0.83, 0.86])	PC12-5	([0.60, 0.75], [0.25, 0.25])
PC11-2	([0.29, 0.35], [0.65, 0.70])	PC12-6	([0.15, 0.22], [0.83, 0.86])
PC11-3	([0.60, 0.75], [0.25, 0.25])	PC13-1	([0.10, 0.20], [0.80, 0.90])
PC11-4	([0.10, 0.20], [0.80, 0.90])	PC13-2	([0.29, 0.35], [0.65, 0.70])
PC11-5	([0.24, 0.31], [0.66, 0.73])	PC13-3	([0.60, 0.75], [0.25, 0.25])
PC11-6	([0.29, 0.35], [0.65, 0.70])	PC13-4	([0.10, 0.20], [0.80, 0.90])
PC12-1	([0.54, 0.59], [0.25, 0.30])	PC13-5	([0.20, 0.30], [0.65, 0.70])
PC12-2	([0.20, 0.30], [0.66, 0.80])	PC13-6	([0.10, 0.20], [0.80, 0.90])
PC12-3	([0.35, 0.60], [0.40, 0.40])	PC13-7	([0.29, 0.35], [0.65, 0.70])
PC12-4	([0.29, 0.35], [0.65, 0.70])	PC13-8	([0.35, 0.60], [0.40, 0.40])

Table 5. *The comprehensive evaluation value.*

Indexes	score value	exact value
PC11	-0.78	0.99
PC12	-0.13	0.86
PC13	-0.34	0.97
总计	-0.30	0.95

5. Conclusion

In this paper, contract risk evaluation index system is established for PPP project. Then, based on the latest research results of fuzzy mathematics and multi-attribute decision-making model, contract risk evaluation method is proposed for PPP project in CMLN. The method solves the problem of information loss of expert evaluation value through intuitionistic fuzzy numbers, and solves the problem of independence hypothesis between indexes through fuzzy measure and Chouqet integral operator. Finally, the applicability of index system and method is verified by applying the evaluation index system and evaluation method proposed in this paper to CMLN PPP project in Shanxi Province.

Fund Project

Liaoning Provincial Philosophy and Social Science Planning Fund Project (L16CGL012)

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