Application of Fuzzy Theory in Contractor Risk Assessment under EPC Model

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***Abstract*—To meet the requirements for being geared to the international standards and to meet the demand for self-development of an enterprise, it becomes more and more common for an enterprise to execute EPC projects. The EPC model compares with the traditional contract model, the risk of general contactor is the biggest undoubtedly. Through the analysis of the EPC model to determine the risk source and loss of general contractor and then use the fuzzy comprehensive evaluation method to realize the quantization of the possibility of risk occurrence and risk loss. By the quantified possibility of risk occurrence and loss consequences to calculate the risk gene and get the risk quantized valve ultimately. The example shows that fuzzy comprehensive risk evaluation method can realize quantitative treatment of fuzzy and uncertain information and can practically and effectively evaluate the EPC general contractor's risk.**

Keywords- EPC; fuzzy evaluation; risk gene; risk occurrence possibility; risk loss consequence

I. INTRODUCTION

EPC engineering general contract means one general contractor or contractor combo manages all process and aspects of project, including design, equipment and materials purchase, construction and trial operation until bringing into service in [1].The general contractor has considered the design, procurement and construction impacts in project early and design term. It brings the contractor opportunities as well as more severe challenges. General contractor not only need to bear the construction risk, it also bear the engineering design and procurement additional risk and the fault risk of owner are often also required the contractor to bear [2]. How to apply systematic and effective way to evaluate the project implementation risks, and makes effective control, it has become an important issues that the general contractor must resolve. The data in project risk evaluation are largely no determinacy and ambiguity. The same time, it has more comprehensive consideration factors and the importance degree of each factor is different. This makes classical mathematical method to be difficulties to solve problems in risk assessment [3]. Fuzzy comprehensive evaluation method is a method that use fuzzy set theory to make an overall assessment on the multi-factor constrained things or objects. It can be used to analyze the impact of project risks that all fuzziness and uncertainty risk factors, and thus make a comprehensive risk evaluation on project..

Foundation item:
1 Beijing Municipal Project for Developing Advanced Human Resources for Higher Education.
2 Scientific Research and Innovation Base Project of Beijing Wuzi University (WYJD200902)
3 Funding project for Academic Human Resources Development in Institutions of Higher Learning under the Juristiction of Beijing Municipality (PHR200907134)

II. RISK QUANTIFICATION ANALYSIS

Risk is the comprehension of loss uncertainty and the consequences deviate from the intended goal [4], which means risk is co-decided by the likelihood risk source and the loss severity. In order to quantify express the risk value, it introduced the risk gene [5]: risk gene FR mainly basic on the possibility of risk occurrence PF and the severity degree of risk loss consequence CF, the relationship between them can express as follow:

$$RF = PF + CF - PF \bullet CF$$

In order to eliminate the dimension difference between the risk sources possibility PF and severity degree of risk loss consequence CF, it use the Fuzzy theory to make an quantified treatment then do the calculation of it.

III. EPC GENERAL CONTRACTOR RISK SOURCE AND RISK CONSEQUENCE ANALYSIS

A. Risk Source Analysis

Through the analysis of the information that already collected [2，6-8], it sorted out that general contractor risk sources mainly includes:

1) Politics: Examining the political situation in the country where the project is stable; researching the neighboring countries with the potential danger of war; to study its domestic laws, regulations, trade policies on the implementation of the project constraints, project site security situation

2) Economy: Researching the aim project country's fiscal policy and monetary policy; examining its exchange rate, interest rate changes, foreign capital and management.

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3) Market: Researching the aim project country's inflation and examining its development of construction and materials market situation, the international contract companies and national construction company has contracted projects the price level and payment conditions.

4) Owners: Understanding the owners' credit conditions and pay ability; studying the ability of owners to oversee works and their requirements on quality, schedule, and tandardized standards.

5) Contracts: Studying the general and special contract conditions of tender documents, and contract with international common terms to do comparative research, doing an analysis on their differences; focusing on the contract terms of payment, tax, foreign exchange, the price adjustment provisions; analyzing their relevant a variety of restrictive description and so on.

6) Natural conditions: Doing a survey on the site conditions of tender , including the external conditions (such as roads, water, electricity, communications and transport, etc.), topography, geology, hydrology, meteorology and the surrounding environmental conditions, in particular, it need to look at built-up areas' natural disasters history

B. Risk Consequence Analysis

The ultimate goal of project management is progress, quality, cost, and the consequences of various risk factors, eventually led the project progress, quality, and cost that three main objectives to losses.

C. Risk Level Division

By consulting the experts, on-site technical staff and referring to information, the impact of risk factors which impact the risk gene can be classified ignored, acceptable, moderate risk, extremely dangerous five grades. As in table I.

IV. RISK FUZZY COMPREHENSIVE EVALUATION MODEL

Project risk assessment depends on the accuracy of various risk factors values, and to a certain extent, these values are subjective, vague. To address this problem, fuzzy comprehensive evaluation method can be used for risk factors quantitative analysis.

A. The Establishment of Evaluation Index System

Based on the EPC project risk factor analysis, the risk evaluation index system is divided into two categories:
The risk source possibility index system P and risk losses consequence index system C, and each of them can express as following:

$$P = (\text{politics}, \text{economics}, \text{markets}, \text{owners}, \text{contractor}, \text{nature condition}) = (p_1, p_2, p_3, p_4, p_5, p_6);$$

$$C = (\text{progress}, \text{quality}, \text{cost}) = (c_1, c_2, c_3)$$

B. Determination of Evaluation Index Weights

Using expert survey method, this paper has done a large number of questionnaire surveys to engineers, designers, managers, professors and on-site technical staff. Then according to the different relative importance degree of each evaluation index to the evaluation purpose, it has given a corresponding weight to each evolution index. The corresponding weight W_p and W_c of evaluation indexes P and C were:

$$W_p = (w_{p1}, w_{p2}, w_{p3}, w_{p4}, w_{p5}, w_{p6})$$

$$W_c = (w_{c1}, w_{c2}, w_{c3})$$

C. Determination of Membership Degree

Since simple shape of triangular membership function and easy to calculate, and to other more complex membership functions, it has a smaller difference in the results, so it has been widely adopted [9]. According to the divided risk level, it has made a determination to the risk level reviews set score as V= {negligible, acceptable, medium, dangerous, and extremely dangerous}={10，30，50，70，90}. It has used triangular membership function to build the fuzzy relationship matrix of risk evaluation index set P, C, and status reviews set V. The distribution of the specific membership functions that each evaluation index belongs to "negligible, acceptable, moderate risk, extremely dangerous," as shown in Fig. 1.

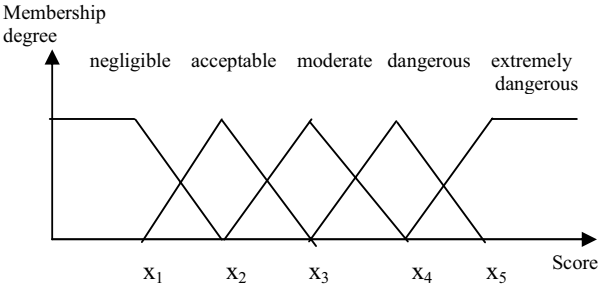

Figure 1. Distribution of the specific membership functions

Constructed the following membership function, the expression as follows:

TABLE I. DEGREE CLASSIFICATION OF RISK FACTORS

The possibility of the risk source						
Degree	***Politics***	***Economics***	***Markets***	***Owners***	***Contracts***	***Natural conditions***
Negligible	Management efforts in government departments	Periodic fluctuations in the economy	Bad Local market order	The requirement of moderate Loaning	General provisions in the contract	Poor weather conditions
Acceptable	Limits of laws and regulations are more cumbersome	Appropriately tight fiscal and monetary policies	Material price fluctuations	The quality and progress requirements.	Differences with international general terms.	Incomplete external conditions
Medium	More stable political situation, but the poor public order	A change in interest rates is too large.	Building materials production ability	The capability of owner in project management.	Restrictive instructions.	Field does not have the external conditions.
Dangerous	Ethnic, religious have a complex relationship.	Fluctuations in the exchange rate at any time.	Disorderly vicious competition.	Funds to pay can not be guaranteed.	Payments, taxes, foreign exchange, price terms	Harsh environmental conditions.
Extremely dangerous	The country is political turmoil, war is very possible	The economic situation is grim.	Serious inflation.	Source of funds is unknown.	Contract unclear.	Disaster-prone areas.

The Severity of the Risk Loss Consequences			
Degree	***Progress***	***Quality***	***Cost***
Negligible	The impact of the project can be ignored, or can use the compensation for the original schedule.	Quality standards in line with the contract.	Does not exceed budget.
Acceptable	Progress has slightly delayed and the task has a little adjustment.	Repaired and up to standard.	Overrun budget more than 1% - 5%.
Medium	Progress has been postponed.	Quality problems need to counter-work.	Overrun budget more than 5%-10%.
Dangerous	Progress has been postponed more than three months.	With major quality problems.	Overrun budget more than 10%-30%.
Extremely dangerous	Progress was considerably delayed, and impact to the project milestones.	Not meet contractual requirements.	Overrun budget more than 30%-50%.

$$D_1=\begin{cases}1 & x\le x_1\\ \dfrac{x_2-x}{x_2-x_1} & x_1<x<x_2\\ 0 & x\ge x_2\end{cases} \quad (1)$$

$$D_2=\begin{cases}0 & x\le x_1\\ \dfrac{x-x_1}{x_2-x_1} & x_1<x\le x_2\\ \dfrac{x_3-x}{x_3-x_2} & x_2<x\le x_3\\ 0 & x\ge x_3\end{cases} \quad (2)$$

$$D_3=\begin{cases}0 & x\le x_2\\ \dfrac{x-x_2}{x_3-x_2} & x_2<x\le x_3\\ \dfrac{x_4-x}{x_4-x_3} & x_3\le x<x_4\\ 0 & x\ge x_4\end{cases} \quad (3)$$

$$D_4=\begin{cases}0 & x\le x_3\\ \dfrac{x-x_3}{x_4-x_3} & x_3<x\le x_4\\ \dfrac{x_5-x}{x_5-x_4} & x_4\le x<x_5\\ 0 & x\ge x_5\end{cases} \quad (4)$$

$$D_5=\begin{cases}0 & x\le x_4\\ \dfrac{x-x_4}{x_5-x_4} & x_4<x<x_5\\ 1 & x\ge x_5\end{cases} \quad (5)$$

x is the measure value of i th indicators; $x_1,x_2,\cdots,x_5$ is the risk level reviews percentile values, each were 10, 30,50,70,90.

D. Single Index Fuzzy Evaluation

In accordance with the given percentage grades, asking expert to mark on various evaluation index system on a

scorecard, and then using the degree membership computing formula to calculate each index's risk assessment sets.

The risk assessment evaluation index set of possibility of a risk source p_i as follows: $p_i = (p_{i1}, p_{i2}, p_{i3}, p_{i4}, p_{i5})$, p_{it} is the degree membership of t th. In this way, it can get six risk source indicator sets for the evaluation .Collection of these 6 sets together, it can obtain the following fuzzy relational matrix:

$$\mathrm{P} = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{15} \\ p_{21} & p_{22} & \cdots & p_{25} \\ \cdots & \cdots & \cdots & \cdots \\ p_{61} & p_{62} & \cdots & p_{65} \end{bmatrix}$$

Similarly, it can get the fuzzy relation matrix of risk consequences indicators as

$$C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{15} \\ c_{21} & c_{22} & \cdots & c_{25} \\ c_{31} & c_{32} & \cdots & c_{35} \end{bmatrix}$$

E. Fuzzy Comprehensive Evaluation

Project risk source possibility comprehensive evaluation set are:

$$PF = W_p \times P = (w_{p1}, w_{p2}, w_{p3}, w_{p4}, w_{p5}, w_{p6}) \times \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{15} \\ p_{21} & p_{22} & \cdots & p_{25} \\ \cdots & \cdots & \cdots & \cdots \\ p_{61} & p_{62} & \cdots & p_{65} \end{bmatrix} \quad (6)$$

Project risk loss consequences comprehensive evaluation sets are:

$$CF = Wc \times C = (w_{c1}, w_{c2}, w_{c3}) \times \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{15} \\ c_{21} & c_{22} & \cdots & c_{25} \\ c_{31} & c_{32} & \cdots & c_{35} \end{bmatrix} \quad (7)$$

Then, the risk gene evaluation set can express as follows:

$$RF = PF + CF - PF \bullet CF = (rf_i, rf_2, \cdots, rf_5) \quad (8)$$

F. Quantitative Formulation Risks Value

It needs to do risk gene valuation set normalization, that is

$$rf_i' = rf_i \Big/ \sum_{t=1}^{5} rf_t \, , i = 1, 2, \cdots, 5 \quad (9)$$

Then, getting the normalized evaluation set as

$$RF' = (rf_1', rf_2', \cdots, rf_5')$$

The ultimate risk value R = $RF' \times$ risk level remark sets

$$= (rf_1', rf_2', \cdots, rf_5') \times \begin{pmatrix} 10 \\ 30 \\ 50 \\ 70 \\ 90 \end{pmatrix} \quad (10)$$

V. EXAMPLE ANALYSIS

Nigeria "AJAOKUTA-LOKOJA-WAGWALADA 330kV double-circuit transmission line EPC project" was June 5, 2006 signed a EPC contract with duration of 15 months. Project is located in Africa, Central Nigeria, and the total length is about 219 kilometers, with an average altitude of 200 meters above sea level. The contract shall pay the way with U.S. dollars and local currency two kinds.

Basing on the analyzed risk level, invited experts give the scoring of risk assessment indicators, showing in Table II.

TABLE II. RISK INDEX'S RISK LEVEL

The Possibility of Risk Source P					
Politics	***Economic***	***Market***	***Owner***	***Contractor***	***Nature conditions***
65	52	45	40	38	46
The risk losses consequence severity degree C					
Progress		***Quality***		***Cost***	
63		36		42	

Through expert survey method and according to the different relative importance degree of each evaluation index to the evaluation purpose, it given a corresponding weight to each evolution index:

$$W_p = (w_{p1}, w_{p2}, w_{p3}, w_{p4}, w_{p5}, w_{p6}) = (0.21, 0.18, 0.11, 0.15, 0.2, 0.15)$$

$$W_c = (w_{c1}, w_{c2}, w_{c3}) = (0.3, 0.5, 0.2)$$

According to (1)-(5), it can calculate the evaluation index for each set and build a fuzzy relationship matrix:

$$P = \begin{bmatrix} 0 & 0 & 0.25 & 0.75 & 0 \\ 0 & 0 & 0.9 & 0.1 & 0 \\ 0 & 0.25 & 0.75 & 0 & 0 \\ 0 & 0.5 & 0.5 & 0 & 0 \\ 0 & 0.6 & 0.4 & 0 & 0 \\ 0 & 0.2 & 0.8 & 0 & 0 \end{bmatrix}$$

$$C = \begin{bmatrix} 0 & 0 & 0.35 & 0.65 & 0 \\ 0 & 0.7 & 0.3 & 0 & 0 \\ 0 & 0.4 & 0.6 & 0 & 0 \end{bmatrix}$$

According to (6), it can calculate the possibility risk source comprehensive evaluation sets:

$$PF = W_p \times P = (0.21, 0.18, 0.11, 0.15, 0.2, 0.15)$$

$$\times \begin{bmatrix} 0 & 0 & 0.25 & 0.75 & 0 \\ 0 & 0 & 0.9 & 0.1 & 0 \\ 0 & 0.25 & 0.75 & 0 & 0 \\ 0 & 0.5 & 0.5 & 0 & 0 \\ 0 & 0.6 & 0.4 & 0 & 0 \\ 0 & 0.2 & 0.8 & 0 & 0 \end{bmatrix}$$

According to (7), it can calculate the risk losses consequence comprehensive evaluation sets:

$$CF = Wc \times C = (0.3, 0.5, 0.2)$$

$$\times \begin{bmatrix} 0 & 0 & 0.35 & 0.65 & 0 \\ 0 & 0.7 & 0.3 & 0 & 0 \\ 0 & 0.4 & 0.6 & 0 & 0 \end{bmatrix}$$

$$= (0, 0.43, 0.375, 0.195, 0)$$

According to (8), it can calculate the risk gene evaluation set:

$$RF = PF + CF - PF \bullet CF = (0, 0.683, 0.801, 0.354, 0) - (0, 0.109, 0.16, 0.031, 0)$$

$$= (0, 0.574, 0.641, 0.323, 0)$$

According to (9), it can do a normalization to the risk gene evaluation set RF:

$$RF' = (rf_1', rf_2', \cdots, rf_5') = (0, 0.373, 0.417, 0.21, 0)$$

The last, according to (10), calculating the risk value:

$$R = (rf_1', rf_2', \cdots, rf_5') \times \begin{pmatrix} 10 \\ 30 \\ 50 \\ 70 \\ 90 \end{pmatrix} = (0, 0.373, 0.417, 0.21, 0) \times \begin{pmatrix} 10 \\ 30 \\ 50 \\ 70 \\ 90 \end{pmatrix} = 46.74$$

From the above analysis, the risk value of EPC general contractor is 46.74, compared with the level of risk scores, with moderate risk level, and the general contractor need to take measures to reduce the risk factors level that with a greater risk rating and ensure the project would operate correctly.

VI. CONCLUSION

EPC general contract model has huge investment, long cycle, involving a wide range, high-impact characteristics, and this determine its high-risk characteristics. In this paper, through the risk analysis of the EPC general contractor, for the ambiguity information in risk assessment, and using fuzzy comprehensive evaluation method to do a fuzzy quantitative treatment of qualitative issues, use of risk gene to calculate the risk values explicitly, it can effectively evaluate the general contractor risk in EPC.

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