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Research on Risk Element Transmission of Enterprise Project Evaluation Chain Based on Trapezoidal Fuzzy Number FAHP

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Abstract: In this study, a new modeling method based on trapezoidal fuzzy number FAHP has been proposed to solve the problem of risk element transmission in enterprise project evaluation chain. We firstly put forward enterprise project chain risk element transmission and constructs enterprise project chain risk element transmission tetrahedron model and then proposed the theory of enterprise project evaluation chain risk element transmission based on trapezoidal fuzzy number FAHP. After that, we introduced COWA operator and expect complementary judgment matrix and make an order about trapezoidal fuzzy number weight. Finally we prove the feasibility of this theory by an example.

Key words: Enterprise project evaluation, F-AHP, risk element transmission, trapezoidal fuzzy number

INTRODUCTION

An evaluation about a whole enterprise project, it starts evaluation task form sub-project and finally make project evaluation form floor to ceiling. Only the lower project evaluation ended can it provide basis data for the upper project evaluation. In this a series of process, if a link evaluation produce deviation, namely the accuracy of the evaluation has a problem, this mistake will bring deviation to the upper level project evaluation. This series of process is like omino effect and utterfly effect a small mistake would bring a big change to whole enterprise project assessment. By extension to the enterprise project risk management, a slight change of risk element, after a chain reaction that is the effect of risk element transmission, could lead to enterprise project evaluation target huge deviation. Therefore, we should pay attention to the research of enterprise project evaluation risk element transmission.

Analytical Hierarchy Process (AHP) is put forward by American operations research T.L. Saaty in the 70s. It is a kind of new qualitative analysis and quantitative analysis of combining the multi-objective decision analysis method. Its characteristic is that quantify the experience of analyst. It is more practical in multi-objective and lack of necessary data of case. It is a system analysis method that is more simple and feasible and effective in dealing with qualitative and quantitative problem in system engineering (Saaty, 1980; Xu, 2001). Using hierarchical analysis method, established a mathematical model of risk employee management and analyzed risk of power supply enterprise employee management. It also proposed the thought of strengthen employee management and prevent labor risk combining with the actual primary power supply enterprise (Yang, 2008). According to complexity and uncertainty existing in project risk assessment influence factors, expanded point scale to interval scale in Analytic Hierarchy Process (AHP). Finally, put forward the engineering project risk assessment method based on interval numbers analytic hierarchy process (Gao and Chen, 2011). Applied fuzzy analytic hierarchy process in the supply chain credit risk evaluation, it provided a set of effective method for supply chain of credit evaluation (Zhao and Li, 2011). For the defect of analytic hierarchy process in the quantitative risk when ignored the fuzziness of artificial judgment, making full use of fuzzy mathematics research results, extended Analytic Hierarchy Process (AHP) to fuzzy environment. Finally, get Fuzzy Analytic Hierarchy Process (FAHP). It also proved the method feasibility in the risk assessment combining with some air engineering project (Zhu, 2010). The above documents from different aspects and different field using analytic hierarchy process to project appraisal and analysis. There are also put forward fuzzy analytic hierarchy process analysis in some literature. Whether for project evaluation or risk analysis, there aren't involved the research of risk element transmission of project evaluation process using analytical hierarchy process.

In the absence of objective data and lack of data, it is hard to get project risk element probability distribution in t actual evaluation. So, it is also very difficult to make comprehensive evaluation of enterprise project risk element using probability quantitative way. And need to

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use the subjective experience of risk experts to estimate the values of risk element. The author has used interval number, triangular fuzzy number and other ways to measure the size of the project risk element. Based on above, it created interval number hierarchy risk element transmission model and triangular fuzzy number fuzzy analytic hierarchy process project risk element transmission model (Li, 2009). Although these model in a certain extent, embodies the man's subjective initiative, still cannot better reflect the real situations of the project risk element (Adrian, 2008). Due to the trapezoidal fuzzy number has interval number and triangular fuzzy number genre outside, still have its own special nature. It the most possible value is a interval value, so it can better reflect the subjective initiative. Therefore, this study put forward enterprise project evaluation chain risk element transmission model based on trapezoid fuzzy number fuzzy hierarchical process.

PROJECT CHAIN RISK ELEMENT TRANSMISSION MODEL

Project is a few set of activities, that is, a project contains a lot of events. The whole project to successfully completed, it must ensure that all the events are project completion. This reflected the integrity of the project. If the project in a certain link have problems that will lead to the project cannot duly completed. For construction project, if not promptly supply raw materials or there is a quality problem, will cause the time delay, lead to project can not complete. Such programs for production, raw material shortages or lack of labor force will lead to product not timely supply and bring to the project of loss. To this kind of phenomenon, because of a small link problems in project that led to the final project goal is not met. We define the produce problem factores as risk element and this kind of level the influence of the recursive called risk element transmission.

About the generalized project risk element transmission, we have done a lot of research and get more research results. Firstly, we constructed the generalized project risk element transmission three-dimensional model. Secondly, based on three-dimensional model, we established relational risk transfer theory, hierarchical transfer theory, tree and chain type of risk transfer theory and network risk element transmission theory.

Because enterprisecomposed by many projects, especially construction enterprise and production enterprise, in addition, enterprise operation of the complexity and variety, the phenomenon of risk element transmission more obvious and more complex. The enterprise is based on earnings for the purpose, but profit and risk coexist. It is the ultimate goal of the enterprise that how to avoid risk and get higher income. Avoiding risk, we must understand risk situation and impact, which needs research enterprise project risk between influence each other. Moreover, a single project exsiting risk element transmission phenomenon, expand to multi-project and because it has business contacts and inevitable risk element transmission. Therefore, this study puts forward the concept of project chain used to describe the existence business contacts between enterprise project. Based on study of generalized project risk element transmission, breakthrough single project risk element transmission, make direction to multi-project risk element transmission. Based on the enterprise management height, make study about multi-project risk under information environment, puts forward enterprise project chain risk element transmission and constructs enterprise project chain risk element transmission tetrahedron model, as Shown in Fig. 1.

This study adopts Fuzzy Analytic Hierarchy Process (FAHP) to research the construction enterprise project evaluation chain risk element transmission. The purpose is analysis the risk element transfer behavior and rich enterprise project risk management theory.

THEORY OF TRAPEZOIDAL FUZZY NUMBER AND AHP

Trapezoidal fuzzy number:

Defineition 1: A fuzzy number T is called trapezoidal fuzzy number, only if its membership functions $f_{T\text{-}}$: R → [0, 1] shown as (1):

$$f_{T-} = \begin{cases} (x-t_1)/(t_2-t_1), & t_1 \le x \le t_2 \\ 1, & t_2 \le x \le t_3 \\ (x-t_4)/(a_3-a_4), & t_3 \le x \le t_4 \\ 0, & other \end{cases} \quad (1)$$

where, $-\infty < t_1 \le t_2 \le t_3 \le t_4 < +\infty$ t_1 and t_4 are the upper and lower bounds of T respectively and closed interval $[t_2, t_3]$ is the median of T. So, a trapezoidal fuzzy number can be expressed as $T = (t_1, t_2, t_3, t_4)$. Shown as Fig. 2.

- **Trapezoidal fuzzy number algorithm:**

Trapezoidal fuzzy number M and N, $M = (m_1, m_2, m_3, m_4)$

$N = (n_1, n_2, n_3, n_4)$ and $M > 0, N > 0$

Trapezoidal fuzzy number addition law:

$M \oplus N = (m_1 + n_1, m_2 + n_2, m_3 + n_3, m_4 + n_4)$

Trapezoidal fuzzy number multiplication law:

$M \otimes N = (m_1 n_1, m_2 n_2, m_3 n_3, m_4 n_4)$

Trapezoidal fuzzy number division law:

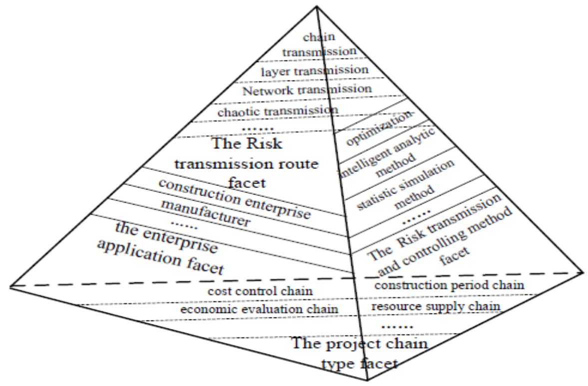

Fig. 1: Enterprise project chain risk element transmission tetrahedron model

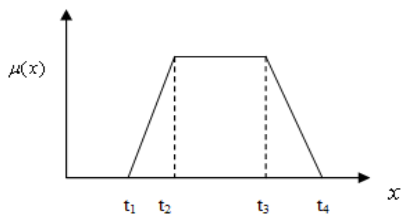

Fig. 2: Trapezoidal fuzzy number (T)

$$M / N = (m_1 / n_1, m_2 / n_2, m_3 / n_3, m_4 / n_4)$$

Definition 2: A fuzzy number $T(x)$, $\alpha \in [0, 1]$, $T_\alpha = \{ x \mid T(x) \geq \alpha \}$ T_α is called α cut set. α is confidence level.

Supposed: $M = (m_1, m_2, m_3, m_4)$, $N = (n_1, n_2, n_3, n_4)$

Under the confidence level α, we can get the two corresponding closed interval M_α, N_α respectively,

$M_a = [m^a_1, m^a_4] = [(m_2 - m_1)a + m_1, (m_4 - m_3)a + m_4]$

$N_a = [n^a_1, n^a_4] = [(n_2 - n_1)a + n_1, (n_4 - n_3)a + n_4]$

$\forall \alpha \in [0, 1]$

M_α, N_α has the following algorithm:

- Addition law: $M_a \oplus N_a = [m^a_1, m^a_4] \oplus [n^a_1, n^a_4] [m^a_1 + n^a_1, m^a_1 + n^a_4] - [M \oplus N]_a$
- Multiplication law: $M_a \otimes N_a = [m^a_1, m^a_4][n^a_1, n^a_4] - [m^a_1 n^a_1, m^a_1 n^a_4][M \otimes N]_a$
- Division law: $M_a \div N_a = [m^a_1, m^a_4] \div [n^a_1, n^a_4] = [m^a_1 \div n^a_1, m^a_1 \div n^a_4] - [M \div N]_a$

- **Sorting of trapezoidal fuzzy number:** Due to the trapezoidal fuzzy number can't directly sorting, therefore, to compare the size of two fuzzy number, need to put the fuzzy number transform into the size of the real number, which use the nature of the real number to export trapezoidal fuzzy number sequence (Wang and Kerre, 2001).

This study uses the COWA operators that put forward by the Wu to sort fuzzy number. This operator is defined as follows (WU, 2010):

Definition 3: Suppose [a, b] and:

$$f_Q([a,b]) = \int_0^1 \frac{dQ(y)}{dv}(b - y(b-a))dy \qquad (2)$$

where, function Q: $[0, 1] \rightarrow [0, 1]$ has those characters as follow:ing:

- $Q(0) = 0$
- $Q(1) = 1$
- if $x \geq y$, so $Q(x) \geq Q(y)$

So, called function Q as Basic Unit interval Monotonic function (BUM). Supposed λ is decision maker's optimistic for a degree:

$$\lambda = \int_0^1 Q(y)dy (0 \leq \lambda \leq 1)$$

So,

$$f_Q([a, b]) = \lambda b + (1 - \lambda)a \qquad (3)$$

when

$$Q(y) = y^r (r \geq 0)$$

COWA operator can be expressed as following:

$$f_Q([a,b]) = \frac{b+ra}{r+1}$$

when the value of r is different values and the value of the different function f, representing different the decision maker's optimistic degree.

Definition 4: Application COWA operator, the trapezoid fuzzy number T change into expectations function precise number form $Exp_Q(T)$:

$$Exp_Q(T) = 2\int_0^1 f_Q([T_\alpha])\alpha d\alpha$$

$$= \frac{(1-\lambda)(t_1+2t_2)+\lambda(2t_3+t_4)}{3} \quad (4)$$

Definition 5: A judgment matrix $G = (g_{ij})_{n\times n}$

where
$g_{ij} = (a_{ij}, b_{ij}, c_{ij}, d_{ij})$is trapezoid fuzzy number.
Subject to:

$0 \le a_{ij} \le b_{ij} \le c_{ij} \le d_{ij} \le 1$

$a_{ij} + d_{ij} = 1$

$b_{ij} + cji = 1$

$c_{ij} + b_{ij} = 1$

$d_{ij} + a_{ji} = 1$

$a_{ii} = b_{ii} = c_{ii} = d_{ii} = 0.5, I, j \in N$

G is called trapezoid fuzzy number Complementary judgment matrix.

Definition 6: If $G = (g_{ij})_{n\times n}$ is trapezoid fuzzy number Complementary judgment matrix,

$Exp_Q(T) = Exp_Q(G_{ij})$ is called expectation value Complementary judgment matrix.

where

$$Exp_Q(g_{ij}) = \frac{(1-\lambda)(a_{ij}+2b_{ij})+\lambda(2c_{ij}+d_{ij})}{3}$$
$$Exp_Q(g_{ij}) = 1 - Exp_Q(g_{ji}) \quad (5)$$

THEORY OF ANALYTIC HIERARCHY PROCESS (AHP)

Analytic Hierarchy Process is always about the decision decomposed into target, criterion elements, such as scheme level, based on the qualitative and quantitative analysis for the decision-making method. This method is the United States house of operations research, a professor at the university of Pittsburgh, in this century's 70 s, in the research for the department of defense, ccording to various industrial department of national welfare contributions and electric power distribution topics, the application of the network system theory and multi-objective synthesis evaluation method, puts forward a kind of level of weight decision analysis method.

AHP is an intuitive method for formulating and analyzing decisions. It uses four steps in solving a problem (Hajeeh and AI-Othman, 2005).

The first step involves structuring of the decision into a hierarchical model. This includes the decomposition of the problem into elements according to their common characteristics and forming a hierarchical model at different levels. Each level corresponds to the common characteristic of the elements in that level. The topmost level represents the main goal or focus of the problem. The intermediate levels correspond to the criteria and sub-criteria, while the lowest level contains the decision alternatives.

In the second step, the elements of a particular level are compared pair-wise with respect to a specific element in the immediate upper level. A judgmental matrix is formed and used for computing the priorities of the corresponding elements. First, criteria are compared pair-wise with respect to the goal. A judgmental matrix, denoted as A, will be formed using the comparisons. Each entry (a_{ij}) of the judgmental matrix is formed comparing the row element (A_i) with the column element (A_j):

$$A = (a_{ij})\ (i, j = 1, 2, \ldots n)$$

After constructing the judgmental matrix of comparisons of criteria with respect to the goal, the next step is to obtain the local priorities of criteria and determine the consistency of the judgments.

The consistency of the judgmental matrix can be determined by the measure called Consistency Ratio (CR), defined as:

$$CR = CI / RI \quad (6)$$

where,

C1 is the consistency index and RI the random index. *CI* is defined as:

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (7)$$

Table 1: Scale method of risk element

Scale	Meaning
0.9	Compared two projects, the first is extremely occurrence risk than another
0.8	Compared two projects, the first is more occurrence risk than another
0.7	Compared two projects, the first is obviously occurrence risk than another
0.6	Compared two projects, the first is a litter occurrence risk than another
0.5	Compared two projects, the first is same occurrence risk than another
0.4, 0.3, 0.2, 0.1	$A_{ji} = 1 - A_{ij}$

C1 is the consistency index of a randomly generated reciprocal matrix from the nine-point scale.

The finally step is hierarchy total ordering and inspection.

Theory of enterprise project evaluation chain risk element transmission based on trapezoidal fuzzy number of FAHP:

- Set up enterprise project evaluation structure chart. According to the structure of project, construct the evaluation chain risk element model.
- Replace the value of traditional AHP comparative matrix by trapezoid fuzzy number. The corresponding substitution values are shown in Table 1. In the project structure chart, the probable occurrence value of each risk project represent by R_i. It is a trapezoidal fuzzy number, which shown as Fig. 1. In the Fig. 1, t_1 is the smallest value, t_4 is the biggest value. $[t_2, t_3]$ is the most possible interval.
- According to AHP principles and procedures, give the pair-wise judgment matrix of enterprise project evaluation chain by experts in project risk assessment, then construct the trapezoidal fuzzy number complementary judgment matrix according to the scaling table. Assume that the number of needing to evaluate sub-projects is n:

  $Y = (y_1, y_2 , \ y_n)$

  The first level evaluation index set is R:

  $R = (R_1,..., R_m)$

  Compared R_i and R_j, we get risk element occurrence possibility that indicate by trapezoidal fuzzy number $(l_{ij}, m_{ij} , u_{ij}, v_{ij})$. l_{ij} stands for the occurrence possibility of risk element when the worst situation. v_{ij} stands for the occurrence possibility of risk element when the best situation. $[m_{ij} , u_{ij}]$ is the most likely value. Based on the fuzzy relations improved risk measurement method, it gets expectations judgment matrix using COWA operator.
- Sorting of trapezoid fuzzy complementary judgment matrix

Table 2: Structure of project evaluation chain

Project A	sub-project A_1
	sub-project A_2
	sub-project A_3
Project B	sub-project B_1
	sub-project B_2
	sub-project B_3
	sub-project B_4
Project C	sub-project C_1
	sub-project C_2

Table 3: Sub-projects trapezoidal fuzzy number judgment matrix of A

	A	$_1A_2$	A_3
A_1	(0.5, 0.5, 0.5, 0.5)	(0.3, 0.5, 0.6, 0.8)	(0.1, 0.6, 0.7, 0.7)
A_2	(0.2, 0.4, 0.5, 0.7)	(0.5, 0.5, 0.5, 0.5)	(0.1, 0.2, 0.3, 0.4)
A_3	(0.3, 0.7, 0.4, 0.9)	(0.6, 0.7, 0.8, 0.9)	(0.5, 0.5, 0.5, 0.5)

According to the literature (Wang *et al*., 2008), the fuzzy complementary judgment matrix ranking formula is following:

$$w_i = \frac{1}{n}[\sum_{j=1}^{n} Exp_Q(g_{ij}) + 1 - \frac{n}{2}] \tag{8}$$

Then we get the ordering vector of trapezoid fuzzy complementary judgment matrix. That is, obtain the weight of risk element transmission in projects.

- The risk element transmission of project and sub-project

.

Assumption: the second level risk element occurrence possibility is w_i . I = 1, 2 ... m

Then, the risk element occurrence possibility of the third level project calculates by formula as following:

$$S_i = \sum w_i \times w_{ij} \tag{9}$$

According to the rules of trapezoidal fuzzy number comparison, we can obtain the risk element occurrence possibility in the project. The bigger of S_i, the higher risk element occurrence possibility of project in enterprise.

EXAMPLE ANALYSIS

- Model the structure of enterprise project evaluation chain risk element transmission. For the identification of enterprise project evaluation chain risk element transmission, establish the following hierarchical analysis structure.

  Assumption: An enterprise has 3 big projects, respectably project A, B, C. Project A owns 3 sub-projects, project B includes 4 sub-projects and project C has 2 sub-projects. The structure of project evaluation chain is a shown Table 2.

- Construction trapezoidal fuzzy number matrix of the third level project assessment.

Table 4: Sub-projects trapezoidal fuzzy number judgment matrix of B

	B1	B2	B3	B4
B1	(0.5, 0.5, 0.5, 0.5)	(0.1,0.3,0.6,0.7)	(0.2, 0.4, 0.6, 0.9)	(0.3, 0.5, 0.7, 0.8)
B2	(0.3, 0.4, 0.7, 0.9)	(0.5,0.5,0.5,0.5)	(0.4, 0.7, 0.8, 0.9)	(0.2, 0.3, 0.6, 0.7)
B3	(0.1, 0.4, 0.5, 0.8)	(0.1,0.2,0.3,0.6)	(0.5, 0.5, 0.5, 0.5)	(0.4, 0.7, 0.8, 0.9)
B4	(0.2, 0.3, 0.5, 0.7)	(0.3,0.4,0.5,0.7)	(0.1, 0.2, 0.3, 0.6)	(0.5, 0.5, 0.5, 0.5)

Table 5: Sub-projects trapezoidal fuzzy number judgment matrix of C

	C1	C2
C1	(0.5, 0 .5, 0.5, 0.5)	(0.3, 0.4, 0.5, 0.6)
C2	(0.4, 0.5, 0.6, 0.7)	(0.5, 0.5, 0.5, 0.5)

Table 6: Fuzzy number judgment matrix

	A	B	C
A	(0.5, 0.5, 0.5, 0.5)	(0.3, 0.5, 0.6, 0.7)	(0.1, 0.6, 0.7, 0.8)
B	(0.3, 0.4, 0.5, 0.7)	(0.5, 0.5, 0.5, 0.5)	(0.4, 0.6, 0.7, 0.8)
C	(0.1, 0.3, 0.4, 0.9)	(0.2, 0.3, 0.4, 0.6)	(0.5, 0.5, 0.5, 0.5)

The sub-projects trapezoidal fuzzy number judgment matrix of A, show in Table 3
The sub-projects trapezoidal fuzzy number judgment matrix of B, show in Table 4.
The sub-projects trapezoidal fuzzy number judgment matrix of C, show in Table 5.

- Using COWA operator construction expectations judgment matrix.

The sub-projects expectations judgment matrix of A:

$$\begin{bmatrix} 0.500 & 0.511 & 0.522 \\ 0.489 & 0.500 & 0.222 \\ 0.478 & 0.778 & 0.500 \end{bmatrix}$$

The sub-projects expectations judgment matrix of B:

$$\begin{bmatrix} 0.500 & 0.367 & 0.456 & 0.512 \\ 0.633 & 0.500 & 0.678 & 0.389 \\ 0.544 & 0.322 & 0.500 & 0.678 \\ 0.488 & 0.611 & 0.322 & 0.500 \end{bmatrix}$$

The sub-projects expectations judgment matrix of C:

$$\begin{bmatrix} 0.500 & 0.423 \\ 0.577 & 0.500 \end{bmatrix}$$

- Using formula (6), we could get sequencing of complementary judgment matrix expectations:

W_{1j} = (0.344, 0.237, 0.419)
W_{2j} = (0.246, 0.174, 0.308, 0.272)
W_{3j} = (0.461, 0.539)

Construction the second level trapezoidal fuzzy number judgment matrix, show in Table 6.
In same way, we get the expectations judgment matrix:

$$\begin{bmatrix} 0.500 & 0.500 & 0.533 \\ 0.500 & 0.500 & 0.600 \\ 0.467 & 0.400 & 0.500 \end{bmatrix}$$

- Using formula (8) gets sequencing of complementary judgment matrix expectations as following:

w_i = (0.344, 0.367, 0.289)

- Utilize formula (9) to calculate the final result:

w = {0.118, 0.082, 0.144, 0.090, 0.064, 0.113, 0.100, 0.133, 0.156}

From the final results, we can see the transmission degree from bottom sub-project to top project. The final results of this example of show that: A_1, A_2, B_3 and C_1 have greatly influence to final project, that is, those projects have the high transmission rate to top project. The other projects own litter transfer rate to top project. Therefore, in project risk management, we should pay attention to the high transfer rate project, so as to achieve the general goal of enterprise project.

CONCLUSION

This study firstly puts forward the enterprise project chain risk element transmission tetrahedron model. Then introduce fuzzy analytic hierarchy process into research of enterprise project evaluation chain risk transmission. Finally, we construct the theory of enterprise project evaluation chain risk transmission based on fuzzy analytic hierarchy process. In using fuzzy evaluation of the of the risk element happening possibility, the study adopts a trapezoid fuzzy number to measure the risk element relative occurrence possibility that two sub-project compared. This improvement will better embody the subjective consciousness of experts and better able to accord with the objective reality. In addition, the theory that enterprise project evaluation chain risk element transmission based on trapezoid fuzzy number Fuzzy Analytic Hierarchy Process (FAHP), is expansion to project risk element transmission theory. At the same time, it provides a new method to project risk element transmission and has great significance for Evaluation of enterprise project risk management.

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