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A Fuzzy ANP Model for Assessing the Construction Risk of a Public Construction Project in Vietnam

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Abstract. For reducing the occupied area of road and alleviating the traffic pressure, laying fabricated half strap method is used to build subway stations in the city. But the technology greatly increases the construction risk, it is therefore necessary for recognizing risk category and quantizing risk to ensure safety. B Based on Analytical Network Process (ANP), fuzzy set theory and survey data of construction site, this paper presents a fuzzy ANP model for rating the construction risk of subway station, as well as the steps of model solution. The construction risk of Ho Chi Minh City Metro Station comprehensively evaluated by the method. It was found that the construction risk is 0.4569 which mean probability of risk is very big, and this result has been accurately proved by the practice.

Keywords: Assessing construction risk; ANP; Station; fuzzy ANP Model

1. Introduction

Speed increase of major city ‘s population and traffic volume become much higher than that of carrying capacity of traffic, which results in the insufficiency of land resources of surface, and the ground space is difficult to make effective development (Qian and Rong (2008)). Especially the subway engineering develop quickly, however the complicated construction environment, immature construction techniques and inadequate construction experience cause loss of personal safety and property, as well as bad social influence (Qian(2012); Zhang , Ding and Pang et al.(2009)). For example the collapse of Xiang hu Hang Zhou subway caused 21 people’s death and 25 people’s injury in November 15, 2008; In March 2007, the metro construction of Nan Jing caused a fracture of the gas pipe, which result in explosion fire. Fracture of a fuel gas pipe in Nan Jing contribute to metro construction caused explosion and fire. In 2007 the tunnel of Line 4, Sao Paulo Metro Brazil had caved in, which leaded to the collapse of the vertical shaft of adjacent station, 7 people dead and 3 people injured.

The construction risk of metro are researched by lots of scholars, and many methods are used to assess the probability of construction risk. Expert investigation method is firstly applied for technical forecasting by Land of the United States (1964), as the method is simple, cost saving and can concentrate suggestions of various experts for the same question. But the accuracy of the method is depended on subjective judgment of experts.

Artificial Neural Network which has the ability to find optimal solutions at high speed is presented by Hopfield (1982, 1985), but it is not suitable for multi-objective evaluation (Hopfield (1985); Zhang, Guo and Wang et al. (2017)). TOPSIS Technique for Order Preference by Similarity to Ideal Solution is originally introduced by Cain wen in 1983. The ranking of alternative project is worked out by utilizing definite mathematical method, and the screening of index of risk evaluation also is realized by the rank of the important of all indexes. Solving contradictory problem is the main method and regularity of TOPSIS (Chen and Song (2012); Wang , Zhao and Zhang et al (2013)). However, construction risk indexes are interrelated rather than contradictory.

Bayesian network, introduced by Pearl (1998), is now by one of the most effective theoretical model for the expression of indefinite knowledge as well as the reasoning field, nonetheless, the model's construction which need the participation of knowledge engineer and domain expert is difficult and complicated (Riascosa, Simoesb and Miyagic et al.(2007)).

AHP (Analytical Hierarchy Process) which originally introduced by Saaty (1980) a usual method for risk assessment. The AHP technique uses pair-wise comparisons between criteria depended on expert opinions and results in determination of their relative weights (Jie, Hu and Li et al. (2004); Wang, Zhao and Zhang et al. (2008); Ding (2011)). Elements of a system can be aggregated into hierarchy or element groups which have the same basically properties, and there are no interaction or domination between elements within a hierarchy (Saaty (1990, 1996); Guo, Shang and Li (2011)).But in application, elements of a system are general connection instead of hierarchical structure, with the result network structure is a preferable form for presenting system structure (Ding (2011).

Fuzzy comprehensively evaluation method is one kind of application of fuzzy mathematics (Zadeh(1965)).Comprehensive considering the impact degree of all risk factors, distinguishing the importance of various factors by setting weight, then working out the various degree of possibility of risk, in which the maximum is the final determination value of risk level, and this is also regarded as the basic idea of risk evaluation of project(Chen(2009); Chu Xu, and Yasufuku et al(2017)); Cai (2016)). The accuracy and reliability of comprehensive evaluation results depend on reasonable selecting factors, weight distribution (the weight will vary with the of vary state and time of the factors), synthesis operator of comprehensive evaluation, as well as representation of knowledge and the selection (Cui (2012); Dai and Li (2016)).

ANP allows for more complex interrelation ships among the decision levels and attributes (Tavanaab, Zandic and Katehakisd (2013); CAI, Dai and Song (2016); Akgun (2009)). The ANP handles interdependence among elements by obtaining the composite weights through the development of a super matrix (Akgun, Kandakoglu, and Ozok (2009); Dagdeviren, Yuksel, and Kurt et al (2008)). In most cases, decision problems are too complex to be understood with certainty .The fuzzy set theory does allow simultaneous treatment of imprecise and precise variables. Therefore the Fuzzy ANP has been proved to be one of the most favorite decision-making approaches. As one of the most popular techniques in risk evaluation, ANP has an advantage in organizing and analyzing complex decisions.

2. Fuzzy Analytical Network Process

2.1 Analytical Network Process

A widespread method for evaluating the weights of risk is AHP (Saaty (1980)). The AHP technique uses pair-wise comparisons between criteria based on expert opinions and results in determining their relative weights (Saaty (1999)). However, as noted by Meade and Sarkis (1999), AHP does not consider interrelationships among the decision levels and attributes.

Based on this fact, ANP was presented on the basis of AHP by Saaty (1986, 1996, and 1999). Decision theory of ANP is essentially identical, the only difference between ANP and AHP is that the former establishes network model, yet the latter establishes hierarchical model (Bayazit (2006)). Furthermore, application and analysis of super matrix are used in ANP for weight synthesis (Saaty (1999)). Representation of network model and weight synthesis are the two main contents of ANP (Saaty (1999)). Graphic form which qualitatively represents the relationship of interactional and feedback of each components and matrix forms which qualitatively represents the degree or magnitude of the interaction or feedback represent the model structure of ANP.

2.2 Fuzzy Set Theory

In most cases, decision problems are too complex to be understood with certainty (Bjegović, Krstić and Mikulić (2006); Brijs, Vanhoof, and Karlis et al (2006)). The fuzzy set theory which introduced by Zadeh (1965) does allow simultaneous treatment of imprecise and precise variables. Triangular Fuzzy Number derived from the concept of Dev fuzzy sets (Zade (1985)) are applied to management of Quality and risk for solving the problems of uncertain environment (Zimmermann (2001); Lan and Zhang (2006)).

2.2.1Triangular fuzzy number

fuzzy number is a fuzzy set $F = \{x \in R | \mu_F(x)\}$, where is in the real line, taking the value form R_1: $\infty < x < +\infty$,and $\mu_F(x)$ is a continuous function mapping .A TFN can be defined by a triplet (l, m, u) and the membership function (1): The membership function μ(x) obtains values in the range [0,1](Zimmerman(2001)).

$$\mu_F(x) = \begin{cases} 0, & x < l \cdot or \cdot x > u \\ (x-l)/(m-l), & l \le x \le m \\ (x-u)/(m-u), & m \le x \le u \end{cases} \tag{1}$$

In the formula and which denotes the ambiguity degree of judgment represent lower bound and upper bound of ,respectively, and the represents mid-value (l≤m≤u). The main algorithms of TFN are as follows (Zimmerman (2001); Tag (2005)):

$$M_1 + M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{2}$$

$$M_1 \otimes M_2 = (l_1 \cdot l_2, m_1 \cdot m_2, u_1 \cdot u_2) \tag{3}$$

$$\lambda M_1 = (\lambda l_1, \lambda m_1, \lambda u_1), \lambda > 0, \lambda \in R \tag{4}$$

$$M_1^{-1} \approx (1/u_1, 1/m_1, 1/l_1) \tag{5}$$

$$M_1 = (l_1/(l_1 + m_1 + u_1), m_1/(l_1 + m_1 + u_1), u_1/(l_1 + m_1 + u_1)) \tag{6}$$

2.3 Fuzzy Analytical Hierarchy Process

Fuzzy ANP, which derived from the integration of ANP and fuzzy set theory, is a quantification method for conducting the question of uncertainty and ambiguity. The basic idea is as follow.

(1). a fuzzy comparison matrices (FCM) can be created by the integration of TFN and pair-wise comparison matrices determined by a group of experts (metro station engineers of relevant disciplines).

(2). Weight vector of FCM can be figured out based on the super matrix operation of ANP as well as the quality and operation method of TFN .Then a process of decision and analysis of interactively weight vector would be got by dealing with weight vector by the idea of the decision

3. Building and implementing the fuzzy ANP Model

3.1 Building the fuzzy ANP Model

3.1.1 Building the factor set of construction risk

Establishment of the factor set is based on the follow process; (1) statistics of construction accident of subway station; (2) analyzing the reason of accidents;(3) designing the questionnaire and surveying field ;(4)integrating the suggestion of professors and metro station engineers of relevant disciplines. The model is illustrated in fig.1

3.1.2 Building judgment set of construction risk of subway station

Because final evaluating result is evaluation vector, the rating of construction risk of subway station can be acquired based on maximum membership principle which is represented that supposing evaluation vector $A = (a_1, a_2, ..., a_n)$ and comment set $V = (v_1\ v_2, ..., v_n)$, if working out $a_1 = \max\{a_n\}$, the rating of construction risk of subway station is. The model separates comments into five levels to build judgment set of construction risk of subway station $V = (V_1, V_2, V_3, V_4, V_5)$ = (great risk, larger risk, ordinary risk, lesser risk, least risk).

3.2 Building fuzzy relational matrix of single factor

The target factors of second level are evaluated by building fuzzy relational matrix, which is the fuzzy relation from to, in accordance with the probability of generating risk, the loss degree caused by risk and controllability of risk. The data is form surveying field and metro station engineers of relevant disciplines in Vietnam. The fuzzy relational matrix RI is shown as bellow

$$R_i = \begin{vmatrix} R_{(i1)V_1} & R_{(i1)V_2} & R_{(i1)V_3} & R_{(i1)V_4} & R_{(i1)V_5} \\ R_{(i2)V_1} & R_{(i2)V_2} & R_{(i2)V_3} & R_{(i2)V_4} & R_{(i2)V_5} \\ R_{(i3)V_1} & R_{(i3)V_2} & R_{(i3)V_3} & R_{(i3)V_4} & R_{(i3)V_5} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ R_{(ij)V_1} & R_{(ij)V_2} & R_{(ij)V_3} & R_{(ij)V_4} & R_{(ij)V_5} \end{vmatrix}$$

3.3 Calculating the weight vector of risk factors

The process of calculating the weight vector of risk factors includes the following steps:

(1) Building FCM

Using the dispersion membership to describe and evaluate object, the membership function of relatively important is represented as follow table 4.

Taking the factor as criterion, the incidence of, and for is compared in relative significance. Then FCM is built, in the equation is TFN, acquired as follows:

$B_{(ij)} = (l_{ij}, m_{ij}, u_{ij})$, $l_{ij} \le m_{ij} \le u_{ij}$ l_{ij}, m_{ij}, u_{ij} can be valued by experts and engineers of relevant disciplines evaluating based on the table 1(Tag and Beynon (2005); Zimmerman(2001); Ge(1989)).

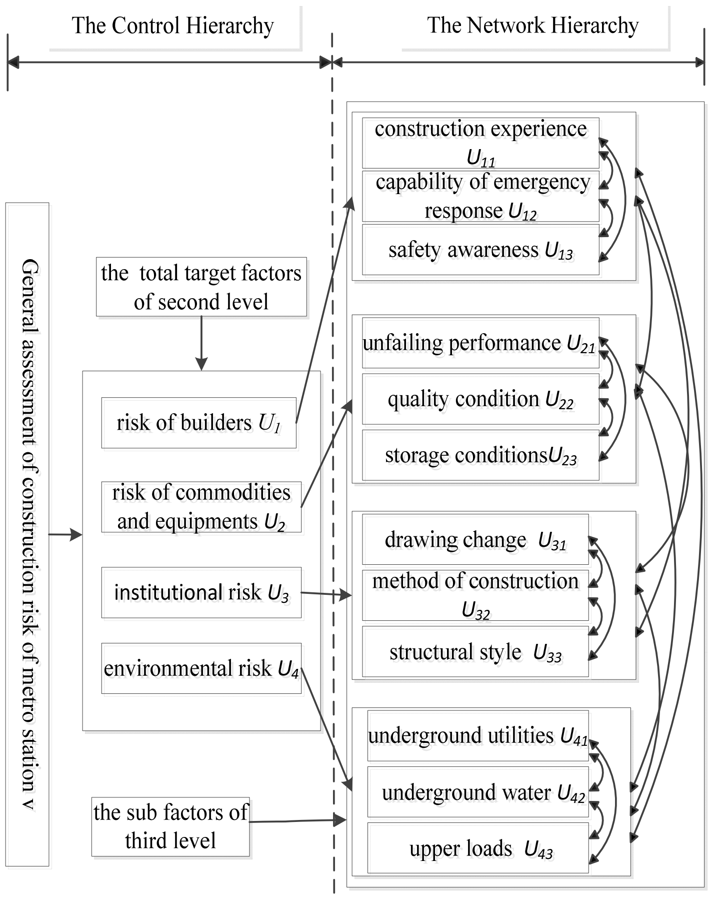

Fig. 1. Fuzzy ANP Model of metro station construction risk

In the weight decision analysis, cut set of fuzzy analysis is used to study anti-blur of weight (Feng (2006)). There are some supposing as bellow

$$w_i = (w_i^L \ w_i^M \ w_i^S) \tag{8}$$

$$w_i^L(\alpha) = (w_i^M - w_i^L)\alpha + w_i^L \tag{9}$$

$$w_i^S(\alpha) = (w_i^S - w_i^M)\alpha + w_i^M \tag{10}$$

Through Integrating Eq(8) ,Eq(9)and Eq(10) ,the Eq(11) is can be obtained (Feng(2006)).

$$w_i(\alpha,\lambda) = \lambda w_i^S(\alpha) + (1-\lambda) w_i^L(\alpha) \tag{11}$$

Where cut parameter α which value [0, 1] represents the change scope of weight of judgment suggestion of experts (Feng (2006)). Because the comments of each experts is valid, the α can be valued 0. where the parameter λ which value [0 ,1] represents the optimistic scope of weight of judgment suggestion of experts(Feng (2006)).Because the attitude of each experts is conservative , the λ can be valued 1.based on the above analysis, fuzzy weight vector is calculated by the Eq $w_i(\alpha,\lambda) = w_i^S(\alpha) = w_i^M$ .then fuzzy weight vector (W_{11}) of FCM is calculated by characteristic root method, which is also the priority vector of the effect the factor U_{11}, U_{12} and U_{13} on factor U_{12}.

In the same way , FCM(W11,W12,W13,W14 ,W21,W22,W23,W24,W31,W32,W33,W34,W41, W42, W43, W44) can be captured.so the quantify of the third level can be represented, which is fuzzy super matrix W (Saaty (2004)).

$$W = \begin{bmatrix} W_{11} & W_{12} & W_{13} & W_{14} \\ W_{21} & W_{22} & W_{23} & W_{24} \\ W_{31} & W_{32} & W_{33} & W_{34} \\ W_{41} & W_{42} & W_{43} & W_{44} \end{bmatrix}$$

Table 1. The importance language scale of triangle fuzzy number

language of importance degree	triangular fuzzy scale	reciprocal of triangular fuzzy scale
equally importance	（0.5 1 1.5）	（0.67 1 2）

weak importance	(2.5 3 3.5)	(0.28 0.33 0.4)
obviously importance	(4.5 5 5.5)	(0.18 0.2 0.22)
highly importance	(6.5 7 7.5)	(2/15 1/7 2/13)
absolute importance	(8.5 9 9.5)	(2/19 1/9 2/17)

The date of (1.5 2 2.5) (3.5 4 4.5) (5.5 6 6.5) (7.5 8 8.5) is the intermediate value fuzzy scale, as well as the data of (0.4 0.5 0.67) (0.22 0.25 0.29) (0.15 0.17 0.18) (0.12 0.13 0.13) is the intermediate value reciprocal of triangular fuzzy scale.

3.4 Building the fuzzy weight matrix of elements of second level factor

Because fuzzy super matrix is normalized, it is need for calculating per sub-block weight of super matrix, and the process is comparing the pairwise blocks to building FCM calculated to get the normalized sort vector of per sub block effecting on other sub blocks. Where represents effecting weight of i sub-block on j sub-block, and =0 represents the effecting doesn't exist. The fuzzy weight matrix of elements of second level factor A is represented as bellows:

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \tag{13}$$

Fuzzy weighted super matrix $\underline{W}$ can be built based on the fuzzy super matrix W and fuzzy weight matrix A, which is shown as bellow.

$$\underline{W} = A \bullet W \begin{bmatrix} a_{11}W_{11} & a_{12}W_{12} & a_{13}W_{13} & a_{14}W_{14} \\ a_{21}W_{21} & a_{22}W_{22} & a_{23}W_{23} & a_{24}W_{24} \\ a_{31}W_{31} & a_{32}W_{32} & a_{33}W_{33} & a_{34}W_{34} \\ a_{41}W_{41} & a_{42}W_{42} & a_{43}W_{43} & a_{44}W_{44} \end{bmatrix} \tag{14}$$

3.5 Calculating limit order sector

Limit order sector T can be obtained through calculating the normalization eigenvector of super matrix W corresponding to eigenvalue 1 (Saaty (2004)).

3.6 Analyzing evaluation results

The comprehensive evaluation matrix V can be figured out through the following equation (15), then acquiring the comment of $\underset{1\le i\le n}{Max}(v_i / \sum_{i=1}^{n} v_i)$ (Maximum membership (Saaty (2004)), which is the evaluation of the model.

$$V = T \bullet R \tag{15}$$

4. Application

4.1 Project overview

The model was applied to Ho Chi Minh station, the transfer station of metro line 1 and line 4 in Xian .The differences of directions, varieties and depths of pipeline, as well as the quantity of tall buildings, have a great influence on construction.

4.2 Building FCM

The model was applied to 20 Xi an Metro stations; each member of the expert group was asked to evaluate sub-elements based on comment set ,and the survey results of sub-elements based on the probability of generating risk are presented in table 2.

Weighting the data of table 5, build the fuzzy relational matrix Rap shown as bellow. In the same way, the fuzzy relational matrix RL，RC can be got based on the criteria of the loss degree caused by risk and controllability of risk. Supposing the relationship of the fuzzy relational matrix is parallel relationship, integrated the matrix RL, RC, Rp to obtain weight matrix R.

$$R_P = \begin{bmatrix} 0.70 & 0.20 & 0.05 & 0.05 & 0.00 \\ 0.65 & 0.30 & 0.05 & 0.00 & 0.00 \\ 0.60 & 0.40 & 0.00 & 0.00 & 0.00 \\ 0.05 & 0.05 & 0.55 & 0.25 & 0.10 \\ 0.05 & 0.10 & 0.40 & 0.30 & 0.15 \\ 0.30 & 0.30 & 0.20 & 0.10 & 0.10 \\ 0.00 & 0.05 & 0.35 & 0.55 & 0.05 \\ 0.30 & 0.40 & 0.10 & 0.20 & 0.00 \\ 0.10 & 0.20 & 0.60 & 0.05 & 0.05 \\ 0.45 & 0.35 & 0.10 & 0.10 & 0.00 \\ 0.75 & 0.15 & 0.10 & 0.00 & 0.00 \\ 0.20 & 0.30 & 0.45 & 0.05 & 0.00 \end{bmatrix} \quad R_C = \begin{bmatrix} 0.70 & 0.15 & 0.15 & 0.00 & 0.00 \\ 0.65 & 0.20 & 0.15 & 0.00 & 0.00 \\ 0.80 & 0.10 & 0.05 & 0.05 & 0.00 \\ 0.60 & 0.25 & 0.05 & 0.10 & 0.15 \\ 0.35 & 0.45 & 0.15 & 0.05 & 0.05 \\ 0.45 & 0.50 & 0.00 & 0.05 & 0.05 \\ 0.40 & 0.20 & 0.35 & 0.05 & 0.10 \\ 0.05 & 0.70 & 0.15 & 0.10 & 0.00 \\ 0.05 & 0.05 & 0.80 & 0.10 & 0.00 \\ 0.00 & 0.40 & 0.55 & 0.05 & 0.05 \\ 0.05 & 0.10 & 0.40 & 0.45 & 0.00 \\ 0.05 & 0.35 & 0.20 & 0.40 & 0.00 \end{bmatrix}$$

$$R_L = \begin{bmatrix} 0.75 & 0.20 & 0.10 & 0.00 & 0.00 \\ 0.50 & 0.20 & 0.25 & 0.05 & 0.00 \\ 0.80 & 0.10 & 0.05 & 0.00 & 0.00 \\ 0.10 & 0.10 & 0.50 & 0.25 & 0.15 \\ 0.40 & 0.45 & 0.15 & 0.05 & 0.00 \\ 0.15 & 0.70 & 0.20 & 0.05 & 0.05 \\ 0.10 & 0.10 & 0.45 & 0.35 & 0.00 \\ 0.80 & 0.15 & 0.10 & 0.00 & 0.00 \\ 0.05 & 0.05 & 0.10 & 0.75 & 0.10 \\ 0.35 & 0.35 & 0.20 & 0.10 & 0.05 \\ 0.70 & 0.20 & 0.10 & 0.05 & 0.00 \\ 0.50 & 0.20 & 0.25 & 0.05 & 0.00 \end{bmatrix} \quad R = \begin{bmatrix} 0.72 & 0.18 & 0.08 & 0.02 & 0.00 \\ 0.60 & 0.23 & 0.15 & 0.02 & 0.00 \\ 0.73 & 0.20 & 0.03 & 0.03 & 0.00 \\ 0.24 & 0.13 & 0.35 & 0.17 & 0.11 \\ 0.26 & 0.33 & 0.23 & 0.11 & 0.07 \\ 0.30 & 0.49 & 0.11 & 0.05 & 0.05 \\ 0.16 & 0.11 & 0.39 & 0.29 & 0.05 \\ 0.38 & 0.42 & 0.10 & 0.10 & 0.00 \\ 0.07 & 0.10 & 0.50 & 0.28 & 0.05 \\ 0.25 & 0.36 & 0.28 & 0.08 & 0.03 \\ 0.50 & 0.15 & 0.20 & 0.15 & 0.00 \\ 0.25 & 0.28 & 0.30 & 0.17 & 0.00 \end{bmatrix}$$

Table 2. survey result of sub-elements based on the probability of generating risk

the index name	great risk	larger risk	ordinary risk	lesser risk	least risk
Construction experience	13	5	1	1	0
Safety awareness	12	7	1	0	0
Capability of emergency response	12	7	1	0	0
Unfailing performance	1	1	10	6	2
Quality condition	1	2	7	7	3
Sstorage conditions	6	6	4	2	2
Drawing change	0	1	6	12	1
Method of construction	6	8	2	4	0
Structural style	2	4	12	1	1
Underground utilities	8	8	2	2	0
Underground water	14	4	2	0	0
Upper loads	5	6	8	1	0

4.3 Weights

(1) In the factor set, taking the factor as criterion, the influence extent of, and for is compared in relative significance. Then FCM is built, which is represented in the table 3.

Table 3. FCM of relative influence

U_{12}	U_{11}	U_{12}	U_{13}	weight vector
U_{11}	$(1\ 1\ 1)$	$(2/11\ 1/5\ 2/9)$	$(2/11\ 1/5\ 2/9)$	0.0759
U_{12}	$(9/2\ 5\ 11/2)$	$(1\ 1\ 1)$	$(13/2\ 7\ 15/2)$	0.7258
U_{13}	$(9/2\ 5\ 11/2)$	$(2/15\ 1/7\ 2/13)$	$(1\ 1\ 1)$	0.1983

Calculating the FCM in the table 6 by characteristic roots method , the weight sector $\left(w_{11}^{(12)}\ w_{12}^{(12)}\ w_{13}^{(12)}\right)^T = (0.0759\ \ 0.7258\ \ 0.1983)^T$ is figured out under the criterion of U_{12} .In the same way capturing the weight sectors accord with the criterion of U_{11} and U_{13},FCM W_{11} of the factor set U_1 can be obtained through the combination of U_{11},U_{12} and U_{13}.

$$W_{11} = \begin{bmatrix} 0.3230 & 0.0759 & 0.1775 \\ 0.1104 & 0.7258 & 0.5190 \\ 0.5666 & 0.1983 & 0.3035 \end{bmatrix}$$

Repeat the calculation in the same way, capturing the FCM according with C_2 、C_3 、 C_4 are represented as bellow

$$W_{22} = \begin{bmatrix} 0.6854 & 0.3236 & 0.4806 \\ 0.2344 & 0.6018 & 0.1140 \\ 0.0802 & 0.0746 & 0.4054 \end{bmatrix}$$

$$W_{33} = \begin{bmatrix} 0.0962 & 0.1884 & 0.1775 \\ 0.3519 & 0.7306 & 0.5190 \\ 0.5519 & 0.0810 & 0.3035 \end{bmatrix}$$

$$W_{44} = \begin{bmatrix} 0.4489 & 0.1336 & 0.1048 \\ 0.3690 & 0.7471 & 0.4991 \\ 0.1820 & 0.1194 & 0.3961 \end{bmatrix}$$

(2) In the factor set U_2, taking the factor U_{21} as criterion, the influence extent of U_{11}, U_{12} and U_{13} for U_{21} are compared in relative important. Then FCM $B=(B_{ij})$ is built, which is represented in the table-7.

Calculating the FCM in the table 7 by characteristic roots method , the weight sector $\left(w_{11}^{(21)}\ w_{12}^{(21)}\ w_{13}^{(21)}\right)^T = (0.6370\ \ 0.1047\ \ 0.2583)^T$ is figured out under the criterion of U_{21} .In the same way capturing the weight sectors accord with the criterion of U_{22} and U_{23} ,FCM W_{12} of the factor set can be obtained through the combination of U_{21}, U_{22} and U_{23} .

$$W_{12} = \begin{bmatrix} 0.6370 & 0.2351 & 0.6000 \\ 0.1047 & 0.1130 & 0.2000 \\ 0.2583 & 0.6519 & 0.2000 \end{bmatrix}$$

$$W_{13} = \begin{bmatrix} 0.6000 & 0.3420 & 0.4934 \\ 0.2000 & 0.1339 & 0.1958 \\ 0.3000 & 0.5241 & 0.3108 \end{bmatrix} \quad W_{14} = \begin{bmatrix} 0.5499 & 0.6337 & 0.2846 \\ 0.2402 & 0.1744 & 0.3668 \\ 0.2098 & 0.1919 & 0.3486 \end{bmatrix}$$

$$W_{21} = \begin{bmatrix} 0.5134 & 0.1307 & 0.2158 \\ 0.2567 & 0.2470 & 0.6817 \\ 0.2299 & 0.6223 & 0.1025 \end{bmatrix} \quad W_{23} = \begin{bmatrix} 0.2970 & 0.6118 & 0.2872 \\ 0.1634 & 0.1789 & 0.6348 \\ 0.5396 & 0.2092 & 0.0780 \end{bmatrix}$$

$$W_{24} = \begin{bmatrix} 0.5525 & 0.2297 & 0.6354 \\ 0.3329 & 0.6483 & 0.2716 \\ 0.1146 & 0.1220 & 0.0929 \end{bmatrix} \quad W_{31} = \begin{bmatrix} 0.2493 & 0.2098 & 0.6250 \\ 0.5936 & 0.5499 & 0.2385 \\ 0.1571 & 0.2402 & 0.1365 \end{bmatrix}$$

$$W_{32} = \begin{bmatrix} 0.5277 & 0.0980 & 0.1700 \\ 0.2274 & 0.4914 & 0.7074 \\ 0.2449 & 0.4106 & 0.1226 \end{bmatrix} W_{34} = \begin{bmatrix} 0.1700 & 0.1020 & 0.5782 \\ 0.7074 & 0.7258 & 0.2627 \\ 0.1226 & 0.1721 & 0.1591 \end{bmatrix} W_{41} = \begin{bmatrix} 0.1365 & 0.1365 & 0.1963 \\ 0.6250 & 0.6250 & 0.6571 \\ 0.2385 & 0.2385 & 0.1466 \end{bmatrix}$$

$$W_{42} = \begin{bmatrix} 0.1350 & 0.1149 & 0.3275 \\ 0.2808 & 0.1210 & 0.2599 \\ 0.5842 & 0.7641 & 0.4126 \end{bmatrix} \quad W_{43} = \begin{bmatrix} 0.1634 & 0.1307 & 0.3220 \\ 0.5396 & 0.2470 & 0.1463 \\ 0.2970 & 0.6223 & 0.5317 \end{bmatrix}$$

$$W_{11} = \begin{bmatrix} 0.3230 & 0.0759 & 0.1775 \\ 0.1104 & 0.7258 & 0.5190 \\ 0.5666 & 0.1983 & 0.3035 \end{bmatrix}$$

Through combining with the FCM(W11,W12, W13,W14,W21,W22,W23,W24,W31,W32, W33,W34,W41,W42, W43,W44,) to constitute the no weighted fuzzy super matrix (Satyr(2004)).

$$W=\begin{bmatrix} 0.3230 & 0.0759 & 0.1775 & 0.6370 & 0.2351 & 0.6000 & 0.6000 & 0.3420 & 0.4934 & 0.5499 & 0.6337 & 0.2846 \\ 0.1104 & 0.7258 & 0.5190 & 0.1047 & 0.1130 & 0.2000 & 0.2000 & 0.1339 & 0.1958 & 0.2402 & 0.1744 & 0.3668 \\ 0.5666 & 0.1983 & 0.3035 & 0.2583 & 0.6519 & 0.2000 & 0.2000 & 0.5241 & 0.3108 & 0.2098 & 0.1919 & 0.3486 \\ 0.5134 & 0.1037 & 0.2158 & 0.6854 & 0.3236 & 0.4806 & 0.2970 & 0.6118 & 0.2872 & 0.5525 & 0.2297 & 0.6354 \\ 0.2567 & 0.2470 & 0.6817 & 0.2344 & 0.6018 & 0.1140 & 0.1634 & 0.1789 & 0.6348 & 0.3329 & 0.6483 & 0.2716 \\ 0.2299 & 0.6223 & 0.1025 & 0.0802 & 0.0746 & 0.4054 & 0.5396 & 0.2092 & 0.0780 & 0.1146 & 0.1220 & 0.0929 \\ 0.2493 & 0.2098 & 0.6250 & 0.5277 & 0.0980 & 0.1700 & 0.0962 & 0.1884 & 0.1775 & 0.1700 & 0.1020 & 0.5782 \\ 0.5936 & 0.5499 & 0.2385 & 0.2274 & 0.4914 & 0.7074 & 0.3519 & 0.7306 & 0.5190 & 0.7074 & 0.7258 & 0.2627 \\ 0.1571 & 0.2402 & 0.1365 & 0.2449 & 0.4106 & 0.1226 & 0.5519 & 0.0810 & 0.3035 & 0.1226 & 0.1721 & 0.1591 \\ 0.1365 & 0.1365 & 0.1963 & 0.1350 & 0.1149 & 0.3275 & 0.1634 & 0.1307 & 0.3220 & 0.4489 & 0.1336 & 0.1048 \\ 0.6250 & 0.6250 & 0.6571 & 0.2808 & 0.1210 & 0.2599 & 0.5396 & 0.2470 & 0.1463 & 0.3690 & 0.7471 & 0.4991 \\ 0.2385 & 0.2385 & 0.1466 & 0.5842 & 0.7641 & 0.4126 & 0.2970 & 0.6223 & 0.5317 & 0.1820 & 0.1194 & 0.3961 \end{bmatrix}$$

(2) Building the fuzzy weight matrix of elements of second level factor A

$$A=\begin{bmatrix} 0.3652 & 0.3406 & 0.2642 & 0.2932 \\ 0.0905 & 0.2219 & 0.0577 & 0.0547 \\ 0.1219 & 0.0545 & 0.5127 & 0.1079 \\ 0.4224 & 0.3831 & 0.1654 & 0.5443 \end{bmatrix}$$

Then obtaining Fuzzy weighted super matrix $\underline{W}$ as bellow

$$\underline{W}=\begin{bmatrix} 0.1180 & 0.0296 & 0.0648 & 0.2170 & 0.0801 & 0.2044 & 0.1585 & 0.0904 & 0.1304 & 0.1612 & 0.1858 & 0.0834 \\ 0.0403 & 0.2542 & 0.1895 & 0.0357 & 0.0385 & 0.0681 & 0.0528 & 0.0354 & 0.0517 & 0.0704 & 0.0511 & 0.1075 \\ 0.2069 & 0.0814 & 0.1108 & 0.0880 & 0.2220 & 0.0681 & 0.0528 & 0.1385 & 0.0821 & 0.0615 & 0.0563 & 0.1022 \\ 0.0465 & 0.0118 & 0.0195 & 0.1521 & 0.0718 & 0.1066 & 0.0171 & 0.0353 & 0.0166 & 0.0302 & 0.0126 & 0.0348 \\ 0.0232 & 0.0224 & 0.0617 & 0.0520 & 0.1335 & 0.0253 & 0.0094 & 0.0103 & 0.0366 & 0.0182 & 0.0355 & 0.0149 \\ 0.0208 & 0.0563 & 0.0093 & 0.0178 & 0.0166 & 0.0900 & 0.0311 & 0.0121 & 0.0045 & 0.0063 & 0.0067 & 0.0051 \\ 0.0304 & 0.0256 & 0.0762 & 0.0288 & 0.0053 & 0.0093 & 0.0493 & 0.0966 & 0.0910 & 0.0183 & 0.0110 & 0.0624 \\ 0.0724 & 0.0670 & 0.0291 & 0.0124 & 0.0268 & 0.0386 & 0.1804 & 0.3746 & 0.2661 & 0.0763 & 0.0783 & 0.0283 \\ 0.0192 & 0.0293 & 0.0166 & 0.0133 & 0.0224 & 0.0067 & 0.2830 & 0.0415 & 0.1556 & 0.0132 & 0.0186 & 0.0172 \\ 0.0577 & 0.0577 & 0.0829 & 0.0074 & 0.0063 & 0.0178 & 0.0270 & 0.0216 & 0.0533 & 0.2443 & 0.0727 & 0.0570 \\ 0.2640 & 0.2640 & 0.2776 & 0.0153 & 0.0066 & 0.0142 & 0.0892 & 0.0409 & 0.0242 & 0.2008 & 0.4066 & 0.2717 \\ 0.1007 & 0.1007 & 0.0619 & 0.0318 & 0.0416 & 0.0225 & 0.0491 & 0.1029 & 0.0879 & 0.0991 & 0.0650 & 0.2156 \end{bmatrix}$$

(3) Calculating limit order sector

The result are as bellow：

T= (0.1266, 0.0896, 0.1076, 0.0327, 0.0332, 0.0172, 0.0426, 0.1087, 0.0388, 0.0693, 0.2407, 0.0930) T

4.4 Analyzing evaluation results

The comprehensive evaluation matrix V can be figured out through the equation (2),

$$V=T*R=\begin{bmatrix}0.1266\\0.0896\\0.1076\\0.0327\\0.0332\\0.0172\\0.0426\\0.1087\\0.0388\\0.0693\\0.2407\\0.0930\end{bmatrix}^T\begin{bmatrix}0.72&0.18&0.08&0.02&0.00\\0.60&0.23&0.15&0.02&0.00\\0.73&0.20&0.03&0.03&0.00\\0.24&0.13&0.35&0.17&0.11\\0.26&0.33&0.23&0.11&0.07\\0.30&0.49&0.11&0.05&0.05\\0.16&0.11&0.39&0.29&0.05\\0.38&0.42&0.10&0.10&0.00\\0.07&0.10&0.50&0.28&0.05\\0.25&0.36&0.28&0.08&0.03\\0.50&0.15&0.20&0.15&0.00\\0.25&0.28&0.30&0.17&0.00\end{bmatrix}=[0.4569, 0.2299, 0.1901, 0.1092, 0.0129]$$

According to the principle of maximum membership, in the V= [0.4569, 0.2299, 0.1901, 0.1092, 0.0129], maximum value is 0.4569, which indicated that the construction risk of the Ho Chi Minh is great.

5. Discussion

Based on the ANP, fuzzy set theory and survey data of construction site, this paper provides insights into the assessing of the construction risk of subway station. Comparing with AHP, expert investigation method, and artificial neural network et al, the model and techniques solves the uncertainties and ambiguities of the opinion of expert, take a full consideration upon interactional relationship of each element, strengthen the risk management of subway project, and lay the foundation of establishing the risk management as the core project management. However the building of the model need lots of construction site investigation work and the participation of many experts so that investigation is difficult and spent lots of time.

6. Conclusions

This paper presents a model for estimating construction risk of metro stations, by explicitly considering interaction in evaluating its different factors. The model was derived based on opinions of an expert group and the apple of analytical network process and fuzzy mathematics extracted. Overall the paper's contribution is the development of an operational tool for metro station constructors, which takes account into interaction of each factors in their judgment for assessing the construction risk of metro stations, and the results are more accurate than AHP. Moreover, the constructors of metro station can work out measures before or in construction to avoid or decrease construction accidents in advance. The model was developed for, and applied to the Ho Chi Minh metro station and is proved to be feasible and reasonable. It could be concluded that the construction risk is great. This result turns out to accord with the opinions of highly trained experts.

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