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Study on comprehensive evaluation of construction safety of urban mass transit railway tunnel based on ANP – fuzzy

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Abstract. In this paper, according to the characteristics of shield tunnel construction, the main factors that lead to the occurrence of risk during tunnel construction are analyzed. In order to solve this problem, this paper proposes ANP-Fuzzy(ANP, analysis network process) model, which takes into account the factors and the mutual feedback and influence of each level, because of the interdependence and feedback ambiguity between the risk factors. This method uses the ANP to obtain the weight of each influencing factor, and then use the fuzzy comprehensive evaluation method to obtain the final risk assessment. Then takes the project of Beijing Metro Line 6 as the research object, and elaborates and calculates the specific implementation process of the risk assessment method. The comprehensive evaluation analysis and calculation results show that the ANP-Fuzzy model can effectively evaluate, control and manage the risk of subway tunnel construction, so as to improve the scientific nature of the risk assessment process.

Key words. tunnel construction; risk factors; index system;ANP-Fuzzy; risk assessment.

1. Introduction

In recent years, railways, light rail, maglev railway, urban high-grade highway construction has developed rapidly[1]. However, the investment in subway project is huge, the life cycle is long, the construction and operation system is complex, the project quality is high, the long term benefit is good, and the influence is huge,

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which determines the construction management of the subway is a very complicated system engineering.

Establishing effective tunnel safety risk assessment method is the key to ensure the safety of tunnel construction. According to the characteristics of complex construction conditions, poor construction environment and uncertain factors in tunnel construction process [2]. Based on ANP and fuzzy comprehensive evaluation, this paper puts forward a risk assessment model based on ANP fuzzy method for urban subway tunnel construction.

2. Establishment of evaluation index system

The establishment of the evaluation index system is an important link in the risk assessment of subway engineering. Evaluation system can better show the safety status of the project and the risk of influencing factors. According to the analysis of the "people, machine, material, method and environment" of the subway construction risk factors [3],[4]. By the five types of risk factors according to the inclusion of the relationship down the stratification, combined with other information, the final risk indicators, as shown in Table 1.

3. Introduction to the ANP-Fuzzy method

3.1. ANP model

Network analysis process is a type of generalization of analytic hierarchy process. The second layer for the network layer, including interdependence, mutual domination of the elements. This model consisting of a control layer and a network layer[5],[6].

Table 1 subway shield construction risk assessment index system

Target layer	level one	Second level
Subway Shield Construction Risk C	Shield machine and its equipment risk C_1	Shield model is not appropriate C_{11}
		Soil and grouting and other auxiliary equipment failure C_{12}
		Excavation, propulsion equipment failure or improper maintenanceC_{13}
	Construction risk C_2	Shield construction parameters improper C_{21}
		Soil reinforcement is not in place C_{22}
		Sealed leak-proof effect is poor C_{23}
		Poor auxiliary process C_{24}
	Material risk C_3	Poor slurry performance C_{31}
		The material at the assembling connection is unqualified C_{32}
	Manage risk C_4	Construction enterprises have low core competence C_{41}
		Construction organization chaos C_{42}
	External environmental risk C_5	The stratigraphic soil is weak C_{51}
		The adverse effects of groundwater on construction C_{52}
		Adverse effects caused by voids in soil formations C_{53}
		Unexplained obstacle exists in the ground C_{54}
		The depth of the shield is too shallow during excavation C_{55}

3.2. ANP calculation principle

3.2.1 Constructs a weightless super matrix

In the control layer a criterion:$P_s(s = 1, 2, \cdots, m)$,an element $C_{jl}(l = 1, 2, \cdots, n_j)$ in the network layer element group C_j is the sub-criterion, according to the influence of each element on the C_{jl} in the other element group C_i, then use the eigenvalue method to get the ordering vector $(W_{i1}^{jl}, W_{i2}^{jl}, \cdots, W_{in}^{jl})^T$. [7],[8],[9]

3.2.2Constructing Weighted Super Matrices and Find the limit super matrix

P_s as the main criterion, can be normalized eigenvector $(a_{1j}, a_{2j}, a_{3j}, \cdots, a_{Nj})^T$. The weight matrix of As can be obtained under P_s. As=[a11 a12 ... a1N; a21 a22 ... a2N; ......; aN1 aN2 ... aNN]. The weight matrix A_s is multiplied by the weightless super-matrix W_s, that is, the weight super-matrix, $W^w{}_S$: $W^w{}_S = A_S W_S$. In the ANP, to determine the stability of the element priority by finding the limit super-matrix method, we must calculate the limit super-matrix: $\lim_{k\to\infty} W^k = W_S^l$.

4. Project Overview of Research Examples

Beijing Metro Line 6, a project 01 tenders of the Youth road station ~ Dalian slope station section, west from the youth road, along the Chaoyang North Road laying to the Dalian slope station so far, the whole length of about 3.4km, from east to west , The use of shield within the interval construction. The buried depth of the tunnel is 14.6 ~ 16.9m[10].

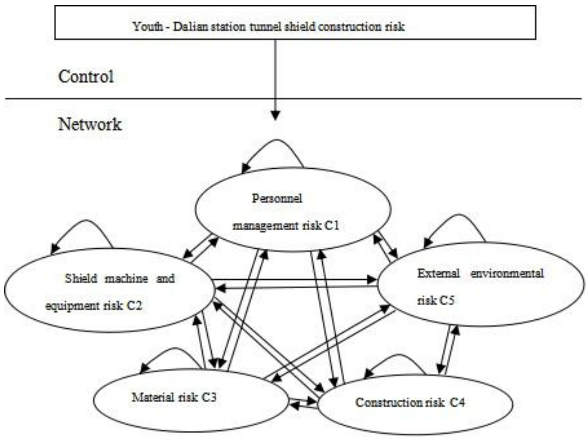

Fig. 1. Youth road station ~ Dalian slope station tunnel shield construction risk ANP map

4.1. Determination of index weight based on ANP method

(1) to determine the weight

In this risk system, there are complex interrelationships between the elements and other elements, and the risk model established in Table 1 and Figure 1 establish the relationship between the elements. Using ANP method to determine the weight of shield interval risk assessment index system of Youth road station Dalian slope station.

(2) the index calculation

The whole calculation of this example involves 25 judgment matrices. Because of the limited length of this paper, we choose W52 as an example to illustrate the construction of fuzzy judgment matrix. the secondary indicators, that is, the adverse effects of groundwater on the construction of C21 as a sub-criteria, and the first-level indicators, that is, the external environment risk C5 under the secondary indicators C51, C53, C54, C55 and so on, to compare, build the judgment matrix. the weight vector is obtained: $[w51^{(21)} w52^{(21)} w53^{(21)} w54^{(21)} w55^{(21)}]$=[0.2245 0.4047 0.2028 0.1135 0.0545]^T.

This is the sorting vector of the degree of influence of the elements in element C5 which affected on element C21. Similarly, the element set C5, respectively, affect on the elements C22, C23, C24 impact degree of the sorting vector is as follows. From the above four weight vectors, the judgment matrix is obtained. W_{52}=[0.224 0.224 0.249 0.249; 0.405 0.405 0.488 0.488; 0.203 0.203 0.112 0.112; 0.114 0.114 0.112 0.112; 0.054 0.054 0.039 0.039]. According to the same method, the judgment matrix W_{11}, W_{12}, W_{13}, W_{14}, W_{15}, W_{21}, W_{22},...W_{54}, W_{55} can be obtained.

(3) Combine the above fuzzy matrices into unweighted fuzzy super-matricesW=[W11 W12 W13 W14 W15; W21 W22 W23 W24 W25; W31 W32 W33 W34 W35; W41 W42 W43 W44 W45; W51 W52 W53 W54 W55] = [0.077 0.263 0.292 0.129 0.132 0.082 0.082 0.089 0.083 0.112 0.076 0.101 0.077 1.104 0.077 0.069;0.211 0.145 0.583 0.242 0.234 0.213 0.213 0.219 0.312 0.204 0.205 0.209 0.206 0.212 0.206 0.226; $\cdots$; 0.031 0.037 0.037 0.054 0.054 0.039 0.039 0.040 0.032 0.032 0.037 0.021 0.036 0.027 0.033 0.029]

(4) Calculate the first level fuzzy weight A. From the obtained first-order index weight A and unweighted fuzzy hyper-matrix W, we obtained the fuzzy weighted super-matrix as :

(5) The normalized limit ordering vector. G=(g1, g2,g3, g4, g5)=(g11, g12 , g13, g21 , g22 , g23 , g24 , g31 , g32, g41 , g42, g51 , g52 , g53 , g54 , g55) = (0.0102, 0.0221 , 0.0578, 0.1897, 0.0708, 0.0817, 0.0634, 0.1066, 0.0569, 0.0271, 0.0113, 0.0692, 0.1272, 0.0550 , 0.0390, 0.0119)

(6) To solve the impact of weight order of the risk factors group. g1=g11 + g12 + g13 = 0.0902, g2=g21 + g22 + g23 + g24 = 0.4057, g3=g31 + g32 = 0.1635, g4=g41 + g42 = 0.0384, g5=g51 + g52 + g53 + g54 + g55 = 0.3022. According to the value of g1, g2, g3, g4, g5, it can be seen that the influence weights of the factors influencing the shield construction risk of the Youth road station Dalian slope station are: external environmental risk, construction risk, shield machine and equipment risk, material risk and management risk.

4.2. Risk Assessment of Tunnel Construction Based on Fuzzy Method of Engineering Example

(1) establish a set of risk factors for the project

Based on the risk assessment index system in Table 1, the set of factors established:R_1=[0 0.6 0.3 0.05 0.05; 0.6 0.2 0.2 0 0; 0.7 0.3 0 0 0]; R_2=[1 0 0 0 0; 0.65 0.35 0 0 0; 0.55 0.4 0.05 0 0; 0.55 0.4 0.05 0 0; 0.3 0.25 0.3 0.15 0]; R_3=[0.9 0.1 0 0 0; 0.3 0.2 0.2 0.2 0.1]; R_4=[0 0 0.7 0.2 0.1; 0 0.1 0.5 0.3 0.1]; R_5=[0.8 0.1 0.05 0.05 0; 0.9 0 0.1 0 0;0.7 0.15 0.15 0 0;0.6 0.15 0.1 0.15 0; 0.3 0.1 0.25 0.25 0.1].

(2) fuzzy comprehensive evaluation

The fuzzy comprehensive evaluation based on ANP is established.

$$B = A\circ R = \begin{bmatrix} 0.0902 \\ 0.4057 \\ 0.1635 \\ 0.0384 \\ 0.3022 \end{bmatrix}^T \circ \begin{bmatrix} 0.62663 & 0.30913 & 0.05599 & 0.004125 & 0.004125 \\ 0.76724 & 0.156145 & 0.054205 & 0.02241 & 0 \\ 0.8193 & 0.11345 & 0.0269 & 0.0269 & 0.01345 \\ 0 & 0.03366 & 0.63268 & 0.23366 & 0.1 \\ 0.80476 & 0.06814 & 0.09123 & 0.03371 & 0.00216 \end{bmatrix}$$

=[0.7449 0.1317 0.0833 0.033 00.0071]

The corresponding comment set is: $V = v_1, v_2, v_3, v_4, v_5\}$ = { The risk is great, the risk is big, the risk is general, the risk is small, the risk is very small}.

According to the principle of maximum membership, the highest value of the evaluation vector is 0.6739, which is corresponding to the risk of the concentration, and the project is more than 50% of the total, We can think that Youth road station ~ dalian slope station subway shield construction range of great risk.

5. Conclusion

(1) Shield tunnel construction safety evaluation index system can better reflect the tunnel construction safety of the various factors required. The weight of each risk index of the tunnel construction system determined by ANP method can reflect the actual situation of the project correctly and provide a reliable basis for the safety evaluation of shield tunnel construction.

(2) According to the actual situation of the tunnel project of the Youth Road Station and the Dalian slope station, the comprehensive evaluation value is 0.6739, which indicates that the project is very risky. Therefore, it is advisable to consider more influencing factors when using ANP-Fuzzy method to evaluate the risk of tunnel construction in order to obtain more accurate results.

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