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Application of Analytic Hierarchy Process in the Selection of Subway Construction Method

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Abstract: In order to select a better method of subway construction, this paper uses the hierarchical weight decision analysis method to analyze and study the methods of CRD, PBA (pile-beam-arch), middle hole method and double sidewall guide pit method. The comparison results show that PBA method is the best construction method. It is proved that the index system and evaluation model constructed in this paper are reasonable and operable. Therefore, the method proposed in this paper is effective and can be used as a reference for the comparison and selection of subway stations in the construction stage in the future.

Keywords: subway; construction; risk analysis; fuzzy synthetic evaluation.

INTRODUCTION

The construction of underground subway station with shallow buried-tunnelling method is carried out in the underground interior. Due to the error of geological data, the limitation of some statistical methods and the uncertainty of some price indexes, the influence factors which can only be described qualitatively but not quantitatively, as well as the unforeseeable factors in all aspects, make the choice of subway station scheme extremely fuzzy, random and unknown. Therefore, according to different construction environment, different construction methods are adopted. At present, the commonly used construction methods in China are CRD, PBA, middle hole method, double side wall guide pit method. In this paper, the analytic hierarchy process (AHP) and fuzzy mathematics theory are applied to the system engineering of subway station scheme selection, and the comprehensive evaluation index system of subway station is established, and the weight of each factor is objectively determined by AHP. According to the theory of fuzzy mathematics, the fuzzy comprehensive evaluation is established to make the subway project construction safe, economical and fast.

APPLICABILITY OF VARIOUS METHODS

At present, the main shallow buried tunnelling method commonly used in China mainly include the meddle hole method, PBA, double side wall guide pit method and CRD, etc., and they all have their own construction characteristics and applicable conditions as shown in Table 1.

Table 1: Application conditions table of the construction methods

No.	Construction method	Application condition	Characteristic
Program 1	PBA method	The applicable settlement requirement is high.	The section utilization ratio is high and the cost is lower.
Program 2	CRD method	Suitable for rock, clay soil layer, sand layer, etc.	The structure is evenly stressed and has a small deformation.
Program 3	Double sidewall guide pit method	The advanced step method cannot meet the requirements of large-section station excavation.	The process is more complicated, the cost is higher, and the progress is slower.
Program 4	Middle hole	The section is relatively large and	High safety, low mechanization and high cost.

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SELECTION AND COMPARISON METHODS OF CONSTRUCTION METHODS

Establishing a Fuzzy Comprehensive Evaluation Model

Using the basic principles of the analytic hierarchy process, a comprehensive evaluation (K) indicator system for underground excavation construction schemes of metro stations can be established: the first one is the safety risk index P1, which can be analyzed from geological conditions (X_1), underground pipelines and surrounding een the upper and lower levels is determined. Assume that the element Ck of the previous level is used as a criterion, and that the elements of the next level have a dominance relationship with A_1, ..., A_n. The purpose is to give the corresponding weight to A_1,..., A_n, according to its certain number of values need to be assigned to the amount of importance. A scale of 1-9 is used here, and the environment (X_2), surface subsidence (X_3), etc.; the second one is the technical risk index P2 which can be analyzed from the design scheme (X_4), the construction technology (X_5) and the construction period (X_6); the third one is the investment risk index P 3 which can be analyzed from the project cost (X_7).

Constructing a Comparison Judgment Matrix to Calculate Relative Weights

After the hierarchical structure is established, the subordinate relationship of the elements bet relative importance under the criterion CK. In this step, answer the questions repeatedly: for the criterion Ck, two elements A and B, which one is more important and how much is the importance. A comparison criteria are shown in Table 2.

Table 2: Comparison criteria score table

Scale	Description	Mark
1	The i factor is as important as the j factor;	Equally important
3	The i factor is a little more important than the j factor;	A little important
5	The i factor is slightly more important than the j factor;	Slightly important
7	The i factor is more important than j factor;	Much more important
9	The i factor is much more important than the j factor;	Very important
2、4、 6、8	The importance of the two factors is between the above two scales;	-
Count backwards	The inverse of the above-mentioned importance is the case where j is more important than i.	-

If the criteria are technical risks, the sub-criteria can be divided into design risks and construction risks. If is taken as 5. The scale of design risk to construction risk is 1/5. For n elements, get a pairwise comparison judgment matrix A:

$$A = \begin{bmatrix} X_{11} & \cdots & X_{11} \\ \vdots & \ddots & \vdots \\ X_{11} & \cdots & X_{11} \end{bmatrix} \quad (1)$$

For A1,...,An. The positive definite reciprocal judgment matrix A is obtained by comparing the two pairs, and the construction risks are considered to be more important than design risks, their scale characteristic root problem is solved:

$$A\omega = \lambda_{max} \quad (2)$$

The obtained ω is normalized as elements A1, ..., An. The weight is sorted under the criterion CK. This method is called the feature root method of the sort weight vector calculation. λ_{max} exists and is unique, ω can be composed of positive components, except that the difference is a constant multiple ω ,is unique. There are many methods for calculating matrix eigenvalues and eigenvectors. In the case where the accuracy requirements are not high, λ_{max} and ω can be calculated by approximation. The calculation is performed using the square root method. In the first step, the product obtained by multiplying the elements of A by the row is opened n times:

In the first step, the product obtained by multiplying the elements of A by the row is opened n times:

$$\overline{\omega}_i = \sqrt[n]{\Pi_i^n a_{ij}}\text{, i=1, 2, 3,...n,} \tag{3}$$

In the second step, the square root vector is normalized, that is, the sort weight vector is obtained:

$$\omega_i = \frac{\overline{\omega_i}}{\sum_{i=1}^{n} \overline{\omega_i}}\text{, i=1, 2, 3,...n,} \tag{4}$$

The third step is to calculate λ_{max} according to the following formula:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(A\omega)_i}{n\omega_i} \tag{5}$$

，式中$(A\omega)_i$，表示向量$A\omega$的第 i 个元素。

hubai's average random consistency index for the 1-15th order repeated calculation of 1000 times is

$\lambda_{max} = \sum_{i=1}^{n} \frac{(A\omega)_i}{n\omega_i}$,in the formula $(A\omega)_i$ represents

the i-th element of the vector $(A\omega)_i$.

In the construction of the judgment matrix, it is not required that the judgment has consistency. When the judgment deviation is too large, the calculation result of the sort weight vector as a basis for evaluation will have some problems. Therefore, after obtaining , a consistency check is required, and the steps are as follows:

Computational consistency index CI

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{6}$$

In the formula, n is the order of judgment matrix.

Computational consistent CR

$$CR = {}^{CI}/_{RI} \tag{7}$$

The average random consistency index RI is obtained by repeating the calculation of the eigenvalues of the random judgment matrix multiple times (more than 500 times) and taking the arithmetic mean. Xu S shown in Table 3.

Table 3 Average random consistency index

Order	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58	1.59

When CR < 0.1, it is considered that there is satisfactory consistency in the judgment. A weight vector for each layer of factors can be obtained.

Establish a Comprehensive Evaluation Set

Let the target factor set be $X=\{X_1,X_2,...X_n\}$, according to some attributes, it is divided into S subsets, $X_i=\{X_{i1}, X_{i2},...X_{in}\}$, and each sub-factor set is comprehensively evaluated. The alternative set $A=\{u_1, u_2,...u_n\}$ selects the comment set as $V= \{v_1,v_2,...v_n\}$, they are all finite sets. The weighting set ω of the factors is determined by the above analytic hierarchy process.

The membership function method for quantitative indicators refers to the target eigenvalue matrix composed of m indicators of n schemes:

$$Y = \begin{bmatrix} Y_{11} & \cdots & Y_{1n} \\ \vdots & \ddots & \vdots \\ Y_{m1} & \cdots & Y_{mn} \end{bmatrix} \quad (8)$$

When $0 \le e_{ij} \le 1$, $e_{ij} = e_{ji}$, the matrix E is called an ordered binary comparison matrix about importance; e_{ij} is the fuzzy scale of the importance of the target i for j when the target i is a binary comparison of the importance of J; e_{ji} is the fuzzy scale of the importance of target j for i.

The overall evaluation is to form the fuzzy relationship matrix R by the evaluation indicators of the basic factor evaluation set under the same level:

$$R = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix} \quad (9)$$

It reflects the correlation between the target factor and the choice. The comprehensive evaluation of the solution set K is the matrix B:B=ωR =$\{b_1,b_2,b_3,...b_n\}$,in the formula B is called output fuzzy vector, $b_j = \sum a_k r_{kj}$,j=1，2，3，...n.

The output fuzzy vector B, the magnitude of its sub-vector will relatively reflect the risk level of the relevant factors in the construction of underground engineering. IV Project example

An underground excavation subway station in Shenyang is located in the prosperous commercial area of Shenyang. The construction site is small and limited. There are many high-rise buildings in the surrounding area, the environment is complex, and there are many types of pipelines. It is difficult to control surface settlement and settlement of buildings.

Table 4 Overall evaluation index system

Criterion	Index	Scheme 1	Scheme 2	Scheme 4
P1	X1	3	2	2
	X2	2	5	4
	X3	5	6	5
P2	X4	7	7	7
	X5	6	6	6
	X6	3	4	5
P3	X7	2	3	3

Construction must be minimized the disturbance of the soil outside the main structure of the station. Four schemes are selected, scheme 1 is the PBA method, scheme 2 is the CRD method, scheme 3 is the middle hole method, and scheme 4 is the double-wall guide pit method, using the hierarchical analysis method and the fuzzy theory to compare the overall evaluation, according to the standard comparison table 1 with the weight of experts, the overall evaluation index system is shown in Table 4.

According to the basic principle of the analytic process, the judgment matrix M corresponding to the O-P factor of the criterion layer is constructed.

$$M = \begin{bmatrix} 1 & 1 & 2 \\ 1 & 1 & 2 \\ 1/2 & 1/2 & 1 \end{bmatrix}$$

The available eigenvalues are λ_{max} =3, CI=(λ_{max}-m)/(m-1)=0, the table shows that RI=0.58, is so CR=0 < 0.1 that the matrix passes the consistency test and can be used for subsequent analysis. The eigenvectors corresponding to the positive reciprocal matrices M and λ_{max} are normalized and used to determine the weights of the evaluation factors, that is, the input fuzzy vector matrix is taken as K = (0.4, 0.4, 0.2)

In the same way, the weight coefficients of each secondary evaluation indicator are obtained as shown in Table 5.

Table 5 Secondary evaluation index calculation table

	[p]	λ_{max}	CI	RI	CR < 0.1
P1	[P1]*	3.037	0.019	0.52	0.037
P2	[P2]*	3.082	0.041	0.52	0.079
P3	1	1	0	0	0

[P1]*=[0.105 0.258 0.637]

[P2]*= [0.094 0.278 0.628]

Normalize [P]* and use it to determine the weight of each evaluation factor, that is, take the input fuzzy vector matrix A:

A={0.443 0.238 0.059 0.103 0.157}. Then you can calculate the weight of the hierarchical overall ordering ω:

ω ={0.042 0.103 0.255 0.038 0.111 0.25 0.2}。

The overall ranking of the hierarchy is consistent with the consistency test results.

The determination of the membership matrix is normalized to the overall membership matrix according to the eigenvector matrix of the indicator system:

$$R=\begin{bmatrix} 0.67 & 1 & 1 & 1 \\ 1 & 0.4 & 0.4 & 0.5 \\ 1 & 0.83 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 0.75 & 0.75 & 0.6 \\ 1 & 0.67 & 0.67 & 0.67 \end{bmatrix}$$

The overall evaluation vector that can be obtained after specifically determining the matrix index membership matrix R and the weight vector ω is:

$$B=\omega\cdot R=\{b_1, b_2 \ldots b_n\}$$

$$=\{0.9851\ 0.7654\ 0.8087\ 0.7815\}$$

According to the principle of relative size of B elements, we can know: the superiority with the engineering scheme 1 of this example is 98.51%, the superiority of the scheme 2 is 76.54%, the superiority of the scheme 3 is 80.87%, and the superiority of the scheme 4 is 78.15%, so the scheme 1 with the greatest superiority is selected. The practical application of the program through practice shows that the construction plan determined by this overall evaluation is the most reasonable.

CONCLUSION

Combining fuzzy mathematics and analytic hierarchy process, this paper uses fuzzy risk judgment matrix to realize the risk probability of risk factors, risk loss and the importance of comprehensive consideration of risk occurrence probability and risk loss. The analytic hierarchy process and fuzzy mathematics theory are used to comprehensively evaluate and select the criteria for the selection of metro station construction schemes, avoiding the disadvantages of too many factors and difficult to assign weights, and avoiding the one-sidedness and subjective understanding of single factor decision-making.The decision-making mistakes caused by the differences, especially when the indicators that affect the selection of various options have superiority, can make more scientific, accurate and theoretically-based judgments.

REFERENCES

[1] M.C. Minguillón, C. Reche, V. Martins, et al. Aerosol sources in subway environments[J]. Environmental Research, 2018, 167:314-328.

[2] Barend L. van Drooge, Raimon M. Prats, Cristina Reche, et al. Origin of polycyclic aromatic hydrocarbons and other organic pollutants in the air particles of subway stations in Barcelona[J]. Science of the Total Environment, 2018, 642:148-154.

[3] Juan Carlos Muñoz, Jaime Soza-Parra, Arturo Didier, et al. Alleviating a subway bottleneck through a platform gate[J]. Transportation Research Part A, 2018, 116:446-455. GencerKoc, CuneytSert, Kahraman Albayrak. Use of artificial neural networks for the prediction of time-dependent air speed variation in metro stations[J]. Proceedings of the Institution of Mechanical Engineers, 2018, 232(8):2186-2197

[4] Jongmin Yu, Kin Choong Yow, Moongu Jeon. Joint representation learning of appearance and motion for abnormal event detection[J]. Machine Vision & Applications, 2018, 29(7):1157-1170

[5] Charalampos Mouzakis,Konstantinos Vogiatzis,Vassiliki

[6] Sheikhi, A., Asadizaker, M., Jahani, S., Koochak, M., Shamloo, M.B.B., Zadeh, M.H.H. " The effect of rosemary topical ointment on phlebitis caused by antibiotic therapy in intensive care units",(2018) Journal of International Pharmaceutical Research, 45, pp. 5-11.

[7] Rakhi Gawde, Apoorva Pahadia, Shikha Agrawal, Nimita Manocha, Umesh Ramchandani (2013) Mucoadhesive Buccal Patches: The Newest Way of Oral Drug Delivery. International Journal of Pharmacy Research & Technology, 3 (2), 01-05.