Research on Graded Management of Construction Risk Factors of a Subway Station

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Abstract. Based on a subway station project, this paper puts forward the risk factors in the process of subway construction. The analytic hierarchy process (AHP) is used to establish the risk factor model of metro station. Establishes the risk judgment matrix at all levels by combining the results of expert investigation method. By evaluating the risk factors of the subway station, the weight values of the above risk factors are calculated and sorted. As a result, the risk management system of subway station is put forward. The research results of this method provide a theoretical basis for the project managers to determine the risk factors, and lay a foundation for the smooth progress of the subway station construction project.

Keywords. Risk factors, analytic hierarchy process, expert investigation method, risk assessment, risk grading management

1. General Situation of a Subway Station

The new subway station is located on the main road of city traffic, above which is a South-North street. The main body of the station is arranged along the street in the South-North direction. The effective platform of the station is 177m in total length, 25.3m in width and 30m in depth. The south side is Commercial Street A. The west side is city hotel. The northeast side is Xinhua Bookstore, and the southeast side is Commercial Street B and cross-street channel. During the construction of the underground excavation of the main structure of the station, there are many surrounding structures, complex underground pipelines and many factors to be considered, as well as many risk factors to be noticed in the construction process. The overall layout of the station is shown in figure 1.

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Figure 1. Overall layout of subway station.

The main body of the station is constructed with eight guide tunnels by the method of "PBA" tunnel piles. Four guide tunnels are arranged on the upper and lower layers of the station, which are divided into four axes A, B, C and D and have three sections. Three construction shafts are set in station construction. No. 1 exhaust shaft and No.2 safety vent are used as shafts for No.1 shaft and No.3 shaft respectively, and No.2 shaft is a new one, whose position intersects with F1 entrance and exit. All shafts are excavated and supported by inverted shaft wall method.

The general construction sequence of the station is firstly to excavate the construction shaft and cross channel, then to construct from three construction channels to both sides at the same time, which will greatly reduce the construction period and improve the construction efficiency.

2. Construction Risk Factors System of a Subway Station

According to the comprehensive analysis of the actual construction risk of the new subway station, the specific factors affecting the subway construction safety are obtained, and the analytic hierarchy process structure is constructed [1-3], as shown in table 1.

Table 1. Subway construction safety evaluation index system.

The target layer	Rule layer	Index layer	The weight	The sorting	level
Subway station construction risk assessment A	Peripheral environmental risks(B ₁)(0.0953)	Square A(C ₁)	0.0952	14	1
		Xinhua bookstore(C ₂)	0.0836	17	1
		City hotel(C ₃)	0.1304	13	1
		Commercial street A(C ₄)	0.1970	8	3
		Commercial street B(C ₅)	0.0517	21	1
		Existing station(C ₆)	0.3904	2	4
	Underground pipeline risk(B ₂)(0.1603)	Adverse formation risk(C ₇)	0.0517	22	1
		Down through the main station pipeline(C ₈)	0.2216	6	3
		Underpass the underground excavation pipeline at the inlet and outlet(C ₉)	0.3542	3	3
		Underpass the open cut pipeline at the inlet and outlet(C ₁₀)	0.0905	15	2
		Replace underground pipelines(C ₁₁)	0.0560	19	1
		Underpass the transfer	0.2216	7	2

The target layer	Rule layer	Index layer	The weight	The sorting	level
		channel pipeline(C ₁₂)			
		Underpass the construction cross passage pipeline(C ₁₃)	0.0560	20	1
		Excavation risk of side piles and central columns(C ₁₄)	0.1391	12	2
		Pipeline leakage risk(C ₁₅)	0.1803	9	3
		Hole collapse risk(C ₁₆)	0.1516	10	3
		Risk of broken pile(C ₁₇)	0.0877	16	2
		Hole offset risk(C ₁₈)	0.0432	23	1
		Risk of land subsidence(C ₁₉)	0.1423	11	3
		The connection between buckle arch and primary branch is weak risk(C ₂₀)	0.2256	5	3
		Design change risk(C ₂₁)	0.0302	24	1
		Subterranean excavation risk of auxiliary structure(C ₂₂)	0.3420	4	3
		Risk of open cut construction of accessory structure(C ₂₃)	0.0811	18	2
		The risk of digging main structure of the station(C ₂₄)	0.5769	1	4
	Risk of construction method(B ₃)(0.4668)				
	Station Own Risk(B ₄)(0.2776)				

3. Establishment of Risk Assessment Matrix

3.1. Calculation of Evaluation Weight Vector W

$$W = (W_1, W_2, \dots, W_n)^T \quad (1)$$

Analytic hierarchy process to determine the weight vector w [4,5] methods are: sum method (arithmetic average), square root method (geometric average), characteristic root method, least square method. In order to facilitate the calculation, the arithmetic square method is used to analyze the weight:

$$W_i = \frac{1}{n} \sum_{j=1}^n \frac{a_{ij}}{\sum_{k=1}^n a_{ik}}, i = 1, 2, \dots, n \quad (2)$$

3.2. Analysis of Expert Questionnaire

According to the expert survey method, the questionnaire survey is conducted, and the scale of 1-9 is introduced. The experts score the factors and calculate the scoring results of each factor, as shown in table 2.

Table 2. Scoring statistics of construction risk indicators of new Metro Station

Rule layer	Score	Factors layer	Score	Factors layer	Score	Factors layer	Score	Factors layer	Score
B ₁	5.14	C ₁	4.85	C ₇	3.20	C ₁₃	3.83	C ₁₉	7.85
B ₂	5.36	C ₂	4.50	C ₈	6.85	C ₁₄	7.82	C ₂₀	8.33
B ₃	7.17	C ₃	5.00	C ₉	7.33	C ₁₅	8.20	C ₂₁	4.32
B ₄	6.64	C ₄	6.75	C ₁₀	4.50	C ₁₆	8.00	C ₂₂	7.33
		C ₅	3.20	C ₁₁	3.50	C ₁₇	7.05	C ₂₃	4.26
		C ₆	8.50	C ₁₂	6.12	C ₁₈	5.75	C ₂₄	8.33

3.3. AHP is used to Evaluate the Weight of each Index

According to the safety risk analysis of the subway construction, the order of the relevant degree of each factor and the subway station construction safety is listed in table 1.

4. Determination of Membership Function of Evaluation System

According to the construction safety situation, the comprehensive evaluation index of risk level is divided into 1 ~ 5 grades: $v [6-8] = \{\text{safe, relatively safe, general, dangerous, extremely dangerous}\}$. The membership function $R_{ij}(x)$ is shown in table 3.

Table 3. Membership function expression.

Level of risk	Membership function
Level 1	$R_{ij}(x) = \begin{cases} 1, & 0 < x \leq 2 \\ 3 - x, & 2 < x \leq 3 \\ 0, & x > 3 \end{cases}$
Level 2	$R_{ij}(x) = \begin{cases} x - 2, & 2 \leq x < 3 \\ 1, & 3 \leq x \leq 4 \\ 5 - x, & 4 < x \leq 5 \\ x - 5, & 5 < x \leq 6 \\ \frac{8 - x}{2}, & 6 < x \leq 8 \\ 0, & x < 2 \text{ or } x > 8 \end{cases}$
Level 3	$R_{ij}(x) = \begin{cases} x - 4, & 4 \leq x < 5 \\ 6 - x, & 5 \leq x < 6 \\ \frac{x - 6}{2}, & 6 \leq x < 8 \\ 1, & 8 \leq x \leq 12 \\ \frac{15 - x}{3}, & 12 < x \leq 15 \\ 0, & x < 4 \text{ or } x > 15 \end{cases}$
Level 4	$R_{ij}(x) = \begin{cases} \frac{x - 12}{3}, & 12 \leq x < 15 \\ 1, & 15 \leq x \leq 20 \\ \frac{25 - x}{5}, & 20 \leq x < 25 \\ 0, & x < 12 \end{cases}$
Level 5	$R_{ij}(x) = \begin{cases} \frac{x - 20}{5}, & 20 \leq x \leq 25 \\ 0, & x < 20 \end{cases}$

5. Establishment of Hierarchical Management of Risk Factors

There are 24 risk events in the risk assessment model mentioned above, which are scored by experts to get P and C values, and then put them into the membership function table 3 to judge the risk level of each risk factor, which is divided into five levels, as shown in table 1.

As can be seen from table 1, the structural self-risk engineering and the existing station risk are the highest level risk factors. The commercial street above the station, the main pipeline under the station, the ground subsidence risk and other risk factors

are the next. The results above provide decision-making basis for safety management of construction site.

6. Conclusion

Based on a new subway station, this paper evaluates the safety risk in the construction process by expert investigation and AHP, and obtains the following conclusions:

(1) The occurrence of subway station construction accidents is random, the complexity of development process and the incomplete existing safety reserve. When carrying out safety analysis, many factors cannot be quantified directly. Therefore, the AHP and expert investigation method are needed to make the safety assessment of project construction more scientific;

(2) When the subway station project is constructed, the risk factors risk ranking obtained by the reference analytic hierarchy process can effectively and emphatically carry out the prevention and safety management of construction accidents.

(3) This paper puts forward the dangerous factors and safety grade division of tunnel pile construction in subway station, which is conducive to the scientific decision-making of construction site.

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