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THE STUDY OF SUBWAY EMERGENCY MANAGEMENT CAPABILITY BASED ON COWA OPERATOR AND MATTER-ELEMENT EXTENSION METHOD- TAKING QINGDAO METRO LINE 3 AS AN EXAMPLE

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ABSTRACT

The subway operation mileage increases year by year, and its operation safety status has received extensive attention. Strengthening the emergency management capability and improving the efficiency of emergency prevention and disposal are very important to the development of the subway. On the basis of the evaluation index system of traditional subway emergency management capability, starting from the two parties of subway operating company and government, combined with the theory of crisis management and the requirements of "One case, three systems" system, this paper establishes a comprehensive and multi-level management of subway emergency capability evaluation index system. Considering the fuzzy incompatibility of subway emergency management capability evaluation, this paper constructs the evaluation of the emergency management capability based on matter-element extension method, and uses the COWA operator to determine the weight of each index, which weakens the effect of expert's subjective preference to index weight, and improves the accuracy of the evaluation model. Finally, this paper takes Qingdao Metro Line 3 as an example to evaluate its emergency management capability. The result shows: Qingdao Metro Line 3 emergency management capability is in a strong level, and its emergency reduction capability, response capability, "One case, three systems" construction and emergency support capability of government departments are in high level, and it needs to improve the level of emergency readiness capability and recovery capability.

1. INTRODUCTION

At present, China's subway mileage is increasing year by year. On the one hand, the subway has brought convenience to travel, while there are also many security problems. Strengthening the safety management and improving the emergency efficiency are of great practical significance to the development of the subway. Since the event of "SARS" in 2003, China has gradually formed a emergency management system of "One case, three systems", and has promulgated the "National emergency plan for public emergencies" "The emergency response law of the People's Republic of China" etc. In the aspect of urban disaster emergency, Guo Dongyan constructed the urban disaster prevention system to improve the ability of urban disaster warning [1]. Deng Yunfeng constructed an index system to evaluate the emergency response capability of a southern city [2]. For rail traffic engineering emergency management: Huang Dianjian took the urban rail traffic as the research object to conduct a comprehensive analysis of the operation risk, and built the dynamic evaluation model of emergency management capability [3]. Chen Xu and Xu Jianguang separately studied the emergency plan of the railway emergency capability and emergency management system [4,5].

Generally speaking, the study of emergency management in China mainly focuses on the management of urban emergency management, while the management of urban rail traffic, especially the operation of the subway, is relatively less. In view of this, combining the theory of crisis management, this paper constructs a more perfect evaluation index system of the subway emergency management capability. This paper uses the combination number ordered weighted operator (COWA) to determine the weight of index, and introduces the matter-element extension method for the qualitative and quantitative analysis to solve fuzzy incompatible problem in emergency management, at the same time indicates weak index for decision makers which have influences on the emergency management capability, so as to take measures to improve the ability of emergency management.

2. CONSTRUCTION OF EVALUATION INDEX SYSTEM FOR SUBWAY EMERGENCY MANAGEMENT CAPABILITY

Robert Heath put forward the 4R model of crisis management in the book "Crisis management". They are reduction, readiness, response and recovery [6]. The four stages of crisis management always run through the whole life cycle of emergency management. Therefore, according to the 4R model of crisis management, this paper establishes subway emergency capability index system, so that the evaluation system is more complete and effective.

Summing up other scholars' construction of subway emergency capability evaluation index, most of them are from the government's point of view. As for the actual situation, the main part of the subway emergency management is the Metro company. In the process of subway emergency management, the metro company is the most direct manager while the government plays a supporting and guiding role in the management of the Metro company. Therefore, based on the theory of crisis management and the requirements of "One case, three systems" system, starting from two parties of subway operating company and government, this paper establishes a more complete index system of the subway emergency management capability. As shown in figure 1:

Figure 1: Evaluation index system of Subway Emergency Management Capability

3. C-OWA OPERATOR WEIGHTING

Ordered weighted averaging operator is a method of information fusion proposed by Professor Yager in 1988. It has been widely used in the determination of index weights after a number of scholars have improved it. Its specific steps are as follows[7]:

(1) A number of experts were invited to mark the importance of the same level of indicators (score 0-10), and the results of the scoring constitute the initial decision data set of the index factors $(a_1, a_2, \dots, a_j, \dots, a_n)$. Sort the decision data from large to small, the result is $(b_1, b_2, \dots, b_j, \dots, b_n)$.

(2) The weight of b_i is determined directly by the number of combinations C_{n-1}^j :

$$\theta_{j+1} = \frac{C_{n-1}^j}{\sum_{k=0}^{n-1} C_{n-1}^k} = \frac{C_{n-1}^j}{2^{n-1}}, j = 0, 1, 2, \dots, n-1 \quad (1)$$

(3) The weight of the decision data is weighted by weight θ_{j+1} , and the absolute weight of the index factor $\bar{\omega}_i$ is obtained: $\bar{\omega}_i = \sum_{j=0}^{n-1} \theta_{j+1} b_j, i = 1, 2, \dots, m$

(2)

(4) Calculate the relative weights of the index factors ω_i : $\omega_i = \frac{\bar{\omega}_i}{\sum_{i=1}^m \bar{\omega}_i}, i = 1, 2, \dots, m \quad (3)$

4. EVALUATION MODEL OF SUBWAY EMERGENCY MANAGEMENT CAPABILITY BASED ON MATTER ELEMENT EXTENSION METHOD

4.1. Model principle analysis

Eltenacs was first proposed by Cai Wen scholars as a solution to the problem of incompatibility. By constructing matter-element models and describing things with "things, features, and fuzzy values", we seek the solution of things through various transformations, thus solving such incompatible problems [8].

4.2. Determination of classical domain and node domain matter elements

The evaluation level of subway emergency management capability is M , and its evaluation index is u , corresponding to the value of index u is v . Therefore $W = (M, u, v)$ is referred to as matter-element.

The classical domain indicates the specific subordinate scope of each evaluation index when the subway emergency management capability is in a certain

level, expressed in V_{ijk} . As shown in the following matrix R_k :

Node field element is a union of classical field matter element. As shown in the following matrix R_p :

$$R_k = \begin{bmatrix} M_k & u_{11} & V_{11k} \\ & u_{12} & V_{12k} \\ & \vdots & \vdots \\ & u_{ij} & V_{ijk} \\ & \vdots & \vdots \\ & u_{mn} & V_{mnk} \end{bmatrix} = \begin{bmatrix} M_k & u_{11} & (a_{11k}, b_{11k}) \\ & u_{12} & (a_{12k}, b_{12k}) \\ & \vdots & \vdots \\ & u_{ij} & (a_{ijk}, b_{ijk}) \\ & \vdots & \vdots \\ & u_{mn} & (a_{mnk}, b_{mnk}) \end{bmatrix} \quad R_p = \begin{bmatrix} M & u_{11} & V_{11p} \\ & u_{12} & V_{12p} \\ & \vdots & \vdots \\ & u_{ij} & V_{ijp} \\ & \vdots & \vdots \\ & u_{mn} & V_{mnp} \end{bmatrix} = \begin{bmatrix} M_k & u_{11} & (a_{11p}, b_{11p}) \\ & u_{12} & (a_{12p}, b_{12p}) \\ & \vdots & \vdots \\ & u_{ij} & (a_{ijp}, b_{ijp}) \\ & \vdots & \vdots \\ & u_{mn} & (a_{mnp}, b_{mnp}) \end{bmatrix}$$

4.3. Determine the correlation function of the object to be evaluated

In order to determine the membership grade of each index, the correlation function is introduced, through the calculation of each index value for the correlation of the level, determine the indicators for the evaluation of membership degree of each level, the formula is as follows.

$$S_k(v_{ij}) = \begin{cases} -\frac{\rho(v_{ij}, V_{ijk})}{|V_{ijk}|}, v_{ij} \in V_{ijk} & \rho(v_{ij}, V_{ijk}) = \left| v_{ij} - \frac{1}{2}(a_{ijk} + b_{ijk}) \right| - \frac{1}{2}(b_{ijk} - a_{ijk}) \\ \frac{\rho(v_{ij}, V_{ijk})}{\rho(v_{ij}, V_{ijp}) - \rho(v_{ij}, V_{ijk})}, v_{ij} \notin V_{ijk} & |V_{ijk}| = |b_{ijk} - a_{ijk}| \\ & \rho(v_{ij}, V_{ijp}) = \left| v_{ij} - \frac{1}{2}(a_{ijp} + b_{ijp}) \right| - \frac{1}{2}(b_{ijp} - a_{ijp}) \end{cases} \quad (4)$$

4.4. Computation comprehensive correlation

The comprehensive degree of association can be obtained by weighting the correlation degree, and the comprehensive correlation degree of each index on an evaluation grade is: $S_k(v_i) = \omega_i * S_k(v_{ij})$ (5)

The evaluation grade corresponding to the maximum of the correlation degree is the subordinate grade of the evaluation index.

5. CASE ANALYSIS

This paper takes Qingdao metro line 3 as an example. Since 2009 the metro engineering started the construction of test section, and entered full line construction stage in 2009, then tested run by the end of 2015. The metro line is 25.2 kilometers long and sets up 22 stations. Its average daily passenger volume is 142 thousand. The maximum speed is 80km/h. The train punctuality rate reached 99.97%. Qingdao metro line 3 formulated and implemented some emergency response mechanisms, such as "Gridding" "Ground and underground integration" "A drill at each station every month".

5.1. C-OWA operator weighting

Taking first-level indicators as examples, 6 experts scoring results are shown in table 1:

Table 1: Expert ratings for first-class indicators

Index	Expert I	Expert II	Expert III	Expert IV	Expert V	Expert VI
A ₁	9	9.5	9.2	9.3	9.8	9
A ₂	7.5	8.1	7.8	7.8	8	7

According to equation (2) to obtain the absolute weight of the index factor: $\bar{\omega}_{A_1} = 9.2594$

Similarly, $\bar{\omega}_{A_2} = 7.7813$. To Calculate the relative weight of the indicator factor according to Eq. (3), that is $\omega_{A_1} = 0.5434, \omega_{A_2} = 0.4566$. The weights of other indicators are shown in Table 2.

5.2. Evaluation model of Subway Emergency Management Capability

(1) According to the relevant research literature, the evaluation results of subway emergency capability are divided into five grades: M1 (Excellent), M2 (Relatively excellent), M3 (General), M4 (Relatively weak), M5 (Fragile), and the classical domains of each index are shown in the following matrix:

$$R = (M, u, v) = \begin{bmatrix} M_1 & M_2 & M_3 & M_4 & M_5 \\ u & [0.9, 1] & [0.8, 0.9] & [0.7, 0.8] & [0.6, 0.7] & (0.0, 0.6) \end{bmatrix}$$

(2) 18 experts with rich experience are invited to conduct a comprehensive evaluation, calculating the mean value as the evaluation value of each index, as shown in table 2:

Table 2: Index weights and evaluation values at all levels

First Level index weights		Second Level index weights	Third Level index weights	Evaluation Values V_{ij}
A ₁	R ₁	0.1371	U ₁₁	0.0446 0.9533
			U ₁₂	0.0459 0.9033
			U ₁₃	0.0466 0.8967
	R ₂	0.1355	U ₂₁	0.0277 0.9012
			U ₂₂	0.0278 0.92

A ₂	0.4566	R ₃	0.1378	U ₂₃	0.0263	0.8334
				U ₂₄	0.0267	0.864
				U ₂₅	0.0271	0.8935
				U ₃₁	0.0264	0.92
				U ₃₂	0.0269	0.8867
				U ₃₃	0.0296	0.87
		R ₄	0.1329	U ₃₄	0.0272	0.88
				U ₃₅	0.0271	0.9133
				U ₄₁	0.0357	0.823
				U ₄₂	0.0347	0.8766
		R ₅	0.2288	U ₄₃	0.0317	0.86
				U ₄₄	0.0309	0.87
				U ₅₁	0.0551	0.89
				U ₅₂	0.0585	0.92
				U ₅₃	0.0592	0.8967
				U ₅₄	0.0560	0.923
R ₆	0.2278	U ₆₁	0.0583	0.9232		
		U ₆₂	0.0561	0.8934		
		U ₆₃	0.0582	0.8834		
		U ₆₄	0.0552	0.923		

(3) Aiming at experts evaluation values of Qingdao metro operation emergency management capability and the government emergency support capability, the correlation degree of each grade index value for each grade can be obtained by the formula (4), taking R1 index as an example, as shown in the following

$$\text{matrix: } S_k(v_{ij}) = \begin{bmatrix} 0.4670 & -0.5330 & -0.7665 & -0.8443 & -0.8833 \\ 0.0330 & -0.0330 & -0.5165 & -0.6777 & -0.7583 \\ -0.0310 & 0.0330 & -0.4835 & -0.6557 & -0.7418 \end{bmatrix}$$

(4) The correlation degree and corresponding weight of the third-level index are weighted by the formula (5), and the correlation degree of second-level index can be obtained, as shown in Table 3:

Table 3: Comprehensive correlation degree of subway emergency management capacity

Index	M_1	M_2	M_3	M_4	M_5	Grade
A_1	-0.007	0.009	-0.028	-0.044	-0.051	M_2
A_2	0.010	-0.010	-0.037	-0.059	-0.070	M_1
A	0.008	-0.009	-0.032	-0.051	-0.060	M_1

6. CONCLUSIONS

Starting from the two parties of subway operating company and government, based on the theory of crisis management and the requirements of "One case, three systems" system, this paper establishes a more complete evaluation index system of the subway emergency management capability to provide a reference for the subsequent evaluation of subway operation ability of emergency management.

Using C-OWA operator to determine the weight of each index, which weakens the effect of expert's subjective preference to index weight, makes the evaluation values more objective and reasonable. In the case analysis, the weights of the emergency management capability of the Metro Company are classified as follows: emergency response capability, reduction capability, readiness capability and emergency recovery capability.

The application of matter - element extension method to the evaluation of emergency management capability of metro is effective in solving the problem of fuzzy incompatibility in metro emergency management, and it is convenient for managers to find the weak index which affects the evaluation results, so as to indicate the direction of management decision.

The case shows that the emergency management of Qingdao Metro Line 3 is in an excellent level, and the metro company needs to improve its emergency preparedness capability and restoration capability, while the government departments need to strengthen emergency support.

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