Safety Assessment for the Dispatch and Command System of High-speed Railway Based on Fuzzy Analytic Hierarchy Process

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Abstract
With the rapid development of high-speed railway, the traits of the high-speed railway are high-speed, high-density, high-tech, high-demand and so on , which have a severe challenges for the safe operation of the dispatch and command system that plays an important role on the production safety of entire railway transportation. Based on this feature, from the viewpoint of systems engineering, the safety factors that affect the safety operation of the dispatch and command system are comprehensively analyzed, and the hierarchical model of safety evaluation is established; the weights of each factor are determined by using the fuzzy analytic hierarchy process, and the safety situation of the dispatch and command system is evaluated, and it can be obtained that the environment factor, the human factor and the management factor are the major factors that affect the safe operation of the dispatch and command system, and according to this result, many appropriate safety management recommendations are proposed, which will provide the better protection for the safety operation of the dispatch and command system of high-speed railway.
Keywords: HIGH-SPEED RAILWAY,DISPATCH AND COMMAND SYSTEM HIERARCHICAL MODEL OF SAFETY EVALUATION,FAHP

1. Safety analysis of high-speed railway scheduling command

The rapid development of high-speed railway in our country pull the domestic demand powerfully, and promotes the development of social economy well and quickly,improves the travel conditions of people, convenients for people's life and work.But in the process of rapid development, also has exposed the serious security problems,seriously threaten the people's

life and property safety. The speed of high-speed train is very high,and once an accident occurs, the consequences is usually serious, catastrophic.

On July 23, 2011 in the evening 8 p.m,the D301 CRH from Beijing South Railway Station to Fuzhou Railway Station crashed the D3115 seriously,in that accident 40 people were killed,172 people were injured, the traffic broke off 32 hours and 35 minutes,the direct economic loss was 193.7165 million yuan, the accident caused great economic losses and casualties.It was a extraordinarily serious accident in Chinese railway history [1].

After investigation concluded that, major cause of the accident are as follows: The material weakness exist in quality of train control equipment;The safety regulations and standards of high speed railway scheduling command was not sane;The organization and management of train was flimsy,and lack of emergency disposal;The safety consciousness of operating personnel was weak,the supervise was leaky,and exist illegal operation.The safe and punctual travel of passengers is influenced by the reliability and security of high-speed railway system,it influences the normal and healthy functioning of the whole city.So it is necessary to research the methods to improve the safety ability of the high-speed railway scheduling command system.

2.Safety elements analysis of high-speed railway dispatch and command system

High-speed railway system [2] is constitute of complex technology and equipment,it operations in a complex environment and achieves complex displacement,the neural center is dispatch and command system,it is constitute of permanent way engineering, traction power supply, communication signal and train control, scheduling command, passenger service and others subsystems,it is a complex giant network system, in different condition, many factors influence the safe reliability.This text based on the basic element of dispatch and command system,the safety factor of high-speed railway scheduling command system were divided into four classes:man, equipment, environment and decision-making management,it incarnates that safety is a entire personnel, total factor, overall process activity,the research significance is universal [3].

This text divided the index of evaluation system into 3 levels based on the design philosophy of safety evaluation index system, safety impacted factors of schedule job and the research achievement of related fields at inland and abroad,the first destination Layer is S layer,is the analysis of the aim, the present situation of high speed railway scheduling command A;the cecond layer is criterion layer,it responses the first layer,it contains: environmental factor C_1, human factor C_2, equipment factor C_3 and management factor C_3;the third layer is base index layer,it specifically reflect the evaluation target and factors. As shown in Fig.1.

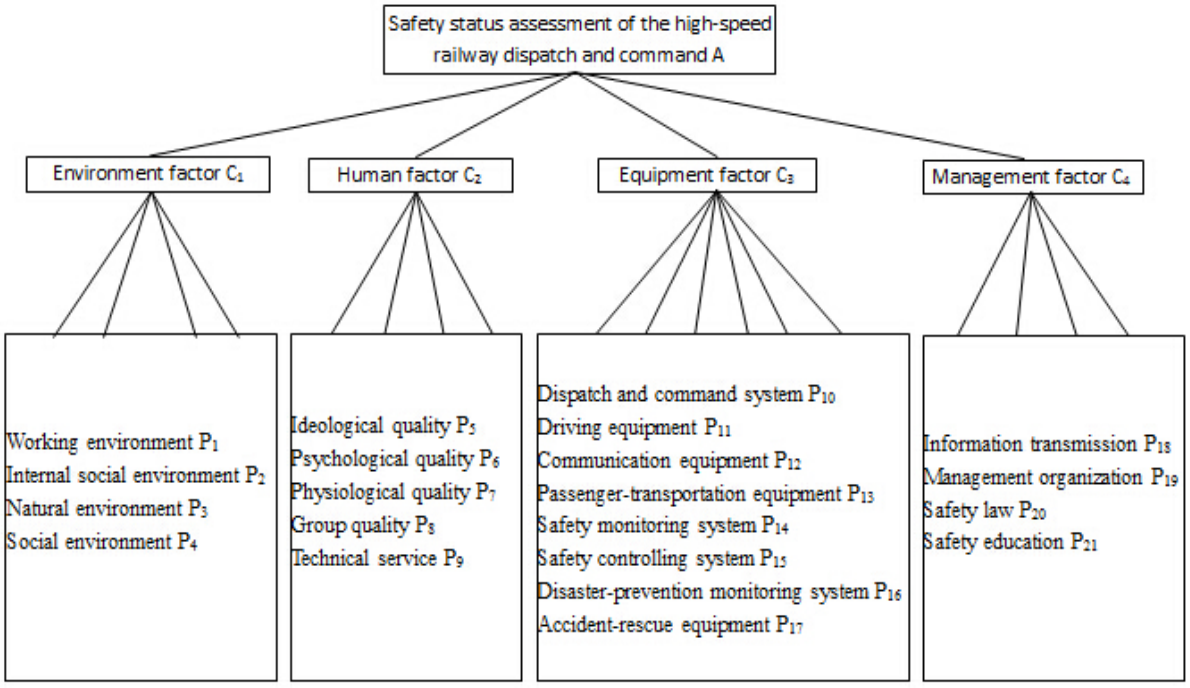

Figure 1. Evaluation hierarchy model of influencing the dispatch and command system of high-speed railway

3 Safety comprehensive evaluation of the dispatch and command system of high-speed railway based on fuzzy analytic hierarchy process

3.1 Determination of evaluation object set

Determination of evaluation object set P={Safety status of the high-speed railway dispatch and command A}.

3.2 Determination of evaluation set

Determination of evaluation set V= (V_1, V_2… V_m). The evaluation was divided into five grades by using the 10 points system, which is shown in Table 1.

Table 1. Weighted values and standard scores of safety grades

Evaluation grades	Very safe grade	Comparative safety grade	General safety grade	Comparative unsafety grade	Unsafe grade
Weighted values	10	8.5	7.0	5.0	1.0
Standard scores	9~10	8~8.9	6~7.9	4~5.9	<4

Notes：1.The numbers of safety assessment grades can be divided differently, which depend on the actual classification needs, and it is generally divided into 5 levels. 2. The weighted values and standard scores were all determined by past experience.

3.3 Constitution of factors set

Constitution of factors set C = (C_1, C_2, C_3, C_4) = (environment factor, human factor, equipment factor, management factor)

3.4 Calculation of first grade indexes weights and second grade indexes weight set

According to the digital measurement scale, the fuzzy judgment matrix that the first grade indexes are relative to the total target is obtained by the comparison of one to one[10-12], which is shown in Table 2.

Table 2. Fuzzy judgment matrix of evaluation criterion

Heading	Evaluation criterion											
	Environmental factorC_1			Human factorC_2			Equipment factorC_3			Management factorC_4		
C_1	1	1	1	1	1.5	2	1	1.5	2	1.5	2	2.5
C_2	1/2	2/3	1	1	1	1	1	1.5	2	1	1.5	2
C_3	1/2	2/3	1	1/2	2/3	1	1	1	1	1	1.5	2
C_4	2/5	1/2	2/3	1/2	2/3	1	1/2	2/3	1	1	1	1

M^j_{Ei} represents that the important degree value, which the i evaluation criterion is compared with the j evaluation criterion in fuzzy judgment matrix, S_i represents the comprehensive importance degree value that the i evaluation criterion is compared with all the other criteriaes in the fuzzy judgment matrix, and the S_i can be calculated by the following formula (1).

$$S_i = \sum_{j=1}^{m} M^j_{Ei} \times \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M^j_{Ei} \right]^{-1} \quad (1)$$

And the comprehensive importance degree value S_i of each first grade index can be calculated by the above formula, which is shown in the following calculation:

$$S_{c_1} = (4.5, 6, 7.5) \times \left(\frac{1}{22.167}, \frac{1}{17.333}, \frac{1}{13.4} \right) \approx (0.203, 0.346, 0.556)$$

$$S_{c_2} = (3.5, 4.667, 6) \times \left(\frac{1}{22.167}, \frac{1}{17.333}, \frac{1}{13.4} \right) \approx (0.158, 0.268, 0.448)$$

$$S_{c_3} = (3, 3.833, 5) \times \left(\frac{1}{22.167}, \frac{1}{17.333}, \frac{1}{13.4} \right) \approx (0.135, 0.221, 0.373)$$

$$S_{c_4} = (2.4, 2.833, 3.667) \times \left(\frac{1}{22.167}, \frac{1}{17.333}, \frac{1}{13.4} \right) \approx (0.108, 0.164, 0.274)$$

$S_1=(l_1, m_1, u_1)$ and $S_2=(l_2, m_2, u_2)$ are two triangular fuzzy numbers, $V(S_1 \geq S_2)$ represents the possible degree that $S_1 \geq S_2$, $V(S \geq S_1, S_2,,,,S_n)$ represents the possible degree that $S \geq Si$, The d' (C_i) represents a criterion C_i that is better than pure measurement of other criteria. When $m_1 \geq m_2$,

$$V(M_2 \geq M_1) = \begin{cases} \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & l_1 \geq u_2 \\ 0, \text{others} \end{cases} \quad (2)$$

When $m_2 \geq m_1, V(M_2 \geq M_1) = 1$。

Due to

$$d'(C_i) = V(S \geq S_1, S_2, ..., S_n) = \min V(S_i \geq S_k) \quad (3)$$

So the weight vectors of all criteria are as follows:

$$W = \left[d'(C_1), d'(C_2), d'(C_3), ..., d'(C_n)\right]^T \quad (4)$$

The normalized weight values of each criterion are obtained by the normalized processing,

$$W' = \left[d(C_1), d(C_2), d(C_3), ..., d(C_n)\right]^T \quad (5)$$

Based on the equation (2)~(5), the following equations can be obtained：

$$d'(C_1) = \min\left[V\left(S_{c_1} \geq S_{c_2}, S_{c_3}, S_{c_4}\right)\right] = 1; \; d'(C_2) = \min\left[V\left(S_{c_2} \geq S_{c_1}, S_{c_3}, S_{c_4}\right)\right] = 0.761$$

$$d'(C_3) = \min\left[V\left(S_{c_3} \geq S_{c_1}, S_{c_2}, S_{c_4}\right)\right] = 0.577; \; d'(C_4) = \min\left[V\left(S_{c_4} \geq S_{c_1}, S_{c_2}, S_{c_3}\right)\right] = 0.279$$

The following result can be obtained by the normalized processing:

$$W' = (0.382, 0.291, 0.220, 0.107)^T$$

In the same way, the weight values of the second grade indexes that are relative to the first grade indexes are shown in Table 3. And according to the information of the dispatch and command system of high-speed railway and the relevant literatures, and combined with experts' opinion, the scores of the second grade indexes can be achieved through the experts, which are shown in Table 3.

Table 3. Weight and fuzzy membership degree of safety status comprehensive evaluation indicators of the dispatch and command system of high-speed railway

First grade indexes	Weight values	Second grade indexes	Weight values	Safety grade				
				Better	Good	General	Bad	Worse
Environment factor C_1	0.107	Working environment P_1	0.188	0.1	0.3	0.5	0.1	0
		Internal social environment P_2	0.472	0.1	0.2	0.5	0.2	0
		Natural environment P_3	0.068	0.1	0.2	0.4	0.2	0.1
		Social environment P_4	0.272	0.1	0.2	0.3	0.3	0.1
Human factor C_2	0.291	Ideological quality P_5	0.068	0.2	0.2	0.4	0.1	0.1
		Psychological quality P_6	0.247	0.1	0.3	0.5	0.1	0
		Physiological quality P_7	0.458	0.2	0.2	0.3	0.2	0.1
		Group quality P_8	0.177	0.3	0.4	0.2	0.1	0
		Technical service P_9	0.050	0.4	0.3	0.2	0.1	0
Equipment factor C_3	0.22	Dispatch and command system P_{10}	0.099	0.3	0.4	0.2	0.1	0
		Driving equipment P_{11}	0.206	0.4	0.3	0.3	0	0
		Communication equipment P_{12}	0.079	0.4	0.3	0.3	0	0
		Passenger-transportation	0.017	0.4	0.3	0.2	0.1	0

		equipmentP_{13}						
		Safety monitoring systemP_{14}	0.188	0.5	0.3	0.1	0.1	0
		Safety controlling systemP_{15}	0.188	0.5	0.3	0.1	0.1	0
		Disaster-prevention monitoring systemP_{16}	0.188	0.5	0.3	0.1	0.1	0
		Accident-rescue equipmentP_{17}	0.036	0.4	0.3	0.3	0	0
Management factorC_4	0.382	Information transmission P_{18}	0.079	0.2	0.4	0.3	0.1	0
		Management organizationP_{19}	0.454	0.1	0.3	0.4	0.1	0.1
		Safety lawP_{20}	0.160	0.2	0.2	0.4	0.1	0.1
		Safety educationP_{21}	0.307	0.1	0.3	0.4	0.2	0

3.5 Fuzzy comprehensive evaluation

Based on the weight W_i of the second index and the corresponding single factor matrix R_i, the first fuzzy comprehensive evaluation is calculated as follows:

$$C_1 = W_1 \times R_1 = (0.188, 0.472, 0.068, 0.272) \times \begin{bmatrix} 0.1 & 0.3 & 0.5 & 0.1 & 0 \\ 0.1 & 0.2 & 0.5 & 0.2 & 0 \\ 0.1 & 0.2 & 0.4 & 0.2 & 0.1 \\ 0.1 & 0.2 & 0.3 & 0.3 & 0.1 \end{bmatrix} = (0.1, 0.219, 0.439, 0.208, 0.034)$$

And in the same way, the membership degree that the four first grade indexes are corresponding to various evaluation grades can be calculated, which are shown in Table 4. At the same time, the fuzzy comprehensive evaluation of the second grade can be calculated by the results of the fuzzy evaluation of the first grade:

$$A = W \times R = (0.107, 0.291, 0.220, 0.384) \times \begin{bmatrix} 0.1 & 0.219 & 0.439 & 0.208 & 0.034 \\ 0.203 & 0.265 & 0.334 & 0.146 & 0.053 \\ 0.447 & 0.310 & 0.176 & 0.068 & 0 \\ 0.124 & 0.292 & 0.392 & 0.131 & 0.061 \end{bmatrix} = (0.216, 0.281, 0.333, 0.130, 0.042)$$

And the calculation results of the membership degree of the evaluation indexes are obtained and are shown in Table 4.

Table 4. Calculation results of the membership degree

Evaluation indexes	Better	Good	General	Bad	Worse
Environment factorC_1	0.1	0.219	0.439	0.208	0.034
Human factor C_2	0.203	0.265	0.334	0.146	0.053
Equipment factor C_3	0.447	0.310	0.176	0.068	0
Management factorC_4	0.124	0.292	0.392	0.131	0.061
Safety status of the dispatch and command system of high-speed railway A	0.216	0.281	0.333	0.130	0.042

It can be known from the Table 4 that the score of each evaluation index is close, and most indexes are good or general. The three first grade indexes that include environment factor, human factor and management factor have high membership degree that is the grade “bad”, which

shows that these three factors are the main limiting factors for the safety of the dispatch and command system of high-speed railway. According to the membership degree of each evaluation index and the value of each evaluation degree, the comprehensive evaluation results of the safety status are evaluated by the weighted calculation, which is shown as follows:

$$V = 0.216 \times 10 + 0.281 \times 8.5 + 0.333 \times 7.0 + 0.130 \times 5.0 + 0.042 \times 1.0 = 7.5715$$

Because the value of V is between 6 and 7.9, which means that the security situation of the dispatch and command system of high-speed railway is "general safety degree" and it need to be improved by improving the quality of personnel, strengthening safety management and so on.

4 Conclusions

(1)Based on the research achievement of safety evaluation index system in high-speed rail dispatching command,this text surveyed and analyzed the safe condition of high-speed rail dispatching command,builted multilevel appraisal index system of the present situation of the high-speed rail dispatching command based on Man-Machine-Environment-Management systemic analysis method.

(2)The FAHP could overcame the boundedness of AHP,it could ensured the objectivity and accuracy of weight coefficient.This text solved the FAHP model and sorted the factors of relative materiality influenced the safety of high-speed rail dispatching command.The results shown: first is environmental factor,second is human factor,third is management factor, last is equipment factor.

(3)Based on the research achivement of this text,three advises to strengthen the system of safety management were concluded as follows: 1.The regulatory framework of high-speed railway scheduling needed to improvement,the safety culture construction needed to rich, at the same time,it needed to strengthen the strike to social violent attacks and improve the external safety of the social environment; 2.The quality level of Scheduling team needs to improved,the preferential access system needs to set in scheduling personnel selection, ideological education should be bring in daily required courses of dispatchers,the dispatchers go to the scene should take questions; 3.The safety management level should be improved,the static control should be combine with dynamic management, various regulations should be enriched and consummated;when the train operation disorder,the plan should be changed in time and be put into effect in time,the affect could be limited to minimum.

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