RETROSPECTIVE ANALYSIS OF CAUSES OF MISTAKES OF TRAFFIC DISPATCHERS IN URBAN RAIL TRAFFIC ACCIDENTS BASED ON CREAM

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Take a subway rear-end accident as an example, and use the CREAM retrospective analysis method to trace its root cause, which are missed observation or identification, poor mental state, decision error, violation of rules and regulations, wrong planning goals, imperfect procedures, poor physiological state, and poor training Fully, use fuzzy analytic hierarchy process to carry out fuzzy analytic hierarchy process on the root cause to get its weight factor.

According to the analysis results, people, technology and organization are improved to improve the safety of urban rail transit.

Key Words : *urban rail transit; human error; cognitive reliability and error analysis (CREAM)*

1. Introduction

Urban rail transit is one of the most important means of transportation for daily travel of residents, and its safety issues are also concerned. Traffic dispatch system is the core of urban rail transit safety operation. In the statistics of major accidents in rail transit, human factors account for 74% [1]. Human error has the characteristics of complex behavior and difficult to quantify. Therefore, it is urgent to effectively avoid and reduce human error in the field of urban rail transit. On the basis of cognitive reliability and fault analysis (CREAM), this paper traces back the causes of human errors in subway accidents, and then finds out the weak links in the dispatching work.

Hollnagel [3] proposed a human factor reliability analysis (HRA) method based on cognitive models and situational control models-CREAM is a representative method of the second generation of HRA.

2. ANALYSIS OF HUMAN ERROR MODES AND ANTECEDENTS IN URBAN RAIL

(1) CREAM retrospective analysis method

CREAM combined with cognitive psychology, etc., considering the impact of situational environment on human cognitive reliability, and emphasizing the analysis of human cognitive errors. In the work of traffic dispatchers of Urban Rail Transit, the situational environment cannot be ignored. In the CREAM method, the observable external manifestations of human error events are called: "error mode" [8]. According to the work tasks and characteristics of urban rail transit dispatchers, the urban rail transit error modes are divided into four modes —— unauthorized, omission, mistake, and invalid [7, 9], as shown in Table 1.

Table 1 Error modes of urban rail transit scheduling

Error modes	Main content
unauthorized	Dispatchers acts in violation of regula-

	tions and operates without authorization
omission	Dispatchers did not complete the operations and tasks strictly according to the procedures
mistake	Dispatchers' subjective conscious choice or judgment wrong
invalid	Dispatchers have nothing to do in the face of emergencies or unexpected situations

The CREAM method refers to the causes of human error accidents [10] as "genotypes", there are three categories of causes (genotypes); Individual, technological and organizational causes. Each category is further subdivided into specific antecedents.

Table 2 Antecedent categories

Category	Code	Antecedent
Individual	I1	*Missing observation or identification*
	I2	*Violation of regulations*
	I3	*Mistakes in decision-making*
	I4	*Delay interpretation*
	I5	*Incorrect planning goals*
	I6	*Poor physiological state*
	I7	*Poor mental state*
technological	T1	*Equipment failure*
	T2	*Communication failure*
organizational	O1	*Management issues*
	O2	*Insufficient training*
	O3	*Imperfect procedures*
	O4	*Imperfect safety measures*
	O5	*Inappropriate team support*

(2) Error Modes and Causes in Urban Rail Traffic Dispatchers

Based on the tasks of urban rail transit traffic controller, summarizes the possible common antecedents of four error modes of urban rail transit.

Table 3 Error modes and possible causes

Error modes	General antecedent
unauthorized	*Violations of regulations, mistakes in decision-making, Incorrect planning goals, insufficient training*
omission	*Missing observation or identification, Poor mental state*
mistake	*Imperfect procedures*
invalid	*Imperfect safety measures*

General antecedents can also be used as consequences. During the operation of traffic dispatching, possible antecedents and specific antecedents can be found. Specific antecedents can directly indicate the root cause. As shown in Table 4, a linked list of cause and effect is obtained.

Table 4 "Consequence-Antecedent" Retrospective Table

Antecedent code	General antecedent code	Specific antecedent
I1	T1, I7	Display failure, slow update of information, unfocused work
I2	O2	Lack of security awareness and lack of responsibility
I3	I6, I7, I4	Low level of professional skills, work overload
I4	T1, I6, I7	Indicator failure, slow response
I5	I3, T2	Conflicting judgment standards, wrong selection
I6	O5	Poor memory, personality, illness, inadequate temporary tasks, work fatigue, boredom, fear
I7	O2, O5	Utopia, distraction, lack of training
T1	O1	Inadequate maintenance，unexpected situations
T2	I6, I7	Noise, temporary interference, unclear expression
O2	O1, O3	Insufficient training time,

		outdated training content
O3	O1	Scene scenarios beyond the scope of procedures
O4	O1, O3	Content of the security rules is not detailed enough
O5	O1	Uncoordinated team members, temporary shifts, schedule changes

3. FUZZY ANALYTIC HIERARCHY PROCESS

Fuzzy Analytic Hierarchy Process (FAHP) is a systematic analysis method combining qualitative and quantitative methods [11][12]. Table 5 shows the number scale of the judgment matrix.

Table 5 Quantity scale table

Scale	Definition
0.5	As important
0.6	Slightly important
0.7	Obviously important
0.8	Much more important
0.9	Extremely important
0.1,0.2,0.3,0.4	Back-comparison

Assume $R=(r_{ij})_{n\times n}$ be the n-order fuzzy complementary judgment matrix, and $G=(k_{ij})_{n\times n}$ be the fuzzy consistent judgment matrix [13]. Among them:

$$k_{ij}=\frac{1}{n}\sum_{t=1}^{n}(r_{ij}-r_{jt}+0.5) \tag{1}$$

Normalized processing [9]

$$W_i=\frac{1}{n}-\frac{1}{2u}+\frac{1}{nu}\sum_{j=1}^{n}k_{ij} \tag{2}$$

Where $u\geq\frac{n-1}{2}$, and $u=\frac{n-1}{2}$, it will get:

$$W_i=\frac{2}{n(n-1)}\times\sum_{j=1}^{n}k_{ij}-\frac{1}{n(n-1)} \tag{3}$$

The root cause's weight vector is:

$$W=(W1,\ W2,\ \ldots,\ Wn)^T$$

4. CASE ANALYSIS

At 14:51 on September 27, 2011, a rear-end collision occurred on Shanghai Metro Line 10, which injured more than 260 people and no one died. After investigating the equipment failure of the metro line, the up and down lines from station b to station h are blocked by telephone, as shown in Fig. 1. Trains run at a limited speed.

About 40 minutes after the operation of the telephone block, two trains in the g-h down section have a rear end accident. After the accident, the temporary stop measure of the section from station a to station i was taken as soon as possible.The lines at two ends of the stop section was operated in a short routing mode, and the public transport emergency plan started at the same time. The public security and armed police shall rush to the site to assist in evacuation. Seven hours after the accident, the scene of the accident was cleaned up and the operation was gradually resumed.

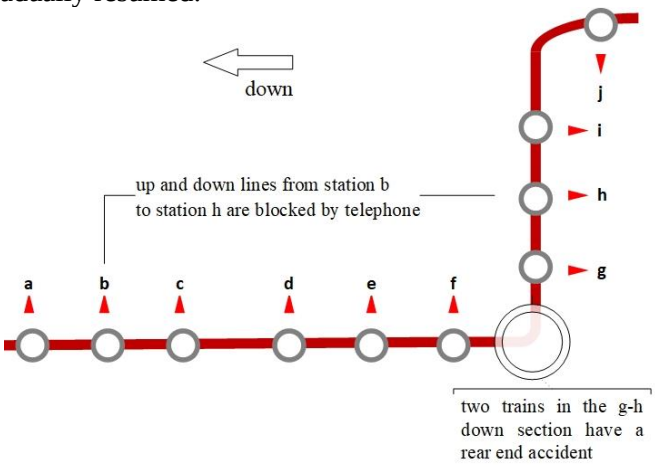

Fig.1 Shanghai Metro Line 10 operation from station a to j.

Based on the manifestation of human error, the type of accident mode of the accident is obtained. The mode of human error in the rear-end subway accident is determined to be omission, mistake and invalid. According to the experts' investigation and analysis of the accident, a number of antecedents were determined to start a retrospective analysis.

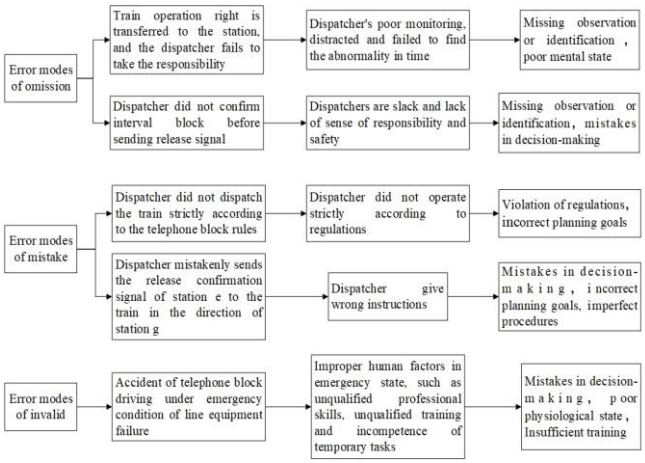

Fig.2 Root cause retrospective analysis.

The root causes of the human error in this rear-end collision are—— missing observation or identification, poor mental state, mistake in decision-making, violations of regulations, incorrect planning goals, imperfect procedures, poor physiological state and insufficient training.

As shown in Tab.6, the weights of these root causes are compared in pairs using fuzzy analytic hierarchy process.

Tab.6 Root cause importance

Index	I1	I7	I3	I2	I5	O3	I6	O2
I1	0.50	0.64	0.58	0.56	0.65	0.72	0.53	0.48
I7	0.36	0.50	0.37	0.28	0.31	0.62	0.49	0.26
I3	0.42	0.63	0.50	0.39	0.45	0.33	0.73	0.42
I2	0.44	0.72	0.71	0.50	0.38	0.43	0.53	0.31
I5	0.35	0.69	0.55	0.62	0.50	0.70	0.42	0.36
O3	0.28	0.38	0.67	0.55	0.30	0.50	0.64	0.42
I6	0.47	0.51	0.27	0.47	0.58	0.36	0.50	0.45
O2	0.52	0.74	0.58	0.73	0.64	0.58	0.57	0.50

The fuzzy complementary judgment matrix R of the root cause weight:

$$R=\begin{bmatrix} 0.50 & 0.64 & 0.58 & 0.56 & 0.65 & 0.72 & 0.53 & 0.48 \\ 0.36 & 0.50 & 0.37 & 0.28 & 0.31 & 0.62 & 0.49 & 0.26 \\ 0.42 & 0.63 & 0.50 & 0.49 & 0.45 & 0.33 & 0.73 & 0.42 \\ 0.44 & 0.72 & 0.71 & 0.50 & 0.38 & 0.43 & 0.53 & 0.31 \\ 0.35 & 0.69 & 0.55 & 0.62 & 0.50 & 0.70 & 0.42 & 0.36 \\ 0.28 & 0.38 & 0.67 & 0.55 & 0.30 & 0.50 & 0.64 & 0.42 \\ 0.47 & 0.51 & 0.27 & 0.47 & 0.58 & 0.36 & 0.50 & 0.45 \\ 0.52 & 0.74 & 0.58 & 0.73 & 0.64 & 0.58 & 0.57 & 0.50 \end{bmatrix}$$

The fuzzy consistent matrix A is obtained based on the fuzzy complementary judgment matrix:

$$A=\begin{bmatrix} 0.500000 & 0.68375 & 0.59875 & 0.58000 & 0.55875 & 0.61500 & 0.63125 & 0.47500 \\ 0.31625 & 0.50000 & 0.41500 & 0.39625 & 0.37500 & 0.43125 & 0.44750 & 0.29125 \\ 0.40125 & 0.58500 & 0.50000 & 0.48125 & 0.46000 & 0.51625 & 0.53250 & 0.37625 \\ 0.42000 & 0.60375 & 0.51875 & 0.50000 & 0.47875 & 0.53500 & 0.55125 & 0.39500 \\ 0.44125 & 0.60375 & 0.54000 & 0.52125 & 0.50000 & 0.55625 & 0.57250 & 0.41625 \\ 0.38500 & 0.56875 & 0.48375 & 0.46500 & 0.44375 & 0.50000 & 0.51625 & 0.36000 \\ 0.36875 & 0.55250 & 0.46750 & 0.44875 & 0.42750 & 0.48375 & 0.50000 & 0.34375 \\ 0.52500 & 0.70875 & 0.62375 & 0.60500 & 0.58375 & 0.64000 & 0.65625 & 0.50000 \end{bmatrix}$$

After calculation, the weight vector W：

$$W=(0.14795,\ 0.09545,\ 0.11973,\ 0.12509,\ 0.13116,\ 0.11509,\ 0.11045,\ 0.15509)^T$$

Sorted by the root cause weight and category, as shown in Table 7:

Table 7 Root cause weight sorting

Individual						*Organizational*	
I1	I5	I2	I3	I6	I7	*O2*	*O3*
0.14795	0.13116	0.12509	0.11973	0.11045	0.09545	0.15509	0.11509

The weights from the highest to the bottom are insufficient training, missing observation or identification, incorrect planning goals, violations of rules and regulations, mistake in decision-making, imperfect procedures, poor physiological state and poor mental state. Six of them are Individual antecedents, and two of them are Organizational antecedents.

The main cause of the rear-end accident is human-related. Insufficient training of the traffic dispatcher led to accidents under special conditions (such as line equipment trouble, transit telephone blocking mode), that is related to outdated or missing training content——adequately given to the dispatcher's corresponding training. Dispatchers miss observations or identifications due to inattention, poor monitoring or forgetting to confirm the position of the front car. The dispatchers' judgment criteria for the target conflicts or the incorrect target selection causes the incorrect planning goals, such as sending wrong signal to confirm the release. When the emergency state of equipment failure occurred, the dispatchers' violation also causes accidents. Because the time of the accident is not close to the shift time, possibility of excessive workload of dispatcher is

excluded. The main reason for the mistake in decision-making is the low level of dispatcher's professional skills. Incomplete procedures are related to unreasonable or absent operating procedures, that factors force people to make mistakes.

Based on the results, the improvement of subway operation procedures and dispatcher operation will help reduce the probability of human error and improve the safety and reliability of subway dispatch operations.

5. CONCLUSION

Firstly, analyzing the error modes in the urban rail transit dispatching work system. According to the CREAM antecedent table, based on the dispatchers' operation behavior and scope of duties, "consequence-antecedent" retrospective Table is determined. Based on this consequence-cause retrospective table, taking a subway rear-end accident as an example, the root cause of human error accidents is traced back.

Using the fuzzy analytic hierarchy process, 8 root causes of *insufficient training*, *missing observation or identification*, *incorrect planning goals*, *violations of rules and regulations*, *mistake in decision-making*, *imperfect procedures*, *poor physiological state*, and *poor mental state* were sorted by the weights.

According to the weight factor and error mode of the root causes, the deficiencies in the dispatchers' work of the traffic are found. For example, the root cause of "insufficient training" has the largest weight.

Improving the training content, updating the training mode and adding training to supplement the difference could enhance the dispatchers' decision-making level and execution ability in emergency situations such as equipment failure, that will help improve the adaptability of emergency situations, and thereby improve human reliability and subway operation safety.

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