Study on Safety Warning Model in the Construction of the Existing Line Electrification Project Using Fuzzy Comprehensive Evaluation

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Abstract: Nowadays, the electrified railway is popular, and the demand of electrification renovation of the existing railway line is increasing. In order to improve the security of railway electrification construction, the research established a safety warning model of the existing line electrification by using AHP and fuzzy evaluation method, which based on analyzing the safety factors. Through the output of warning signal, it can help us make early countermeasures and improve safety level in production.
Keywords: Existing railway line electrification project, Safety factor, Safety warning model

1 Introduction

Electrified railway is a kind of modern railway transportation, and it is one of the most important symbols of modern city traffic. From the first electrified railway—Bao Feng section built in China in 1961 to the end of the year 2010, the total length of electrified railway in China has reached 42000 kilometers and the electrification rate has been up to 46.6%, up 4.9% from last year. In 2010, the existing line capacity expansion revamping completed investment of ¥75.392 billion increased 2.3% than last year. Accordingly, the electrification of the railway has become irresistible. Therefore, establishing a complete set of existing line electrification project construction safety warning model is very necessary.

2 Identify Construction Safety Factors of the Existing Line Electrification Project

Identifying the safety factors correctly is a prerequisite for effective establish the safety warning model. The passage is based on the theory of the safety management and human-machine-environment-management system. In process of constructing the existing line railway electrification project, the paper analyzing the influence of Men-Machine -Environment-Management on the constriction safety.

2.1 The human's impact on the construction safety analysis

Human is the main body of the project construction in the system, so the human's behavior has a great impact on the construction safety. Unsafe behavior of human can divided into intentional and unintentional. In the process of construction, the people unsafe acts mainly including following several points: (1) The illegal operation; (2) The illegal command; (3) The technical is not qualified; (4) On-site supervision is not in place; (5) Improper deal with the emergency.

2.2 The things' impact on the construction safety analysis

The things here mainly refer to which play a certain role in the process of construction, such as the machinery, material, productions or other factor of the production. Among the multiple factors of them, the state of mechanical equipment has a particularly important influence on the construction safe. The affecting factors which the unsafe state of engineering machinery act on the construction have several kinds of situations: (1) Engineering equipment design flaws; (2) Defect in quality of the engineering equipment; (3) The problem of the engineering equipment installation. The second unsafe state of the engineering equipment's impact on the construction safe mainly has the following several kinds of situations: (1) Construction machinery disrepair; (2) Construction machinery design flaws; disoperation construction machines.

2.3 Unsafe state of engineering materials

(1) The defect of material quality: during the process of the construction, the railway line will consume a large number of kinds of materials, so the quality of the material is the foundation of the construction safety. When the materials transport into construction site, the supervision institutions must take serious inspection to them. If they overlook the strict inspection to the material, the project will face amount of safety problems; (2) Material stacking problems at the construction of the existing line electrification project, part of the project construction site disperse, those site just consume small amount of material, so the material can transport to the construction site, setting small warehouse to store them. If the material stack in an unreasonable way, for example, not according to the prescribed distance region and special material, which not to set the warehouse to store. All those improper measures may lead to fire or other safety accident, there is no doubt that those accident will interfere in the construction of the project.

2.4 Analysis of the influence of the environment on construction safety

There are many environment factors putting impact on the construction of the existing line railway electrification, including on-site operation environment, weather conditions, geological environment, and hydrological environment. Among of them, the operation environment and weather condition have more influence than others. (1) The influence of working environment on construction safety: the working environment directly affects the implementation of the safe production; the bad working environment will brings a lot of negative factors to the construction process. All those may lead to the occurrence of safety accidents; (2) The influence of natural environment on construction safety: the natural environment contained the hydro-geological and the weather environment. Geological and hydro-logical of the railway included terrain conditions, surrounding roads, rivers and lakes. When the railway is located in the complex terrain conditions, the construction risk is big, correspondingly, the more chance of the hidden safe trouble; (3) The influence of social environment on construction safety: construction safety is not only affected by the internal factors of construction personnel, equipment and materials, but also affected by the social environment of the external factors. For example, external personnel may invade the workplace, or the theft of equipment and materials may happen. What is worse, if not discover the risk in time, it may cause safety accident.

2.5 Analysis the influence of management system on the construction safety

(1) Analysis of the safety management system: the unsafe acts of people and material insecurity state is the direct cause of the accidents, both of which have a direct relationship with the management system. Therefore, a construction enterprise whether establishes the prefect system of safety management has a direct relationship with the safe produce; (2) Analysis of the construction safety culture: the condition of the enterprise safety culture is of great significance to the safety in production. Among of the human, machine, environment, management, human is the most important, and the influence of safety culture on people is intrinsic, it can improve the basic quality of the human. So there are great significance meanings to construct safety culture in the construction enterprise.

3 Safety Warning Model of the Existing Line Railway Electrification

3.1 Using AHP to establish security early warning index system

The main steps are as follows:

(1) Establish the hierarchical structure for the system;

(2) According to the scaling theory, to construct the two-two comparison judgment matrix;

(3) Calculate relative weights of elements under a single rule, and the consistency test.

Table 1 Safety index system of existing line electrification

First class index	Second class index	Third class index
Safety evaluation index of personnel u_1=0.375	Professional skill u_{11}=0.412	The technical level of the staff u_{111}=0.389
		Technically training accept by the personnel u_{112}=0.366
		u_{113}=0.245
	Working skills u_{12}=0.265	The level of education u_{121}=0.366
		Length of service u_{122}=0.350
		The number of accidents during past three month u_{123}=0.284
	The condition of the body u_{13}=0.323	The intensity of labor u_{131}=0.281
		The condition of the work spirit u_{132}=0.262
		Physical quality of the staff u_{133}=0.250
		Age u_{134}=0.207
Index system of the equipment and material u_2=0.137	The condition of the equipment u_{21}=0.351	Equipment design rationality u_{211}=0.275
		The quality of equipment state u_{212}=0.374
		The state of the equipment installation u_{213}=0.351
	The condition of the machinery u_{22}=0.332	Mechanical strength u_{221}=0.083
		Machine running state u_{222}=0.301
		Mechanical quality state u_{223}=0.175
		Component wear and aging state u_{224}=0.239
		Machinery and equipment repair status u_{225}=0.202
	The condition of the material u_{23}=0.317	Material quality status u_{231}=0.643
		Material storage state u_{232}=0.357
Index system of the environment u_3=0.058	The condition of the geological u_{31}=0.336	Geological conditions u_{311}=0.201
		Changes of geological conditions u_{312}=0.412
		Geologic and hydro-geology conditions u_{313}=0.387
	The condition of the climate u_{32}=0.132	The local climate conditions u_{321}=0.456
		The situation of climate change u_{322}=0.401
		The condition of weather comfort u_{323}=0.143
	The environment of the site u_{33}=0.532	u_{331}=0.098
		Site lighting and lighting conditions u_{332}=0.042
		Sub grade condition u_{333}=0.241
		The status of underground pipeline u_{334}=0.210
		On-site spatial layout u_{335}=0.133
		The security situation of the site u_{336}=0.276
Index system of safety management u_4=0.430	Safety measures u_{41}=0.367	The degree of perfection of the safety measures u_{411}=0.262
		The implementation of safety measures u_{412}=0.638
	Safety institution u_{42}=0.144	The degree of perfection of the safety management system u_{421}=0.383
		The degree of implementation of safety management system u_{422}=0.617
	Safety culture u_{43}=0.096	The construction of safety culture u_{431}=0.613
		Personnel safety awareness u_{432}=0.387
	Safety organize u_{44}=0.403	Safety management organization structure u_{441}=0.427
		The allocation of the burden of safety management u_{442}=0.418
		Cooperation with other departments u_{443}=0.115

Table 2 Comparison matrix of construction safety factors (first class index)

	Men	Equipment and materials	Environment	Safety management
Men	1	a_{12}	a_{13}	a_{14}
Equipment and materials		1	a_{23}	a_{24}
Environment			1	a_{34}
Safety management				1

Asking every expert is graded according to one class index of two-two factors on the construction safety degree of impact, shown in Table 3.

Table 3 The result of ten experts scoring on the first class index of the construction safety

Experts	a_{12}	a_{13}	a_{14}	a_{23}	a_{24}	a_{34}
1	2	4	1	3	1/4	1/5
2	3	3	1	3	1/3	1/4
3	2	4	2	3	1/4	1/4
4	2	4	1	2	1/4	1/5
5	3	4	1	3	1/3	1/4
6	2	4	1	2	1/4	1/5
7	1	2	1	2	1/2	1/3
8	2	3	2	3	1/3	1/4
9	2	4	1	3	1/4	1/4
10	2	4	1	2	1/3	1/5

According to the average marks of ten experts on the construction, we can calculate the comparison matrix of four factors of first class.

$$A=\begin{pmatrix}1.000 & 2.100 & 3.600 & 1.200\\ 0.476 & 1.000 & 2.600 & 0.308\\ 0.278 & 0.385 & 1.000 & 0.238\\ 0.833 & 3.247 & 4.202 & 1.000\end{pmatrix} \xrightarrow{\text{vector A normalized}} \begin{pmatrix}0.387 & 0.312 & 0.316 & 0.437\\ 0.184 & 0.149 & 0.228 & 0.112\\ 0.107 & 0.057 & 0.088 & 0.087\\ 0.322 & 0.482 & 0.368 & 0.364\end{pmatrix}$$

According to "Summation method", solving A maximum characteristic roots and eigenvector sage:

a. Sum each row of the matrix to obtain the column vector:

$$\begin{pmatrix}1.372\\ 0.673\\ 0.339\\ 1.536\end{pmatrix}$$

b. The column vector is normalized to the weight vector W :

$$W = (0.350 \quad 0.172 \quad 0.086 \quad 0.392)^T$$

Consistency check: $\lambda_{\max}$=4.077, $CI = \frac{\lambda_{\max} - n}{n-1} = 0.026$, $CR = \frac{CI}{RI} = 0.029 < 0.1$.

So the consistency test meet the requirement and the weight vector of first class index are determined. Similar to the method of the weight vector of the first class to the second class, the weight vector of the first class to second class and the second class to the third class also take the same method

3.2 Comprehensive evaluation of safety index system model

The comprehensive evaluation functions of construction safety:

$$f(A)=\sum_{i=1}^{t}\left\{u_i\sum_{j=1}^{m}\left[u_{ij}\sum_{v=1}^{n}\left(u_{ijv}\bullet a_{ijv}\right)\right]\right\}$$

3.3 Determine the limit of warning and the transmit the warning signal

(1) Determine the limit of warning: In this research, risk warning system adopt warning interval division by 5 points, so the risk early warning is divided into: danger zone, more danger zone, general safety zone, more safe area and safe area. To "dangerous" = 2, "security"= 8, the middle is divided into "more dangerous", "general safety", "safe" three grades, and the assignment are detailed in Table 5 (L means comprehensive evaluation of index value).

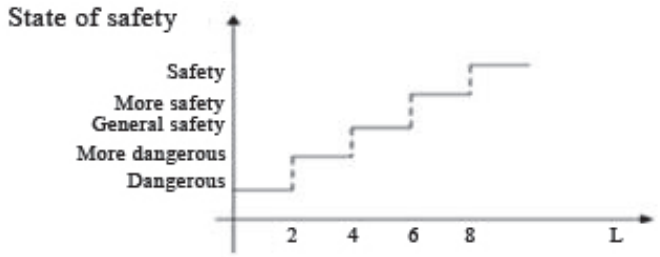

Figure 1 The law of safety warning

Table 5 The law of safety warning

Safety state	Law of warning
Safety	L≥8
More safety	6<L≤8
General safety	4<L≤6
More dangerous	2<L≤4
Dangerous	L≤2

We can see from the early warning evaluation process, even if in different time, the same evaluation value correspond with the same safety state, but the cause and the hidden danger of accident may be different. Of course the construction enterprise should take different countermeasures.

(2) Output of the warning signal: System of signal output, using the horizontal axis represents time, according to the warning period, the paper set the year, season, month, week, day, etc. The vertical axis represents the critical value of early warning value of evaluation, red, orange, yellow available light, green light; blue light said five security statuses. According to the security state of different time, drawing out the early warning signal, as shown in Figure 2.

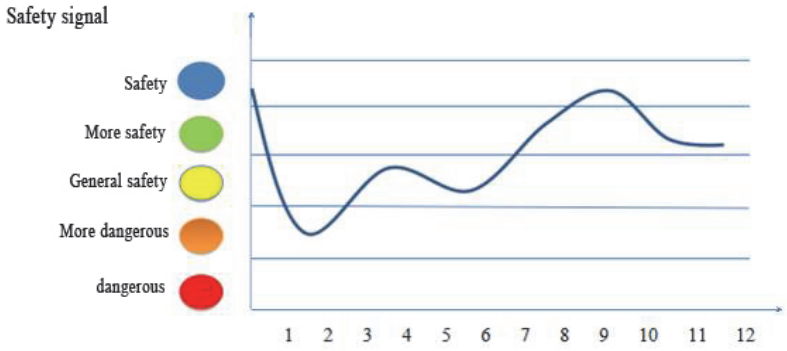

Figure 2 Safety signal of the existing railway electrification engineering construction

For different signal different strategies should be adopted, the reaction is shown in the Table 3-6.

Table 6 The reaction to the warning signal

Countermeasures of the warning signal	Blue light	Green light	Yellow light	Orange light	Red light
Focus	√	√			
Monitor		√	√	√	√
Measures				√	√

4 Summary

According to the present situation, the existing railway electrification construction in China is lack of security management measures. On the basis of identification the risk factors of the construction, the paper using AHP and fuzzy method to build security early warning model of railway electrification transformation construction of existing railway. It's no doubt that this paper will make great contribution to preventing safety accidents. In some degree, the paper also provides method and basis for enhancing the construction safety management of existing railway line electrification project.

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