Research on the influence mechanism of safety risk factors on traffic organization of high-speed railway construction

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Abstract. In the development of high-speed railway construction, the high-speed railway construction scheme and technology are constantly improved. Nowadays, the high-speed railway construction mainly relies on the traffic organization of the railway to organize the transportation of prefabricated components and carry out hoisting. In the process of traffic operation organization of railway engineering, the construction company often faces many safety risks. Therefore, it is of great significance to analyze the influence mechanism of various risk factors on the operation and safety of Railway Engineering and put forward corresponding suggestions. In this paper, through literature analysis and expert interviews, nine key factors are selected. The safety risk factors are divided from four dimensions of personnel, machinery, management and environment. The importance of these risk factors is ranked by AHP, and Through the method of interpretative structural model, this paper uses these nine key factors to build a five layer interpretative structural model, and uses interpretative structural model to analyze the influence mechanism of safety risk factors on driving organization safety.

1. Introduction

As the most important part of the construction and planning of the city and road network, high-speed railway construction is the most important part of the transportation construction. In the process of continuous development of high-speed railway construction, high-speed railway construction scheme and technology are also constantly improved. Nowadays, prefabricated box girder, track bed and other components are widely used in the high-speed railway construction. At this time, the construction of high-speed railway mainly depends on the traffic organization of construction line and transportation of components and lifting. In the process of traffic organization on the project line, the construction party often faces many safety risks. Therefore, it is of great significance to analyze the influence mechanism of various risk factors on the traffic organization and safety of the project line.

Guangsheng Wu (2013) proposed that professional technical level, safety awareness, geological and climatic conditions and construction site planning of personnel should be considered in the safety risk management of high-speed railway construction[1]. Yanfeng Zhao (2013) proposed that professional technical level, safety awareness, communication and coordination between management personnel and technical personnel, transportation equipment status and defects, safety education and safety inspection management, natural environment impact should be considered in railway freight safety risk management[2]. Jianhua He (2017) proposed that in the process of railway vehicle safety risk management, risk factors such as professional and technical level of staff, safety education and safety
supervision, transportation equipment status, technical scheme selection of management personnel should be considered\[3\]. Xilong Chen (2018) proposed to consider the professional and technical level of professional and technical personnel, the ability of coordination and communication between management personnel and professional and technical personnel, the selection and implementation of technical scheme of technical management personnel, construction safety education and management\[4\]. Daoxiao Wang (2019) described the risks from four dimensions: human, equipment, management and environment. The human dimension includes factors such as professional and technical level, inadequate emergency treatment; the equipment dimension includes factors such as different equipment and facilities status, different degree of aging, different models; the management dimension includes communication and coordination issues between managers and other staff, miscellaneous documents, technical management confusion. The environmental dimension includes factors such as the random arrangement of waste rails and overgrowth of weeds\[5\]. At present, scholars have done some research on the identification and evaluation of the safety risk of railway traffic organization, but lack of research on the influence path and hierarchical structure of the risk factors of railway traffic organization in the process of construction. The research on the influence mechanism of safety risk factors can more clearly grasp the relationship between safety risk factors and help enterprises control these risk factors from the source.

2. Materials and Methods

2.1. Identification safety risk factors

In order to construct the list of risk factors and divide the risk dimensions, this section adopts expert interview method and literature analysis method, and invites 1 senior engineer and 2 engineers of China Railway Third Engineering Bureau electric service company, 1 senior engineer and 1 technician of line bridge company of China Railway Third Engineering Bureau. Among them, there are 2 technical management personnel, 2 field management personnel and 1 locomotive driver. Through expert interviews and literature analysis, nine risk factors were obtained\[1-5\]. The professional and technical level of on-site workers refers to the level of on-site hoisting personnel, locomotive drivers and other technical operators. The level of technical management personnel refers to the level of engineer's technical management, mainly including the preparation of technical scheme of traffic organization, technical disclosure. Coordination of various types of work on site refers to the communication and organization coordination of professional technical personnel and management personnel on the construction site. The status of on-site staff includes staff safety awareness, emergency response ability. The status of locomotive and rack laying equipment refers to the status of mechanical equipment used in traffic organization, including aging degree, model, operation. Track conditions refer to the conditions of track erection, rail joints. of Railway Engineering lines. Construction site planning refers to the site planning of railway engineering line, including whether there is waste stacking along the line, whether there is conflict with other project traffic organization. Geographical environment refers to the topographical and geological conditions of the railway engineering line. Climatic conditions refer to the climatic conditions in the process of driving organization, including gale, rain, snow and other weather conditions. We discussed with experts and finally got Table 1.

| Number | Dimension | Factors |
|--------|-----------|---------|
| 1      | People    | Professional and technical level of field staff |
| 2      | Site staff status |
| 3      | Machine  | Status of locomotive and rack laying equipment |
| 4      | Track condition |
| 5      | Management | Technical management |
| 6      | Development and implementation of safety control measures |
| 7      | Coordination of various types of work |
2.2. Methods
Analytic Hierarchy Process (AHP) is often used in risk assessment. First of all, according to the risk dimension of risk factors, this paper establishes hierarchical structure model, which takes risk dimension as the criterion and each risk factor as the index. According to the requirements of analytic hierarchy process, the expert scoring table is established according to the hierarchical structure model of risk factors, and experts are invited to make two comparative judgments on the elements I and J of this layer and score A_IJ. The scale of 1-5 is used in scoring. The more important element I is to J, the higher the score is. A_IJ and A_JI are reciprocal. Then, the author will construct a judgment matrix based on the recovered expert scoring table, and obtain a 4 × 4 judgment matrix of risk dimension (criterion level) and a judgment matrix of risk factors (indicator level) under four different risk dimensions.

The interpretative structural modeling (ISM) can help to build an intuitive and well structured model to analyze the relationship between various factors, and decompose this relatively complex system into a multi-layer structured subsystem that is easier to explain. Abuzeinab (2017) used the research method of interpretative structural modeling to determine the influencing factors of business model innovation and the internal logical connection of the factors[6]. Therefore, this paper uses the interpretative structure model to analyze the influence path and hierarchy among 9 security risk factors.

3. Analysis
3.1. Risk factors assessment.
We use AHP to assess risk factors. According to the AHP method and expert feedback, the author obtains five judgment matrices, among which the judgment matrix of risk dimension (criterion level), weight value and consistency test are shown in Table 2.

Use the same method to calculate the weight value of risk factors under each risk dimension and conduct consistency test. After the consistency test is passed, multiply the weight value of the criteria layer and the weight value of the indicator layer to get the overall weight value of each risk factor.

| Number | Dimension | Factors                                                                 | Weight | Total weight |
|--------|-----------|------------------------------------------------------------------------|--------|--------------|
| 1      | People (0.1825) | Professional and technical level of field staff | 0.6667 | 0.1217       |
| 2      | Machine (0.4340) | Site staff status | 0.3333 | 0.0608       |
| 3      | Management (0.2856) | Status of locomotive and rack laying equipment | 0.2500 | 0.1085       |
| 4      | Environment (0.0980) | Track condition | 0.7500 | 0.3255       |
| 5      | Technical management and implementation of safety control measures | 0.2581 | 0.0737       |
| 6      | Coordination of various types of work on site | 0.5161 | 0.1474       |
| 7      | Construction site planning | Geographical and Climatic conditions | 0.4898 | 0.0480       |
| 8      | People 1 1/2 1/2 2 | 0.1825 | 0.0480       |
| 9      | Machine 2 1 2 4 | 0.4340 | 0.0499       |

Table 3. Table of overall weight value of risk factors.
3.2. Influence structure model

First of all, the author will select nine safety risk factors, we discuss and identify the relationship between any two risk factors with experts, and transform it into 9-order adjacency matrix A, where factor I has a direct impact on J, then the number of corresponding row I, column J in adjacency matrix A is \( A_{ij} = 1 \), otherwise \( A_{ij} = 0 \). According to the algorithm of ISM method, the author uses Excel software to calculate the matrix multiplication of adjacency matrix A, and finally gets the reachable matrix R. By analyzing the reachability matrix, the reachability set and the antecedent set of each risk factor are listed, and their intersection is obtained. Through reachable set, antecedent set, reachable set \( \cap \) antecedent set, the level of each factor is obtained. Finally, it will be divided into five levels for analysis. \( L1=[4] \); \( L2=[3] \); \( L3=[6,7,8] \); \( L4=[1,2,5] \); \( L5=[9] \).

| Factors | Reachable set | Antecedent set | Reachable set \( \cap \) Antecedent set |
|---------|---------------|----------------|----------------------------------------|
| 1       | 1,3,4,6,7,8   | 1,2,5,9        | 1                                      |
| 2       | 1,2,3,4,6,7,8 | 2,9            | 2                                      |
| 3       | 3,4           | 1,2,3,5,6,7,8,9| 3                                      |
| 4       | 4             | 1,2,3,4,5,6,7,8,9| 4                                      |
| 5       | 1,2,3,4,5,6,7,8 | 5              | 5                                      |
| 6       | 3,4,6,7,8     | 1,2,5,6,7,8,9  | 6,7,8                                  |
| 7       | 3,4,6,7,8     | 1,2,5,6,7,8,9  | 6,7,8                                  |
| 8       | 3,4,6,7,8     | 1,2,5,6,7,8,9  | 6,7,8                                  |
| 9       | 1,2,3,4,5,6,7,8,9 | 9              | 9                                      |

| Traffic organization of high-speed railway construction | Track condition |
|--------------------------------------------------------|-----------------|
| Status of locomotive and rack laying equipment          | L1              |
| Development and implementation of safety control measures| L2              |
| Construction site planning                              | L3              |
| Coordination of various types of work on site           | L4              |
| Site staff status                                      | L5              |
| Professional and technical level of field staff         |                 |
| Technical management level                              |                 |
| Geographical and Climatic conditions                    |                 |

**Figure 1. Figure of Interpretative Structural Modeling.**

4. Discussion

Based on the five layer structural model, this paper divides the risk factors into five levels: L1 track, L2 mechanical equipment, L3 construction site conditions and organization, L4 personnel level and state, and L5 natural environment. The risk factor in the first layer (L1) of the model is the most direct track condition factor that affects the traffic organization. If there is a problem in the track, it will directly lead to the occurrence of safety production accidents. The risk factor of the bottom layer (L5) is the geographical and climate condition, which has direct or indirect influence on the risk factor of L1. It is the most basic condition to ensure the safety of the traffic organization. It is obviously not suitable for the traffic organization of high-speed railway construction under the adverse geographical and climate conditions.
There is a transitivity between the risk factors of the model. For example, technical management level → professional technical level of field staff → construction site planning situation → locomotive, rack laying equipment status → track status. These risk factors influence the path for the traffic organization personnel to control the key links. Check the most direct risk factors; prevent the basic risk factors, and put an end to production safety accidents from the source; control the risk factors in the middle of the path to prevent accidents caused by the accumulation of risks.

5. Conclusion
In this paper, through literature analysis and expert interviews, we discussed the safety risk factors of high-speed railway construction organization. The safety risk factors are divided from four dimensions of people, machine, management and environment, and the importance of these risk factors is assessed by AHP. Through the method of interpretative structural model, this paper uses these nine key factors to build a five layer interpretative structural model, and uses interpretative structural model to analyze the influence mechanism of safety risk factors on driving organization safety. From the model, climate conditions and other natural environmental factors are the most basic factors affecting the safety of traffic organization. Technical management personnel, on-site staff and other personnel factors directly affect the on-site operation conditions, on-site organization and management, thus indirectly affecting the traffic organization and safety. The status of locomotives and racking equipment is affected by the risk factors of the last three layers, which will have a direct impact on the safety of traffic operation organization, as well as the track status. The condition of track directly affects the safety of traffic organization, is the most important and direct factor affecting the safety of high-speed railway construction.

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