Railway Passenger and Freight Transportation Operation Risk Identification and Evaluation Technology

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Abstract. With the continuous increase of railway operating mileage and the increasing complexity of railway operation system, this paper proposes a real-time security state identification method based on equipment detection and a risk factor identification method based on security inspection, and under the framework of risk factor classification and identification. The paper proposes to use the existing data information to determine the risk value of the risk factor and determine the risk criteria and the relevant methods of the early warning level judgment standard, and then determine the risk warning level, and provide theoretical support for the security early warning analysis and pre-control decision implementation.

1. Introduction
With the rapid development of China's railways, the railway operating mileage has reached more than 131,000 kilometers, and the total length of high-speed railways has accounted for 2/3 of the world's total. With the large-scale operation of the new railway, the safety problem of railway operation becomes more and more serious. Railway transportation is an extremely complex systemic project. The operating organization involves a wide range of factors, and the safety of railway operations involves a wide range of challenges. In the process of railway operation, any unsafe factor may cause a large area of delay, even heavy casualties and economic losses. Railway operation safety is the top priority of railway operation management. Therefore, how to scientifically and efficiently identify transportation risk factors in railway transportation, and determine the risk judgment standard and warning level according to the danger level and hazard scope has become a key problem to guarantee the safety of railway operation.

According to the definition of the international organization for standardization, risk is a measure of danger, which is the combination of the probability of a harmful accident and the consequences of the accident. In the field of railway transportation, railway operation risk can be defined as the combination of the probability of different risk events and the loss caused in the process of railway operation. At present, there is no in-depth study on railway risk assessment in China, and no systematic analysis of specific risks in the operation of high-speed railway, and no risk assessment framework has been formed, which has affected the research and development of risk management. Based on the information type of railway safety data, this paper presents two kinds of identification methods of railway risk factors, and puts forward the judgment standard and calculation method of determining the risk level and warning level of railway operation.
2. Identification method of railway transportation risk factors

According to the type of railway safety data, the identification method of risk factors can be divided into the real-time status identification method based on equipment monitoring and the identification method based on safety inspection.

2.1. Real-time status recognition method based on equipment monitoring

Real-time status information comes from various information monitoring systems and detection equipment, and its risk identification is mainly completed by modern information technology. It can be seen that the design, operation and maintenance of information monitoring system and testing equipment will greatly affect the accuracy and reliability of risk identification. Therefore, it is necessary to focus on the use of various monitoring systems and testing equipment, and to timely upgrade and transform the system according to the characteristics of safety problems in the new situation, so as to ensure the effective risk identification.

2.2. Identification method based on security check

The main body of the identification method based on safety inspection is the operating personnel of each specialized department. Therefore, under the existing organizational framework and system of safety management, it is necessary to improve the organizational efficiency of risk factor identification while ensuring the effectiveness of risk factor identification. According to the characteristics of risk factors and the practice of safety inspection, the risk identification methods based on safety inspection are divided into several categories according to different organizational levels and scopes.

2.2.1. Daily identification.

Daily identification is not only the main method of risk factor identification, but also the basic way of field safety information acquisition. Its main combination of daily field operations, maintenance, maintenance, monitoring and other work, regular identification of various risk factors. In the early stage of the construction of early warning management system, risk factors can be regularly identified according to the period of ten days or weeks, and the basic status of risk factors can be recorded and reported. In the future, with the improvement of informationization of monitoring methods, it is possible to identify risk factors in a daily cycle.

2.2.2. Comprehensive identification.

The comprehensive identification mainly takes the safety inspection as an opportunity. From the perspective of the national railway, the whole situation and the whole section, it focuses on the identification of risk factors in the management joint department and the on-site operation combination department. In the work of flood control and construction which contain a wide range of integration, in addition to identifying this unit itself, controlling the risk factors and its own risk factors, comprehensive identification system also give full consideration to this system, the unit may give the safety hidden danger of other system and other units. In addition, comprehensive identification is still an important period for risk factors identification and classification. According to the actual situation of safety inspection and the new form of railway transportation safety, the determination standard and classification method of risk factors should be adjusted timely. According to the practice of railway safety management, it is suggested to carry out comprehensive identification every six months.

2.2.3. Thematic identification.

Thematic identification refers to the targeted and purposeful implementation of special actions to identify risk factors in different periods, regions and departments. For example, for flood season to carry out flood risk factors identification; To identify the risk factors of geological disasters for railway in mountainous areas; Special risk factor identification was carried out for departments and units with multiple accidents and faults. Thematic identification is not only an effective supplement to regular identification, but also an implementation means of key control of early warning. The development of thematic identification can be carried out according to the actual organization of the security situation. Generally speaking, the identification of thematic identification can be carried out for major changes such as Spring Festival transport, summer transport, special transport, map adjustment, flood control and other major holidays.
2.2.4. **Professional recognition.** Professional recognition refers to the various professional system around the transport organization, equipment maintenance, railway line construction, passenger cars, flood control, crossing, dangerous goods transport safety and security prevention work, to respectively determine the key assignments, key equipment, key parts and key period, key positions and key links and key content, organize professional and special recognition. For example, according to key risk items, to organize special inspections such as dispatching orders and operation disclosure management, LKJ using management, implementation of measures to prevent accidents, fire prevention of vehicles and trains, transportation of dangerous goods, etc. Professional identification is also a kind of supplementary identification organization of daily identification, which can be quarterly in the identification cycle.

2.3. **Page Numbers**

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3. **Risk factor criteria**

Under the framework of risk factor classification and identification, how to use the existing data information to reasonably determine the risk value of risk factors, scientifically determine the criteria of risk factors and the criteria of warning level, and then determine the warning level of risk is the basis of safety warning analysis and pre-control decision implementation.

3.1. **Criteria for single risk factor**

According to the implementation steps and specific contents of risk assessment, the criteria for determining a single risk factor can be divided into two levels. The first level is to judge the presence or absence of danger, and the second level is to determine the severity of the danger. The risk factor evaluation process is shown in figure 1.

![Risk factor evaluation flowchart](image)

**Figure 1.** Risk factor evaluation flowchart

3.1.1. **Criteria for determining the presence of risks.** To judge the presence or absence of danger means to determine whether the environment is in a "dangerous" or "safe" state. The evaluation basis is based on the technical standards, rules and regulations and codes of conduct related to safety
operations of various specialized transportation departments and safety supervision departments. In addi-
tion, the historical experience of accident and fault is also an important basis for risk evaluation.

3.1.2. Criteria for determining risk levels. The decision evaluation of risk factors, to fully estimate
risk occurrence probability and severity, predicting risk out of control can lead to traffic work,
equipment, etc., and comprehensive consideration may cause accidents, personal injury, bad social
influence, etc., for estimating the economic loss control risk criteria to determine the risk level of risk
factors. In the concrete operation, the risk factor grade should be determined scientifically according to
the actual experience of site management.

The classification of risk factors mainly includes two basic elements, the probability of risk factors
and the severity of possible consequences caused by risk factors. Risk factors for the determination of
risk level should be in a particular scenario to consider the possibility of a risk factors and the severity
of comprehensive evaluation results, the possibility of the same risk factors under different scenarios
and may cause consequences severity also have differences, therefore, the risk factors in the
determination of risk level is of practical significance to combine the specific scene.

For calculation and evaluation of risk factors, risk grade, at present only "the major hazards
identification (GB18218-2009)" hazardous substances is given in the form of major hazard installation
identification and evaluation method, but for the railway transport safety, due to the particularity of
operation links and operating equipment, puts forward the corresponding method is not applicable in
standard. Based on this, this paper uses the risk assessment method in risk management for reference,
and uses the form of risk matrix to evaluate the possibility and severity of risk factors.

① Criteria for determining the probability of risk factors
Risk factors for the possibility of judgment according to the principle of risk classification,
combined with the railway transport safety management personnel and the worker's experience to
determine, from two aspects of probability and frequency of the possibility of decision criteria, according
to the size of the possibility of a risk factor, set the possibility of a risk factor value range of 0 ~ 1,
from small to large, as the six levels of risk factors likely level decision criteria as shown in table 1:

| Level | P1       | P2       | P3       | P4       | P5       | P6       |
|-------|----------|----------|----------|----------|----------|----------|
| Value P | 0%~5%   | 5%~10%   | 10%~30%  | 30%~50%  | 50%~90%  | 90%~100% |
| Possibility | Nearly impossible | Very impossible | Low possible | Possible | Very possible | Much possible |

② Criteria for determining the severity of risk factors
The determination of the severity of the consequences caused by risk factors is based on the
classification of accidents and faults in the Railway Traffic Accident Investigation and Treatment
Rules and the Measures for the Investigation and Treatment of Railway Traffic Equipment Faults,
which may cause railway transportation accidents, personal reflects, public reflects and environmental
reflects. According to the risk factors, the percentage system of the severity of the consequences, from
small to large, is set to six levels.

C1(value 1~5): May cause malfunction of equipment (illegal operation), delay train operation, cause
personal psychological trauma;

C2(value 5~15): May cause D21 class accidents and malfunction of equipment, (Serious illegal
operation), delay passenger train operation, need personal emergency treatments, cause minimal scale
public reflects and pollution;

C3(value 15~25): May cause D class accidents (Interrupt security days), (Including passenger train
accidents, excluding D21 accidents), need medical treatment, cause small-scale public reflection and
minor environmental accident;
C4 (value 25–50): May cause C class accidents (General B2 accident with only one serious injury, excluding general C accident), cause individuals lose working ability, local public pressure and medium environmental accident;

C5 (value 50–90): May cause B class accidents (General Class C accident involving, excluding general B2 accidents involving only one serious injury), cause personal severe injury, domestic public pressure and large environmental accident;

C6 (value 90–100): May cause class A accidents (Interrupt security days), cause death, stop railway operation and environmental disaster.

According to the judgment criteria of the probability of occurrence of risk factors and the severity of consequences, and combined with the calculation method of risk value, it can be known that the calculation formula of the safety state index of a single risk factor in a certain statistical cycle:

\[
SR_{ij}^{jk} = \sum_{n=1}^{N} P_{in}^{jk} \cdot C_{in}^{jk}
\]  

Table 2 Symbols and parameters.

| Symbols and variables | Explanation |
|-----------------------|-------------|
| \(SR_{ij}^{jk}\)     | Represent the safety state index of risk factor \(i\) in category \(k\) in the statistical cycle in section \(j\) of \(l\) railway bureau; |
| \(P_{in}^{jk}\)      | Represent the probability that the risk factor \(i\) of the \(j\)-company of the railway bureau \(l\) belongs to the \(k\)-type factor in the \(n\)-th safety information record in the statistical period; |
| \(C_{in}^{jk}\)      | Represent the risk factor \(i\) of the \(j\)-company of the railway bureau \(l\), which belongs to the \(k\)-type safety factor. The severity of the consequences may be dangerous in the \(n\)-th safety information record during the statistical period; |
| \(N\)                | Represent the risk factor \(i\) of the \(j\)-company of the \(l\) railway station belonging to the \(k\)-class factor. The total number of times the safety information is collected and recorded in the statistical period; |

In order to facilitate the evaluation and classification of the early-warning level of risk factors, deviation standardization method is adopted to normalize the safety state index of risk factors. After normalization, the calculation formula is as follows:

\[
R_{ij}^{jk} = \frac{SR_{ij}^{jk} - \sum_{n=1}^{N} d_{in,\text{min}}^{jk}}{\sum_{n=1}^{N} d_{in,\text{max}}^{jk} - \sum_{n=1}^{N} d_{in,\text{min}}^{jk}}
\]
\(d_{i,n,\text{min}}^{jk}\) is the minimum value of the safety index obtained by recording the n-th safety information of the risk factor \(i\) in the category \(k\) factor in company \(j\) of railway bureau \(l\) in the statistical cycle.

\[d_{i,n,\text{min}}^{jk} = \min(P_{i,n}^{jk} \cdot C_{i,n}^{jk})\]

\(d_{i,n,\text{max}}^{jk}\) is the maximum value of the safety index obtained by recording the n-th safety information of the risk factor \(i\) in the category \(k\) factor in company \(j\) of railway bureau \(l\) in the statistical cycle.

\[d_{i,n,\text{max}}^{jk} = \max(P_{i,n}^{jk} \cdot C_{i,n}^{jk})\]

When \(\max(P_{i,n}^{jk} \cdot C_{i,n}^{jk}) = 100\% \times 100\), \(\min(P_{i,n}^{jk} \cdot C_{i,n}^{jk}) = 0\% \times 1\)

\[R_{i}^{jk} = \frac{\sum_{n=1}^{N} P_{i,n}^{jk} \cdot C_{i,n}^{jk}}{N(100\% \times 100)} \tag{3}\]

4. Conclusion

According to the type of rail safety data information, this paper gives the real-time state recognition method based on equipment testing of operational risk and hazard identification method based on the safety inspection, and according to the different scope of organizational hierarchy and organization, risk identification method based on the safety check can be divided into daily recognition and comprehensive recognition, feature recognition and professional recognition of four categories.

At the same time, this paper also gives the criteria for determining the possibility and severity of risk factors by using the existing data information for a single risk factor, quantitatively analyzes various risk factors that affect the operation safety, and provides theoretical support for railway companies to determine the risk warning level and standard support for the safe operation of railway.

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