Optimization of High-speed Railway Emergency Plan Based on Safety Big Data

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Abstract. This paper investigates the optimization of the emergency plan for High-speed Railway based on the analysis of big data. We introduce the current situation of emergency management, construct the framework of the emergency plan system and life cycle management of the emergency plan. By analyzing the management process of existing emergency plans in detail, we put forward the optimization plan. Finally, we analyze the emergency plan optimization scenario and the source of safety big data, and carry out case study of High-Speed Railway emergency plan optimization based on typical case data. This paper provides an important basis for departments at all levels to deal with emergencies.

Introduction

With the rapid development of High-speed Railway, it not only brings convenience to people's life, but also brings new challenges to railway transportation command, especially emergency command. Ensuring the safety of High-speed Railway and passengers has been elevated to the strategic height of national security development. To implement this development concept, the railway needs to improve its emergency command capacity in an all-round way. In response to railway emergencies, on the one hand, it is necessary to further strengthen the coordination between railway emergency organizations and continuously improve the ability to deal with railway emergencies. On the other hand, a sound emergency linkage mechanism should be established to form a joint force to deal with major railway emergencies.

Emergency management of High-speed Railway is a process of effective early warning, control and treatment of High-speed Railway emergencies in order to reduce the harm of High-speed Railway emergency and achieve the goal of optimization decision, which is based on the analysis of causes, processes and consequences of High-speed Railway emergencies and effectively integrate relevant resources of internal and external aspects of the railway. In essence, High-speed Railway emergency management is the management of the entire railway emergency life cycle. In general, High-speed Railway emergency management manages all processes before, during, and after the railway emergencies. The prevention stage before the emergency is the starting point of the entire railway emergency life cycle. During the emergency control stage, the emergency situation can be controlled and the loss can be reduced by taking corresponding emergency actions and relevant measures. After the emergency, it is the stage to recover the affected objects. By applying the experience and lessons to the construction of railway emergency management system, it can pre-judgment and prevent the next emergency.

The railway emergency plan is the core element of the "one case, three systems" emergency management system, and is an important part of the railway emergency management work. It stipulates emergency agencies and responsibilities, emergency equipment, emergency response procedures, emergency command and coordination from various aspects. It also clarifies who is responsible for what, when and how to do before, during and after railway emergencies, and plays an important role in standardizing railway emergency management workflow, improving railway system's ability to prevent and deal with risks, and reducing casualties and property losses. At present, within the railway system, in accordance with the level of emergency management, a four-level railway emergency plan system has been formed, which basically covers all filed and
levels of railway safety production. It is China Railway Corporation emergency plan—the emergency plan of the unit of the China Railway Corporation—the emergency plan of the grass-roots organization—the post emergency disposal method. The number of plans in the 18 railway administrations under China Railway Corporation is different, and the number of plans of grass-roots organizations in each railway administration is even more different. By 2017, nearly 14,000 emergency plans at all levels have been prepared.

In the construction and operation of China’s High-speed Railway, there are great differences with existing railways, such as advanced equipment and high speed of operation. At the same time, the whole line is usually built with a large scale of viaduct. These characteristics all put forward new requirements for the methods and technologies of High-speed Railway emergency plans and emergency rescue. In addition, most of the existing railway emergency plans are qualitative and lack quantitative indicators. With the accumulation of accident case data of High-speed Railway and the application of big data technology, the optimization of High-speed Railway emergency plans with big data analysis means and methods is a new direction of emergency management development.

Overview
In terms of railway emergency management, Jia Limin et al[3, 4] proposed a railway emergency management system from five aspects of emergency management system, mechanism, legal system, plan and guarantee system. Chen Zhensong[5] put forward a new framework of railway emergency management system. On this basis, the sub-system of railway emergency plan is constructed from the top-level design of emergency plan, risk analysis, emergency capacity evaluation, emergency plan system and other aspects. Xu Jianguang[6] built a railway emergency response management system based on the four stages of prevention and early warning, emergency preparedness, emergency response and recovery of the emergency management process.

In terms of the optimization of emergency plan, relevant scholars at home and abroad have also studied, mainly focusing on simulation, algorithm process optimization and other aspects. For example, Yang Liang et al[7] proposed to introduce traffic simulation technology in the preparation of emergency plans, simulating and optimizing passenger evacuation schemes in stations (intervals) in emergencies such as fires, further evaluating and improving the coordination of network train operation organization through train operation simulation, quantifying the schemes of rail transit passenger flow guidance and bus connection, and finally simulating and evaluating the influence of passenger flow evacuation on relevant stations, so as to optimize the emergency plan and improve its operability. On the basis of detailed analysis of the existing text-based emergency plans for metro operations, Wang Moli et al[8] established a time-based Petri net for early warning response process, emergency response process and post-disposal process, analyzed and optimized the fire time Petri net model metro stations, improved the operability of emergency plans, shortened emergency response time and improved emergency rescue efficiency. Cao Haifeng[9] proposed a method for the preparation and optimization of grass-roots emergency plans based on the risk analysis of all kinds of disasters, that is, with the comprehensive use of positive scenario construction and negative consequence presupposition methods, integrate and analyze various risk scenarios and potential consequences, merge and optimize the corresponding tasks to form a task list. The above emergency plan optimization methods provide a reference for the optimization of High-speed Railway emergency plan. However, the optimization of emergency plans based on big data has not been widely analyzed at home and abroad.
High-speed Railway Emergency Plan

Emergency Management Process

In order to realize the whole life cycle management concept of railway emergency management, that is, the entire process management from prevention-preparation-response-recovery, the specific information processing method at each stage is designed, as shown in Figure 1.

High-speed Railway Emergency Plan System

Railway emergency plan is an important reference document and basis for departments at all levels to deal with emergencies. It is closely related to the business of management departments at all levels and specific executive departments. According to the characteristics of the construction, operation and management of High-speed Railway in China, as well as the differences of emergency management organizations and business responsibilities of High-speed Railway, the emergency plan system of High-speed Railway can be divided into different categories, including: (1) According to the overall and professional division of the plan, It can be divided into two categories: the general plan and the special plan; (2) According to the level of organization and management of railways, it can be divided into three categories: China Railway Corporation level plan, Railway Administration/High-speed Railway Passenger Dedicated (Company) level plan and station/base level plan; (3) According to the type of railway emergency emergencies, it can be
divided into four categories: natural disasters, accident disasters, public health and mass incident emergency plan; (4) According to the construction period and operation period of High-speed Railway, it can be divided into two categories: construction period emergency plan and operation period emergency plan.

In view of the characteristics of High-speed Railway operation, in order to adapt to the characteristics of emergency disposal and rescue of High-speed Railway and meet the needs of emergency disposal and rescue of High-speed Railway, based on the National Emergency Plan for Disposal of Railway Traffic Accidents, a High-speed Railway emergency plan system has been established according to the level of organization and management, and the Emergency Plan for High-speed Railway Emergencies (Trial) has been formulated to further enhance the ability to respond to High-speed Railway emergencies and implement standardized, scientific, accurate and rapid emergency response. At the same time, the series of plans are formulated, such as the Emergency Disposal Measures for Abnormal Conditions of Passenger Transport in High-speed Railway, Emergency Disposal Measures for Derailment Accidents of High-speed Railway EMUs, Emergency disposal measures for abnormal operation of High-speed Railway, Emergency Disposal Measures for Vehicle Failures of High Speed Railway EMUs, High-speed Railway engineering equipment failure emergency treatment measures, Emergency Disposal Measures for High-speed Railway Traction Power Supply Equipment, High-speed Railway signal equipment failure emergency disposal measures, High-speed Railway communication equipment failure emergency disposal measures and High-speed Railway emergency communication support measures.
All the above-mentioned High-speed Railway emergency plans have optimization room in terms of start-up conditions, response process, emergency response time, and accident classification.

**Life Cycle Management of Railway Emergency Plan**

Emergency plan, also known as emergency scheme, is a plan or scheme formulated in advance for possible accidents or disasters in to ensure rapid, orderly and effective implementation of emergency, rescue operations and reduce accident losses. It is an operational guide for emergency response. The contents of emergency plan generally include basic information, general rules, organizational command system and responsibilities, prevention and early warning, emergency response, post-disposal, propaganda of safeguard measures, training and exercises, supplementary rules etc., to guide the whole process management of emergency prevention, preparation, response and recovery.

At present, China Railway has formed a four-level railway emergency plan system, which includes the emergency plan of the China Railway Corporation, the emergency plan of the units...
affiliated to the China Railway Corporation, the emergency plan of the grass-roots organizations and the post emergency disposal method. According to the content of the plan, the emergency plan of the China Railway Corporation and its affiliated units can be divided into general plan, special plan and department plan. Besides the emergency plan of grass-roots organizations can be divided into general plan, department plan and on-site plans. The number of plans in the 18 railway administrations under China Railway Corporation is different, and the number of plans of grass-roots organizations in each railway administration is even more different. By 2017, nearly 14,000 emergency plans at all levels have been prepared. Emergency plan management is the core content of emergency management. Considering that the railway emergency plan covers a large amount of information, and the types and quantities of plans are numerous, how to effectively manage the emergency plan is an important part of the current railway emergency management work. This paper will discuss the management of emergency plan from the perspective of the whole life cycle to improve the practicality and disposal efficiency of the plan.

Railway emergency plan management is a complex system engineering. Every emergency plan goes through a process of dynamic cycle and continuous improvement from preparation, review and release, training and exercise, implementation, revision and update[7]. The content of the emergency plan covers the specific tasks and personnel division of the emergency from different stages such as prevention, preparation, response, and recovery. It turns out that the management of emergency plan is a dynamic management process of the whole life cycle, as shown in Figure 4.
High-speed Railway Emergency Plan Optimization

High-speed Railway Emergency Plan Optimization and Analysis Scenario

Based on the real historical event data and big data analysis technology, typical features are extracted, such as the occurrence time, interruption time, location/regional geological conditions, seasonal/meteorological factors, the cause of the accident, responsibility unit, accident categories/types/nature, etc. Besides, event portraits are developed to provide decision-making support for the formulation of emergency disposal plans of High-speed Railway. The optimization of High-speed Railway emergency plan based on big data can be roughly divided into four scenarios:

(1) Analyze the categories/types/nature of High-speed Railway emergencies and provide decision-making support for classification of High-speed Railway emergency plans.
(2) Analyze the interruption time of High-speed Railway emergency and provide decision-making support for the scheme of resuming operation in corresponding plans.
(3) Analyze the location/regional geological conditions, seasonal/meteorological factors, and cause of the accidents of the High-speed Railway emergency, and provide decision-making support for the High-speed Railway emergency plan disposal method based on the scenario analysis method.
(4) Based on the High-speed Railway safety information database, explore other data analysis dimensions to provide decision-making support for security early warnings.

Optimization of Data Sources of High-speed Railway Emergency Plan

The optimization of High-speed Railway emergency plan needs to collect data, improve the high-speed rail safety information database, and provide data support for decision analysis firstly. From the perspective of data sources, High-speed Railway safety early warning related data can be divided into four categories.

(1) The basic data mainly includes risk category, risk level, risk hazard degree, hidden danger level, accident type, fault type, over-limit type, security nature, business department and station name.
(2) Safety supervision data mainly includes safety supervision report, safety risk database, safety hidden danger database, safety accident database, safety failure database, accident and fault
investigation materials, safety supervision and inspection, key work and leadership Listing Supervision and other data, as well as safety-related standards and documents.

(3) Relevant professional data, vehicle, locomotive, electricity and other professional data. For example, the passenger train delay information, the real-time monitoring and alarming information of dangerous goods and dramatic drugs in the field of freight transportation, as well as the real-time monitoring and alarming information of the freight measurement security detection and monitoring system, etc.

(4) Other data, weather forecast data along the railway and external environment data such as wind, rain, snow and earthquake.

**Optimization Case of High-speed Railway Emergency Plan Based on Big Data**

**Traffic Interruption Time**

The accident case data of various professions from 2014 to 2016 are collected from the National Railway Administration, among which 605 cases are valid and 210 cases are recorded the traffic interruption time. The case attributes are sorted out, including event name, occurrence location, event category, event level, date, location, train number, start time, end time, disposition time, interruption time (minutes), number of cranes used, number of injured, number of deaths, event source, event type, event profile, incident handling, remedial measures, cause of the incident, Responsibility investigation, experience lessons learned, etc.

Based on the above data, the analysis of the interruption time is carried out, and its distribution is shown in Figure 5.

![Figure 5. Distribution of interruption time.](image)

In the figure, the abscissa represents the date of the accident, and the ordinate represents the interruption time (minutes) caused by the accident. The bubble points represent the maximum and minimum interruption time respectively, and the dashed line represents the average interruption time. The average interruption time from 2014 to 2016 is 42.38, 30.42 and 157.48 minutes respectively. Based on the results of the case analysis, it can be seen that the interruption time caused by the High-speed Railway accident shows a gradual growth trend, which can provide a scientific basis for the event classification of the High-speed Railway emergency plan.
Big Data Analysis for Security

The failure data of the electrical profession in the Safety Section of the Electrical Affairs Department of a railway administration are analyzed. The main attribute information includes occurrence time, repair time, failure delay time (minutes), occurrence process and cause (In case of material failure, fill in the equipment manufacturer, model, date of leaving the factory, date of going on the road, etc.), the cause of the fault, fault location, impact, assessment delay (minutes), type, responsibility workshop, responsibility team, date of failure occurrence, etc. Distribution of interruption time of electrical equipment failure events in this Railway Administration is shown in Figure 6.

The average interruption time from 2012 to 2016 is 46.95, 49.16, 42.64, 33.7 and 40.92 minutes respectively. Based on the above data, it can be seen that the interruption time caused by electrical equipment failure is generally longer than that caused by comprehensive accidents. Therefore, it is necessary to focus on formulating the emergency plan for the electrical profession to reduce the interruption accident.

The distribution of electrical equipment failure events in a Railway Administration is shown in Figure 7. The horizontal axis indicates the year of the accident, the vertical axis indicates the number of accidents, and the pie chart indicates the number of accidents for all types of accidents between 2012 and 2016. As can be seen from the figure, track, turnout, power supply, signal machine failures account for a large proportion of power equipment failure events, with an overall increase trend year by year, which is correlated with the increase in the number of power equipment and points out the direction for the development of special plan for various types of power equipment.
Summary

The optimization of High-speed Railway emergency plan based on the application of High-speed Railway safety early warning big data is another hot direction after the simulation optimization and algorithm optimization. Based on the analysis of big data, the composition, start-up, response conditions and disposal methods of various types of emergency plans in the emergency plan system can be optimized. The analysis of interruption time based on typical cases can provide data support for accident classification in the plan. With the gradual establishment and improvement of High-speed Railway safety early warning big data application system, more support will be provided for the optimization of emergency plan.

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