

Research on Identification and Analysis of Extreme Behavior Risks in High-Speed Railway Stations' Key Areas

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Abstract:

Introduction: High-speed rail stations serve as vital transportation hubs connecting different cities, regions, and even countries. They not only accommodate high-speed trains but also enable seamless transfers with other modes of transportation, facilitating rapid and comfortable travel for passengers. The establishment of high-speed rail stations often coincides with economic development in surrounding areas, attracting investments, businesses, and talents. However, extreme individual behaviors can pose severe destructive impacts on high-speed rail stations and their operations, including violent attacks on passengers and staff, destruction of station facilities, illegal intrusions into restricted areas or tracks, and placement of dangerous items. These behaviors threaten the lives of passengers and staff, disrupt station order, and affect the punctuality and overall efficiency of high-speed trains.

Objectives: This study focuses on the warning methods and technologies for extreme behavior in high-speed rail environments, analyzing the causes, characteristics, and prevention and control methods of extreme behavior. It points out the blind spots in the research of extreme behavior warning for high-speed rail both domestically and internationally, such as the lack of research on the aggregation, classification, and risk assessment techniques of extreme behavior in high-speed rail environments.

Methods: This study uses the R-LVC method to evaluate the extreme behavior risks of high-speed rail systems, taking into account the vulnerability and attractiveness of stations, as well as the direct consequences of extreme behavior. By using expert scoring and AHP method to obtain risk source coefficients, this study proposes a vulnerability assessment method for high-speed railway networks based on station levels to evaluate the impact of extreme behaviors on the high-speed railway system.

Results: The study identifies and assesses extreme behaviors in key areas of high-speed rail stations, calculates risk values, and demonstrates the application of risk assessment through a case study.

Conclusions: The research contributes to the identification and analysis of extreme behavior risks in high-speed rail stations, proposing risk assessment techniques and an early warning model based on the R-LVC method. It highlights the importance of considering station level, vulnerability, attractiveness, and direct consequences of extreme behaviors for comprehensive risk evaluation.

Keywords: high-speed railway Stations, key areas, R-LVC, vulnerability

INTRODUCTION

High speed railway stations are important transportation hubs that connect different cities, regions, and even countries. They not only serve high-speed railway trains, but may also seamlessly transfer with other modes of transportation such as subways, buses, taxis, long-distance buses, and even airlines. Through high-speed railway stations, passengers can quickly and comfortably reach their destinations, and the establishment of high-speed railway stations often accompanies the economic development of surrounding areas. New commercial, residential or industrial areas are easily formed around the station, attracting investment, enterprises and talents.

Individual extreme behavior has extremely serious destructive effects on high-speed railway stations and operations. These behaviors include violent attacks on passengers and staff, destruction of station facilities, illegal intrusion into restricted areas or tracks, and placement of dangerous goods. These behaviors not only threaten the safety of passengers and staff, but may also lead to disorder at the station, affecting the punctuality and overall efficiency of high-speed rail operations. In order to prevent and respond to these behaviors, it is necessary to strengthen station security forces, improve safety prevention capabilities, and equip necessary security equipment and devices. At the same time, improve relevant laws and regulations, clarify legal responsibilities and punishment measures, increase the crackdown on illegal activities, and form effective legal deterrence. Through these measures, the destructive impact of individual extreme behavior on high-speed rail stations and operations can be minimized to the greatest extent possible, ensuring the safety of passengers and staff, and maintaining the normal operation of the high-speed rail network.

OBJECTIVES

The extreme behavior targeted by this study refers to the actions taken by individuals or groups in a short period of time or specific situations to meet their own interests and needs. These actions are usually harmful, and depending on the circumstances, extreme behavior may also have illegality and negative social impact. There is no direct research on methods and technologies for extreme behavior warning in high-speed rail environments both domestically and internationally. However, there are a certain number of research results in areas similar and related to this project, such as extreme behavior analysis and prevention, perception, evaluation, and prediction of extreme behavior and public safety events, and high-speed rail safety risk assessment.

A few domestic studies have analyzed the causes of extreme behavior from the perspective of public security risk assessment. For example, Renmin University of China has classified and rated the generation and mode of extreme behavior, and proposed that the risk source of extreme behavior is the interaction between public security risk and social service risk[1]. There are also a certain number of studies on the analysis of extreme behavior characteristics and prevention methods in non high-speed rail scenarios, such as how to use public crisis theory, setback attack theory, governance theory, and government function theory to conduct research on government emergency prevention and control of sudden individual extreme events on campus[2]. Xing Yuqiu has studied the disposal methods of extreme violent events in multiple scenarios through multiple typical case analyses [3], and Bu Jianhua et al. have conducted research on extreme nationalism in cyberspace from a social psychology perspective [4].

The research on extreme behavior started earlier in foreign countries, and the types and theoretical basis for studying extreme behavior are also very rich. Early research mainly analyzed the motivation for extreme behavior from the perspectives of sociology and psychology, and then verified the intervention methods through experiments. For example, DuCette conducted a comparative analysis of the psychological motivation sources of non-destructive extreme behavior through experiments [5], McCauley et al. proposed a psychological framework model for the generation of extreme terrorist behavior through data analysis [6], Mathes et al. used the responsibility diffusion hypothesis method to analyze the motivation for extreme behavior in group competitive environments, and verified the motivation sources for competing groups to implement extreme behavior through experimental data [7].

Based on the analysis of the current research status, there are the following blind spots in the study of extreme behavior warning for high-speed rail:

(1) Lack of summary and classification research on extreme behaviors that affect the normal operation of high-speed rail in the high-speed rail environment. Although there is research on the classification of extreme behavior in China, the research results or research objects are too broad, such as classification research on extreme behavior in the entire social environment, or too abstract, such as research on the laws of certain types of extreme behavior, such as analysis and research on the laws of terrorist attacks at airports. However, there are few research results on extreme behavior in high-speed rail environments, and research needs to focus on the summary, classification, hazard tracing, consequences, and impacts of extreme behavior in the domestic high-speed rail environment;

(2) Lack of risk assessment technology research on extreme behaviors that affect the normal operation of high-speed rail in the high-speed rail environment. There are many studies on risk assessment in the field of public safety both domestically and internationally, mainly focusing on monitoring specific crisis events before they occur, preventing the occurrence of emergencies, and implementing response strategies. The methods have certain reference value, but when it comes to extreme behavior in high-speed rail environments, the direct application of research results cannot be achieved, and further analysis is needed based on the characteristics of the high-speed rail environment and the extreme behavior characteristics in that environment. The risk sources and consequences of various extreme behaviors in different scenarios of high-speed rail are different. Therefore, the identification, analysis, and evaluation criteria for extreme behaviors that affect the normal operation of high-speed rail in the high-speed rail environment are special, and there is a need for research on risk assessment techniques for extreme behaviors in high-speed rail environments.

METHODS

High speed railway stations generally have a hierarchical structure, which usually includes three types: entrance function layer, exit function layer, and passenger boarding and alighting train function layer. The high-speed railway operation technology and equipment contained in each functional layer have differences. Due to factors such as station level and terrain, the physical spatial distribution of these three functional level stations is not the same. The common hierarchical structure is: the first floor platform is used for boarding and alighting passengers, the waiting room is located on the second floor, spanning above the platform as a

whole, and the basement level is the arrival level. Of course, there are also different designs, such as the structure of elevated platforms where the waiting room and arrival level are both on the first floor, and the second floor is the platform.

A small number of stations have underground platforms, with transfer levels, waiting levels, and platforms extending from ground to underground in order, extending to the third underground level. Taking Futian High speed Railway Station as an example, the underground three parts include the transfer layer, waiting layer, and platform. The transportation transfer layer is located on the negative first floor of the station, with multiple passages for passengers to enter and exit. There are external shops, backup station buildings, underground garages, urban subways, bus stations, and taxi stands distributed in four directions: east, west, north, and south. The intersection of pedestrian flow is well connected. The waiting hall is located on the negative second floor of the station and is connected to the underground garage through a passage. Other spaces on the negative second floor are occupied by the equipment area, office area, subway track area, VIP waiting area, and dedicated passage in sequence. The underground third floor is the railway platform level, where platform screen doors are installed; Both long and short platforms are equipped with escalators for entering and exiting the platform level.

The exterior of the station includes urban roads and station squares, mainly used for passengers to enter and exit the station, with a high density of pedestrian flow.

After the above analysis, based on the common functional areas of various stations, the key areas of high-speed railway stations are divided as shown in Table 1. There are a total of 10 key areas, all of which are directly related to high-speed railway operation and passenger safety. All of these areas are protected by a combination of "civil defense, physical defense, and technical defense" protection methods.

Table 1. Key areas of high-speed railway stations

Number	Key Area	Function
1	Surrounding area of the station	Station opening and closing
2	Station Square	Traffic function, pedestrian flow buffering
3	Entrance and exit	Passenger identity verification
5	Motor vehicle entrance and exit passage	Station operation vehicles entering and exiting
6	Security check area	Goods inspection
7	Waiting room (area), Ticket sales room (area)	Passenger business
8	Ticket Check	Passenger diversion
9	Passenger platform	Passengers boarding and disembarking
10	Independent signal tower	Traffic dispatch, signal control, communication

High speed railway stations have the characteristic of dense pedestrian flow. After statistical analysis, extreme behaviors that often occur include:

1. Obstructing the start stop behavior of trains (PC). Such as jumping into the main line to interfere with train start and stop, opening train doors to organize train start, hitting the driver's cab glass, etc.
2. Obstructing the orderly entry and exit of passenger flow at the station (PG). Such as maliciously blocking passenger flow entrances and exits, maliciously blocking vehicle entrances and exits, etc.

3. Disturbance and disorder behavior (SR) in the "quiet passenger flow area". Such as individuals or groups expressing illegal interest claims, fighting, damaging the environment or infrastructure, etc.

4. Violent terrorist attacks (T). Such as wielding a knife to kill, placing explosive devices, human bombs, etc.

By distributing questionnaires, 5 experts were asked to rate the high-speed railway stations in their respective cities. The rated data was averaged and rounded to an integer before taking effect. The analysis of risk sources in high-speed railway stations, trains, and lines is shown in Table 3. The final result is calculated according to formula 1

$$C = |normalize[(L + S + P) * C1 * C2 * C3]| \quad (1)$$

Table 2. Extreme Behavior Outcome Evaluation Form

Extreme Behavior		Illegality	Purpose	Suddenness	Media Harmfulness	Property Damaging	Riot	Result
		L	P	S	C1	C2	C3	C
PC	Stations	1	2	6	3	1	3	0.02
PG		1	1	5	1	1	1	0
SR		1	4	2	6	1	1	0.01
T		6	6	5	4	6	6	0.666

The occurrence of risk events comes from risk sources, and the impact of each risk source on the occurrence of risk events varies. Therefore, this study decomposes the conditions under which extreme behavior occurs into the prevention level of the occurrence area, diversity of means, suddenness, and material conditions. Using the Delphi method, five experts covering railway security, operation, maintenance, and other business fields are organized to score and obtain the risk source coefficient through the AHP method, as shown in Table 3. The larger the coefficient, the greater the impact of the risk source on the occurrence of extreme events.

Table 3. Risk Source T Analysis

Extreme Behavior Occurrence		Prevention Level of Occurrence Area	Diversity of means	Suddenness	Material Conditions
PC	Stations	0.412	0.245	0.267	0.076
PG		0.173	0.403	0.371	0.053
SR		0.259	0.426	0.311	0.096
T		0.628	0.14	0.031	0.201

This study proposes a vulnerability assessment method for high railway networks based on station levels. The vulnerability assessment is based on the traffic efficiency of the road network and the level of stations in the road network, and the calculation method is shown in formula 2.

$$V = E_g \times A \quad (2)$$

In formula 2, $E_g = \frac{2}{N(N-1)} \sum \frac{1}{d_{ij}}$ is the connectivity of the road network, and d_{ij} represents the maximum value of the weight of the line connecting two stations, that is, the number of nodes on the shortest path between the two nodes. N represents the total number of nodes in the current network. $A = \sum p_i$, p_i indicate the level of high-speed railway stations in the network, as shown in Table 4.

Table 4 Station Levels and Weights

Station Level	Special Station	First Class Station	Second Class Station	Third Class Station	Fourth Class Station	Fifth Class Station
Weights	6	5	4	3	2	1

RESULTS

The role of risk assessment is to comprehensively consider the possibility and consequences of risk occurrence, with the aim of making clearer judgments on risks and providing a basis for future risk response strategies. This study adopts the R-LVC method to comprehensively consider the vulnerability and attractiveness of stations, trains, and lines, as well as the direct consequences of various extreme behaviors in the extreme behavior risk assessment of high-speed rail systems. The calculation is carried out according to formula 3.

$$R = T \times V \times C \quad (3)$$

Its meaning is that when the vulnerability, attractiveness, and risk sources of a high-speed rail target are on the rise, the likelihood of its risk occurring increases, and under the premise that the risk consequences of extreme behavior are determined, the risk becomes greater. Provide an example to illustrate the application of risk assessment.

Organize 5 designers in the fields of railway security, criminal investigation, and railway management to first evaluate the regional prevention level, diversity of risk sources, suddenness of risk, and material conditions of risk sources for extreme behavior of obstructing train start and stop on the passenger platform of this special station. The scores are divided into 5 levels according to the high and low scores of specific projects, as shown in Table 5.

Table 5. Expert Rating Form

Special Station 's PC Assessment	Regional Prevention Level	Diversity of Risk Sources	Risk Suddenness	Risk Source Material Conditions
Expert 1 (R1)	3	5	5	3
Expert 2 (R2)	4	3	4	2
Expert 3 (R3)	5	5	4	2
Expert 4 (R4)	3	5	4	2
Expert 5 (R5)	3	3	2	2

Due to the diversity and suddenness of risk sources having a positive effect on risk occurrence, while the level of regional prevention and the material conditions of risk sources are obstacles to risk occurrence, therefore the weight is formula 4.

$$w = [-0.412, 0.245, 0.267, -0.076] \quad (4)$$

By taking the average of the opinions of 5 experts, $T=0.124$ can be obtained, which means that the current experts believe that the probability of PC extreme behavior occurring without considering the attractiveness of the station is 12.4%. When considering network vulnerability, the risk warning value for obstructing train start stop at special class station is formula 5.

$$\begin{aligned} R &= T \times V \times C \\ &= 0.124 \times 0.5 \times 6 \\ &= 0.372 \end{aligned} \quad (5)$$

DISCUSSION

This study extracted a 5-level risk criterion for high-speed rail transportation safety through the technical equipment composition structure of the high-speed rail system, the organizational structure for safe operation of high-speed rail, and relevant regulations and rules. Analyzed the spatial structure and function of high-speed railway stations, the equipment composition of high-speed trains and EMUs, the physical structure and facilities of high-speed railway lines, and divided the key protection areas of high-speed railway stations, EMUs, and high-speed railway lines.

This study proposes a vulnerability assessment method for high-speed railway networks based on the level of basic stations, which comprehensively considers the connectivity of the road network and the characteristics of station levels to evaluate the impact of extreme behavior on the high-speed railway system.

This study proposes a high-speed rail extreme behavior risk warning model based on the R-LVC method, which uses the possibility, vulnerability, and consequences of extreme behavior to provide regional warning for extreme behaviour.

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