Research on Emergency Evacuation of Railway Accidents Based on Simulation

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Abstract: With the rapid development of railway in life, the number and capital investment of railway projects such as the platform design and construction, equipment maintenance and replacement are increasing year by year, and the resulting construction safety risks and operational safety management risks are increasing day by day. Most of the safety hazards in the construction stage can easily affect the train operation, and bring many adverse safety impacts to the lives of construction workers, staff and passengers during operation. By summarizing and analyzing relevant literature, this paper conducts safety risk assessment and emergency evacuation simulation for a station yard construction project, briefly analyzes the influencing factors of emergency evacuation for subway accidents, and proves the effectiveness of safety risk management for the station construction project through simulation. At the same time, by simulating emergency evacuation, it simulates the evacuation efficiency of iron station accidents, so as to put forward emergency measures for emergency evacuation and rescue of subway stations, improve the related functions of monitoring system, and achieve the purpose of promoting the prevention and control of potential safety hazards, reducing the frequency of safety accidents, reducing accident losses and reducing casualties.

Keywords: Railway Safety; Safety Risk Assessment; Emergency Evacuation; Modeling and Simulation; Monitoring System

1. Introduce

1.1 Research Background and Significance

Railway is a common mode of transportation in modern society. It uses locomotives to draw trains on two parallel tracks. According to the Railway Statistical Bulletin 2021, both passenger volume and freight volume of railways continue to grow. In 2021, the number of passengers sent nationwide reached 2.612 billion, an increase of 18.5 percent over the previous year. The total freight volume of railways in China was 4.774 billion tons, an increase of 4.9 percent over the previous year. In 2021, there were no particularly serious and serious accidents in railway traffic in the whole country. In this year, 748.9 billion of national railway fixed assets investment was completed, and 4,208 kilometers of new lines were put into operation, including 2,168 kilometers of high-speed railways. The operating mileage reached 150,000 kilometers, including 40,000 kilometers of high-speed railway. Nowadays, with the advantages of large transport capacity, high transport efficiency, low operating cost and high safety performance, all kinds of railways have become the main land transportation modes in China, providing great convenience for people's lives. At the same time, the state and local governments attach great importance to the continuous development of railways, and the investment in railway large-scale capital construction projects and existing line renovation projects has increased year by year. However, with the increasing number of railway renovation and reconstruction projects, how to scientifically and effectively prevent safety risks, effectively ensure the orderly and controllable implementation of construction projects, and ensure the safety of railway traffic and construction has gradually become the focus and problem for the management units of renovation and reconstruction projects and the managers of participating units to think together.

Theoretically, the research and development of railway construction project safety risk management is conducive to broadening the theory of railway construction safety risk, improving the awareness, level and ability of risk management, promoting the scientific, coordinated, harmonious and sustainable development of railway construction, and providing better services for economic and social development and the broad masses of the people. From a practical point of view, we can more objectively determine the high-risk areas in the process of railway construction by combining qualitative and quantitative risk assessment methods, and use limited available resources to prevent and control risks as much as possible, so as to achieve the lowest accident rate, the least loss and the best safety investment benefit, thus minimizing the safety risks of construction projects.

1.2 Research Status

Some foreign scholars began to investigate and study the evacuation in accident situation at an early stage, and they formed a separate research field, theory, data and research results. Foreign scholars Ansgar, K. and Andreas, S. put forward cellular automata model based on bionics Floor Flied model, and successfully applied it to the study of emergency evacuation [1]. This is the first time in the study of emergency evacuation process of emergency personnel to use probability knowledge to generate evacuation paths. Yang, L. took Dalian Metro as the research object, and simulated the evacuation of the station by BuildingEXODUS software, which once again proved that the spatial layout of the station must be scientifically planned in the planning and construction of the underground railway, especially considering the evacuation capacity of the stairs and escalators in the station, so as to continuously improve the guidance and emergency response ability of managers in the follow-up work and strive for more safe evacuation time for the people in the station when the accident occurred [2]. Weisdorfi et al believes that the emergency evacuation process of subway personnel is a process of continuous change, so he suggests that subway operating units should regularly evaluate the evacuation ability of emergency accident personnel during the operation stage, constantly update, revise and improve the evaluation indicators to achieve authenticity and reliability, and then improve the emergency response level of subway [3]. Zhang X.H. et al. built the Petri net of subway signal system, analyzed and studied the reliability of Petri net in the case of signal system failure, which provided important reference value for the formulation of emergency plans. [4]. Shin et al. used heuristic algorithm to study the influence of evacuees on the choice of evacuation routes and exits, and put forward suggestions to improve evacuation efficiency [5]. Tamang, N. And Sun, Y. used dynamic Monte Carlo (DMC) method to study the two-dimensional lattice model of crowd evacuation dynamics. A 2D cellular automaton model for studying crowd evacuation dynamics by DMC is proposed [6].
Domestic research on emergency evacuation started relatively late, and in the process of development, foreign advanced technology was introduced to study the safety of China's railway industry. In 2001, Chen, D.R. first introduced the structure and system of safe evacuation of subway accidents, as well as the procedures and measures for emergency treatment [7]. Song et al. established a cellular automata model, studied the influence of the interaction between evacuees on emergency evacuation, and also considered the influence of the width and thickness of the subway station exit [8]. Based on the internal structure of the subway station, the characteristics of pedestrian traffic and the characteristics of passenger flow during rush hours, Zhang, S.Y. took Fenglin Road Station of Shaoxing Rail Transit Line 1 as an example to simulate the Legion passenger flow [9]. On the basis of improving the passenger's social force model, Li, X.F. and others set some behaviors such as sudden accelerated escape, retrograde reentry and fainting on the ground caused by passengers' own factors such as psychological panic and weak health, and took Wangfujing subway station in Beijing as an example to carry out Anylogic simulation experiment [10]. Lu et al verified the reliability of the evacuation passage design of the emergency rescue station in the tunnel by calculation, and put forward the fire treatment scheme and the safe and rapid evacuation strategy of personnel in the case of train fire in the tunnel [11].
In order to solve the bottleneck problem of

passenger evacuation in subway stations during peak hours, Wang, C.Y. and others put forward a set of repeatable simulation optimization scheme based on Anylogic software, which provided a new research idea for solving the problem of passenger evacuation in subway stations [12]. Yang, L.C. et al. established a new crowd evacuation model to solve the stagnation problem of traditional social force model in complex and dense scenes. Through model optimization, it was concluded that the method to solve the disorderly evacuation of pedestrians caused by excessive crowd density in the evacuation process was to solve the optimization parameters [13].

The above-mentioned research on emergency evacuation of subway stations has some limitations: the social force model is not suitable for large-scale crowd evacuation simulation, and the data calculation of a large number of people is too large, which makes the research more difficult; Legion software can't carry out mixed simulation, and the research on influencing factors is objective, which can't better reflect the relevance; FDS fire simulation software lacks integrity, so it can't fully reflect the details such as the building environment of the subway station in the study. Therefore, this paper will comprehensively analyze the subjective and objective factors such as the internal environment of the station, the characteristics of buildings and personnel in the station, and the behavior response of personnel, and select Pathfinder software with simpler calculation to study and observe the evacuation process more flexibly and intuitively.

2. Influencing Factors of Emergency Evacuation

Major operational accidents and disasters in urban rail transit mainly include train accidents, fire accidents, terrorist attacks, natural disasters and systematic floods. Among them, the fire accident is the first disaster in subway station, which occurs frequently and causes great harm. Therefore, this paper studies the emergency evacuation of subway station with the background of sudden fire accident in subway station. The occurrence of accidents is related to human factors such as the physical factors in the station and the specific behavior of personnel. In order to reduce the interference between various factors, this paper studies the related influence of various influencing factors on the emergency evacuation of subway stations from the perspectives of people, things and environment.

2.1 Human Factors

Crowding and congestion caused by human behavior, the density and flow of pedestrians, the location of pedestrians, the behavior decision-making of pedestrians (the initial state is random distribution), conformity and following psychology means following the exit chosen by the nearest person and making the same choice with it. People's competitive psychology, psychological reaction, and the walking speed of pedestrians at different ages, sexes and different safety conditions (as shown in Table 1) will all affect the evacuation process and results in a certain environmental situation.

Table 1. Normal Moving Speed of Pedestrians of Different Ages and Sexes

Different groups of people	Horizontal walking speed/($m\ s^{-1}$)	Ascending speed of stairs/($m\ s^{-1}$)
Young and middle-aged men	1.25	0.67
Young and middle-aged women	1.05	0.63
Old people and children	0.76	0.40

2.2 Material Factors

Garbage cans, safety signs, etc. in emergency environment, support in architectural design and other factors that may delay evacuation and other adverse effects.

2.3 Environmental Factors

The inherent characteristics such as the width of the safety exit in the space, the different locations and evacuation directions of the safety exit in the space are very important to the evacuation time. The location of pedestrians and the location and width of the exit must be above the critical value in order to complete the overall safe evacuation in the corresponding time. At the same time, in the event of an accident, the concentration and density of smoke and other harmful substances produced at the scene will seriously affect the walking speed of pedestrians, causing psychological burden, thus affecting the evacuation speed and prolonging the evacuation time.

3. Simulation of Emergency Evacuation

In a dangerous environment, pedestrians will have a stress reaction, and the sense of tension will lead pedestrians to speed up their walking under unsafe conditions. Therefore, in the simulation, it is assumed that the stress factor of pedestrians is 1.3, and the moving speed of pedestrians in an emergency is 1.3 times of the normal speed. At the same time, in order to unify the gate exit in the station into a 3.56 meters exit for convenience of calculation, stairs and escalators are arranged at both ends of the waiting area.

In the event of an accident, the staff will try their best to open all the passages leading to the safety exit after receiving the alarm to assist the personnel to evacuate safely. In order to fit the reality better, the peak passenger flow will be selected for simulation.

3.1 Simulation of Evacuation without Train Stop

Through investigation, the peak number of people in the station without train stops is 880. The simulation results of Pathfinder show that after evacuation, people start to move after reaction time. With the passage of evacuation time, some people's evacuation behavior on the stairs is hindered, and people who are limited by the width of the stairs cannot respond quickly. As shown in Figure 1, at 72.8 secondes, there was a queue on the stairs due to the congestion, but it only lasted for a short time. According to Figure 2, the first evacuee successfully evacuated from the station to a safe place after 45.2 secondes, and the last one evacuated from the station to a safe place after 134.6 secondes. According to the simulation experiment, the station can complete the evacuation of all personnel within the time required by the code (6 min required by the code) without the arrival of the train. This means that: according to the requirements of the existing code, all the people in the subway station will be evacuated to a safe area at the 134.6 secondes after the evacuation of the people in the subway station starts, and the 134.6 secondes is less than 6 min, which meets the requirements of the code.

After the evacuation, by observing the 3D animation of the evacuation process, we will find that there is no obvious congestion and queuing in the gate and stairs of the station lobby during the evacuation process without the arrival of the train. Through the simulation results, we can know that the existing gate and stairs of the subway station can meet the evacuation of people who arrive at the peak of people flow without the train.

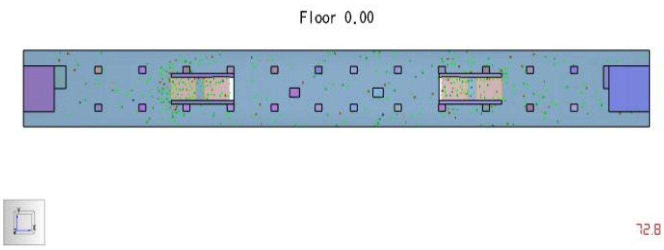

Figure 1. Personnel Flow Sign

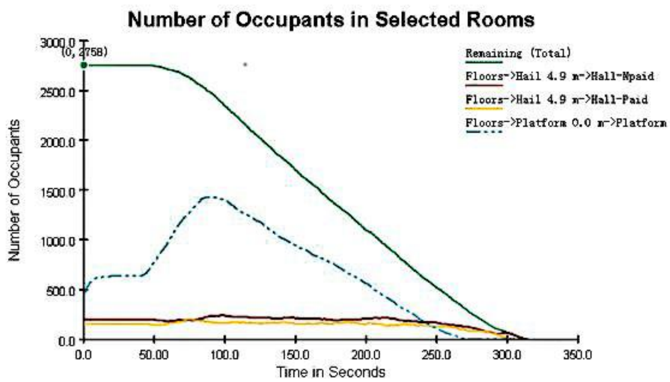

Figure 2. Evacuation when there is no Train Stop

3.2 Simulation of Evacuation when Unilateral Train Stops

After investigation, when there is a train stopping at one side of the station, taking the general subway as an example, if the train is full, at this time, there are 1800 passengers in the train and 880 people stay in the station, and 2480 people need to be evacuated at this time.

Through the simulation results, it can be seen that compared with the evacuation in the peak passenger flow when the train arrives at the station, there is a very obvious queuing and congestion phenomenon at the exit around 70.0 secondes due to the excessive number of people in the peak passenger flow when the train enters the platform and leaves.

In the process of simulating the 3D animation of evacuation by software, we know that the first passenger who successfully evacuated was evacuated to a safe place in 46.1 secondes, and the last passenger was successfully evacuated to a safe place in 290.5 secondes after the evacuation began. This shows that all passengers can complete the evacuation task within the specified time under the specified conditions under the peak passenger flow when a single train arrives at the station, indicating that the station can complete the evacuation within 6 minutes in case of emergency, which meets the specified requirements. As shown in Figure 3, at 315.7 secondes after evacuation, all personnel in the platform and station hall were evacuated to a safe area.

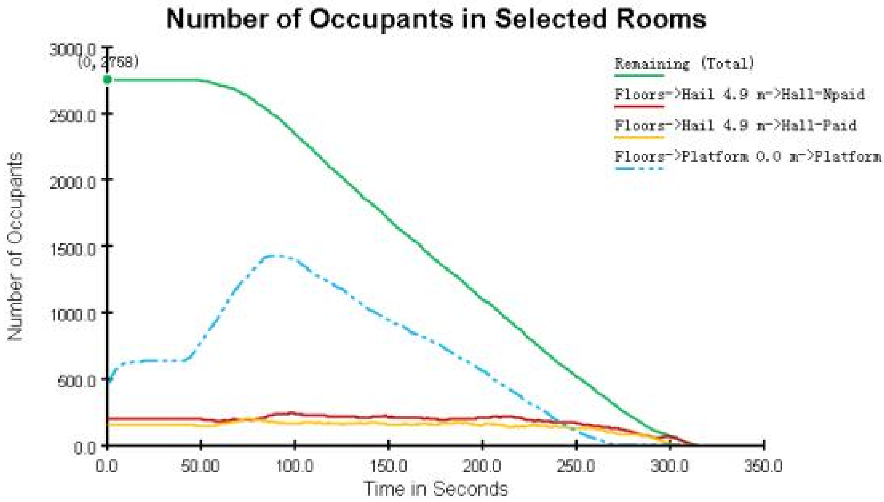

Figure 3. Evacuation when a Unilateral Train Stops

4. Optimization of Safety Monitoring System

Through the simulation study, it can be known that the current subway design can complete the safe evacuation of passengers in different situations within the specified time when an accident occurs. In order to further improve the safety factor and improve the quality of safe evacuation in various critical situations, the improvement measures are put forward for the subway station safety monitoring system.

In railway safety, preventing accidents is to ensure the safety and avoidance of people's lives. Therefore, the application of cloud platform and Internet "+"technology in the subway safety monitoring system and the use of computer network technology to monitor the safety status of the station in real time, once unsafe hidden dangers occur, the safety inspection and rectification will be carried out at the first time, which can more accurately carry out safety prevention and control and personnel protection.

Strengthen the rigor in daily maintenance, upload relevant information through the cloud platform in time, and prepare emergency plans in advance. During the railway operation, the staff in the station are in close contact with the computer room, and the personnel in the station can be located at any time through the infrared thermal effect. When unsafe conditions occur, the crowded places in the area can be sorted out in time and the corresponding evacuation command and judgment can be made in time. At the same time, optimize the fire control system in the safety system, and respond immediately to ensure the safety of passengers and staff when potential safety hazards appear.

5. Summarize

Through the above research and analysis, it shows that urban rail transit such as subway is more complicated than high-rise buildings on the ground, and the risk factors are far more than simple office buildings, shopping malls and other buildings. Therefore, more influencing factors must be considered as much as possible in the safety assessment, so as to make a more accurate and precise judgment, ensure the safety of personnel on a larger level, and also better reduce economic losses and avoid social impact. As far as the current social and local traffic development is concerned, more simulation technology will be used in the safety research of subways and other railways, which will provide more value for the future traffic development decisions and provide people with better and more convenient traffic environment and conditions.

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