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Simulation Analysis of Emergency Evacuation of Subway Station during Rush Hour with Different Gender Ratios

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Abstract

In order to study the emergency evacuation characteristics of subway stations during peak hours, this paper uses the Pathfinder numerical simulation software to establish different evacuation scenarios by introducing an example of a subway station, and analyzes the evacuation simulation results under the conditions of different gender ratios. The results showed that when the proportion of males was 5%, the evacuation time was the longest, which was 298.8s; when the proportion of men was 95%, the evacuation time was the shortest, which was 283.3s. And in the evacuation process, the evacuation bottlenecks are mainly escalators, walking stairs and the entrance of the station hall.

Keywords

Gender Ration; Subway Station; Emergency Evacuation.

1. Introduction

When the subway station has a large passenger flow, in the event of an emergency, it is easy to cause panic among people, and then cause disasters such as crowding and stampede. Therefore, it is necessary to study and analyze the emergency evacuation of subway stations during the peak flow of people.

For personnel evacuation research, it mainly focuses on evacuation behavior characteristics and evacuation simulation research. For the study of the characteristics of evacuation behavior, the main method of tracking passengers is to analyze the influence of psychological factors on the speed of escape personnel under different panic levels [1], and the impact and collision behavior of personnel under panic psychological conditions [2]. For evacuation simulation research, Anasta-sios et al. [3] conducted a safety assessment of the evacuation of passengers in subway stations in accordance with NFPA standards. Li Danchen et al. [4] studied the effects of escalators, stairs, gates, etc. The degree of influence of passenger evacuation time. Peng Lei [5] discussed the evacuation plan of people under different fire occurrence low points under the fire warning system and mechanism of large subway stations.

At present, there is a lack of progress in the research on the impact of different genders on the evacuation of people. Therefore, this paper takes an island-type subway station as the research object, uses Pathfinder software to build a 3D model of the subway station, sets up multiple evacuation scenarios, and simulates the fire scene. Effects of different sex ratios on evacuation time. The research results can provide a theoretical basis for personnel evacuation under disaster accidents in subway stations.

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2. Theory and Methodology

When a building fire occurs, whether people can evacuate safely depends on the available safe evacuation time (ASET) being greater than the required safe evacuation time (RSET), which can be expressed as Eq. (1) [6].

$$T_{AEST} > T_{RSET} \tag{1}$$

If the above formula is established, it shows that all personnel can be evacuated to a safe area when a dangerous state comes; otherwise, accidents are prone to occur. When it does not meet the requirements, it is necessary to optimize the evacuation path, speed up the evacuation, or strengthen the fire protection measures to delay the advent of the dangerous state. The determination of the safe evacuation time of personnel is shown in Figure 1.

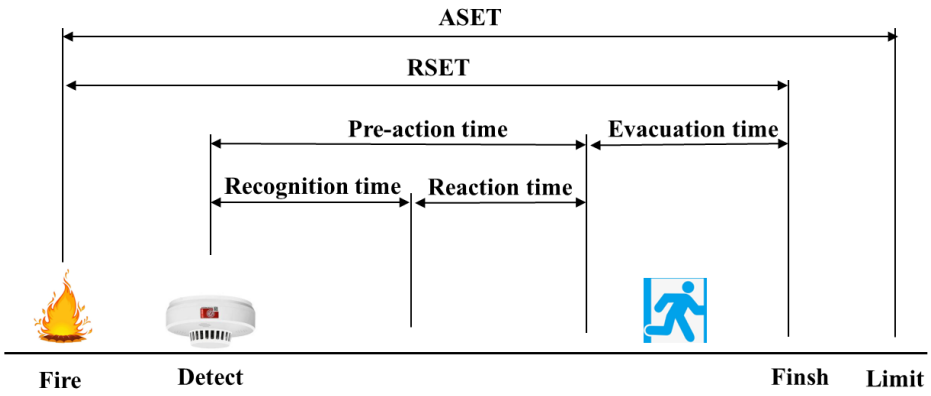

Figure 1. Criterion on judge whether a person can evacuate safely

3. Case Study

3.1. Modeling

Taking an underground two-story island subway station as an example, the building plan of the negative floor is shown in Figure 2.

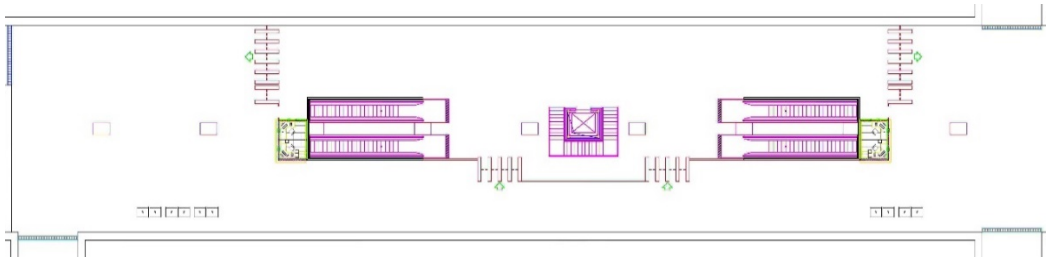

Figure 2. The floor plan of the subway station building on the first floor

Using Pathfinder, based on the construction drawings of the subway station, the 3D evacuation model established is shown in Figure 3. In the Pathfinder numerical simulation software, the movement of personnel includes Steering and SFPE modes. According to the research [7], the Steering mode is closer to the actual evacuation situation, so this paper chooses the Steering mode for personnel evacuation.

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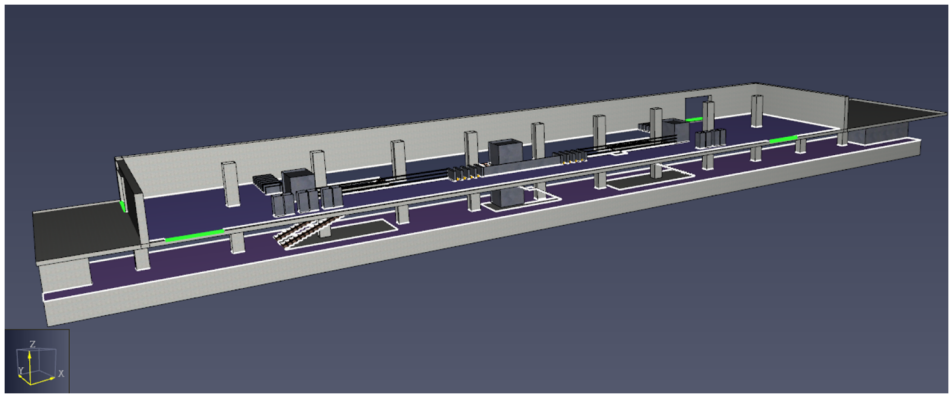

Figure 3. 3-D model of the subway

3.2. Establish Evacuation Scenarios

During the rush hour, subway stations are dominated by young men and women, as well as middle-aged men and women. According to relevant research [8-10], the parameter values of personnel characteristics during peak passenger flow are shown in Table 1.

Table 1. Personnel characteristic parameter values during peak passenger flow

People	Young men	Young women	Middle-aged men	Middle-aged women
Speed (m/s)	1.1~1.81	1.0~1.74	1.03~1.76	0.97~1.67
shoulder Width (m)	0.42	0.38	0.43	0.39

Since young men and middle-aged men and young women and middle-aged women have small differences in evacuation speed and shoulder width, for the convenience of simulation, young men and middle-aged men are classified into one category, and the range of evacuation speed is 1.4m /s, the shoulder width is 0.43m; young women and middle-aged women are classified into one category, the evacuation speed range is 1.3m/s, and the shoulder width is 0.39m. At the same time, the personnel reaction time is set to 60s [11], that is, the personnel can be safely evacuated after 60s. Since it is not easy for subway stations to be all men or all women, the established evacuation scenarios are shown in Table 2.

Table 2. Evacuation scenarios

Male proportion	5%	15%	25%	35%	45%
Female proportion	95%	85%	75%	65%	55%
Male proportion	55%	65%	75%	85%	95%
Female proportion	45%	35%	25%	15%	5%

When the subway station has a large passenger flow, the long-term forecast passenger flow of the subway station is 10,800 people. Combined with the subway design specification [12], it can be calculated that during the evacuation process, there will be 1,500 people on the station hall floor (750 people in the billing area and 750 people in the non-billing area) and 1,500 people on the platform floor. In the process of emergency evacuation, vertical elevators are not used for personnel evacuation, and personnel can only be evacuated through walking stairs [6]. Figure 4 is a three-dimensional evacuation model of a subway station with people placed.

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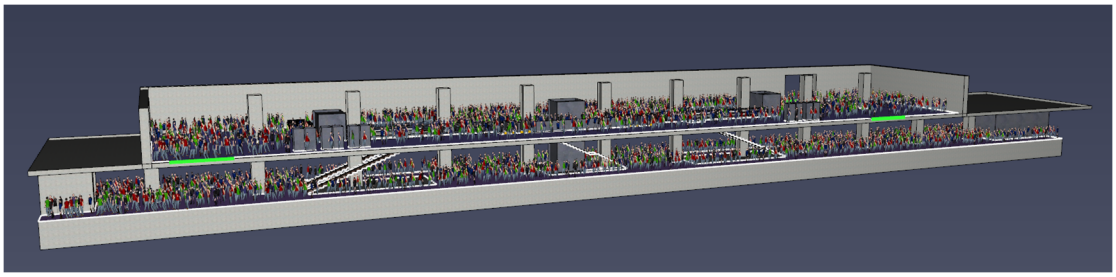

Figure 4. 3-D model of the subway

3.3. Results and Discussion

According to the simulation results, the evacuation time under different gender ratios is shown in Table 3.

Table 3. Evacuation time under different gender ratios

Male proportion	5%	15%	25%	35%	45%
Time/s	298.8	295.3	288.0	292.0	291.3
Male proportion	55%	65%	75%	85%	95%
Time/s	288.8	291.5	286.8	286.3	283.3

According to the simulation results, all working conditions meet the minimum evacuation time requirements. Among them, when the proportion of males is 5%, the evacuation time is the longest, which is 298.8s; when the proportion of men is 95%, the evacuation time is the shortest, which is 283.3s. Mainly because men are evacuating faster than women. Among them, Figure 5 shows the relationship between the number of people evacuated and the time under the conditions of different male proportions.

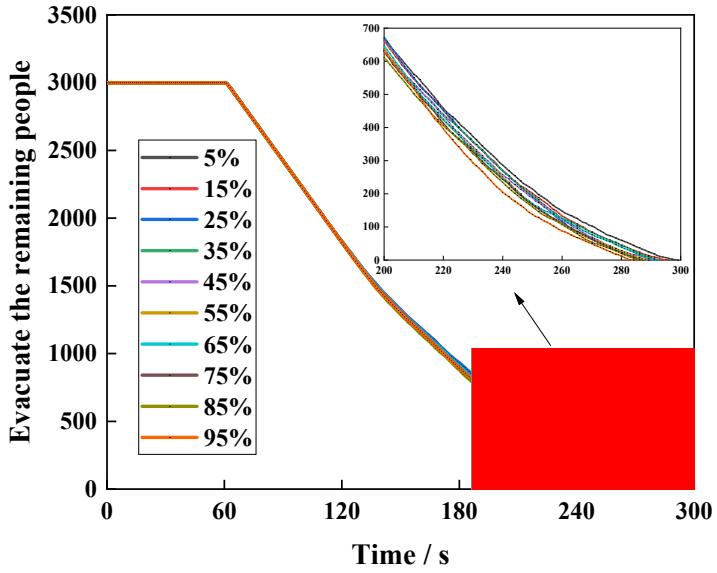

Figure 5. Evacuation time under different proportions of males

Taking the longest evacuation time, that is, 5% of males, as an example, the distribution of evacuees at different times is shown in Figure 6. According to the numerical simulation results, the safe evacuation path for personnel is "platform floor - escalators and walking stairs - station hall floor chargeable area - station hall floor non-billed area - station hall floor doorway". The evacuation bottlenecks are mainly escalators, walking stairs and the entrance of the station hall.

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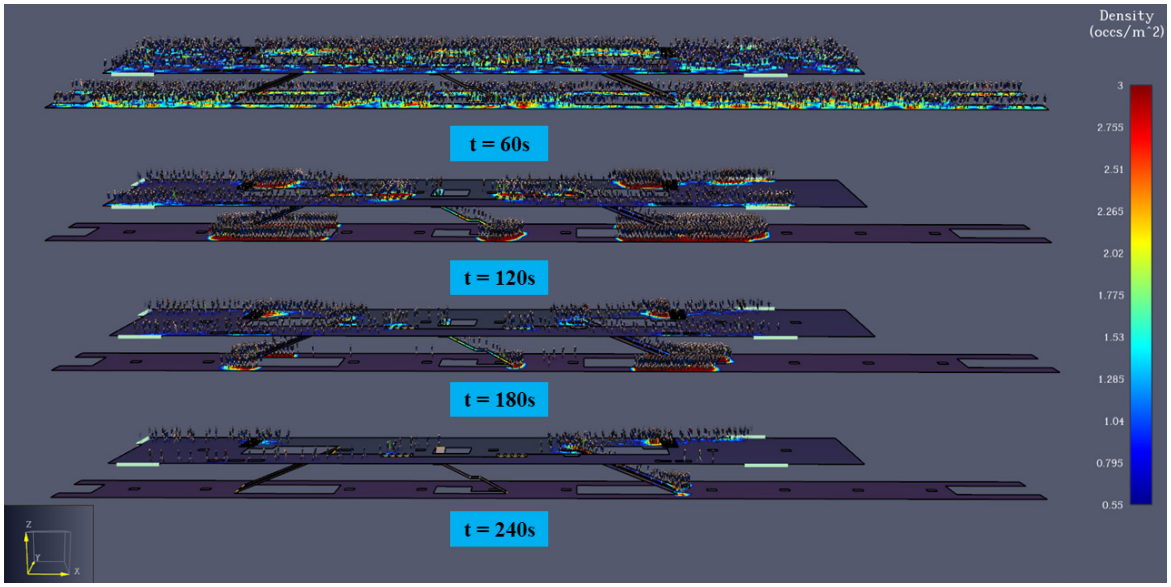

Figure 6. Evacuation situation at different times

4. Conclusion

(1) This paper uses the Pathfinder numerical simulation software, combined with an island-type subway station, and establishes different evacuation scenarios to obtain the influence of different male proportions on the evacuation time of personnel. The research results can provide a theoretical basis for safe evacuation in emergencies.

(2) When the proportion of males is 5%, the evacuation time is the longest, which is 298.8s; when the proportion of men is 95%, the evacuation time is the shortest, which is 283.3s, all of which meet the evacuation time requirements. In the evacuation process, the evacuation bottlenecks are mainly escalators, walking stairs and the entrance of the station hall.

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