Numerical simulation of evacuation in a subway station

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Abstract

The subway station was built as a rail transit system in the underground; due to its characteristics of closure and a heavy passenger flow, it may cause many deaths and injuries and extensive property damage if an accident occurs, such as a fire. Therefore, the subway safety evacuation is not only one of the important contents of the subway disaster prevention design, but also public safety emphasis and hot issue in the domestic and foreign research field. In the paper, the evacuation in the condition of fire is mainly carried out research. Firstly, the subway passenger flow parameters are caught by the shooting and measurement of the subway station. Finally, the safety egress time is calculated. Then, according to the obtained parameters, Pathfinder simulation software based on technology of Agent is used for simulating and analysing the evacuation process of the personnel. The result indicates that: the station safety egress time is 3 min 8s. It accords with 'code for metro design requirements'; stairs and gates are export bottlenecks during the evacuation, which has a considerable space of optimization in the subway evacuation design.

1. Introduction

With the development of the city, because of Metro's unique advantages, Metro has rapidly developed into one of main transportation in the city. Meanwhile, evacuation in a subway station gradually becomes the focus of attention in the industry. Safety evacuation in the subway station requires to divert passengers and staff to a safe area before a variety of harmful factors threaten the safety of the subway passengers and staff. Although it had some researches on the safety evacuation, it didn't form the scientific research system of evacuation in the subway station [1-7]. With the development of computer technology, engineering issues combined with computer technology and the application of computer simulation technology in engineering problem have become one of a convenient research method. In this paper, Pathfinder simulation software based on the technology of Agent is used for simulating and analyzing the evacuation process of the personnel in subway station, which tests whether the station conforms to subway design Chinese standards that the time of personnel evacuating to the safe area must be less than 6 min and how the station should be improved in order to more convenient evacuation.

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2. model Building and calculation conditions

2.1. model Building

According to Guangzhou subway station, personnel evacuation physical model in a typical subway station is established in this paper, as shown in Figure 1, which includes the automatic staircase, the staircase, the vertical elevator and the evacuation passageway. The platform floor is 128 m in length by 7 m in width and equipped with two automatic staircases, staircase and vertical elevator. And the station hall floor is 99 m in length by 16 m in width and equipped with four automatic ticket gates (A, B, C, D) and two exit (A, B). Ticket gates B and D have five brakes, while Ticket gates A and C have four brakes. The specific parameters are shown in Table 1. Note that: according to the standard 'metro design code' [8], the vertical elevator in this simulation will not be considered as an evacuation tool.
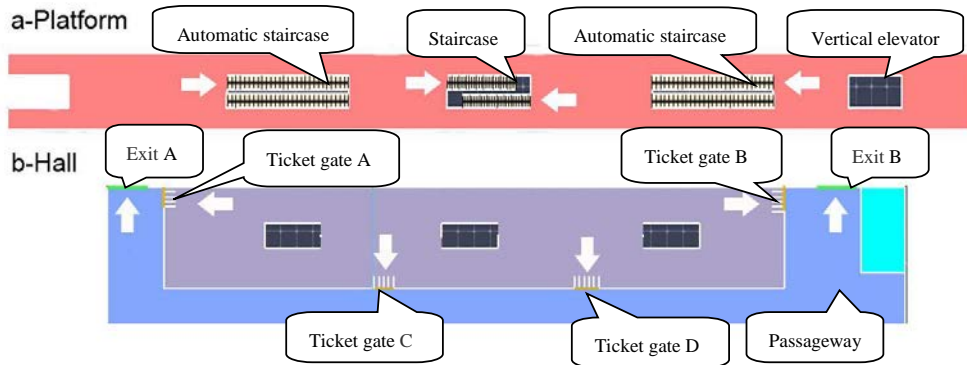

Fig 1. Schematic structure of a Guangzhou subway station

Table 1. The specific parameters of a Guangzhou subway station

area	sector	length (m)	width (m)
	automatic staircase room	15.5	3
	staircase room	11.2	3
Station platform	automatic staircase	—	1
	staircase	—	1.5
	automatic staircase room	7	3
	staircase room	7	3
Station hall	each brake of ticket gate	1.5	0.55
	exit	—	4
	passageway	—	2.5

2.2. Simulation Settings

1) The evacuation direction. The evacuation direction expresses as the arrow in Figure 1. When emergency evacuation begins, ticket gates of station hall are opened entirely so that passengers go through Ticket gate to Exit A, B. At the same time, passengers in the station platform are evacuated to a safe place by the upward automatic staircase or staircase on both sides of station platform. This default simulation setting is that passengers go through ticket gate in the order, doesn't climb fence which split fare zone with free area.

2）The number of evacuation crowd. According to the field survey in a Guangzhou subway station, average passengers flow per train reaches to about 180 persons during the rush-hour; the number of passenger waiting in the station platform and walking in the station hall is about 100, 80, respectively. Considering future developments and the case of super peak flow in the subway station, peak factor of 1.2 is introduced in this simulation. Therefore, the number of evacuation crowd is 430.

3) The moving speed. The passengers' moving speed is effected by many factors, such as gender, age, and the case of passengers taking packages, but in this simulation writer mainly considers the gender difference has an impact on passengers' moving speed. Passengers' moving speed shows in table 2.

Table 2. The mobile speed of different gender in different position

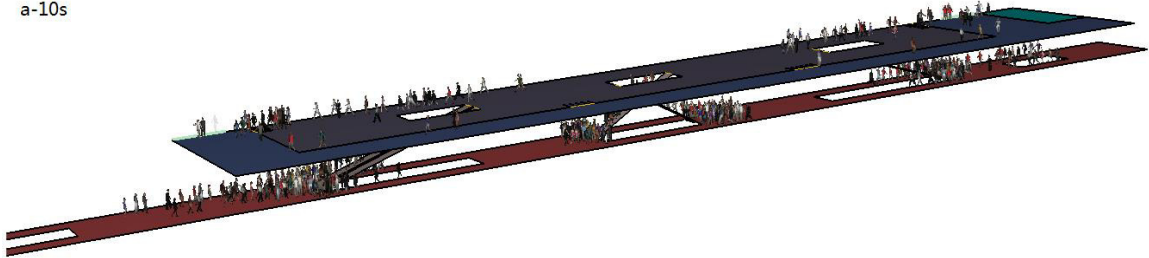| gender	In the horizontal direction	On the stairs	Through Ticket gate
man	1.322m/s	0.860m/s	1.275m/s
woman	1.159m/s	0.678m/s	1.384m/s

4) Passengers parameters. According to the research data at home and abroad, shoulder width of man and female is 41 cm, 38 cm, respectively; chest thickness of man and female is 25.8 cm, 25.7 cm, respectively.

5) Passengers distribution. Total number of passengers in the platform and station hall is approximately 320, 110，respectively. Passengers randomly distribute in the platform and station hall, in accordance with the proportion 1:1 of men and women.
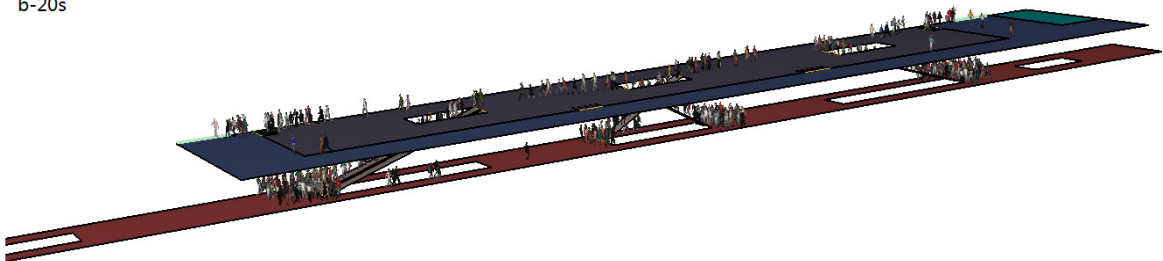
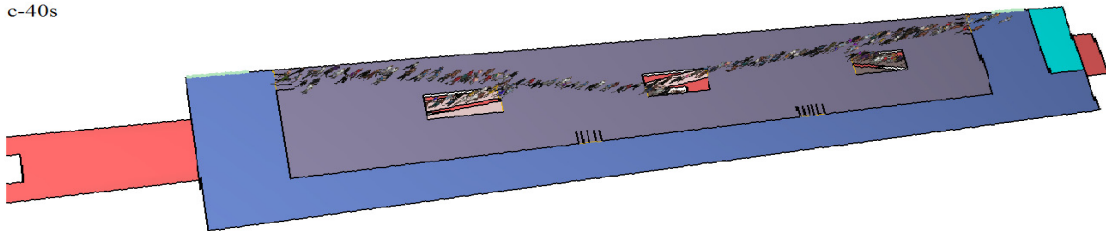## 3. Simulation results and analysis
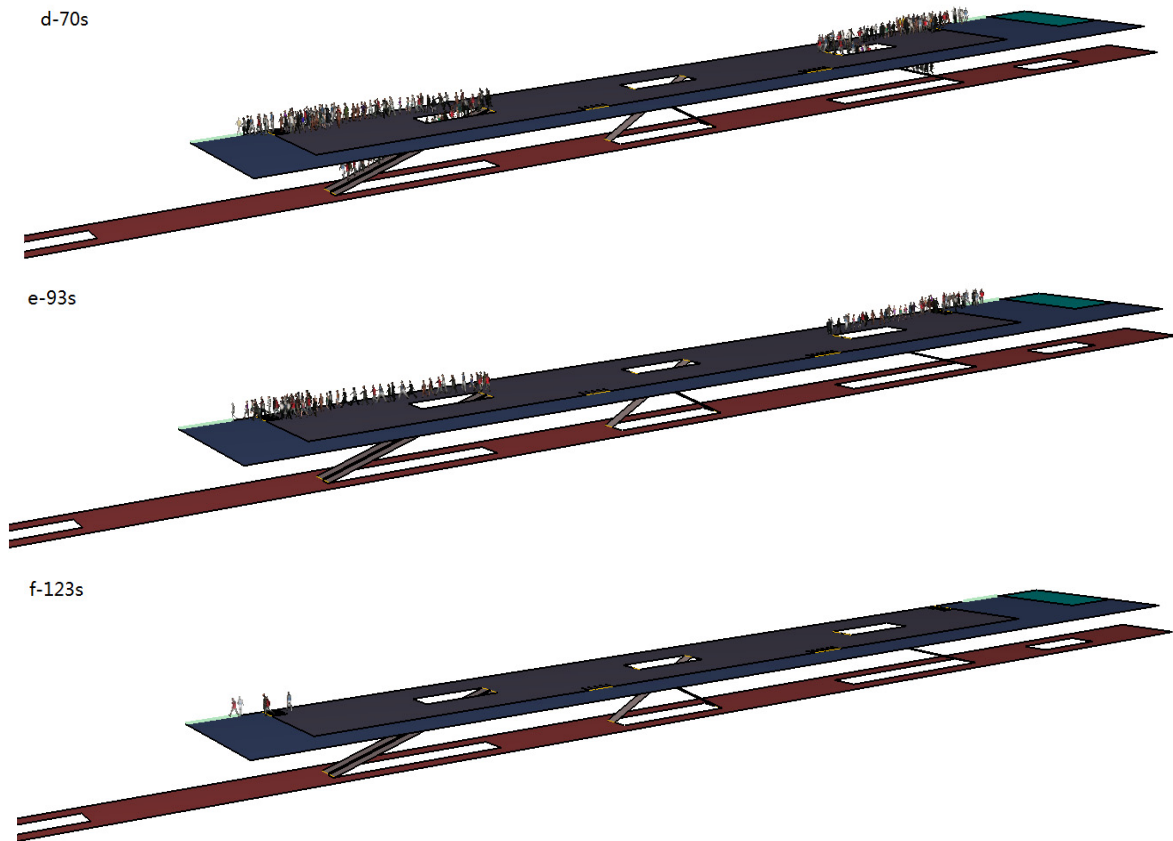
3.1. Simulation results

Fig 2. (a)(b)(c)(d)(e)(f) The passengers distribution after the evacuation time 10 s, 20 s, 40 s, 70 s, 93 s and 123 s, respectively.

After finishing the above simulation settings parameter, writer sets out the dynamic simulation process, which is shown in Figure 2. When evacuation begins, passengers in the platform run to the nearest upward automatic staircase or upward staircase; at the same time, passengers in the station hall run to the nearest exit for evacuation.

As seen in Figure 2, when the evacuation time reaches to 10 s, all passengers in the platform run to the entrance of automatic staircase or staircase so there is a phenomenon of congestion at the entrance of automatic staircase or staircase. Meanwhile, all passenger in station hall run to ticket gates, which causes a congestion at ticket gates. After 20 s, some passengers in the station hall have been evacuated to a safe place, and some passengers in the platform have begun to reach the station hall and are going to run to ticket gates. When the evacuation time reaches to 40s, most of the passengers in the station hall have been evacuated, and some passengers in the platform have already began to arrive at the turnstiles. Ticket gates' entrance is still in the crowded condition. After 70 s, a majority of passengers in the platform have been evacuated to the station hall. The congestion has not been improved at ticket gates' entrance. After 93 s, evacuation work finishes in the station hall and the congestion at ticket gates has been greatly eased. The whole evacuation process lasts 129 s.

This simulation evacuation's time amounted to 129 s, during which all 430 passengers completes the safety evacuation. Note: it is just the time for evacuation, not including personnel response time. Considering personnel response time with 1 min, the safety egress time is 3 min 8 s.

3.2. Analysis of simulation results

Figure 3 shows the relation between the number of the stranded passengers in the platform layer and the time. As seen in Figure 3, when evacuation begins, the evacuation process is relatively stable with the evacuation rate of 6 persons per second; when it is 40 s since evacuation happened, the evacuation rate starts to slow to 3 persons per second. According to the evacuation process, the platform's passengers begin to reach ticket gates when the evacuation time reaches to 10 s. At this time, the evacuation is affected by the turnstiles, thus the overall evacuation speed begins to decline. After 71s, the

number of passengers in the platform layer is 0, which means evacuation work complete in the platform. Taking 60 s of personnel response time into account, the egress time of station hall is 130 s, which meets the subway station safety egress time standard requirements for less than 6 min.
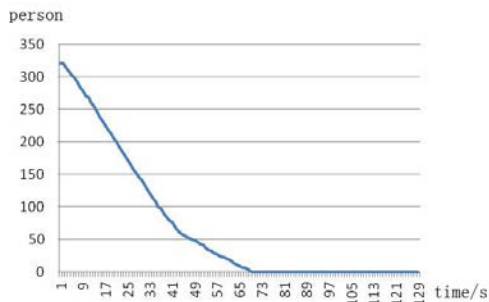

Fig 3. The relation between stranded crowd number in the platform and the time

The relation between the number of the stranded passengers in the station hall and the time is shown in Figure 4. The passengers' number curve decrease steadily at the beginning of evacuation, which means passenger evacuation is carried on orderly. After 23 s, the curve begins to rise, because original stranded passengers in the station hall have been thoroughly evacuated and the original stranded passengers in the platform layer have begun arriving at station hall. When it is about 56 s since evacuation happened, the curve begins to decline, because the number of original stranded passengers in the platform who arrive station hall is more than number of stranded passengers who evacuate through the safety exit A and B. Therefore, it takes 127 s to evacuate stranded passengers to a safe place in the station hall.
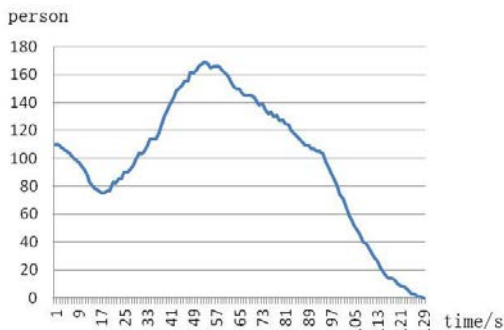

Fig 4. The relation between stranded crowd number in the station hall and time

As seen in Figure 5, when evacuation begins, the number of subway station reduce steadily, which show evacuation in the station hall is ongoing orderly. From 35 s to 42 s, total number of stranded passengers slowly decline, because evacuation of original stranded passengers in the station hall is completed.
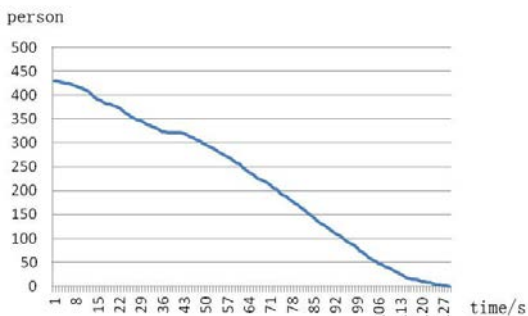

Fig 5. The relation between stranded crowd number in the station and time

4. Results and discussion

This simulation result shows Required Safe Egress Time (RSET) of a Guangzhou station is about 3 min 8 s, which is far less than 6 min. According to above analysis, the subway station conforms to 'code for metro design requirements', thus its design is reasonable.

Why the safety egress time is too short?

1. Although the station covers large area and accommodates a large number of people, a peak passengers flow is relatively small. So the safety egress time is shorter.

2 as a non-transfer subway station, it is equipped with two automatic upward staircases and two upward staircases that ensure passengers arrive the station hall within a short time after the fire.

Nonetheless evacuation simulation shows there is a congestion at the entrance of automatic upward staircases, staircases and ticket gate, which are main factors affecting the evacuation time.

To sum up, one Guangzhou station evacuation capability meets the specification for subway design.

5. Conclusion

Based on passenger parameters got by shooting and measurement in a Guangzhou subway station, considering about the proportion of men and women and movement speed, this paper use Pathfinder software as a tool to simulate the process of evacuation. The conclusions are listed as follows:

One Guangzhou station safety egress time is about 3min8s, which is in line with the requirements of the national standard. Nonetheless there is still space for optimization.

Stairs and ticker gate are export bottlenecks during the evacuation, mainly because entrance of the stairs and ticket gates is so narrow that many passengers can't pass through together and are stranded at the entrance. So increasing the width of the stairs, or the number of gates are good methods for evacuating more effectively to a safe place.

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