Journal of Computing and Electronic Information Management

ISSN: 2413-1660

Simulation of crowd evacuation in subway station based on Pathfinder

Xudong Yang [1], Baoyun Wang [2,*]

[1] School of Information Science and Technology, Yunnan Normal University, Yunnan, China;

[2] School of Institute of mathematics Yunnan Normal University, Yunnan, China;

Abstract: In case of emergency, aiming at the problem of congestion in the subway station during personnel evacuation, taking a subway station in Kunming City as an example, the simulation model of personnel emergency evacuation in the subway station is established by using the evacuation simulation software Pathfinder, and the evacuation situation and evacuation path of the people in the subway station are simulated. Based on the analysis, it is concluded that the subway station is prone to crowd congestion at the stair entrance during evacuation, and accordingly, it is proposed that the nearest exit should be selected for evacuation. Through simulation comparison, the total evacuation time is increased by 25s compared with that before optimization. The optimization effect is obvious.

Keywords: Subway station; Pathfinder. Evacuation path optimization.

1. Introduction

With the development of society and the continuous progress of science and technology, people's means of transportation have changed a lot. With the characteristics of fast, portable and large passenger flow, subway has become the first choice for people to travel and is much loved by people. Although the subway as a useful instrument in the travel, but it itself have flaws and can not be ignored, such as due to large subway traffic, one thousand emergencies, whether can safe evacuation has become the primary problem, but most of the subway built in underground, the space is lesser, when traffic is bigger, can produce adverse effect to evacuate. Therefore, how to evacuate passengers to safe areas faster and more safely has been a hot issue for current researchers.

There are also a lot of researches on the evacuation of subway station personnel. Lan WHK[1] et al. studied the two-way flow characteristics of signalized pedestrian crossing facilities in Hong Kong through video recording technology, and determined the relationship between pedestrian walking speed and traffic flow. Henderson LF[2] et al.also studied the walking speed of pedestrians. Mu Nana[3] et al. studied the influence of the length and layout of the diversion railing on the subway platform floor on group evacuation by means of numerical simulation. The results show that the longer the length of the push-pull guide railing is, the smaller the evacuation time is. Tang Fei [4]et al. used computer simulation software to simulate the evacuation process of personnel in the subway transfer station under the two conditions of rush hour and full train. Dai Xiaoya [5]combined the experiment with simulation to analyze the influence of exit guidance setting and railing setting on personnel evacuation. The guiding Angle of the guide railing and the setting of the separation railing were studied. Finally, the optimization scheme of the railing was put forward. In order to study the influence of guiding personnel on evacuation, this paper takes the setting of guiding personnel as the entry point and selects a subway station in Kunming as a simulation example. Based on evacuation simulation, it provides reference basis for emergency evacuation optimization of subway station through favorable evacuation guidance of personnel.

2. Model construction

2.1 Simulation Software

Pathfinder is an emergency evacuation assessment system software developed by American Thunderhead Engineering Company [6]· The simulation system can be modeled according to the actual size of the building, and the movement and shape parameters of each person are set to simulate the way of action of each person, and the simulation results can be visualized output.

In the specific parameter setting, Pathfinder software includes two modes of human movement: SFPE mode and Steering mode [7]. In SFPE mode, the path length of pedestrians is taken as the main criteria for path selection, and the speed of pedestrians is determined by the crowd density in the room, while the Steering mode is controlled by path planning, guidance mechanism and collision processing. When people are evacuated, the route is confirmed according to the path and the distance of people [8]-[9].The Steering mode was closer to the actual situation, so the latter was used as the personnel movement mode in this paper.

2.2 Parameter Setting

2.2.1 Model construction

In the model, the total length of the station is 232.5m and the width is 20m. The underground station hall structure is adopted and it is an island station. The platform is located on the second floor underground and the height of the public area is 4 meters. The station hall mainly includes two entrances: the East Square Exit (Exit A) and the West Square Exit (Exit B). There are 8 gates at the East Square Exit and 14 gates at the West Square Exit, each gate with A height of 0.99 meters and A width of 90 centimeters. The total area of the station hall is 3809.25m ². There are two sets of stairs in the middle of the platform floor. Each group is composed of 1.5m wide escalators and 2.8m wide stairs. In the event of an emergency evacuation, the escalator will be out of service and can be used as a staircase for evacuation. To establish a specific simulation physical model is shown in Figure 1 below.

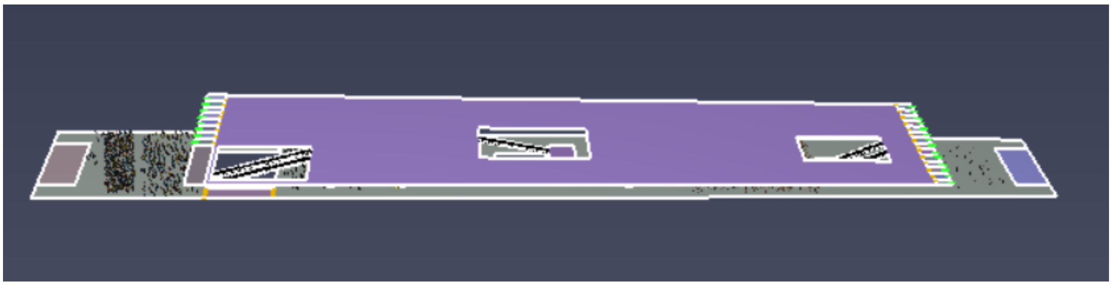


Fig. 1 Stereo structure of subway station

2.2.2 Personnel parameter setting

The behavioral parameters of the simulated crowd in this simulation are set according to the speed data of evacuation facilities, and according to the actual conditions and the age of the personnel. The evacuees were divided into three categories: middle-aged people aged 30-50, teenagers aged 13-20, and older people aged over 60. Due to the difference in physical quality and evacuation speed of young men and women, the evacuation process is greatly affected. Therefore, people in this age group are divided into two groups: men and women. The specific personnel parameters are shown in the table below:

personnel	Evacuation	speed (m/s):	Shoulder width(cm):	Height (m):
Middle-aged men	37.5%	1.2	37.5	1.70
Middle-aged women	51.9%	1.05	35.0	1.58
The young	5%	1.0	32.0	1.55
The old man	5.6%	0.75	37.2	1.50

In the evacuation process, according to GB 50157-2003 Metro Design Code [10], the station shall, in case of a fire, evacuate all the passengers and waiting personnel on the platform carried by an incoming train in a long term or an overpeak hour with passenger flow control, to a safe area within 6 minutes. At the same time, the personnel response time is 30s, so all personnel should be evacuated to the safety point within 330S.

2.2.3 Set the number of personnel

According to the survey, the total number of passengers on the subway platform is about 1125, plus 40 station staff, and about 435 people are waiting for the train on the platform, a total of 1600 people are evacuated.

3. Scene Simulation

3.1 Analysis of pedestrian evacuation results

According to the simulation evacuation results, the total time from the start of evacuation to the last person leaving the station is 325.8s. Figure 2-4 shows the heat diagram of evacuation. In the figure, the Density represents the heat map of the Density of people. The darker the color, the higher the Density of people in this area[11]. The flow of people can be clearly seen by the heat map. At the beginning of evacuation at 9.2s, there was congestion at the stairway access, as shown in Figure 2. There are three blocks of congestion. As can be seen from Figure 2, the number of passengers who choose the left exit for evacuation is greater than that who choose the right exit for evacuation. At 274.7s, all passengers at the right exit evacuate from the platform, as shown in Figure 3. At 325.8s, all passengers at the left exit are evacuated, as shown in Fig. 4. So far all the passengers have been evacuated. The reason is that after the evacuation begins, people will choose the nearest exit for evacuation, which leads to a surge of people at the left exit and a large area of congestion. Therefore, choosing the nearest evacuation path is not the optimal choice. In an actual evacuation, the longer the jam lasts, the greater the security risk. Aiming at this phenomenon, it is necessary to optimize the evacuation passage.

Fig. 2 Evacuation and aggregation state of personnel at 32.9s

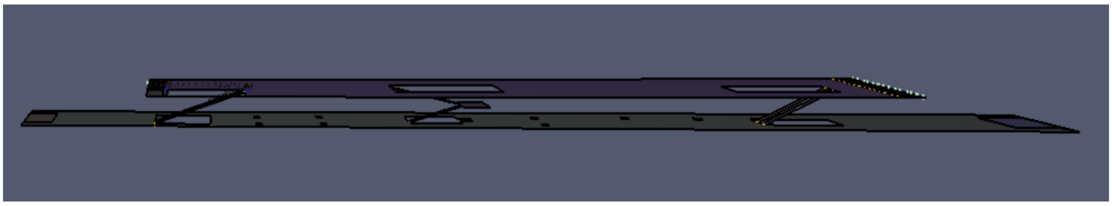


Fig. 3 Evacuate all personnel at the right exit at 287.8s

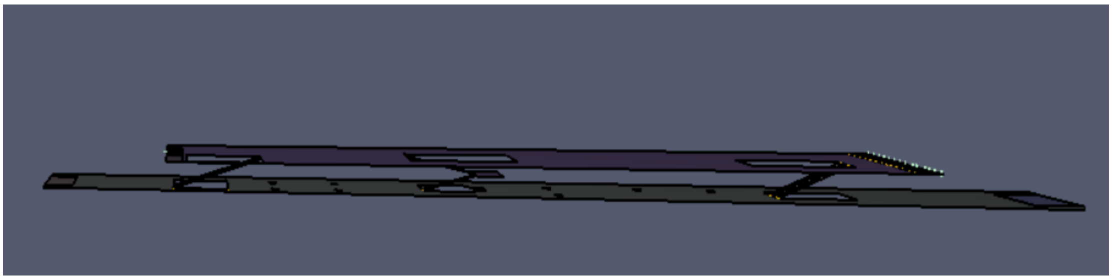


Fig. 4 All personnel evacuated at 325.8s

3.2 Cause analysis of evacuation congestion

According to the simulation analysis, the left channel of the platform floor lasts from 16.0s to 259.5s. There was a total of 243.5 seconds of congestion. Cause the platform layer when the influx of a large number of short time and small platform through export on the left side of the evacuation of personnel in the middle, and in figure 5, the congestion area are mainly concentrated on the left side of the narrow escape, because the evacuation channel narrow, lead to staff through when under the influence of channel size gradually gathered here, cause congestion.

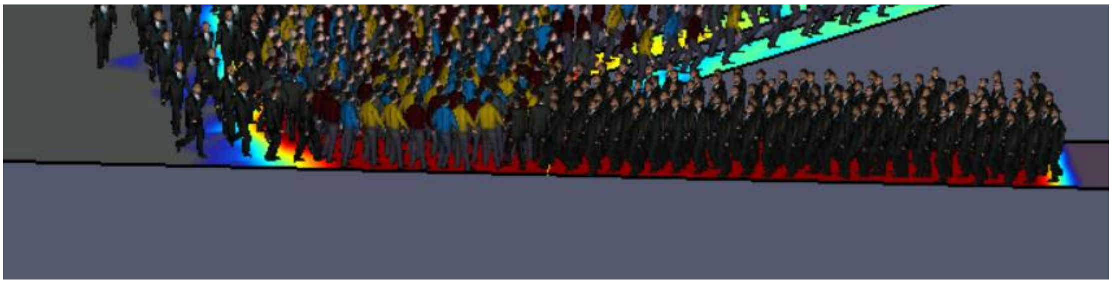


Figure 5. Congested blocks

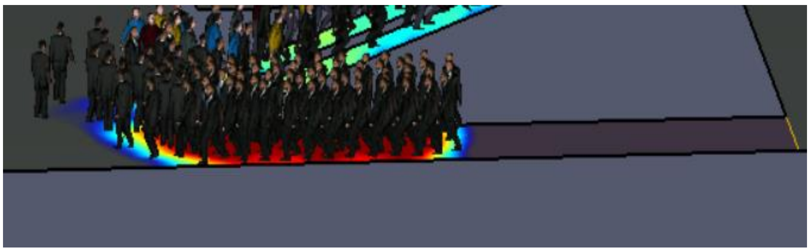
4. Evacuation path optimization

4.1 Evacuation path optimization

Subway train stations adhere to the concept of designing for relieving congestion when evacuating personnel, and the principle of optimizing evacuation path is to alleviate congestion and reduce evacuation safety risks on the basis of meeting evacuation time requirements. The optimized evacuation scheme in this paper is to evacuate people from the block in the platform that is prone to congestion and from the middle exit and the right exit to the platform floor respectively according to the principle of nearby evacuation. During evacuation, passengers abandon the nearest exit and choose the middle passage near them to evacuate to the platform floor. In the simulation, the choice of path parameters is artificially defined to achieve the goal of path optimization. After optimization, the simulation results show that the evacuation time of platform layer personnel through the right exit is 295.1s, and the evacuation practice through the left exit is 299.5s. Compared with before optimization, 26.3s was saved. After optimization of the path, the congestion of the station hall floor and platform floor was

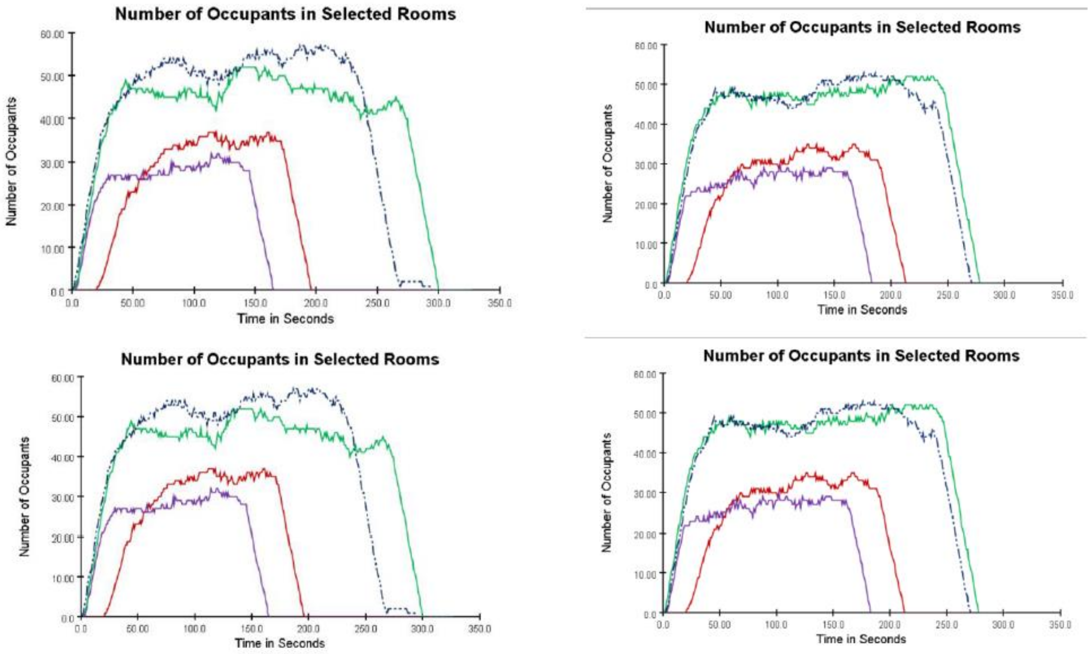
reduced, and the personnel stranded at the entrance of the stairs were reduced.
The simulation results show that the optimal evacuation path has a better alleviating effect on the congestion situation of the station hall near the landing. The personnel congestion situation at the left landing before and after optimization at 187s is intercepted, as shown in Figure 7 below. After optimization, the left exit began to gather at 69.7s and continued to finish at 178.7s, with a total duration of 109s, which was 134.5s less than that of 243.5s before optimization. At 99.6s, the right exit reaches the first person who turns from the left exit and continues until 161.9s. At the right exit at 256.9s, all the personnel are transferred from the platform to the station hall. At the right exit at 299.5s, the evacuation of the personnel is completed. People on the left side will complete the evacuation at 299.5. At this point, the evacuation of the station will be completed.
According to the evacuation numerical results in Pathfinder, the relationship between the personnel flow at the back exit and the practice before the optimization of the evacuation path is obtained, as shown in Fig. 8(a) and (b). After the optimization of the evacuation path, the personnel flow value at the left stairway of the evacuation path is allocated to the right exit, which improves the utilization rate of each exit. On the premise that the evacuation practice meets the standard requirements, the number of people passing through each evacuation channel should be reasonably allocated as far as possible to avoid a series of safety chain reactions caused by excessive flow of people. At the same time, more guidance personnel should be equipped at the entrance and exit of the channel to provide safety assistance to ensure the evacuation safety of personnel in the small-caliber and large-flow evacuation channel.

Before optimization



After optimization

Figure 7. Optimized congestion at the front and rear landing at 187s



(a)Before optimization (b)After optimization

Fig. 8 Relation diagram of personnel flow and time at exits and exits before and after path optimization

Aiming at the problem of subway congestion, through the evacuation simulation in this paper, the path optimization scheme is obtained. On the basis of reducing the overall evacuation time, the evacuation efficiency is improved and the evacuation safety risk is reduced. Reasonable regulation of the number of passengers in and out of the station is helpful to improve the evacuation efficiency in emergency situations.

5. Conclusion

Through the above analysis, the conclusion is as follows:

(1) In the evacuation of subway platform, there is a large area of congestion at the landing passageway, which is a safety risk.

(2)The optimized evacuation results show that the overall evacuation efficiency is improved. Compared with before optimization, the total evacuation time of personnel is shortened by 24s. The congestion time at the top of the stairs was shortened by 10.5s. It improves the safe evacuation space of personnel and makes each evacuation port get a higher utilization rate. Eliminate the risk hidden danger.

(3)In order to improve the traffic capacity and maintain the good fluidity of evacuation channels, more staff should be allocated at evacuation ports with large passenger flows to provide evacuation guidance.

References

[1] Lam W H K,LeeJ Y S,Cheung C Y.A study of the bi-directional pedestrian flow characteristics

at Hong Kong signalized crosswalk facilities[J].Transportation,2002,29(2):169－192.
[2]Henderson L F,LYONS D J.Sexual Differences in Human Crowd Motion[J].Nature,1972，240(5380):353－355.
[3]Wang Baoyun. Risk Assessment Algorithm of Crowding and Stampede in Crowd Gathering Places [J]. China Safety Science Journal.2019,29(06)
[4]Mu Nana, Shi Cong ling, Xu Xuan, Li Jian. Study on the Influence of the Diversion Handrails on the Evacuation of the Subway Platform [J]. China Science and Technology of Production Safety，2018，14(12):175－179.
[5]Tang Fei, He Qing, Zhu Kongjin, Xu Tong, Shi Qin, Li Heng, Study on the Characteristics of Mass Evacuation in a City Subway Transfer Station under the Condition of Fire [J], Journal of Safety and Environment，2018,18(04):1419-1426.
[6] Dai Xiaoya. Study on the Influence of Exit Guidance on the Efficiency of Evacuation [D]. Beijing; China University of Mining and Technology,2017
[7]Fang Xiaoyu, Yang Zhenshan. Simulation Research on Emergency Evacuation of Tall Buildings Based on Pathfinder [J] Journal of Bohai University (Natural Science Edition). 2016;37(2):177-183.
[8]NELSON H，MOWRER F. Emergency movement,the SFPE hand-book of fire protection engineering(3rd edition) ［M］. Bethesda: Society of Fire Protection Engineers,2002
[9] ZHAO Zhe, CHEN Qingguang, WANG Hairong, et al. An emergency induced evacuation of public gathering places based on Pathfinder [J]. Fire Science and Technology, 2013 (12):1327-1330.
[10] WANG Jing, WANG Wei, KE Qicai, et al. Research on Simulation of Staff Evacuation in a University Library Based on Pathfinder [J]. Security Technology,2011(6):3-11.
[11]Urban rail transit engineering design code: DB11/995 -- 2013[S]. Beijing: Beijing Urban and Rural Planning Standardization Office,2013.