Analysis and Simulation Optimization of Passenger Flow in Urban Rail Transit Station

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ABSTRACT

To alleviate the congestion of the passenger flow in the station, improve the passenger service level of the urban rail transit station. Based on the characteristics of passenger mustering and evacuation, this paper establishes a passenger traffic behavior model based on social forces to discover key bottlenecks in passenger flow. At the same time, a set of urban rail transit station passenger distribution capacity mustering and evacuation systems is proposed to evaluate and optimize its traffic flow. Taking the morning peak at the Gangding rail station in Guangzhou as an example, Massmotion software was used for simulation modeling to determine the bottleneck points that affect the distribution of passenger flow, and targeted countermeasures were put forward. The simulation results show that the cost of pedestrian queuing time has been reduced by 35.44% after optimization, and the local congestion index at the concourse and platform levels has been reduced by 16.06% and 25.66%, respectively. The simulation of passenger mustering and evacuation behavior provides a targeted and systematic research idea for alleviating the congestion of passenger flow in the station and improving the service level of passengers.
Keywords: traffic engineering, analysis of mustering and evacuation behavior, pedestrian simulation, social force model, traffic flow evaluation

1. INTRODUCTION

With the rapid development of the country's urban rail transit construction, the unreasonable layout of various facilities and pedestrian flow lines in the station can easily lead to low pedestrian collection and distribution efficiency, which leads to congestion. It has become a major bottleneck restricting the passenger service capacity of urban rail transit stations[1]. The traditional pedestrian modeling theory is difficult to dig into the mustering and evacuation behavior of passengers in the station in a precise and in-depth manner, and it cannot reflect the interaction between the station facility environment and the pedestrian movement. Therefore, it is difficult to quantitatively evaluate the implementation effect of the optimization plan of the urban rail transit station. Therefore, how to simulate and analyze the peak passenger flow in the station according to the characteristics of passenger mustering and evacuation, discover the key bottlenecks restricting the mustering and evacuation of passengers and propose countermeasures, is a major hot issue that needs to be solved urgently.

Classical pedestrian modeling theory research can be divided into three categories: macro level[2], medium level[3], and micro-level. Due to the semi-closed and high-density characteristics of rail transit station scenes, the macro and medium level models are difficult to reflect the complex and changeable behavior of pedestrians. At the same time, it also ignores the interaction between traffic scenes and pedestrian behavior[4]. Compared with these methods, micro-models can better reflect the interaction between service facilities and pedestrian distribution behaviors based on analyzing the intersection characteristics and channelization of pedestrian flows. It is a commonly used solution at present. Cellular automata theory and gravity theory were first used to model pedestrian behavior. Li et al.[5] studied the evacuation behavior of pedestrians based on the cellular automata model, and simulated them with MATLAB software. He, therefore, discovered the mechanism of the influence of walking speed and exit width on pedestrian evacuation time. Okazaki[6] proposed a gravitational model, which decomposes the complex individual motions of pedestrians into multiple simple charge motions based on the influence of the station object on pedestrian walking. The destination is set to a negative charge, and the pedestrian itself and obstacles are set to a positive charge. The pedestrian movement model is established based on the principle of "same-sex repulsive, opposite-sex attracts". However, the above-mentioned research cannot reflect the

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interweaving behavior of pedestrians, so the simulation results often deviate from the pedestrian behavior in the actual scene. To overcome the above difficulties, the concept of queuing network model was proposed, and many scholars started a new round of research. Yin[7] used the queuing network model to conduct a simulation study on the pedestrian ticket purchase business at the station. By constraining the threshold time and the maximum number of service windows, he explored the interaction between passenger waiting time and the number of windows. Although the queuing network model reflects the interaction between pedestrians, its use of the "first in, first out" evacuation strategy is prone to low simulation accuracy. The social force model and the agent model bring new solutions to this problem. Wang[8] analyzed the influence of the channel attributes in the station on the evacuation behavior of pedestrians through the Agent model and used the NetLogo simulation platform to study the movement of one-way and two-way pedestrian flows in the channel. Because the realization of the Agent model requires the setting of complex parameters, the simulation is more difficult, and the actual application requirements are higher, so the social force model is often used as the theoretical basis of pedestrian behavior modeling.

Current researches mostly use the analysis of passengers' characteristics to construct social force models, and there is little research on the interaction between the layout of station facilities and the behavior of pedestrians. To this end, this paper analyzes the characteristics of passenger mustering and evacuation behavior in urban rail transit stations, based on the social force model, and uses Massmotion software for simulation modeling. By proposing a passenger mustering and evacuation level evaluation system, a comprehensive assessment of the passenger flow in the station is carried out, thereby determining the bottleneck points and conflict points of the passenger flow in the station, and finally proposing countermeasures.

2. ANALYSIS OF THE CHARACTERISTICS OF PASSENGER MUSTERING AND EVACUATION BEHAVIOR

2.1 Passenger traffic characteristics analysis

Passenger traffic characteristics include macro characteristics and micro characteristics. Many scholars have conducted extensive research[9][10] on it, and the traffic characteristics of passengers in the urban rail transit stations have their characteristics in addition to the basic characteristics of ordinary pedestrians. Mainly reflected as follows:

(1) The route that passengers walk in the station is more complicated, and the tolerance time is longer. At the same time, its travel activities are diversified, usually consisting of multiple micro behaviors (moving, waiting, queuing, etc.) and a large number of potential non-traffic behaviors (buying tickets, security checks, inquiries, etc.).

(2) Passengers are susceptible to the location and size of the guidance signs, and the timeliness of broadcast notifications. The more reasonable the design of the directional logo, the more timely the broadcast notification, the faster the passengers can muster and evacuate in the station.

(3) Pedestrians in the station will speed up their walking speed due to the arrival of the train, and the walking speed of passengers who have not boarded the train will decrease and tend to be flat after the train departs. This situation will be repeated when the next train arrives at the station.

(4) Group is widespread in rail transit stations, and the average walking speed of the group decreases with the increase of the group size. Therefore, when the station is in a high-density state, large-scale groups will greatly affect the overall distribution speed of the station passenger flow.

(5) Due to the diversity of travel purposes, long-distance passengers usually carry medium and large pieces of luggage when they take the rail transit system. The size, weight, and quantity of luggage will affect the space requirements and walking speed of passengers when they are walking.

2.2 mustering and evacuation characteristics of arriving passengers

The essence of the urban rail transit station arrival passenger flow distribution is the accumulation of a large number of passenger behaviors in a short period. Compared with passenger traffic behavior in other environments, the arriving passenger flow in the urban rail transit stations has the following characteristics:

(1) Uneven distribution of passenger flow in time and space

The time distribution of passenger flow is mainly affected by the train timetable, showing strong volatility. When the vehicle arrived at the platform, a large number of short-term passengers appeared in a concentrated manner; when the vehicle left the platform, no new passenger flow arrived at the station within the interval. In terms of space, passenger flow is mainly affected by the layout of station facilities and equipment. It is easier for people to muster in functional areas such as entrances and exits, ticket sales, security checks, elevators, etc., which are mainly distributed in stripes or dots.

（2） Passenger flow is uncertain

Passenger distribution lines are not only affected by the layout of station facilities and equipment, but also by other passenger behavior characteristics. Due to the limited equipment service capabilities of the front, when crowds are congested, passengers will change the original flow line to find a faster and more comfortable route.

（3） Passenger behavior is restrictive

Due to the corresponding service equipment and related control measures in the station, passengers are not free to walk in the station. They are restricted by passages and facilities, and their routes are somewhat restrictive. At the same time, the direction of the passenger mustering and evacuation flow line is mainly affected by the line guidance facilities in the station.

3. PASSENGER TRAFFIC BEHAVIOR MODELING AND EVALUATION SYSTEM ESTABLISHMENT

3.1 Passenger traffic behavior modeling based on social forces

3.1.1 Basic principles of the model

The social force model is a microscopic simulation model that is based on Newtonian mechanics and uses social force ideas to study the rules of pedestrian walking. It believes that pedestrian walking is the result of a combination of driving force generated by itself, the repulsive force between pedestrians, the repulsive force between pedestrians and obstacles, and attraction generated by pedestrians and the external environment[10]. The speed and acceleration of pedestrians are calculated by Newton's second law, and then the movement displacement of pedestrians is obtained. The specific formula is as follows:

（1） Pedestrian's driving force

Assume that pedestrian α moves from $\bar{r}_\alpha^1$ to destination $\bar{r}_\alpha^0$, via $\bar{r}_\alpha^2, \bar{r}_\alpha^3 \cdots \bar{r}_\alpha^n$ and so on. At moments t and $t+1$, pedestrian α is located at $\bar{r}_\alpha(t)$ and $\bar{r}_\alpha(t+1)$ respectively. Therefore, the walking direction of pedestrians at a time t can be expressed as:

$$\bar{e}_\alpha(t) = \frac{\bar{r}_\alpha(t+1) - \bar{r}_\alpha(t)}{\left\| \bar{r}_\alpha(t+1) - \bar{r}_\alpha(t) \right\|} \tag{1}$$

When the pedestrian's expected speed is ω_0 and the actual speed is $\bar{v}_\alpha$, the pedestrian's own driving force can be expressed as:

$$\bar{F}_\alpha(\bar{v}_\alpha, \omega_\alpha \bar{e}_\alpha) = \frac{1}{\tau}(\omega_\alpha \bar{e}_\alpha - \bar{v}_\alpha) \tag{2}$$

Where τ represents the time required for pedestrians to accelerate from the actual speed to the desired speed, also known as the relaxation time.

（2） Pedestrian repulsion

The pedestrian α and another pedestrian β maintain a certain distance $\bar{r}_{\alpha\beta}$. Under the effect of field strength, the repulsive force between pedestrians can be expressed as:

$$\bar{f}_{\alpha\beta}(\bar{r}_{\alpha\beta}) = -\nabla_{\bar{r}_{\alpha\beta}} V_{\alpha\beta}[b(\bar{r}_{\alpha\beta})] \tag{3}$$

Where b represents the short axis distance of the ellipsoid in the pedestrian model and $V_{\alpha\beta}$ represents the field strength function.

（3） The repulsive force between pedestrians and obstacles

A certain distance $\bar{r}_{\alpha\beta}$ is maintained between the pedestrian α and the obstacle B. The repulsive force between the pedestrian and the obstacle can be calculated as:

$$\bar{f}_{\alpha B}(\bar{r}_{\alpha B}) = -\nabla_{\bar{r}_{\alpha B}} U_{\alpha B}[\|\bar{r}_{\alpha B}\|] \tag{4}$$

(4) Attractiveness between pedestrians and the external environment

For example, pedestrians encounter shops, newsstands, etc. while walking. This attraction can be calculated as:

$$\bar{f}_{\alpha i}(\|\bar{r}_{\alpha i}\|, t) = -\nabla_{\bar{r}_{\alpha i}} W_{\alpha i}(\|\bar{r}_{\alpha i}\|, t) \tag{5}$$

Therefore, the social force $\bar{F}_{\alpha}(t)$ experienced by a pedestrian α at t moments in the walking process can be expressed as:

$$\bar{F}_{\alpha}(t) = \bar{F}_{\alpha}(\bar{v}_{\alpha}, \omega_{\alpha} e_{\alpha}) + \sum \bar{f}_{\alpha\beta}(\bar{r}_{\alpha\beta}) + \sum \bar{f}_{\alpha B}(\bar{r}_{\alpha B}) + \sum \bar{f}_{\alpha i}(\bar{r}_{\alpha i}, t) \tag{6}$$

Most of the parameters in the social force model can be measured according to the actual physical meaning. Since the repulsive force generally decreases to zero as the distance increases, the field strength function is generally calculated using an exponential equation. The basic attributes of passengers' walking and special parameters such as reaction time are calibrated as follows.

3.1.2 Parameter calibration

(1) Expected walking speed

Due to the complex composition of passenger groups in urban rail transit stations, walking speed is affected by many factors such as age and gender. Moreover, it has a large variation range, so it is difficult to use the 1.52 m/s general expected speed standard. To reflect the expected speed of passengers in the station more objectively, this paper uses discrete distribution to define the expected speed range and value probability. In the simulation, the expected speed value can be randomly generated for each passenger to reflect their different physiological characteristics.

$$E(x) = x_1 p_1 + \sum((x_i - x_{i-1}) p_i) \tag{7}$$

Where x_i is all possible values of the expected speed, and p_i is the probability value corresponding to the expected speed.

(2) Static space requirement

In the simulation model, the pedestrian is usually regarded as a sphere, and the thickness of the front and back chest or the width of the two shoulders of the pedestrian is taken as the radius of the sphere. With reference to the research of Hoogendoorn et al.[11], this article assumes that the static space demand occupied by the passenger's body obeys a uniform distribution of (0.4, 0.6).

(3) reaction time

Pedestrians generally respond to simple or complex decisions after being stimulated by the outside world, and the reaction time of different decisions varies. Since pedestrians in rail transit stations are stimulated and usually only need to make simple decisions, this paper takes the reaction time as 0.5 s.

3.2 Passenger mustering and evacuation capability evaluation system

To observe the movement of pedestrians in the station more clearly and intuitively, this paper proposes an evaluation system for the passenger mustering and evacuation capacity of urban rail transit stations. It can comprehensively consider qualitatively and quantitatively the efficiency of passengers in the station. In terms of qualitative aspects, by viewing the pedestrian density images and comparing the density changes at different simulation moments to determine whether pedestrian delays and congestion occur, to intuitively discover the time and location of potential bottlenecks and streamline conflict points in the station. In terms of quantification, not only indicators such as pedestrian walking speed and queuing time are used to evaluate the overall congestion level of the station, but also to identify the movement status of passengers. In addition, the pedestrian intertwined area and local congestion index are used in the local space to evaluate the rationality of the layout of service facilities. Figure 1 shows the framework of the evaluation system.

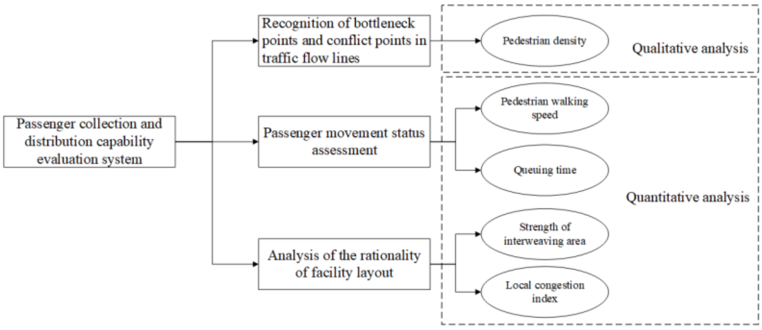


Fig. 1 Framework diagram of passenger mustering and evacuation behavior evaluation system

3.2.1 Pedestrian interweaving area

The urban rail transit station is a semi-enclosed, high-density place. Passengers are greatly affected by the layout of station facilities and equipment, and internal passenger evacuation routes are relatively fixed. Therefore, it is easy to form a clear mustering and evacuation streamline. During peak passenger flow, pedestrian groups in different directions are prone to cross each other at different angles and then leave in a predetermined direction. The intersecting area is called the pedestrian interweaving area[12]. The speed and direction of the interweaving passenger flow will change greatly due to the pedestrian interweaving area. Therefore, for passengers to quickly complete the mustering and evacuation behavior in the station, it is necessary to minimize the number of pedestrian interlaced areas that seriously interfere with the main flow of people.

To find and evaluate the potential pedestrian interweaving area in the station, this paper adopts the main flow velocity in the interweaving area as the evaluation index. The improved Drake model can be used to calculate the main flow velocity in the interweaving area. The formula[13] is shown below.

$$v_r = v_f \exp[-\theta_r(\rho_r + \rho_c)^2]\exp[-\theta_c(1-\cos\varphi)\rho_c{}^2] \tag{8}$$

Where v_r is the main flow speed; v_f is the unobstructed speed; ρ_r is the main flow density; ρ_c is the interference flow density; θ_r is the main flow sensitivity coefficient; θ_c is the interference flow sensitivity coefficient; φ is the interweaving angle.

According to the standard of pedestrian service level, when the pedestrian walking speed of the main pedestrian line in the interphase line drops below 0.8 m/s, the passenger flow in this area is prone to conflict and stagnation, which may affect the passing efficiency of passengers in the station. At this time, the main pedestrian flow is more severely affected by the interference flow, and the pedestrian interlaced area needs to be optimized and improved.

3.2.2 Local congestion index

When the pedestrian flow of various service facilities exceeds their service capacity, passenger congestion will occur in the service area. However, through actual investigations, it is found that congestion often occurs in some facilities. The traditional evaluation index using the average density of people flow can only express the overall congestion degree of the station. To better reflect the congestion situation in the station, this paper adopts the local congestion index to evaluate the congestion phenomenon. The local congestion index is not only related to the area and the number of pedestrians but also depends on the distribution of pedestrians in the movement space. The calculation formula[14] is as follows.

$$\xi = sqr(\sum_{k=1}^{t}\sum_{i=1}^{m}(n_{ik}/s)^2/tm) \tag{9}$$

Where n_{ik} is the number of passengers in the i area in the k control period; s is the area of the area; t is the total number of control periods; m is the total number of unit areas.

4. CASE ANALYSIS

4.1 Data collection and simulation scene construction

This paper takes Guangzhou Gangding Urban Rail Transit Station as an example research object and conducts a field investigation on the facilities at the hall floor and platform floor and the passenger flow during the morning rush hour

(7:45-9:00) on Tuesday. The field survey data included 173 sets of pedestrian speed data, 56 sets of automatic ticket vending machine service time data, 200 sets of pedestrian entry and exit gate time data, and pedestrian entry and exit traffic data at 20-minute intervals. According to Zhang's [15] research on the temporal and spatial evolution of passenger flow in rail transit stations, it can be seen that the time-varying coefficient of passenger flow in stations throughout the working day changes greatly, and the changes in holidays are small. The research shows that compared with holidays, the morning and evening peaks of passenger flow are more obvious on working days in the same week, and the distribution of passenger flow is similar in time and space. Therefore, this paper collects the single-day morning peak passenger flow for station simulation.

The simulation first obtains the dimensions of the internal parts of the rail transit station (such as the length and width of the station, the area of the ticket area, etc.), the number of facilities and the arrangement of the facilities, and draws the plane layout of the station. Secondly, select the video collection method to collect data such as the number of passengers at each entrance and exit, the length of ticket purchase security check service, and pedestrian walking speed. The result of the acquisition part is shown in Fig. 2 and the simulation result is shown in Fig. 3.

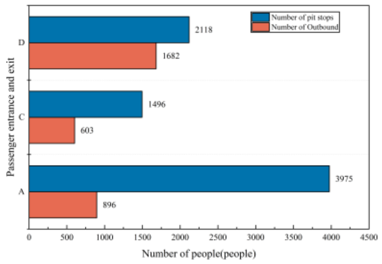


Fig. 2 Passenger flow in Gangding station and the proportion of tickets purchased

Fig. 3 Comparison of the simulated scene and the actual scene

As can be seen from the above figure, the passenger flow at Gangding Station during the morning rush hour mainly enters from entrance D and exits from exit A, and the proportion of ticket purchases from self-service ticket machines is relatively low. This is mainly because entrance A of Gangding Station is close to modern department stores, Tianyu Plaza, and other commercial areas, and entrance D is close to residential areas such as South China Normal University, Jinan University, and the Third Hospital of Sun Yat-Sen University. In the morning rush hour, residents mainly take the subway from the living area to the company to go to work, while store employees take the subway to work in the mall, which caused a lot of passenger flow in entrance D and more passenger flows out of exit A. The low proportion of self-service ticket purchases is due to the convenience of electronic payment in Guangzhou Metro. Most passengers use WeChat mini-programs, APPs, etc. to scan through the gates, while the elderly or tourists mainly purchase tickets through self-service.

According to the statistical analysis of collected data, the walking speed of adults is 1.28 m/s -1.84 m/s, the walking speed of the elderly is lower than that of adults, and the walking speed of children is more random. The average travel speed of men is 1.54 m/s, while that of women is 1.37 m/s. The service time of entrance and exit gates and self-service ticket vending machines obey the normal distribution of (1.58, 6.06) and (23.62, 33.81) respectively, and the mathematical expectation is 2.94 and 26.13. The rest of the simulation basic parameter settings are shown in Table 1.

Table 1 Simulation parameter setting

Scene elements	**Parameter name**	**Assignment**	**Parameter name**	**Assignment**
Ticket sales	Capacity limit	1	Service times	Normal (00:00:24,00:00:34)
Security check	Capacity limit	1	Service times	Normal (00:00:10,00:00:30)
Passengers pitting	Capacity limit	1	Service times	Normal (00:00:02,00:00:06)
Buy tickets	Probability of online ticket collection	Uniform (0.9,0.95)	Probability of on-site ticket purchase	Uniform (0.05,0.1)
Train in and out of the station	waiting time	Uniform(00:00:20,00:00:30)	Vehicle capacity limit	150*6

4.2 Simulation model check

The circulation in the station is more complicated, and the pedestrian movement is unpredictable. Therefore, real data is used to further verify the simulation model. Compare the simulated passenger flow with the actual passenger flow. The software's statistical module is used to collect 20-minute pedestrian flow data on escalators, stairs, and entrances and exits. The comparison result is shown in Figure 4 below.

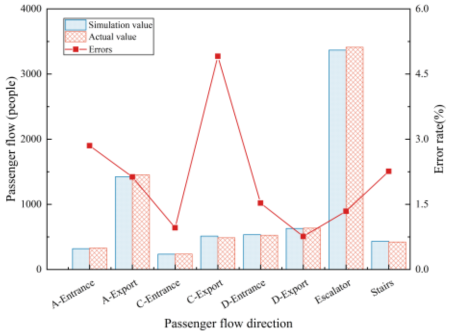


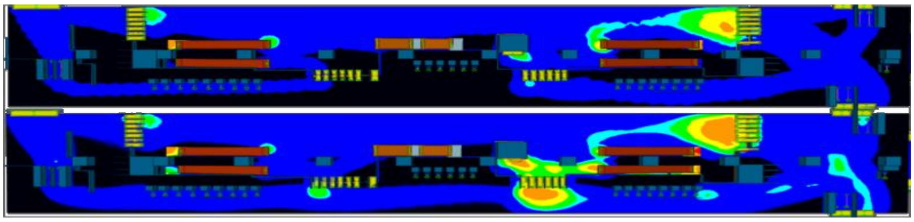
Fig. 4 Simulation error of each passenger flow direction

It can be seen from the above model verification that the error of passenger flow in and out of the station is kept below 5%. Therefore, the established pedestrian flow simulation model based on social forces is feasible for the analysis of passenger flow mustering and evacuation in rail transit stations.

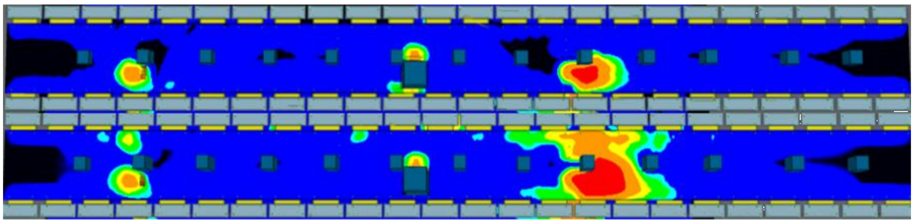
4.3 Simulation result analysis

4.3.1 Qualitative analysis of in-site service capabilities

Simulate the Gangding rail transit station in Guangzhou. The simulated pedestrian flow density of 2 min and 20 min at the concourse and platform levels is shown in Figure 5 (the former is the 2 min scenario and the latter is the 20 min scenario). It can be seen from Fig. 5 that after 20 minutes of simulation, the pedestrian density on the east side of the station hall floor and the east side of the platform floor escalator is higher. This shows that the service capacity of the facilities in this area can no longer meet the needs of pedestrian flow, and the station is in a state of a high density of pedestrian flow. It needs to further optimize the flow of traffic organization and the layout of facilities and equipment.



(a) The hall floor



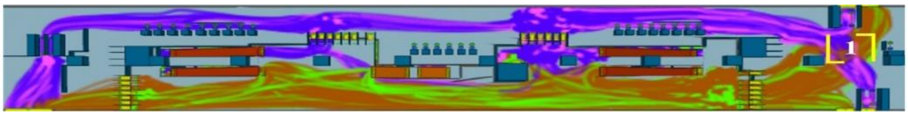
(b) The platform level

Fig. 5 Pedestrian density map of Gangding Subway Station 2min and 20min

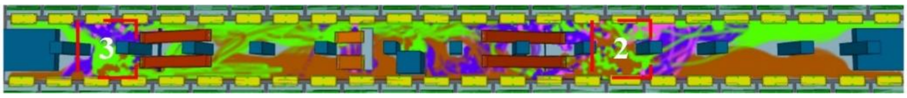
With the passage of simulation time, the pedestrian density and queuing time at the exit gate on the east side of the hall floor gradually increase, while the walking speed of pedestrians in the station decreases. When the simulation runs to 20 minutes, the average walking speed of pedestrians entering the station is 1.37 m/s, and the average queuing time is 1.88 minutes. At the same time, the walking speed out of the station is 1.35 m/s, and the queuing time is 2.37 min.

4.3.2 Determine the pedestrian crossing area

During the peak period, a large number of passengers at various entrances and exits have gathered and dispersed, causing multiple passenger flow lines to cross and interfere with each other. It can be seen from Figure 6 that there are 3 crowded areas in Gangding Station. Through the calculation of the improved Drake model, it is found that the host flow velocity in two interweaving areas is lower than 0.8 m/s. It shows that there is serious interference in the flow of people and needs to be optimized and improved. The relevant data is shown in Figure 7.

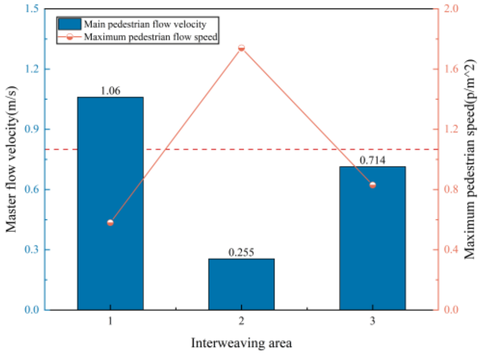


(a) The hall floor

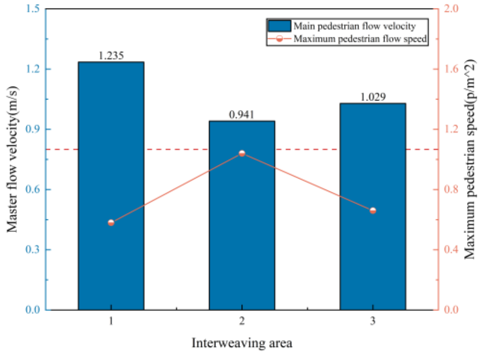


(b) The platform level

Fig. 6 Pedestrian streamline map of Gangding subway station



(a) Before optimization



(b) Optimized

Fig. 7 Optimized speed of human flow interweaving area

4.4 Optimization and improvement of traffic organization

Generally speaking, the optimization of traffic organization mainly optimizes the pedestrian flow line by adjusting the location and number of facilities in the station. The former reduces or eliminates pedestrian flow line conflict points by changing the location of facilities, reduces pedestrian density, and enables an orderly mustering and evacuation of passenger flow. The latter breaks through the bottleneck of the flow line by changing the number of facilities balance the utilization of facilities and accelerate the speed of passenger flow.

4.4.1 Optimization and improvement plan

Through simulation, it is found that in terms of equipment, the service capacity of the escalator on the east side of the rail transit station cannot meet the needs of passengers, and it is difficult for pedestrians to evacuate quickly. In terms of streamlines, the inbound streamlines of A/D on the platform layer and the up and down escalator streamlines on the hall floor are intertwined, which reduces the efficiency of passenger mustering and evacuation. By adjusting the location and quantity of station facilities, the following improvement plans are proposed:

(1) Expand the paid area on the south side of the station hall floor. Two additional escalators are installed at the escalator to increase the carrying capacity of the platform's exit escalator and increase the speed of pedestrians exiting the station. At the same time, a fence is set up at the exit of the escalator to guide pedestrians at the A/D entrance and exit, and eliminate the conflicting points of the flow lines in the paid area of the station.

(2) Move the self-service ticket vending machine on the east side of the station hall floor east to the wall. Avoid intertwining the flow of pedestrians entering the station and pedestrians purchasing tickets, affecting the speed of entering the station.

(3) Move the inbound gate on the east side of the hall floor to the south side. At the same time, part of the gates will be transformed into gates to enhance the exit capability of the A/D gates.

(4) Move the A/D entrance security inspection equipment to each channel. Reduce the intersection of the flow of people in the security queue at the station hall level and the flow of people out of the station.

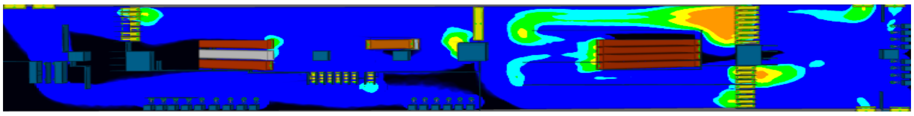
4.4.2 Comparison and analysis of simulation results of improved schemes

(1) Analysis of Pedestrian Density in Subway Station

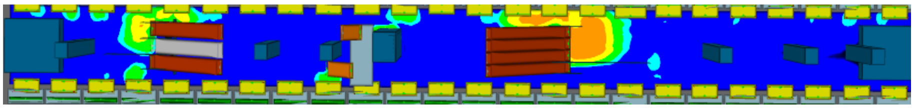
It can be seen by comparing the pedestrian density before and after optimization. The overall pedestrian density has been reduced, and the number of high-density areas has been reduced compared to before. Among them, the congested area at the exit of the station hall floor has reduced the pedestrian density by queuing extension. Eliminate high-density areas at the platform level escalators. This shows the effectiveness of the optimization measures. The details are shown in Figure 8.

(2) Analysis of the movement in the pedestrian station

After the optimization, the speed of pedestrians entering and leaving the station has been improved, and the pedestrian queuing time for entering the station has been extended to 1.96 min, which is 4.3% longer than before the optimization. The outbound pedestrian queuing time is shortened to 1.53 min, which is 35.44% shorter than before. This is because the number of pedestrian exits at the station during peak hours is much greater than the import volume. Therefore, by changing the layout of entrances and exits, setting guardrails to guide pedestrians, eliminating the intersection of flow lines, so that the time in the station for exiting pedestrians is greatly reduced, and the overall travel time cost of passengers is significantly reduced.



(a) The hall floor



(b) The platform level

Fig. 8 Optimized post-site pedestrian density map

(3) Analysis of facilities and equipment layout

As shown in Figure 7(b), the interweaving area of the flow of people is significantly reduced, and the degree of interweaving is greatly reduced. Calculating the speed of the main passenger flow in the interweaving area again, it is found that the two conflicting points have disappeared. It shows that the interference flow in the interweaving area has a limited impact on the master flow, and the walking speed of the master flow is greatly increased. At the same time, the local congestion index at the station hall level dropped from 0.355 to 0.298, and the platform level dropped from 1.068 to 0.794. The two were reduced by 16.06% and 25.66% respectively compared with before optimization.

On the south side of the station hall floor, isolation facilities are added at the up and down escalators. It helps to eliminate the mutual interference of opposing people and speed up the walking speed of passengers. The A/D entrance and exit security inspection equipment is moved to the passage, which reduces the intersection of the flow of people in the security queue and the flow of people in the station, and improves the passage efficiency of passengers in the station.

The analysis of quantitative indicators before and after optimization shows that the local congestion of the station has been significantly improved. The conflict points are completely dissipated, and facility utilization is more balanced. Pedestrian circulation in all entrances and exits is reduced, and passenger queuing and walking time is shortened. Pedestrian circulation and facility layout tend to be rationalized.

5. CONCLUSION

Based on the analysis of the characteristics of passenger mustering and evacuation, this paper reproduces and simulates the distribution of pedestrian activities in the station by establishing a model of passenger traffic behavior based on social forces. At the same time, this paper proposes a set of evaluation systems for the passenger distribution capacity of urban rail transit stations to evaluate and optimize its traffic flow. At the same time, taking the morning peak of the Gangding rail transit station in Guangzhou as an example, the simulation modeling was carried out by using Massmotion software. Through the comprehensive qualitative and quantitative analysis of the evaluation system, the bottleneck points and conflict points affecting the passenger flow distribution at Gangding Station are determined. Finally, targeted optimization measures are proposed. The simulation results show that the cost of pedestrian queuing time has been reduced by 35.44% after optimization, and the local congestion index at the concourse and platform levels has been reduced by 16.06% and 25.66%, respectively. The simulation of passenger mustering and evacuation behavior provides a targeted and systematic research idea for alleviating the congestion of passenger flow in the station and improving the service level of passengers.

However, the characteristics of passenger mustering and evacuation behavior are uneven in time and space. In this paper, the simulation analysis of passenger flow in the station during the morning rush hour only illustrates the effectiveness of the research method in simulating the passenger gathering and dispersing behavior in the station in local time and space. However, this method may have some deviations in the study of global time and space. Therefore, in the follow-up research, we will conduct further analysis on the collection and distribution behavior of passenger flow in the station during the evening peak and peace peak periods.

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