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Optimization and evaluation of rail transit station hall based on Any Logic

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ABSTRACT: In recent years, China's urbanization development process is constantly accelerating, along with the acceleration of the urbanization process and the continuous expansion of population scale, public transportation system, especially rail transit system, plays a more and more important role in all cities in our country. As an important node of passenger travel, the rationality of rail transit station layout directly affects the passenger's travel experience, the transfer efficiency and the operating efficiency of the entire public transit system. AnyLogic software is used to simulate and analyze the situation of Xiaolingwei subway station of Nanjing Railway Line 2. This study first analyzes the current status and existing problems of the layout of rail transit stations, and then uses AnvLogic simulation software to build a model of the layout of rail transit stations. Through simulation experiment and analysis of the model, based on the results of simulated passenger flow density, the optimization scheme of the station hall layout design and the improvement effect of the optimization scheme on the station congestion and passenger smooth condition were proposed. The results show that the proposed optimization scheme can effectively improve the passenger travel experience, relieve the congestion in the station, improve the operating efficiency of the public transport system, save resources and reduce costs. This study provides beneficial theoretical and practical enlightenment for the optimization of rail transit station layout in China.

Key words: Station hall; Rail taffic; Relieve traffic; AnyLogic emulation

INTRODUCTION

The structure and equipment layout of urban rail transit station hall have a significant impact on passenger flow crossing and traffic efficiency, which directly relates to passenger travel experience and the overall service quality of rail transit. With the acceleration of urbanization, subway as an efficient and convenient means of public transport, its passenger flow continues to grow. However, many early rail transit stations are faced with many challenges due to the limitations of design concept, construction conditions and planning cycle. These old stations usually have problems such as insufficient hall area, serious cross passenger flow and congestion when entering and leaving the station and transferring. These factors not only affect the travel efficiency of passengers, but also cause pressure on subway operation. In the modern society, passengers' expectation of subway service quality is increasing, especially in the rush hour, the congestion degree of the station hall has become one of the important standards to measure the service quality. The research shows that people's walking behavior in the station is significantly affected by the physical properties and layout design of the facility. Therefore, optimizing the station layout to effectively alleviate the congestion of old stations has become an important issue to be solved.

At present, the research on the layout of subway hall facilities at home and abroad mainly focuses on transfer facilities, passages, stairs and platforms. Researchers usually use the method of model construction and simulation analysis to discuss how to improve the efficiency of station operation. For example, based on the social force model, Fu Zhiyan and other scholars used Anylogic software to simulate and analyze the process of passengers' agglomeration and dispersion in the station. They focused on assessing the population density and flow intensity in major areas to identify system bottlenecks and make corresponding improvement suggestions. This method can not only visually show passenger behavior, but also provide data support for subsequent design. On the other hand, Fei Shuang et al. took passenger flow density as an evaluation index, identified transfer congestion points through simulation analysis, and proposed flow limiting measures and facility renovation plans to achieve optimization. In addition, Li Zhijuan used Anylogic to evaluate the efficiency and evacuation capacity of different channel facilities, and conducted an in-depth analysis of passenger flow characteristics in urban rail transit channels. Through the comparison of different design schemes, she provides an important basis for improving the efficiency of channel use. At the same time, based on the social force model, Yang Senyan and other scholars also studied different isolation setting conditions through simulation, so as to improve the effect of passenger flow organization in subway channels, so as to reduce congestion. Based on AnyLogic simulation software, this paper builds the station hall structure model of Xiaolingwei Station of Line 2 and optimizes and evaluates the design of rail transit station hall based on AnyLogic, which can simulate the passenger flow distribution, passenger walking path and transfer time under different design schemes. By comparing the relevant information of station passenger density and streamline before and after the optimization, the station congestion situation before and after the renovation is evaluated. The continuous optimization of station hall design can provide strong support for the development of China's rail transit industry and promote the sustainable development of urban transportation industry.

1 basic information

Xiaolingwei Station is located on Nanjing Metro Line 2 and is divided into the first and second floors. The station covers a total area of 11,330 square meters and is equipped with 3 entrances and exits. The platform level has 3 entrances and exits, 8 inbound gates, 5 eastern exit gates and 5 western exit gates. The layout of Xiaolingwei subway station is shown in Figure 1.

Xiaolingwei subway station is located in Xiaoling Scenic spot, Xuanwu District, Nanjing, near the Ming Xiaoling Mausoleum, Meihua Mountain, Purple Mountain and other scenic spots. The station is a transfer station between Nanjing Metro Line 2 and Nanjing Metro Line 10, Line 2 runs north-south and Line 10 runs east-west. Therefore, Xiaolingwei subway Station has become an important transportation hub connecting the east, west and north of Nanjing. There are complete supporting facilities around Xiaolingwei subway station, including commercial, residential, school, medical institutions and so on. Nearby are mainly Nanjing University of Science and Technology, Nanjing Agricultural University and other universities, as well as Zhongshan Scenic spot, Ming Xiaoling Mausoleum scenic spot and other tourist attractions. In addition, there are several bus stops near the Xiaolingwei subway station, which make it easy for passengers to transfer buses to other areas of Nanjing. In the vicinity of Xiaolingwei subway station, there are a number of historical and cultural sites, such as Ming Xiaoling Mausoleum, Guishan Hall, and Eight character Mountain Park. These attractions attract a large number of tourists, making the subway station an important tourist

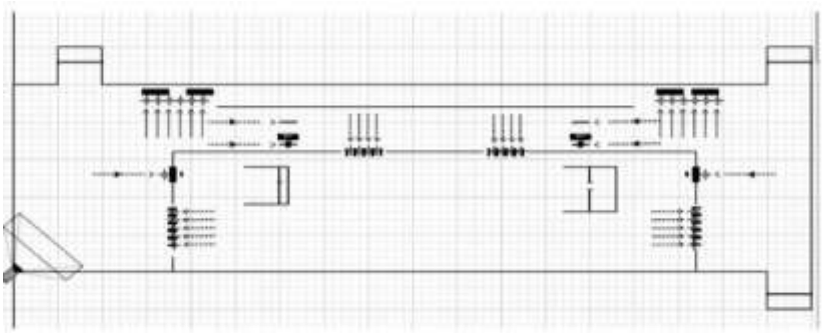

Fig. 1 Layout of the original facilities of Xiaolingwei subway station

2 Xiaolingwei subway station hall floor modeling

2.1 environment modeling

In the simulation modeling area, we create detailed models for buildings, facilities, queuing areas, pedestrian rest areas, and pedestrian walking signs. In this part, we set relevant parameters to the facilities and equipment of each plate to conduct environmental modeling work, so as to show the actual scene more realistically. According to the behavior rules of passengers, we assume that pedestrians in various links such as ticket purchase, security check, exit and exit will spontaneously choose the shortest line to wait. Using the data collected from the field investigation, we can establish the distribution function of the delay time in the process of ticket purchase, security check, exit and so on. The specific parameter Settings are shown in Table 1.

Table 1 Table of environmental modeling parameters

template	Corresponding facility	name of parameter	assignment
	security inspection machine	delay time	uniform(0,2.0)*second
	gate machine	delay time	normal(0.5,2.5)*second
Ped Services	ticket vending machine	delay time	uniform(10,40)*second
	security inspection machine	queue select	Minimum queue
	gate machine	queue select	Minimum queue
	ticket vending machine	queue select	Minimum queue

2.2 Pedestrian behavior modeling

AnyLogic, pedestrians aim at individual optimality, move according to the social force model, avoid collision with other objects (or people), and make corresponding decisions to make the interaction between pedestrians and pedestrians, pedestrians and buildings. Pedestrians purchase tickets or swipe cards to enter the station. Passengers can choose to purchase different types of ticketing methods such as one-way tickets, one-day passes or monthly passes, depending on individual needs and ride frequency. Passengers can also use the transportation card or mobile payment app on their mobile phones to swipe the card to enter the station [5]. When entering the station, passengers need to place their ticket or transportation card in the sensor area of the gate and wait for the gate to open before passing through. Then passengers choose to take the elevator and escalator to enter the underground station and wait for the train according to the principle of proximity. As the number of people choosing the escalator accounts for the majority, in order to facilitate the selection of the escalator only considering pedestrians entering and leaving the station. As shown in Figures 2 and 3.

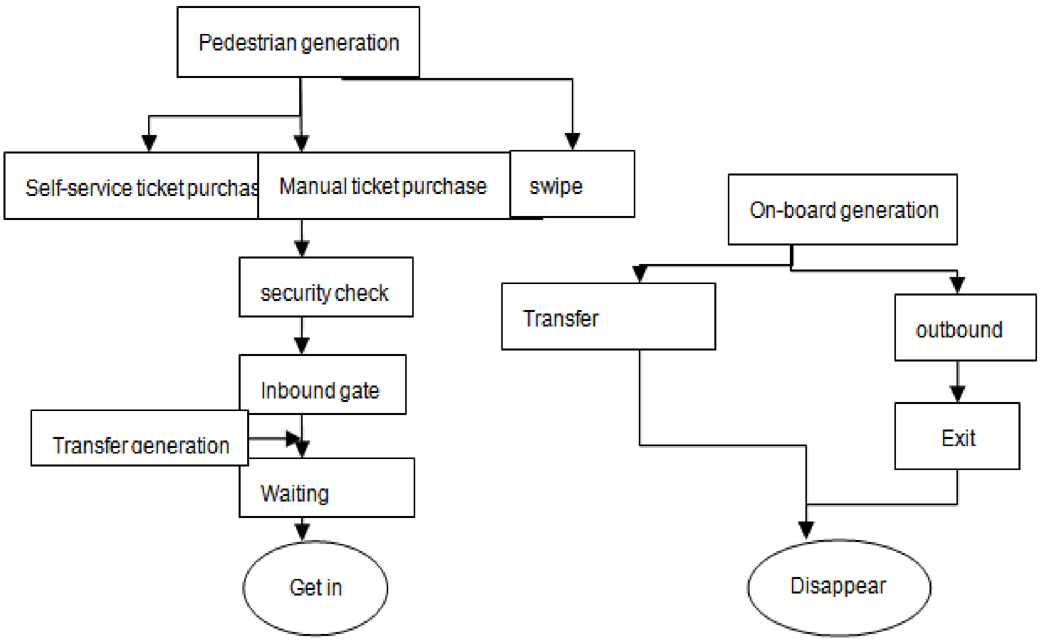

Fig. 2 Flow chart of pedestrian entry logic Fig. 3 Flow chart of pedestrian exit logic

2.3 data input

Through field investigation and data collection, the number of people at the three entrance gates from 3:00 PM to 5:00 PM and the number of people leading to the exit gates on the east and west sides are counted, as shown in Table 2.

Table 2 Table of passenger flow meter of Xiaolingwei subway station

Gate type	Daily person flow	Peak traffic
East side entrance gate	848	1158
West side entrance gate	34	65
East side exit gate	1272	1687
West side exit gate	90	162

Different travel habits lead to different consumption patterns when entering the station, thus affecting the service time of entering and leaving the gate. Generally speaking, passengers who swipe cards and take a one-time ride enter and exit the gate faster, while the speed of two-dimensional code scanning when entering the station is slower due to network and other reasons. Table 3 shows the proportion of people with different ticket purchasing methods, and Table 4 shows the service time distribution of each facility.

Table 3 Table of the proportion of people with different ticket purchasing methods

Ticket purchase method	proportion	Inbound gate service mode	service time distribution
scan QR codes	46.7%	Code sweep into station	Triangular(3,10,30)
metro card	17.3%		
Self-service ticket machines	32.4%	Swipe your card into the station	Uniform(2,3)
manual ticketing	3.6%		

Table 4 Distribution of service hours by facility

Environmental element	name of parameter	Assignment parameter
escalator	movement speed	0.6m/s
Automatic ticket machine	delay time	Triangular(12,30,190)
manual ticketing	delay time	Uniform(20,30)
security inspection machine	delay time	Uniform(12,15)

3 simulated analysis

3.1 Current situation simulation

Anylogic software takes the social force model as the modeling basis of the bottom pedestrian database, which can easily establish the evacuation model, and quickly output, statistically and comprehensively analyze the simulation results [5]. By dragging the pedestrian behavior module and connecting it to form a flow chart, it is used to determine the route, so as to simulate the evacuation process of pedestrians. According to the actual situation of the station, the following parameters are set: the security inspection facility time is 5 to 7 seconds, the check-in facility time is 2 to 4 seconds, the occupancy time of the automatic ticket machine is 10 to 15 seconds, and the manual ticket hall is 15 to 30 seconds. The figure of pedestrian density before optimization is shown in Figure 4.

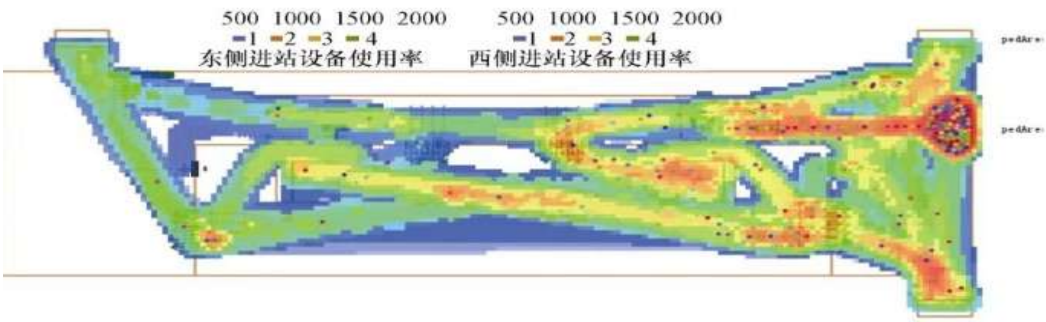

Fig. 4 Optimized pre-pedestrian density map

Based on the above and the conclusions obtained from the field investigation and combined with the above mentioned, Figure 5 was drawn and the relevant parameters listed in Table 5 were summarized

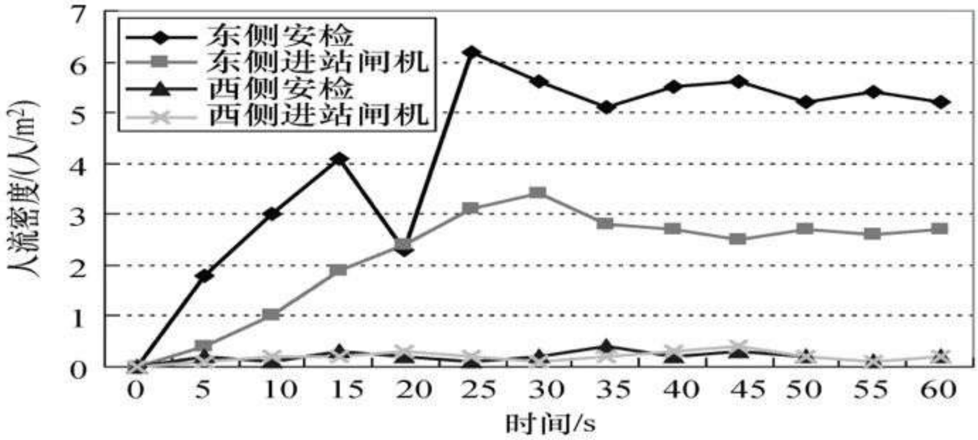

Fig. 5 Optimize the population density map of the front side entrances

Table 5 Maximum, minimum and general average walk time before optimization

Time type	entrance		
	First port	Second entrance	Exit three
Maximum average travel time	170	54	183
Minimum mean travel time	33	25	46
General walking time	118	39	127

3.2interpretation of result

3.2.1problem analysis

1)The flow line conflict point will be generated when the flow density in and out of the subway is higher, and the flow line diagram of the station passenger flow is shown in Figure 6.

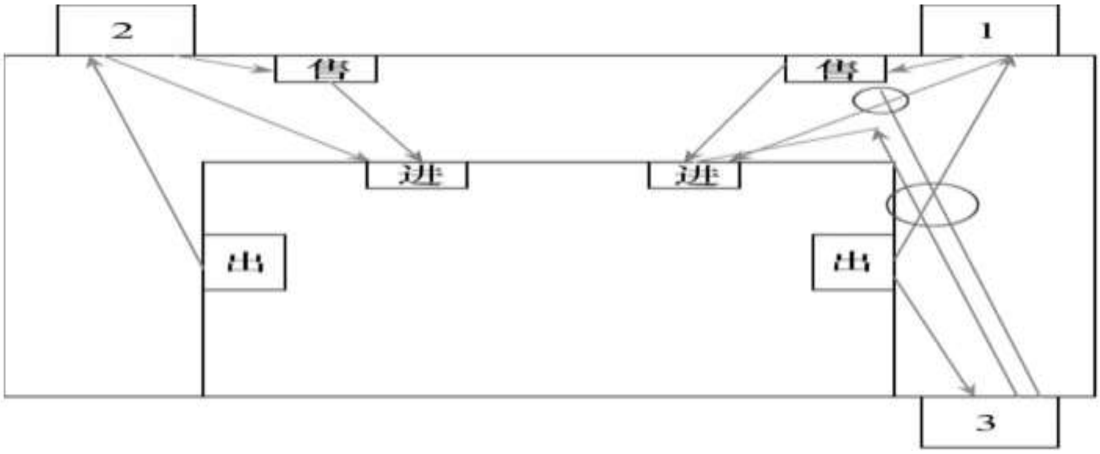

Fig. 6 Passenger flow diagram of the station

2)As can be seen from Table 2, there is an obvious imbalance in the number of people entering and leaving the station from the east side of the gate, and the number of people coming and going from the east side is significantly more than that of the west side of the gate, but the number of the east side of the gate and the ticketing equipment are consistent. On the one hand, this situation leads to excessive pressure on the east side of the gate and low utilization rate of the equipment on the west side, especially during peak hours. The number of people leaving every two minutes at the peak of the subway makes the queue problem on the east side serious, and the crowd is congested.

3)The spatial layout of the station hall has obvious regional differences. Some areas are overcrowded

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while others are relatively empty. This unbalanced layout can lead to congestion, reduced passenger comfort, and even affect safe evacuation.

4) In terms of the overall layout, the paid area has relatively small space, while the non-paid area is relatively large. In the case of a large number of transfer passengers, the space utilization rate is low, which is not conducive to the daily management of the station and may lead to uneven distribution of passenger flow, further aggravating the pressure of station management.

3.2.2modification scheme

From the above problems, the following measures are proposed:

1) Isolate the south toll booth and keep the north toll booth unchanged.

2) It is necessary to optimize the layout of subway station facilities to reduce streamline conflicts and improve operational efficiency. In the optimization scheme, the distance between the automatic ticketing system equipment and the pedestrian flow line should be fully considered to ensure sufficient space for passengers to enter and exit the station, thus reducing the possibility of passenger flow conflict. In addition, it is alsonecessary to pay attention to the flow conflicts between inbound passengers and outbound passengers at exit 1 and 3, and realize the smooth flow of passengers in and out of the station through reasonable adjustment of facility location and flow line design.

3) It can be seen from Table 2 that the balanced layout of subway station facilities is crucial. In order to solve the congestion problem on the east side, firstly, increase the number of gates on the east side to improve the traffic efficiency of the east station; Secondly, adjust the location of the ticket sales and inspection equipment to make it closer to the east station to reduce the pressure of the east station; Finally, the equipment on the west side should be reasonably adjusted to improve its utilization rate, so as to achieve the balance of the entire subway station operation. The optimized flow line of Xiaolingwei subway Station is shown in Figure 7.

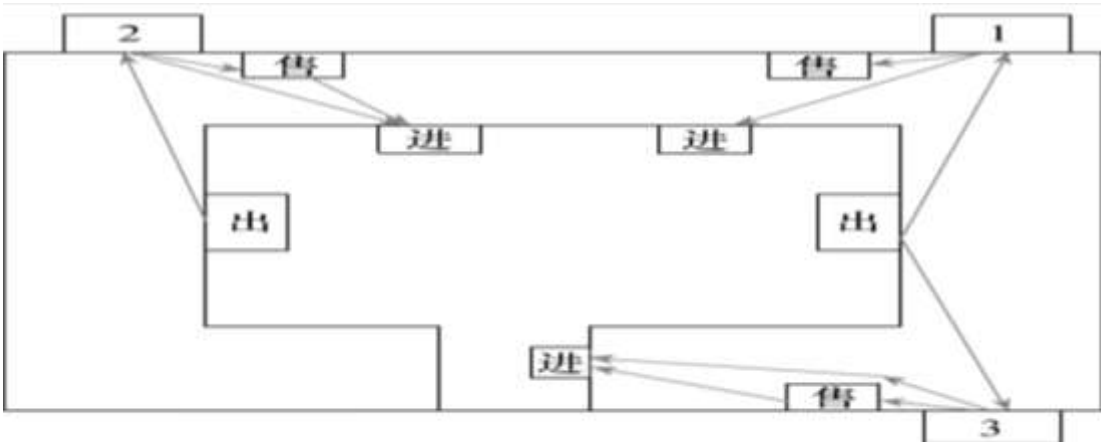

Fig.7 Streamline optimization diagram

Adjustment strategy In view of the problems in the original layout, the position of the gate was re-planned. By placing the inbound gates on the north and south sides and the outbound gates on the east and west sides respectively, the dispersion of the flow line is realized and the congestion degree is reduced. This optimization measure is in line with the requirements of rationalizing the subway station layout and helps to improve the overall operational efficiency. The final facility layout is shown in Figure 8

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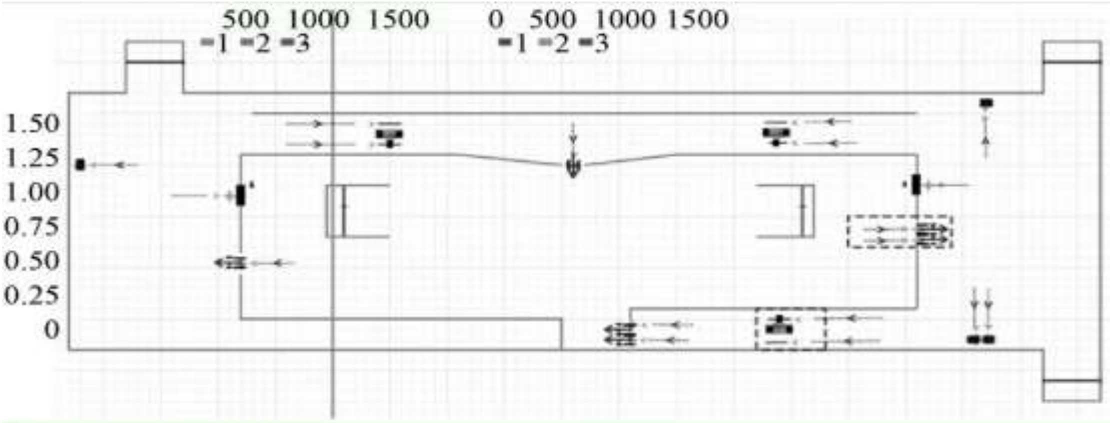

Fig.8 The optimized layout of Xiaolingwei subway facilities

4 Simulation and comparison after optimization

3.2 Post-optimization simulation

After modifying the simulation modeling and process, the simulation results of the optimization measures are shown in Figure 9, 10 and Table 6.

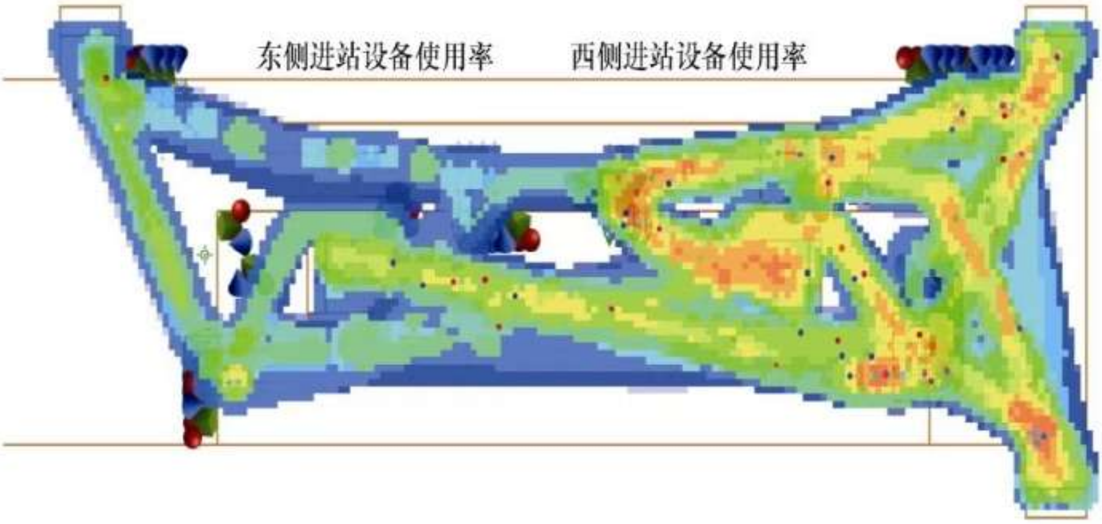

Fig.9 Optimized pedestrian density map

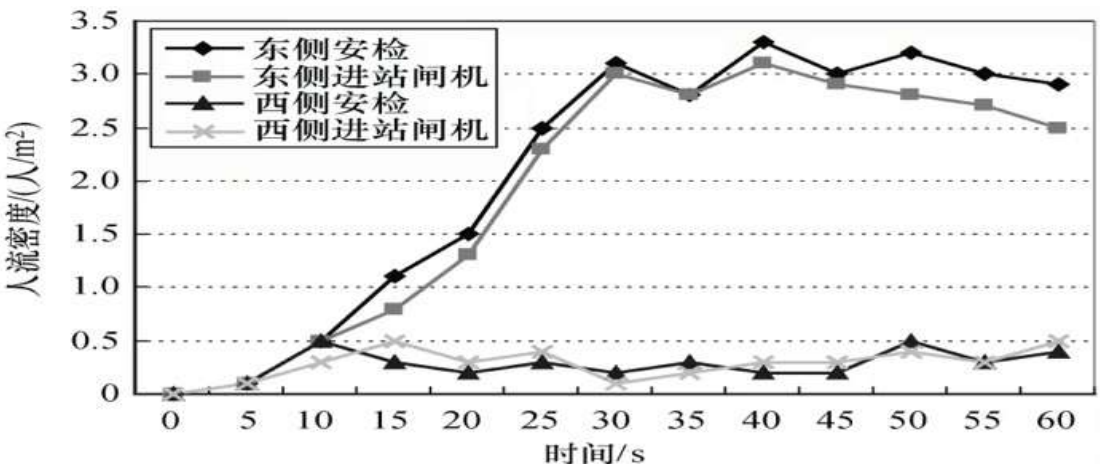

Fig.10 Optimized pedestrian density map of each side entrance

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Table 6 Maximum, minimum and general average walk time after optimization

Time type	entrance		
	First port	Second entrance	Exit three
Maximum average travel time	132	63	145
Minimum mean travel time	29	28	43
General walking time	74	41	90

3.2 Comparison before and after optimization

The traffic density map, the maximum and minimum and the average travel time before and after optimization were compared. It can be found that the optimized subway congestion layout is more reasonable with fewer conflict points, significantly reduced conflict areas, less waiting time, and more uniform and orderly passenger density, thus effectively meeting the needs of peak passenger flow. This optimization result highlights the importance of subway station facility layout adjustment. According to the actual situation, reasonable arrangement and optimization of facility location, quantity and streamline design can effectively improve the operation of subway stations and improve passengers' travel experience.

It can be seen that, taking into account the elements of safety and flow control, the maximum traffic density of the security checkpoint on the east side is successfully reduced to 3.1 persons /m²; At the same time, the pedestrian density in front of the entrance gate on the east side also decreased, reaching 3.0 persons /m². The achievement of this achievement is mainly due to the relocation of some entrance and exit gates on the west side to the east side, thus easing the passenger flow pressure on the east side. Although the maximum density of passenger flow on the west side increased slightly, it remained at a low level, which effectively improved the overall operational efficiency compared to the east side. In this context, the station is still able to provide passengers with a smooth entry and exit service, resulting in a reduction of various entry times by 25%, 5% and 29% respectively.This shows the importance of optimization of subway gate layout for improving operational efficiency and passenger travel experience. Through the reasonable adjustment of the number, location and people flow line of the gate, the congestion degree can be effectively reduced, the queuing time can be shortened, and the operation efficiency of the station can be improved. In addition, in practical applications, it is also necessary to implement dynamic adjustment strategies according to the characteristics of the flow of people in different time periods to cope with the peak passenger flow.

4 epilogue

With the rapid development of urban rail transit, optimizing the design and evaluation of rail transit station has become an important topic in current research. The purpose of this study is to explore the methods and strategies of optimization and evaluation of station hall design through AnyLogic simulation software. First, collect and analyze the relevant data of the station hall, build AnyLogic model, and simulate the passenger flow dynamics under different scenarios. Then, according to the operation results of the model, a specific optimization design scheme is proposed, such as adjusting the layout of facilities, improving the design of channels, increasing the convenience of transfer. Then, the AnyLogic model is used to simulate and evaluate the optimized station hall to analyze its operational efficiency and passenger satisfaction. Finally, through the empirical analysis and verification, the feasibility and effectiveness of the optimization scheme in the actual project are evaluated. This study provides a useful reference for the design of rail transit stations in China, which is helpful to improve the operational efficiency of station halls and passenger satisfaction, and promote the modernization and development of station construction. Here, we summarize the optimization design and evaluation research of rail transit station concourse based on AnyLogic. It is hoped that this method can provide useful reference for the design of rail transit stations in China and promote the modernization and development of station construction. In the future, we will continue to further study other related fields to make greater contributions to our country's transportation industry

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