Prediction and Analysis of Subway Passenger Flow Based on AnyLogic in the Context of Big Data

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Abstract. The model uses computer pedestrian simulation software as the platform and Hefei Tianzhu Road Metro Station as the research object. Using the pedestrian library in Anylogic, the passenger flow distribution of a subway station in a certain place is simulated, and the service level of the platform, the number of ticket gates and self-service ticket vending machines, and the layout of stairs are estimated. It can effectively provide technical support for urban rail transit planning.

Keywords: Anylogic · Model · Pedestrian library

1 Problem Description

Metro Line 2 is the second metro line in Hefei, Anhui Province. Line 2 is an east-west line with a total length of 30.06 km and a total of 24 stations. Hefei Metro Line 2 is an important subway line in Hefei City. With the increase in passenger flow, ticket sales time and passenger waiting time are the main reasons for passenger delays. This paper takes Tianzhu Road subway station as the research object. During the rush hour, the number of people queuing at Tianzhu Road subway station exceeds 1,000, which greatly reduces the travel experience of passengers. Therefore, measures need to be taken to improve the management and service level of Tianzhu Road Metro Station.

With the increase in the passenger flow of Metro Line 2, it is urgent to solve the problem of queuing of passenger flow. As the preliminary construction of urban rail transit costs a lot of manpower, material resources and financial resources, a lot of financial support should be given to the infrastructure improvement of the station. Therefore, in order to bring convenience to the travel of passengers, it is necessary to improve the business level and management ability of the station. Optimize the site and analyze the incoming and outgoing passenger flow to improve the travel experience of passengers, thereby, it can bring convenience to the travel of passengers and improve the national economy.

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2 Significance of Problem

In recent years, the rapid development of urban rail transit has brought convenience to the life and work of urban residents. At the same time, with the rapid increase of urban population, the queuing problem of urban rail transit is also an urgent problem to be solved. Has been solved. With the increase of queuing time, the patience of passengers will become shorter and shorter, which will not only increase the economic cost of passengers, but also lead to the aggravation of passengers' psychological problems. Therefore, according to the forecast of the number of passengers entering and leaving the station within a certain period of time, it is necessary to formulate the actual guidance for passengers entering the station, boarding/transferring, getting off the station and leaving the station.

By optimizing the subway layout for ticketing and personnel, and formulating a guiding plan that conforms to the actual subway station, passengers can travel smoothly.

3 Related Work

Combined with the spatial pattern of the subway station and the subway operation law, the behavior law of subway pedestrians is studied, Through the simulation of Anylogic, we can better understand the operation of the Tianzhu Road rail transit subway station, which is of great significance to prevent accidents in the subway station and ensure the safety of pedestrians.

Scholars at home and abroad have proved the convenience of different dynamic simulation software in the field of transportation through case practice profit. WMP van der Aslst [1] and others studied the walking characteristics of pedestrians in railway junctions, and proposed an optimization scheme for service facilities. Fateh Kaakai [2] used simulation software to evaluate railway passenger station facilities and study the safety of pedestrian transfer. Sex. Rivers E, Jaynes C et al. [3] proposed to use evacuation time, travel time, velocity and flow as indicators to verify pedestrian movement and path selection evacuation models. In China, Lu Cheng [4] simulated the pedestrian flow simulation of in-station transfers at Beijing South Railway Station, and proposed to use customer service equipment for intra-station transfers; Li Dewei [5] used Markov process to simulate complex phenomena such as pedestrian self-organization; Kong Dexuan and many scholars [6–10] also analyzed the behavior characteristics of subway pedestrians according to various influencing factors, and put forward relevant suggestions and methods. In a recent study by Ebia and Remirez (2014), it is stated that there are 16 trains running during peak hours, when the travel time interval is 5 min, the optimal interval time is determined to meet the demand of passengers during peak hours [11].

4 Modeling Questions

Due to the large amount of manpower, material and financial resources spent in the preliminary construction of urban rail transit, there is no corresponding financial support for the improvement of the station's infrastructure. Therefore, in order to bring convenience to the travel of passengers, it is necessary to improve the business level and management ability of the station. For example, a common problem is congestion in traffic queues, and whether stations can be optimized to increase the number of passengers. This project proposal mainly builds a model to solve the following problems:

- What management actions will reduce the waiting time of passengers queuing up to buy tickets?
- What management actions will optimize the queuing at the entry ticket gate?
- How will the number of subway arrivals optimizes the throughput of the station?

5 Proposed Methodology

This article presents the background and results of a case study designed to develop a simulation model to gain insight into passenger flow and service conditions around the Tianzhu Road subway station in Hefei. The simulation model, implemented in Anylogic 8.7, provides optimization capabilities for exploring strategies to improve the efficiency of queue management and station design. The study followed the general methodology shown in Fig. 1.

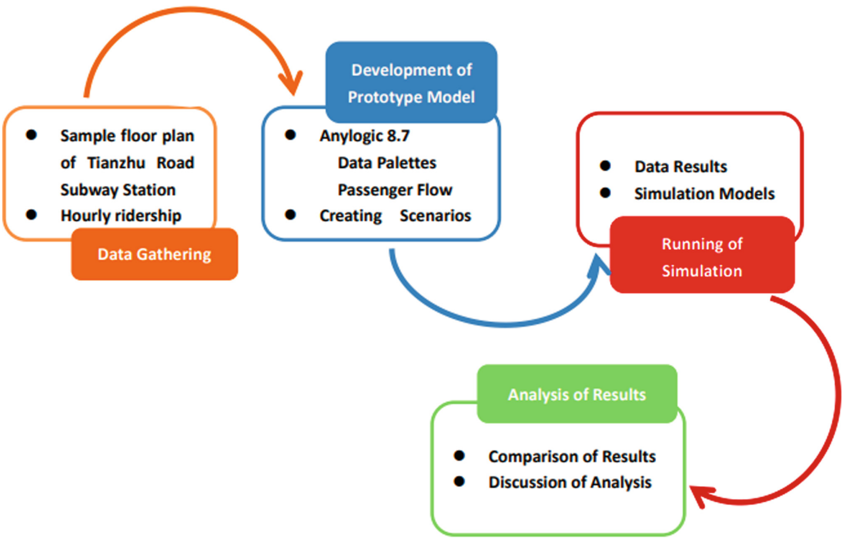


Fig. 1. General Research Methodology

5.1 Data Collection

The datasets used in this simulation are:

- Floor plan of Tianzhu Road Station in the ticketing area;
- The average number of passengers or number of passengers per hour;
- The number of ticket booths open each day;
- The number of gates available;
- Percentage of passengers holding stored value tickets.

The above data were obtained through on-site communication with the subway staff and investigations conducted by myself and members of the group to Tianzhu Road subway station. During the two-day field trip from January 21 to 22, 2023, data such as the number of turnstiles and ticket vending machines, the number of people holding subway cards and the arrival rate of the four subway entrances and exits were collected.

5.2 Development of Prototype Model

After acquisition, the data is accessed by a simulation model implemented in Anylogic 8.7. Two simulation methods were employed: discrete event and agent-based. Discrete events are used to simulate kiosk and gate operations, while agent-based is used to simulate passenger flow.

To create the simulation model, the first step was to digitize the Tianzhu Road subway station floor plan to place the location of the station entrance, ticket machines, and gates. To model the passenger flow, the pedestrian library built into Anylogic was used. The hourly average passenger arrival rate is used to simulate passenger arrivals at the station. In the simulation model, every 20-s step is simulated to be equivalent to 1 h, 4 entrances and exits are set to the southeast, southwest, northeast, and northwest.

Figure 2 shows the process implemented in Anylogic for modeling passenger flow. There are passengers arriving from the south and passengers arriving from the north. They can choose to arrive at the station hall from the west escalator and the east escalator. Passengers who take the west escalator exit from the south ticket gate, and those who take the east escalator go out from the station. Diversion will be implemented at the exit of the south ticket gate. Thereby, it is can reduce the departure time of passengers.

Passenger arrivals are manually injected every hour based on the average passenger arrival rate. Based on percent chance, the model creates two types of passengers, described in percentages: those who will go to the ticket machines and those who already have a card and can go directly to the gate. Service windows and service doors are used to model ticket booths and turnstiles, respectively. Passengers entering and leaving the station can choose the nearest escalator and gate to enter and exit the station, saving time and improving the efficiency of traffic.

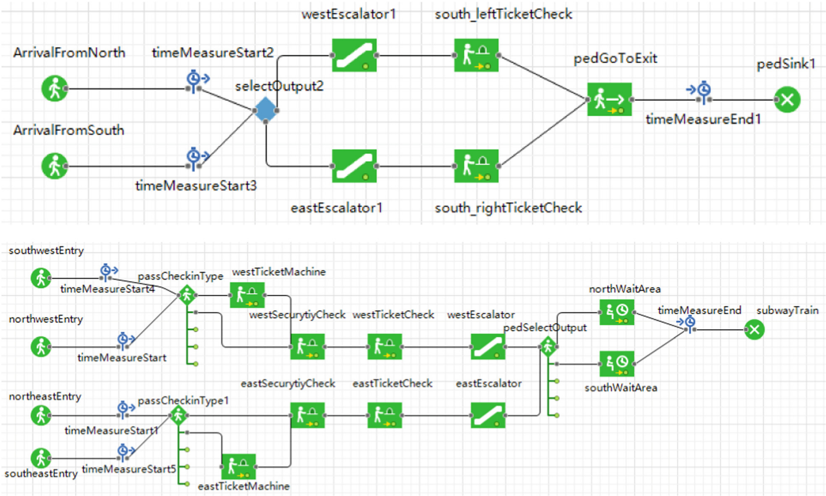


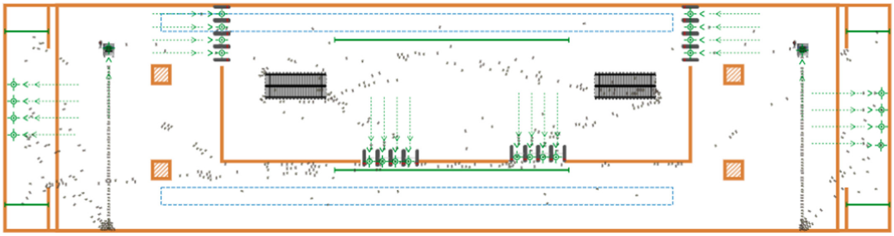
Fig. 2. Passenger Flow implemented in Anylogic

In order to explore the possible ways to optimize the queuing management of Tianzhu Road subway station, the existing queuing system was modeled and optimized. In the current queuing system, the existing 2 automatic ticket machines and 2 security gates are optimized and replaced with 4 automatic ticket machines and 4 security gates for simulation. At the same time, the subway arrival time interval is calculated. Changed from 6 min to 4 min. It was found that by optimizing the simulation, the efficiency of the safe passage of passengers was improved.

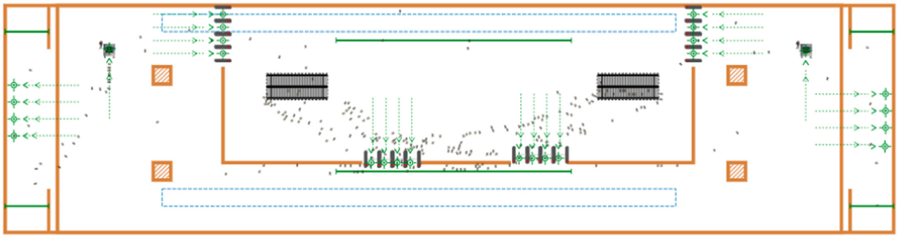
Four main scenarios were observed in this study, as shown in Table 1. Figure 3 also shows snapshots of each scenario. By simulating two entrances, four ticket vending machines and the time interval between subway arrivals, the efficiency of subway traffic can be seen.

5.3 Running of Simulation

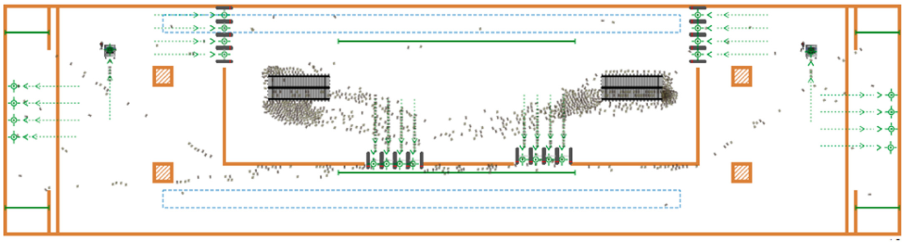
The simulation realizes that the proportion of passengers owning the subway stored value card is 30% and 70% of the simulation run. During each run, the number of passengers in the queue and the number of passengers leaving through the gates are monitored, and these values are then stored. Figure 4 shows example images of the scene from the Tianzhu Road subway station simulation model in action.



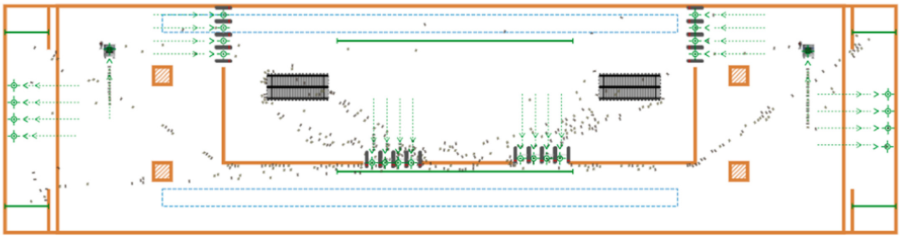
Scenario 1



Scenario 2



Scenario 3

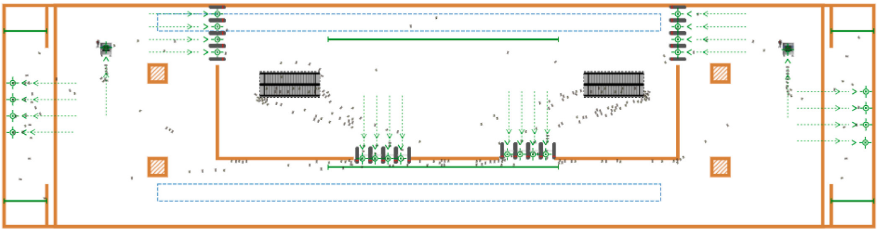


Scenario 4

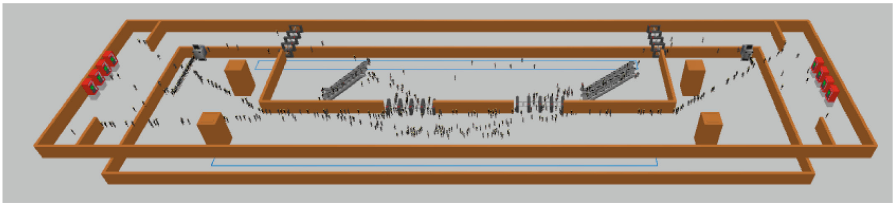
Fig. 3. Four Scenarios simulated in the Model

Table 1. Four Major Scenarios in the Simulation Model Scenario Description

Scenario	DESCRIPTION
1	2 gates and 2 automatic ticket machines are available for east and west
2	4 gates and 4 automatic ticket machines available in the east and west
3	Arrival time interval is 6 min
4	Arrival time interval is 3 min



Scenario 5



Scenario 6

Fig. 4. Example 2D and 3D images of the Tianzhu Road Station Scenario 5 simulation model

6 Results

In all simulation models, the percentage of passengers queuing at ticket booths and turnstiles was monitored throughout the simulation time. The 1-2-1 filter is given by:

$$\mathrm{f(t)} = {}^{1}\!\big/_{4} f(t-1) + {}^{1}\!\big/_{2} f(t) + {}^{1}\!\big/_{4} f(t+1) \quad (1)$$

Apply twice to the time series. For the case where 30% of passengers have the opportunity to buy tickets, the remaining 70% buy tickets more or less through the ticket window. It can be found that when the proportion of holding a stored value card is 70%, the number of people queuing in front of the automatic ticket machine is small, but the queue that may pass through the security check may be slightly longer. However, if the number of automatic ticket machines is increased, the difference between the two may not be very big.

In the simulated system, the difference in queuing through turnstiles with two turnstiles and four turnstiles is slightly larger. Therefore, it can be found through simulation

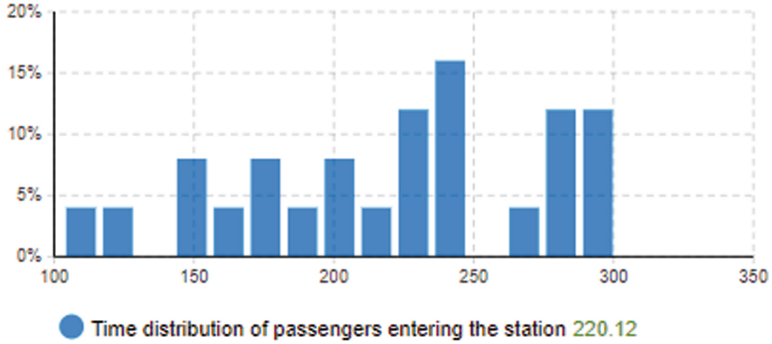


Fig. 5. Time distribution of passengers entering the station

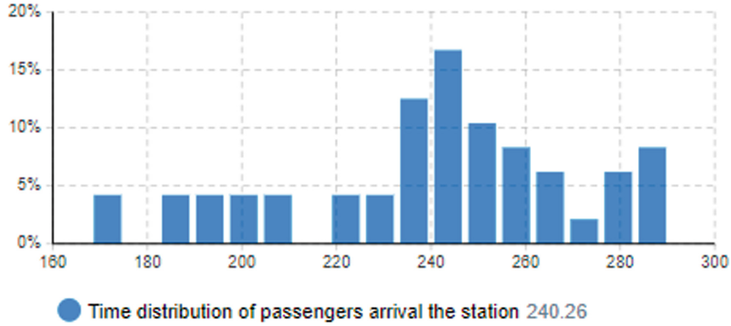


Fig. 6. Time distribution of passengers arrival the station

that the probability of passengers queuing in front of the security gate is higher in the scenario with four security gates than in the scenario with two security gates.

When the time interval between subway arrivals is simulated and set, it can be found that if the time interval between arrivals is prolonged, there will be congestion at the escalator entrance. If the time interval between arrivals is shortened, the flow at the entrance of the escalator will be reduced and safety will be increased.

The optimized model is set with four automatic ticket machines, four security gates, and the time interval between arrivals. It can be seen from Figs. 5 and 6 of the distribution of passengers entering and leaving the station that the number of people entering and leaving the station is the proportions are relatively balanced, and overall, the model is reasonable.

7 Conclusion and Recommendation

We have shown that the type of queuing system in a subway can play a vital role in optimizing its operations. Research has shown that the system has been further optimized for the subway self-service ticket vending machines, security gates, and station arrivals. Another important feature observed in the simulations is that as the number of passengers holding stored value cards increases, the number of queues at the ticket machines decreases sharply, while the queues in front of the gates increase slightly. This means that operations become more optimized as more passengers have to bypass self-service ticket machines. Using this model can be used to examine the safety and performance improvement of the subway ride system.

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