Simulation and analysis of pedestrians in the station of urban rail transit

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Abstract. The hall of Wuhan Dazhi road station of urban rail transit is modelled by Anylogic. Based on the data surveyed in the morning peak period of some workday, walking paths of pedestrians are simulated and utilization of equipments is analyzed. To reduce pedestrian waiting time, security checkpoints are added. Then the average passage time going through the station hall is reduced.

1. Introduction  
With the accelerated development of urbanization, rail transit has gradually become the backbone of public transportation networks in large and medium-sized cities [1, 2]. Due to its characteristics of large capacity, convenience, punctuality and fast speed and environmental protection, urban rail transit attracts more passengers. At the same time, in some crowded places and rush hours, passenger flow shows the explosive growth and tidal characteristics. To ensure the order and safety of passengers, reasonable planning during the construction and timely adjustment of facilities during operation are needed [3, 4]. Zhang analyzed the influence of ticket equipment, stairs and escalators on the passage efficiency [5]. Yanget al. analyzed the subway station channel layout and facilities with focusing on the crowd gathering conflict points [6]. Wang et al. proposed three static identification methods for the form, capacity and congestion bottleneck in the passenger flow distribution state, sorted the static bottleneck based on the time, set the first dynamic bottlenecks as the starting point of each stairs [7].  

Wuhan Dazhi road station of urban rail transit is modelled. Based on the data of equipment and pedestrian, walking paths are simulated. Pedestrian flow, area density and passing time are compared on different conditions. Then service facilities and equipment are adapted to reduce waiting time for security checkpoint.

2. Dazhi road station  
2.1. Overview  
Dazhi road station of urban rail transit is located in the center of Hankou district, Wuhan city. It is at the intersection of Jinghan avenue and Qiuchang street. It is the transfer station of rail transit line 1 and line 6. There are multiple transportation connections, such as bus, taxi and sharing bike.

2.2. Layout and facilities  
Dazhi road station is a four-story building composed of the underground, ground, second floor and third floor. The station layout is shown in Figure 1. The underground is the space for line 6. The ground is mainly for in, out and transfer, and it has four entrances, namely E (E1 and E2), F and G.
The second floor is mainly for in, out and transfer too. It has four entrances, namely A, B, C and D. The third floor is the space for line 1. The ground is analyzed in this paper.

Figure 1. Layout of Dazhi road station.

There are two ticket machines, two security checks, a manual service desk, three entry gates, two exit gates, a direct elevator, three escalators and pedestrian stairs in the ground. The station is not very large, but capable of handling passenger flow. There are five passenger sources respectively from line 1, line 6, entrance G, entrance E and F. Layout of hall in the ground is drawn by Anylogic software, shown in Figure 2.

Figure 2. Layout of hall in the ground.
Pedestrians from gate G, gate E and F, line 1, line 6 make different route choices to the destination. Pedestrians entering from gate G. Firstly, some pedestrians go through security check 1 directly, the other go to the ticket machine 1 and then go through security check 1. Secondly, some go through the inbound brake 1, the other go to the service desk and then go through the inbound brake 2. Finally, some go to the direction of line 1, the other go to the direction of line 6 using escalator group1 (means escalator 1 and stairs 1).

Pedestrians entering from gate E and F. Firstly, some pedestrians go through security check 2 directly, the other go to the ticket machine 2 and then go through security check 2. Secondly, some go through the inbound brake 3, the other go to the service desk and then go through the inbound brake 3. Finally, some go to the direction of line 1, the other go to the direction of line 6 using escalator group3 (means escalator 3 and stairs 3).

Pedestrians coming from line 1. Most pedestrians go to line 6. Among them, some walk to the middle escalator group2 (means escalator 2 and stairs 2) according to the nearest path principle, a few walk to escalator group 3, a few walk to escalator group 1, very few walk to direct elevator. Some go to exit G through the outbound brake 1. Some go to exit E or F through the outbound brake 2.

Pedestrians coming from line 6 by escalator group 1, escalator group 2, escalator group 3 and elevator. Some go to line 1 for transfer, some go to exit G through the outbound brake 1, and the other go to exit E or F through outbound brake 2.

3. Simulation and analysis of pedestrian flow

3.1. Data survey

As a transfer station, there are many passengers in the morning and evening peak period at Dazhi road station. In this paper, the passengers on the ground were observed in the morning peak period on some workdays (7:30-8:30). The data including the number of passengers entering from line 1, line 6, entrance E, F and G. Passengers enter on average from E, F and G, while passengers arrive at an exponential distribution within a certain interval from line 1 and line 6.

| Source | Traffic                          |
|--------|---------------------------------|
| G      | 420 people/h (average arrival)  |
| E      | 540 people/h (average arrival)  |
| F      | 360 people/h (average arrival)  |
| Line 1 | 132 people/3min (arrival interval: 3min) |
| Line 6 | 312people/5.5min (arrival interval: 5.5min) |

3.2. Parameters set

Pedestrian parameters are set as follows. The proportion of passengers going to ticket machines or not is about 1:10, and the proportion of passengers going to the service desk or not is about 1:10. The proportion of passengers from line 6 to the ground by escalator and stairs is about 10:4. Passengers from line 6 to exit E, F, G and line 1 is about 9:2:2:2. Passengers from line 1 to exit E, F, G and line 6 is about 12:1:1:1.

Equipment parameters are set as table 2.

| Parameters                        | Set                      |
|-----------------------------------|--------------------------|
| Ticket machine delay time         | triangular(7,12,40)      |
| Manual ticket delay time          | triangular(7,12,40)      |
| Security check delay time         | uniform(2.0, 4.0)        |
| Brake delay time                  | uniform(2.0, 4.0)        |
| Escalator moving speed            | 0.5m/s                   |
| Pedestrian walking speed          | uniform(0.8, 1.3)        |
3.3. Simulation

The ground hall of Dazhi road station are modelled and pedestrian flow are simulated by Anylogic. Because the number of passengers is not too large, the hall is not very crowded. There are crossing paths between passengers to line 1 and from line 1, so passenger flow conflict appears frequently. Using barriers can isolate traffic conflict effectively, but walking along the right-angle edge of the wall is not comfortable for pedestrians. So if there is a relatively smooth turning, pedestrians will go through the passage easily. Passengers from entrance E and F go through the same security checkpoint, there is a long queue. In order to reduce waiting time, a security checkpoint is added. Passenger flow, traffic volume, area density and passing time are compared.

(1) Passengers to line 6

Table 3 shows the number of passengers going to line 6 by elevator group 1, 2 and 3. For elevator group 1 and 2, there is little difference before and after optimization. But for elevator group 3, the number of passengers increases by 60. It means that waiting time is reduced and passengers go through security checkpoint quickly after optimization. Then more passengers pass gate 3 within a period of time.

(2) Area density

A large pedestrian density is easily appeared around the area to and from the direction of line 1, then congestion will happen. Three values of pedestrian density are observed in areas which are green rectangles on the left side of three elevator groups, as shown in Table 2. From top to down they are named Area 1, 2 and 3. Pedestrian density of Area 2 is the maximum, because it is located in the crossing paths from and to line 1. Pedestrian density of Area 1 is the medium, and Area 3 minimum. The changes of pedestrian density in three areas before and after the optimization are not significant, because the increase of security checkpoints do not affect the pedestrian density in these areas.

(3) Passage time

Figure 3 and Figure 4 show the passage time through the hall. Before optimization, the maximum passage time is 245.104, the minimum 51.699, and the average 117.104. After optimization, the maximum, minimum and average passage time is 175.5, 53.731 and 109.264 respectively. The maximum decreases by nearly 70 seconds and the average decreases by nearly 8 seconds. It indicates that the addition of security checkpoint significantly reduces the queuing time and improves the efficiency of passengers passing through the station hall.

| Elevator | The number of pedestrians before optimization | The number of pedestrians after optimization |
|----------|---------------------------------------------|---------------------------------------------|
| Group 1  | 205                                         | 202                                         |
| Group 2  | 283                                         | 304                                         |
| Group 3  | 396                                         | 456                                         |

| Area     | The number of pedestrians before optimization | The number of pedestrians after optimization |
|----------|---------------------------------------------|---------------------------------------------|
|          | Maximum          | Average          | Maximum          | Average          |
| Area 1   | 0.369            | 0.102            | 0.347            | 0.097            |
| Area 2   | 0.499            | 0.161            | 0.499            | 0.173            |
| Area 3   | 0.347            | 0.076            | 0.282            | 0.081            |
4. Conclusion
This paper takes Dazhi road station as an example. Based on the field survey the station hall is modeled and simulated by Anylogic. Utilization of equipments and facilities are analyzed. To reduce the passenger waiting time, security checkpoints are added. Then the average passage time going through the station hall is reduced.

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