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Simulation Research on Large Passenger Flow Guidance of Urban Rail Transit Based on Multi-Agent

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ABSTRACT. *Distribution of the passengers on rail transit is an important basis for urban rail transit operators to control and manage, and is meaningful to schedule and optimization. Agent can adjust their status to make decisions at the environment, according to the program. Based on the actual rail operation systems, a simulation for rail transit passenger flow of single linear propagation is taken on a multi-agent software. From the two aspects of process and time nodes, the distribution of the passenger on Shanghai Metro Line 16 is analyzed, under the different conditions capacity and interval time. Then, the operations of Shanghai Metro Line 16 would be improved on purpose, to reduce the extent of the stations' large passenger flow.*

KEYWORDS: *ShanghaiMetro Line 16, large passenger flow, multi-agent, simulation*

1. Introduction

The choice of rail transit by a large number of passengers in the city not only plays the role of rail transit, but also improves the efficiency of urban residents. However, in a megacity like Shanghai, the passenger traffic during peak hours of rail transit is much larger than its transport capacity. During peak hours, rail traffic often runs at high load, and it makes it easy for passengers to gather in the station, posing safety risks and hidden dangers. Therefore, it is urgent to study the law of the generation and dissemination of large passenger flow in rail transit in order to improve and improve the service level of urban rail transit.

The reason for the occurrence of large passenger flow at urban rail transit stations can be attributed to the quantitative relationship between station capacity, station transport capacity and passenger arrival. Under the condition that the parameters such as station capacity and passenger arrival amount are certain, the influence law of station transportation capacity on the large passenger flow event at the station is analyzed.

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2. Construction of multi-agent simulation model for urban rail transit

NetLogo is a simulation modeling software based on multi-agent that programmatically issues instructions to hundreds of independently running "agents". In the set environment, the agent can continuously adjust its own state to make decisions according to the goals set by the program. At the same time, NetLogo can simulate the traffic phenomenon of pedestrians and collect relevant data, which is suitable for complex systems whose simulation changes with time.

Taking Shanghai Rail Transit Line 16 as the background line, programming on NetLogo software, and establishing a simulation model of large passenger flow propagation on Rail Transit Line 16, the main body of the model is trains and passengers. Simulated simulation of the number of passengers waiting in the station as the train travels between stations.

2.1 Factor analysis of the model

The rail transit system is a complex system integrating passengers, trains and lines. It is in a state of balance under normal conditions, and the elements in the system have interactive adaptability. In the event of an unexpected event such as a large passenger flow, the original balance will be broken, resulting in delays in train operation, decreased operational capacity, and increased passenger detention time. These factors interact and influence each other. Passengers are subjective active agents. The choice of trains is affected by the running capacity of the train, the passenger's residence time, and the congestion level of the station. Conversely, the passenger's concentration at the station is counterproductive to the running condition of the train. Therefore, the various factors interact and influence each other.

2.2 Overview of multi-agents

A multi-agent is a computing entity that is social, autonomous, reactive, and motivating, operating and interacting autonomously according to changes in the external environment to achieve a balanced state. Generally speaking, multi-agents involve multi-agent systems. Multi-agent systems are an important branch of distributed artificial intelligence. The research focus is on the coordination and interaction between multiple agents to form a system.

For rail transit, the train moves in the urban rail transit network, and the station and the station interact with each other through the transmission of trains; passengers and trains influence each other through the congestion of the station. Therefore, passengers, stations, trains and other agents interact and communicate with each other to achieve a balanced state of train system operation.

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2.3 Simulation Hypothesis

Establish a simulation model and make the following assumptions.

1) The simulation takes Shanghai Rail Transit Line 16 as the background, and its early peak time is from 7:00 to 9:00, and the main passenger flow direction is to the urban (downward) direction;

Table 1 Inbound passenger flow during peak hours of rail transit line 16

Site name	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Passenger flow	1000	500	1500	800	6000	2800	3800	2000	8000	5000	800	400

2) Consider only the propagation process of large passenger flow between stations during peak hours under the single-line operation of rail transit;

3) The transmission capacity of the station mainly depends on the train transportation capacity and the passing capacity of the station passage and the boarding and landing equipment. The paper ignores the influence of secondary factors such as station passages and boarding equipment, and sets the station's transmission capacity as the train transportation capacity;

4) The train transportation capacity is $G = \frac{60}{I} g$, G is the transmission capacity of the station per unit time; I is the train departure time interval; g is the designed passenger capacity of each train;

5) The simulation operation starts at the early peak time, and the peak time duration is 7200s;

6) In the simulation, the train moves at a design speed of 120km/h, and the stay time at each station is 60s;

7) The station area is 200 m^2, that is, when there are 500 people waiting on the platform, a large passenger flow event occurs at the station;

8) Set the passenger flow of the inbound station to the Poisson distribution with a mean value of 30, and obtain the probability that the passenger flow will enter the station at each time point, and calculate the number of inbound passenger flows of the station at each time point;

9) On the 16th line, each group of trains is set up with 3 groups of doors to open, and each group of doors is opened for 2 people/s.

2.4 Simulation Concept

The agent of the simulation model is passengers and trains. Passengers travel from different routes to the station, arrive at the station, and wait for the train to arrive. The train runs on the rail transit network and arrives at the station to pick up

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and drop off passengers. When the train arrives at the destination, all passengers get off. The conceptual principle of the simulation is shown in Figure 1, Figure 2, and Figure 3.

Under the different conditions of running passenger volume and departure interval, the propagation process of large passenger flow of Shanghai Rail Transit Line 16 is studied, and the influence of station transportation capacity on the mass transit flow of urban rail transit is further derived.

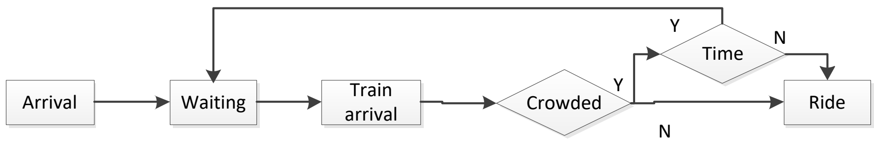

Figure. 1 Passenger waiting principle

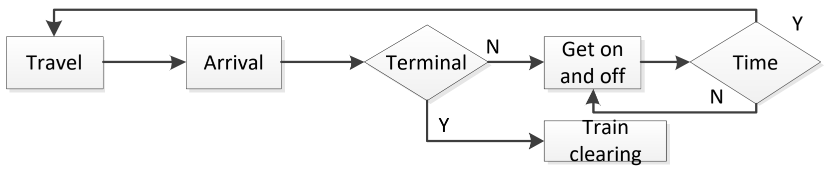

Figure. 2 The operating principle of the train

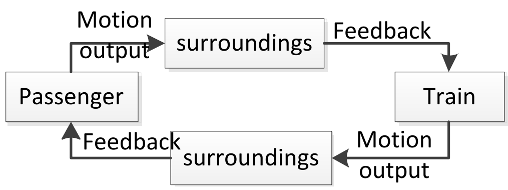

Figure. 3 Principle of interaction between passengers and trains

2.5 System Modeling

According to the principle of passenger waiting, the principle of train operation and the interaction principle of the two, the simulation modeling principle is obtained, as shown in Figure. 4.

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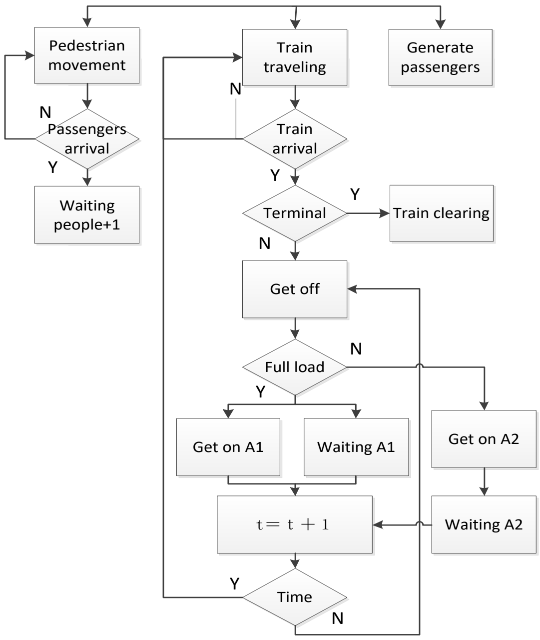

Figure. 4 Simulation modeling principle

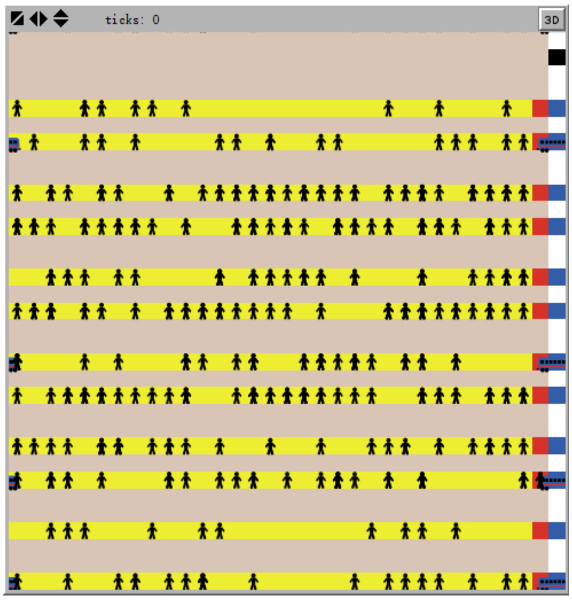

Figure. 5 Simulation interface

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The yellow horizontal line in the simulation interface indicates the path of the passenger to the station. White vertical lines that indicate the orbit of the train. The red squares and blue squares are represented as stations, where the red squares are the waiting parts for passengers and the blue squares are the parts where the trains are parked. The black square in the upper right corner indicates the terminal. The simulation interface is shown in Figure 5.

3. Simulation analysis of large passenger flow propagation based on multi-agent

The simulation simulates the large passenger flow propagation process of the three operational schemes. And from the two perspectives of the propagation phase and the time node, the differences in the propagation of large passenger flows between stations under the three schemes are compared and analyzed. The principles for programming are as follows.

1) Using the control variable method, adjust the train departure interval and the train passenger capacity one by one;

2) Ensure that the transportation capacity of the adjusted plan has been improved, and the train delivery capacity of the two programs is the same.

Table 2 Simulation scheme

Scheme1	Scheme2	Scheme3
Departure interval 240s Carrying capacity 1100p Delivery capacity 16500 *p*/h	Departure interval 240s Carrying capacity 2200p Delivery capacity 33000 *p*/h	Departure interval 120s Carrying capacity 1100p Delivery capacity 33000 *p*/h

In order to ensure the accuracy of the simulation data, the data used are the average values obtained after the maximum and minimum values are removed after 12 simulation runs.

3.1 Comparison of various programs under different stages of communication

Comparing three different schemes from the communication stage, it is possible to observe the time difference of each stage of the train under different conditions of passenger capacity and departure interval. Under different schemes, the occurrence time of each stage in the process of large passenger flow propagation is shown in Table 3.

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Table 3 The occurrence time of different stages in the process of large passenger flow propagation under each scheme

	Scheme1	Scheme2	Scheme3
The time of the station5	3150	3150	3750
The time of the station6	3840	4090	—
The time of the station7	3990	—	—
The time of the station8	3950	—	—
The time of the station9	3050	3050	3780
The time of the station10	3090	3090	3700
The time of station 6~ station 9 is dissipated	5741	4511	4451

Comparing the occurrence time of different stages in the process of large passenger flow propagation under each scheme, you can see:

1) The large passenger flow at the station will affect the downlink station, which will easily cause large passenger flow at the downstream station;

2) Under schemes 1 and 2, the station 9 first has a large passenger flow, indicating that the trains in the early morning peak have fewer shifts and the traffic is insufficient;

3) Compared with Option 1, Scheme 2 and Option 3 have the same capacity for transportation, and there are fewer passengers in the station;

4) The train delivery capacity of scheme 3 and scheme 2 is the same, but the departure interval is shorter, and the station passenger flow is less.

3.2 Comparison of different schemes under different time nodes

Comparing three different schemes from the time node, it is possible to observe the difference of the passenger flow state of the station at each time node in the case of different passenger capacity and departure interval. When the program runs to 2400s, 3600s, and 4800s, the passenger flow parameters of the stations under each scheme are shown in Table 4, Table 5, and Table 6, respectively.

Table 4 Parameters of each scheme when the simulation runs 2400s

Downstream site	Scheme1	Scheme2	Scheme3
Station 1	0	0	0
Station 2	2	3	3
Station 3	1	1	1
Station 4	4	4	4
Station 5	58	59	12
Station 6	24	24	2
Station 7	0	0	0
Station 8	9	9	9
Station 9	222	0	222
Station 10	130	129	129
Station 11	4	4	4
Station 12	2	2	2

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Table 5 Parameters of each scheme when the simulation runs 3600s

Downstream site	Scheme1	Scheme2	Scheme3
Station 1	71	31	1
Station 2	20	20	20
Station 3	371	120	120
Station 4	221	66	65
Station 5	457	457	35
Station 6	276	213	16
Station 7	343	263	75
Station 8	164	82	82
Station 9	811	731	529
Station 10	604	564	185
Station 11	89	89	32
Station 12	20	20	20

Table 6 Parameters of each scheme when the simulation runs 4800s

Downstream site	Scheme1	Scheme2	Scheme3
Station 1	6	0	0
Station 2	7	7	6
Station 3	605	4	4
Station 4	317	11	10
Station 5	339	189	58
Station 6	68	68	7
Station 7	123	0	0
Station 8	48	48	48
Station 9	768	0	0
Station 10	1671	33	33
Station 11	2	2	2
Station 12	6	7	7

Comparing the passenger flow status of each program at different time points in the process of large passenger flow propagation, you can see:

1) When the program runs to 2400s, the passenger flow retention of each station is similar under the three schemes;

2) When the program runs to 3600s, under the scheme 3, the passenger flow in the station is the least, and the scheme is 2 times. The passenger flow in the scheme 1 is the most frequent;

3) When the program runs to 4800s, under the schemes 2 and 3, the large passenger flow stranded in the station is completely dissipated.

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4. large passenger flow diversion measures

According to the analysis of the simulation results, we have developed the 16-line large passenger flow diversion measures from the following two aspects: train operation organization optimization and passenger flow control.

4.1 Train operation organization optimization

The optimization of train operation organization is actually to adjust the transportation capacity of the train system. By adjusting the operation plan of the train, the existing equipment is used to complete the transportation of the station and the line. There are mainly the following options:

1) Increase the number of trains on Line 16 to improve the transport capacity between stations during peak hours;

2) Increase the number of trains on the 16th line or shorten the interval between trains to improve the train capacity and slow down the flow of large passengers;

3) Add a short-term operation plan between the stations with the largest passenger flow to the terminal station, and run the mode of long-term and short-term operation simultaneously.

4.2 Passenger flow control

Passenger flow control is different from the adjustment of train operation organization. The passenger flow control in the station mainly adjusts the number and capacity of equipments in the station, and strengthens the guidance of the staff in the station to improve the capacity of large passenger flow in the station during peak hours and control the total passenger flow within the station. Improve the orderliness of passenger flow. There are mainly the following options:

1) Adjust the functions of the entrance and exit stairs and escalators in the No. 16 line station, such as the escalated escalator at the station to the upstream or closed part of the entrance;

2) Adjust the ticketing capacity of the 16th line station to increase the ticket sales speed and slow down the passenger flow, such as increasing the ticket booth or semi-automatic ticket vending machine;

3) Adjust the security passability of each site. When the large passenger flow is mainly concentrated in the station floor, the number of security inspection channels can be increased, the number of security personnel can be increased, and the security inspection procedure can be simplified to quickly complete the movement of passenger flow from the station floor to the platform level. When the passenger flow is mainly concentrated at the platform level, the security check speed can be appropriately reduced to control the station-level passenger flow to remain within a safe and orderly range.

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5. Conclusion

On the basis of simplifying the process of passengers getting on and off the train, the thesis analyzes the propagation process of large passenger flow in urban rail transit stations by modeling on multi-agent software NetLogo. Under the condition that the station capacity and passenger arrival parameters are fixed, the influence of station transportation capacity on the large passenger flow propagation process between rail transit stations is analyzed. It is concluded that when the train transportation capacity (station transmission capacity) is the same, the train departure interval is shortened. It is more obvious than increasing the number of passengers in the vehicle to slow down the large passenger flow in the station. Finally, according to the simulation results, some measures of passenger flow guidance are proposed from the aspects of train operation organization optimization and passenger flow control, which has certain theoretical significance and practical value for improving the level and service level of rail transit.

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