Optimization of Passenger Guidance Signs at Urban Rail Transit Stations

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Abstract: With the development of society, the scale of cities and the population is getting bigger and bigger. The pressure on people to travel is increasing day by day. In order to ease the travel pressure, urban rail transit needs to be developed vigorously. Urban rail transit stations are the key nodes for people to travel. At the stations, a perfect guidance sign system is an important reason for the formation of an orderly passenger flow. Therefore, in order to prevent passengers from getting lost in the station and staying in the same place for a long time, the guidance sign system should be reasonably designed. In this paper, we establish a model for the selection of layout points according to the characteristics of the problem. Then solve the calculation of the optimization model by lingo software. Nanchang metro central station is selected for case study, the location of guidance signs in metro central station are optimized. In conclusion, the calculated result is more scientific and accurate than that at the metro central station, which verify the validity of the model.

Keywords: Urban rail transit stations, Guidance signs of stations, Optimization of guidance sign system, Lingo

1 INTRODUCTION

With the continuous development of cities, people rely more and more on urban rail transportation. In the modern metropolis, urban rail transit has become an indispensable means of transportation in people's life [4]. The service object of guidance signs is passengers in urban rail transportation, it is a kind of medium to transmit information to passengers, which is important to shorten the travel time of passengers. On the one hand, guidance signs can provide passengers with effective information. But too many guidance signs not only do not make passengers' travel more efficient, but also make passengers unable to make previous choices due to their disorganized arrangement [2]. Therefore, the function of urban rail transit can be maximized by reasonably setting the location of guidance signs so that passengers can directly and effectively obtain the information they need and plan their travel routes. The purpose of this paper is to optimize the spatial location of guidance signs for urban rail transit and improve the efficiency of passengers' travel.

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2 ANALYSIS OF FACTORS INFLUENCING PASSENGER GUIDANCE SIGNS IN URBAN RAIL TRANSIT

2.1 Functional Division of Urban Rail Transit Stations

Urban rail transit station is an important node for controlling trains and passenger flow, consisting of entrance, exit, platform and channel. Guidance signs will be mainly arranged at these key node locations.

(1) Entrance and exit

The exit and entrance of the station is the only way for passengers to enter and exit the station, so the smooth entry and exit of passengers is a prerequisite for the high efficiency of station operation. However, during the peak hours and train arrival time, there will be a large number of passengers crowded in the narrow entrance/exit. If an accident happens at this time, the consequences will be unimaginable, so that the signs at the entrance/exit must have a good function of evacuating the passenger flow.

(2) Channel

The station channel is an important part for connecting the station entrance and exit as well as the platform, including corridors, escalators and other parts. Some of the stations are built on a large scale, so the complex passageways can easily cause passengers to lose their way and thus create a sense of inner fear. Therefore, in order to solve this problem completely, the corridors should be kept as simple, spacious and bright as possible when they are built.

(3) Platform

The station platform is the space where passengers get on and off and wait for trains and is the most important part of the station. Passengers generally transfer to other lines through the station concourse or concourse plus aisles. The platform is very important for passengers. Not only for their safety, but also as a place to wait for their turnaround to their destination.

2.2 Passenger Characteristics Analysis

2.2.1 Analysis of Passenger Types

Passengers using urban rail transit can be broadly divided into three categories：

(1) Local passengers

For local passengers, using urban rail is a part of their lives and they are already familiar with the rules of travel. Many of them can enter and exit the station and ride without relying on guidance signs.

(2) Out-of-town passengers

Out-of-town passengers include non-local domestic passengers and foreign passengers. For domestic passengers, most of them have the experience of traveling by public transportation. In general, they are unfamiliar with urban rail transit, so that they can ask the station staff if there is a special situation. For foreign passengers, since the design method of guidance signs in foreign urban rail transit stations is somewhat different from that in China. They might have some difficulties in cognition, so each sign needs to be marked in both Chinese and English.

The translation must be accurate as well.

(3) Vulnerable groups

Vulnerable groups include the elderly, children, the sick, the disabled, pregnant women and passengers with small children. For the disadvantaged groups, there are more or less mobility and vision and hearing problems. Therefore, the font size, placement height and color of station guidance signs need to take into account the needs of the vulnerable groups. This not only benefits the vulnerable groups, but also reflects the society's care for them and the station's humanized service.

2.2.2 Analysis of Passengers Travel Behavior

Each passenger has different familiarity with the station and different cognitive ability of the guidance signs in the station [3]. After investigation and research, it is found that the behavior of passengers in the use of guidance signs is roughly divided into the following three types: autonomous behavior, dependent behavior, and herd behavior.

(1) Autonomous behavior

The so-called autonomous behavior is the behavior of passengers who are more familiar with the spatial environment of the station and can reach their destination without relying on the guidance signs. For example, commuters who take the same subway every day. They know which gate to enter the station, how to transfer, etc. Their actions are basically fixed and will not change because of the change of guidance signs

(2) Dependent behavior

Dependent behavior is the behavior exhibited by unfamiliarity with the spatial environment within a station, and it occurs mostly among out-of-town passengers and vulnerable groups. They need to rely on guidance signs or ask staff to travel and may make round trips or pauses in order to determine the accuracy of the information they receive.

(3) Herd behavior

Herding behavior in a broad sense is when a person is influenced by the majority in a certain situation and thus does the same thing as others. It is manifested in the station as unfamiliarity with the spatial environment of the station, following the movement of people when exiting the station, and acting with a certain blindness.

2.3 Passenger Flow Line

The so-called flow line refers to the route passengers take to reach their destination by some means at a certain location in the station, where some means includes the guidance of signs, so the guidance signs play an important role in the passenger flow line. Therefore, by analyzing passenger flow lines, it is possible to find more suitable locations for placing guidance signs and reduce blind spots.

Passenger flow lines can be divided into entry flow lines, transfer flow lines, and exit flow lines. The passenger flow lines of entering, exiting and transferring are shown in Figure 1/2/3 respectively.

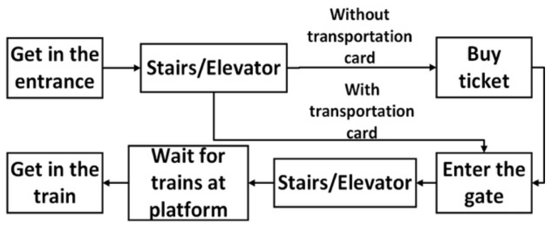

Figure 1: Entry flow line

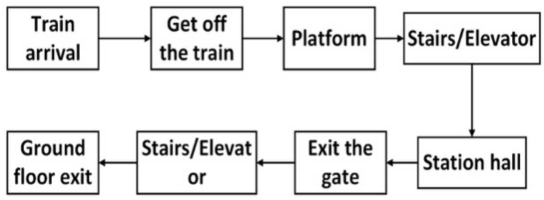

Figure 2: Exit flow line

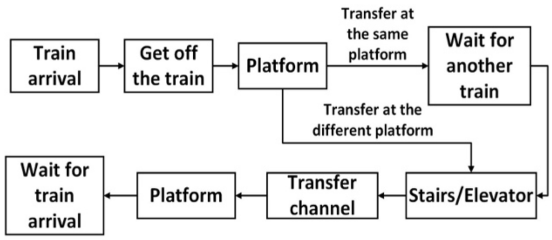

Figure 3: Transfer flow line

3 MATHEMATICAL MODELS

3.1 Problem Description

The mathematical model for the optimization of passenger guidance signs in urban rail transit stations can be expressed as follows: from *m* points, *n* target points with the best effect are selected for placing guidance signs under certain conditions.

3.2 Assumptions

(1) All alternative guidance signs setting points consist of key node points with spatial characteristics at corners, stairways, entry and exit points, etc.

(2) The guidance sign for each location displays information only within three key nodes of that location.

(3) Using a separate floor in the station as the object of study.

3.3 Definition of Parameters

The definition of parameters are shown in table 1.

Table 1 Definition of parameters

Parameters	Definition
j	Alternative points for guidance signs, taking values of 1, 2, 3...m
i	The final target point for passengers, taking the values 1, 2, 3...n
$f(t)$	represents the 0-1 function, when $f(t)$ takes the value of 0, it means no sign is set at point j; when $f(t)$ takes the value of 1, it means sign is set at point j
y_{ji}	The guide factor, when y_{ji} takes the value of 1, indicating that the passenger at point j arrived at point i based on the identification information here, and vice versa, 0
g_{ji}	Number of nodes, indicating the number of nodes that have passed from point j to point i
w_{ji}	The volume of passenger traffic from point j to point i
μ	The weighting factor, which indicates the equilibrium relationship between signage induced passenger flow and induced distance, in this study μ is taken as 1.5.
w	Passenger flow
I_w	The collection of alternative points for marking in different directions after the wth passenger flow enters the station
Si	Passengers arriving at the target point pass through all signage alternative points of assembly.

3.4 Optimization Goal

The optimization goal is to find the maximum value of the induced level of the region, and the formula is shown below.

$$\text{Max } z=\sum_{j=1}^{m}\sum_{i=1}^{n}\frac{f(t)y_{ji}w_{ji}^{\mu}}{g_{ji}} \tag{1}$$

From the above model, it can be seen that the more passengers are guided by the guidance signs when determining the constraints, the more the amount of information of the guidance signs is accepted by the passengers. At the same time, in the process of passengers being guided to the target point by the guidance signs, if the number of nodes passed is less and the distance to the target point is smaller, the more specific information provided and the clearer the route is, the better the guidance role of the guidance signs is reflected. Therefore, this model can reflect the influence of the location of the guidance signs on the guidance of passengers to a certain extent.

3.5 Constraints

a. Limitation on the number of signs.

$$\sum_{j=1}^{m} f(t) = b \tag{2}$$

Definition of parameters:$1 < b < m$ and b is an integer, this constraint indicates that the sign has m alternative points and b of them is selected to set the sign.

b. All passengers entering the station are guided by signs at least once.

$$\sum_{w}^{I_w} f(t) > 0 \tag{3}$$

c. Passengers have been guided at least once to each target point.

$$\sum_{i}^{Si} f(t) > 0 \tag{4}$$

4 CASE STUDY

4.1 Background Introduction

In this paper, choosing Metro Central Station which is the interchange station of Nanchang Metro Line 1 and Line 2 for case study, and select the passenger flow line from Line 1 as an example. There are three routes from the platform of Line 1 to the station hall, one is up through escalator No. 1, the second is up through elevator No. 2 and stairs (the exit direction of the elevator is to the left and the exit direction of the stairs is to the right), and the third is up through escalator No. 3, and then exit the station through the gates in three different directions respectively. Therefore, the number of departure points s is 3, which are departure point 1, departure point 2 and departure point 3. The number of target points i for passengers is 3, which are target point 1, target point 2 and target point 3. According to the field survey, there are 9 alternative points for guiding signs, and the hourly passenger flow is derived from the field survey. The flow diagrams of passenger flow for the three departure points are shown in figure 4/5/6/7 respectively.

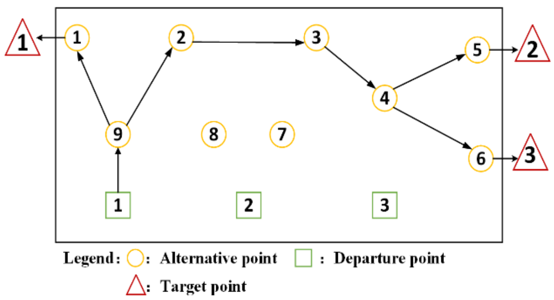

Figure 4: Schematic diagram of passenger flow line at departure point 1

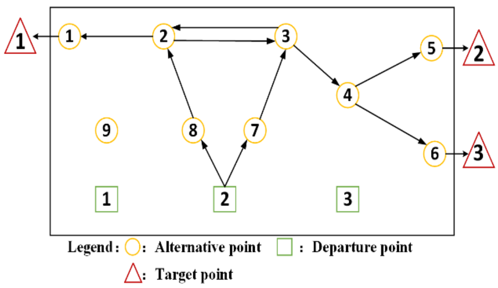

Figure 5: Schematic diagram of passenger flow line at departure point 2

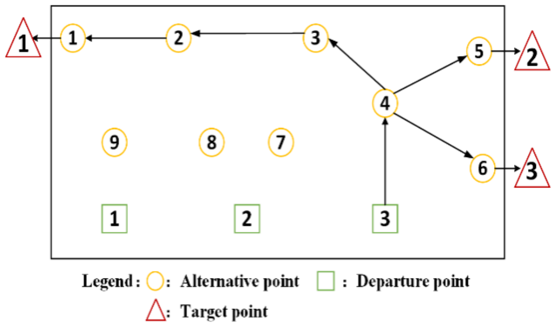

Figure 6: Schematic diagram of passenger flow line at departure point 3

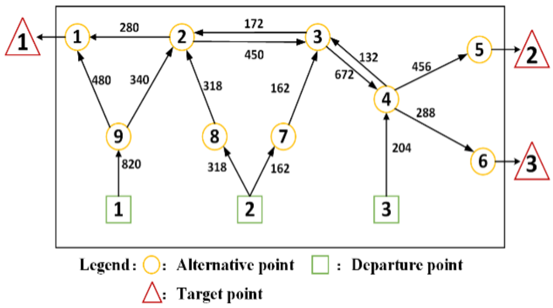

Figure 7: Schematic Diagram of Exit Passenger Flow of Line 1

Integrate the three routes into one flow chart and fill in the corresponding passenger flow as shown above.

The values of the relevant parameters are shown in the table 2.

Table 2: Model Parameters

j	$f(j)$	i	w_{ji}	g_{ji}
1	$f(1)$	1	720	1
2	$f(2)$	1、2、3	280,517,35	2,4,4
3	$f(3)$	1、2、3	172,400,30	3,3,3
4	$f(4)$	1、2、3	132,456,288	4,2,2
5	$f(5)$	2	456	1
6	$f(6)$	3	288	1
7	$f(7)$	1、2、3	40,92,30	4,4,4
8	$f(8)$	1	148	3
9	$f(9)$	1	480	2

(1) Determine optimization goal

According to equation (1), the corresponding optimization goal can be obtained as follows:

$$\text{Max } z=\sum_{j=1}^{9}\sum_{i=1}^{3}\frac{f(t)y_{ji}w_{ji}^{1.5}}{g_{ji}} \tag{5}$$

Based on table 1 and optimization goal, the optimization function can be obtained as follows:

$$\text{Max } z=\frac{f(1)\times 720^{1.5}}{1}+\frac{f(2)\times 280^{1.5}}{2}+\frac{f(2)\times 517^{1.5}}{4}+\frac{f(2)\times 35^{1.5}}{4}+\frac{f(3)\times 172^{1.5}}{3}+\frac{f(3)\times 400^{1.5}}{3}+\frac{f(3)\times 30^{1.5}}{3}+\frac{f(4)\times 132^{1.5}}{4}+\frac{f(4)\times 456^{1.5}}{2}+\frac{f(4)\times 288^{1.5}}{2}+\frac{f(5)\times 456^{1.5}}{1}+\frac{f(6)\times 288^{1.5}}{1}+\frac{f(7)\times 40^{1.5}}{4}+\frac{f(7)\times 92^{1.5}}{4}+\frac{f(7)\times 30^{1.5}}{4}+\frac{f(8)\times 148^{1.5}}{3}+\frac{f(9)\times 480^{1.5}}{2}$$

(2) Determine constraints

a. According to equation (2), the number of signs is set as follows:

$$\sum_{j=1}^{9} f(t)=7 \tag{6}$$

b. According to equation (3), the passenger flow constraints for different directions from the same departure point can be obtained as follows:

Departure point 1:

$$f(1)+f(2)+f(9)>0 \tag{7}$$

Departure point 2:

$$f(2)+f(3)+f(7)+f(8)>0 \tag{8}$$

Departure point 3:

$$f(3)+f(4)+f(5)+f(6)>0 \tag{9}$$

c. According to equation (4), the passenger flow constraints corresponding to the arrival of passengers at different target points can be obtained as follows:

Target point1:

$$f(1)+f(2)+f(3)+f(4)+f(8)+f(9)>0 \tag{10}$$

Target point2:

$$f(2)+f(3)+f(4)+f(5)+f(7)+f(8)+f(9)>0 \tag{11}$$

Target point3:

$$f(2)+f(3)+f(4)+f(6)+f(7)+f(8)+f(9)>0 \tag{12}$$

4.2 Model Result

In this paper, LINGO solver is used to solve the model. According to the known formula and parameters, which can calculate the optimal sequence of signs as 1-0-0-1-1-1-1-1-1-1, that is, No. 1, No. 4, No. 5, No. 6, No. 7, No. 8 and No. 9 alternative points should be set as the selection points for guidance signs. As shown in the figure 8. Guidance signs 4, 7, 8 and 9 are chosen because they are close to the departure point, have a high passenger flow and can prompt passengers to different routes and exit directions. Guidance signs 1, 5 and 6 are chosen because they are close to the exit and can guide and evacuate the passenger flow.

The calculated result is more scientific and accurate than that at the Metro Central station. Setting the location points allows passengers to determine the direction of travel, whether to turn left or right or forward. Passengers can find the signs within a suitable line of sight, maintaining the continuity between signs and verifying the validity of the model.

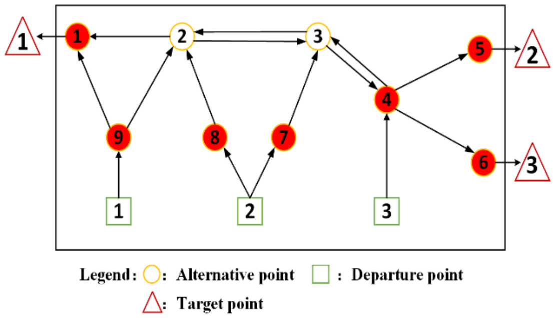

Figure 8: Optimization results of guidance signs

5 CONLISION

With the continuous progress of the times, the pace of human society is accelerating. In this case, urban rail transit, as the main means of transportation for people to travel must have the characteristics of punctual arrival, safety and efficiency. The setting of passenger guidance signs in urban rail transit station is the top priority to improve passengers' travel efficiency. Thus, how to set the guide sign both correctly and scientifically is worth studying.

In this paper, we analyze the influencing factors of passenger guidance signage system in urban rail transit and construct a model for optimal selection of guidance signs deployment. Through the case study of Metro Central station, a more efficient method of guidance sign arrangement is obtained to achieve optimization and verify the effectiveness of the model. In the future research, further research can be conducted on the guidance signage layout scheme for large interchange stations and stations with high passenger flow.

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