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Research on Planning of Rail Transit Connection Facilities --Taking Dongfang Square Station as an Example

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Abstract

How to use the advantages of the subway to a greater extent, make the subway and other modes of travel more effective, planning multi-mode combined travel connection facilities based on subway stations, is to integrate urban transportation resources, expand the radiation range of the new subway, and reduce the overall travel cost of the city Useful exploration. This paper combines the cutting-edge travel demand theory to study the planning of multi-mode combined travel connection facilities, which has certain theoretical value and practical significance. In this paper, a number of logistics models are constructed and the models are calibrated to obtain the connection sharing rate prediction method. Based on the relevant facility construction standards, the scale of the connection facilities is matched with the passenger flow data to obtain the scale demand forecast model of each connection facility and perform parameter calibration . Finally, take the Dongfang Square Station of Changchun Metro Line 2 as an example to make a specific analysis and give a planning scheme.

Keywords

Connection Facilities; Rail Transit; Demand Forecast.

1. Introduction

Urban rail transit originated in Western countries. As a fast and large-volume transportation method, rail transit plays an important role in urban public transportation. The planning and construction of rail transit and its supporting infrastructure is always the top priority of urban planning. Good rail transit facility planning and design can effectively improve the utilization rate of rail transit. Conventional bus stops, taxi stops, P&R parking lots and bicycle parking lots are important connection facilities for urban rail transit stations, and connection facilities of appropriate scale are the basic guarantee for smooth connection.

1.1 Basic Ideas for Planning of Rail Transit Connection Facilities

1.1.1. Rail transit travel survey and characteristic analysis:

First of all, through data collection, status investigation, etc., we must comprehensively understand the current situation of the development of the cities along the track, the shape of the road network, transportation facilities, and traffic management. Then analyze the current traffic situation along the track and evaluate the main problems of the track connection transportation system. Finally, it is necessary to analyze the future development characteristics of the track along the track in combination with the development planning of the land along the track and the urban design.

The travel survey can obtain the travel data of rail transit passenger flow, and further analyze the characteristics of the travel data to obtain the travel characteristics of passengers.

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1.1.2. Forecast of the demand for rail transit connection facilities

The scale of transportation connection facilities should be determined based on the connection demand forecast, and the demand forecast should be based on urban rail transit passenger outflow data. According to relevant theoretical models, data analysis software can be used to combine the results of the analysis with passenger outflow data to obtain the results of the demand forecast for connection facilities.

1.1.3. Determination of the scale of rail transit connection facilities

Rail transit connection facilities include a variety of infrastructure. The scale should be determined according to the relevant construction standards or examples of various facilities, and finally combined with the actual situation of urban traffic.

1.1.4. Planning of the layout of rail transit connection facilities

Plan the connection facilities around the station, including bus depots, bus stops, car parking lots, taxi parking lots, slow traffic systems, station squares and other facilities to build a convenient and safe connection system.

1.2 Analysis on Influencing Factors of Rail Transit Connection Facilities Planning

1.2.1. Factors related to the overall characteristics of travel

Generally speaking, the overall characteristics of travel include three main parts, including traveler characteristics, travel characteristics and travel mode characteristics. The research on the characteristics of traveling passengers is mainly to study the characteristics of different travel modes such as different ages, education levels, monthly income and gender. The so-called travel characteristics refer to characteristics that have different preferences for travel modes due to different travel time, travel purpose, travel distance and other factors. The characteristics of travel modes refer to the different characteristics of different travel modes in terms of time, expense and other costs.

1.2.2. Factors related to the nature of land use

As an important part of the urban transportation system, the good construction and operation of rail transit connection facilities are inseparable from the nature of land use. It is important to study the relationship between the two and the location of the connection facilities. From the perspective of urban spatial layout, different land use attributes will produce different traffic demand distributions and different traffic demand intensities, such as schools, hospitals, shopping malls and other large-scale passenger distribution places.

1.2.3. Related factors of rail transit

From the relevant conclusions of public transportation research in the United Kingdom, the United States and other countries, it is known that the travel time of public transportation must exceed 50% of the total travel time before people like to change to public transportation. The frequency, speed and service level of rail transit will affect the demand for connection facilities.

1.2.4. Related factors of policy guidance

In order to ensure the effective implementation of connection facilities, there must be corresponding safeguard policies. Such as the policy of changing the mode of transportation, the policy of reducing the demand for transportation, and the policy of increasing the parking fee in the city center. The implementation of these related measures has increased the cost of car travel, which in turn forced people to change their travel modes and switch to public transportation.

1.2.5. The characteristic factors of stopping of each connection mode

The connection facilities of urban rail transit stations mainly serve passenger flow. Therefore, the passenger flow shared by various connection methods is the main factor affecting the scale of connection facilities. In addition, the stopping characteristics of each connection mode will directly affect the scale of connection facilities.

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2. Forecast of the demand for rail transit connection facilities

2.1 Forecast model of connection sharing ratio

2.1.1 Basis of model building

The accuracy of the share rate forecast will directly affect the forecast results of the scale of each connection facility. The commonly used method of sharing rate prediction is based on multiple logistics regression models, which use maximum likelihood estimation to estimate model parameters. This article uses public transportation as a reference item in the forecast. It also assumes that passengers will make the most reasonable choice of connection methods according to their needs, and can obtain the relative efficiency of walking, non-motorized vehicles, cars, and taxis relative to public transportation.

The choice of variables mainly comes from the factors that affect the choice of rail transit connection mode, and reflects the above survey content. It mainly includes the following characteristics of travelers (age, personal income, whether to own a car, whether to own a private bicycle, whether to own a private electric car). As some influencing factors cannot be quantified, various influencing factors will be designated to deal with:

(1). Set gender as x_1: x_1=1 (male), x_1=2 (female);

(2). Set age as x_2: According to the traveler's age change range, x_2=1 (0-20 years old), x_2=2 (21-40 years old), x_2=3 (41-60 years old), x_2=4 (Over 60 years old);

(3). Set monthly income as x_3: According to the income change range of passengers, x_3=1 (less than 1000 yuan), x_3=2 (1000~3000 yuan), x_3=3 (3000~6000 yuan), x_3=4 (greater than 6000 yuan);

(4). Whether to have a car set to x_4: x_4=1 (with a car), x_4=0 (without a car);

(5). Whether to have a private bicycle set to x_5: x_5=1 (with bicycles), x_5=0 (without bicycles);

(6). Whether to own a private electric car set to x_6: x_6=1 (with electric car), x_6=0 (no electric car).

2.1.2 Natural logarithmic model

With the help of SPSS software to conduct a large number of statistical regression analysis on the survey data of subway passenger transport connection, we can get the natural logarithmic model of the share ratio of pedestrians, non-motorized vehicles, cars and taxis to buses.

1) Walking—bus:

$$\begin{aligned}V_1 = \ln\left(\frac{P(y=1)}{p(y=5)}\right) &= 21.092 - 0.628x_1 - 2.359\times(x_2=1) - 16.988\times(x_2=2) - 16.927\times(x_2=3)\\ &+5.984\times(x_3=1)+1.799\times(x_3=2)+0.786\times(x_3=3)-0.701\times(x_4=1)-0.074\times(x_4=2)\\ &-1.007\times(x_4=3)-2.033\times x_5+1.917\times x_6\end{aligned} \tag{1}$$

2) Non-motorized vehicles—public transport:

$$\begin{aligned}V_2 = \ln\left(\frac{P(y=2)}{P(y=5)}\right) &= -36.405+15.106x_1+0.701\times(x_2=1)-29.822\times(x_2=2)-28.988\times(x_2=3)\\ &+5.984\times(x_3=1)+4.247\times(x_3=2)-12.739\times(x_3=3)-8.693\times(x_4=1)+4.239\times(x_4=2)\\ &+1.165\times(x_4=3)-13.202\times x_5+13.651\times x_6\end{aligned} \tag{2}$$

3) Car—bus:

$$V_3 = \ln\left(\frac{P(y=3)}{P(y=5)}\right) = -23.803-29.632x_1+12.917\times(x_2=1)-43.140\times(x_2=2)-57.968\times(x_2=3)$$

$$+3.064\times(x_3=1)+20.370\times(x_3=2)+33.179\times(x_3=3)-8.693\times(x_4=1)+4.239\times(x_4=2)$$
$$+1.145\times(x_4=3)-12.616\times x_5+25.090\times x_6 \quad (3)$$

4) Taxi—bus:

$$V_4=\ln(\frac{P(y=4)}{P(y=5)})=-54.737-0.153x_1+13.719\times(x_2=1)+15.378\times(x_2=2)-2.261\times(x_2=3)$$
$$+61.718\times(x_3=1)-2.039\times(x_3=2)+14.516\times(x_3=3)-12.389\times(x_4=1)+28.828\times(x_4=2)$$
$$-12.955\times(x_4=3)+2.035\times x_5-2.42\times x_6 \quad (4)$$

Then the probability of each mode connection choice of the corresponding station passenger is:

1) Probability of walking connection choice:

$$P_1=\frac{e^{V_1}}{(e^{V_1}+e^{V_2}+e^{V_3}+e^{V_4}+1)} \quad (5)$$

2) Probability of non-motor vehicle connection choice:

$$P_2=\frac{e^{V_2}}{(e^{V_1}+e^{V_2}+e^{V_3}+e^{V_4}+1)} \quad (6)$$

3) Probability of car connection choice:

$$P_3=\frac{e^{V_3}}{(e^{V_1}+e^{V_2}+e^{V_3}+e^{V_4}+1)} \quad (7)$$

4) Probability of taxi connection choice:

$$P_4=\frac{e^{V_4}}{(e^{V_1}+e^{V_2}+e^{V_3}+e^{V_4}+1)} \quad (8)$$

5) Probability of bus connection selection:

$$P_5=\frac{1}{(e^{V_1}+e^{V_2}+e^{V_3}+e^{V_4}+1)} \quad (9)$$

2.2 Model for forecasting the scale demand of connection facilities

1) For the square in front of the subway station, it is mainly used to realize the collection and distribution of passengers at the subway entrance. The scale prediction model of the station plaza takes the passenger flow of the station as the research premise and comprehensively considers factors such as pedestrians' stay time. The area of the station plaza is

$$S_{quare}=N_w\times\gamma_w=\frac{N_1\times T}{60}\times\gamma_w \quad (10)$$

where

N_w = Passenger flow in the square at the same time during peak periods,

γ_w = The ratio coefficient of passenger flow and square area,

N_1 = Hourly passenger flow inbound during peak hours,

T = Average time spent by pedestrians in the square.

2) The planning of pedestrian crossing facilities is mainly based on the traffic organization around the site and adapts measures to local conditions, so as to plan the corresponding crosswalk lines, pedestrian bridges, etc., we have not established a clear model of pedestrian crossing facilities.

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3) Non-motorized vehicles around subway stations include not only non-motorized vehicles owned by travelers, but also public non-motorized vehicle equipment such as shared bicycles. When planning a non-motor vehicle parking lot, not only the area required for non-motor vehicle parking is considered, but also the area required for turnover in the parking lot is taken into account to obtain the following model. So the area of the non-motor vehicle parking lot is

$$S_b = N_b \times \bar{S}_b \times (1+\alpha_b) = \frac{N_2}{\beta_b \times \tau_b} \times \bar{S}_b \times (1+\alpha_b) \tag{11}$$

where

N_b = Demand for non-motor vehicles during peak hours,

$\bar{S}_b$ = Parking area required for a single non-motor vehicle,

α_b = The proportional coefficient of the area required for the turnover of a single non-motor vehicle (in and out of the parking lot),

N_2 = Non-motorized vehicle connection passenger flow during peak hours,

β_b = Average number of non-motor vehicle riders,

τ_b = Average turnover rate of non-motor vehicle parking lot.

4) The scale and width of conventional bus stops not only depends on the size of the passenger flow waiting for the bus, but also depends on the scale required for the bus stop. Two different planning conditions are considered: one is that when the width of the passenger station is greater than the length of the bus stop, priority should be given to meeting the passenger station conditions; the other is that when the length of the bus stop is greater than the width of the passenger station, priority should be given Meet the bus stop conditions, so the stop width is

$$W_{bus} = \max\left\{L_{wait}, L_{stop}\right\} \tag{12}$$

where

L_{wait} = Width of passenger station,

L_{stop} = Length of bus stops.

The width of the passenger station is

$$L_{wait} = N_{wait} \times \gamma_{wait} = \frac{N_3 \times T'}{60} \times \gamma_{wait} \tag{13}$$

where

N_{wait} = Passenger flow at the bus station at the same time during peak periods,

γ_{wait} = The coefficient of the ratio of passenger flow to waiting area,

N_3 = Passenger flow of bus connections during peak hours,

T' = Average time waiting for passengers at bus stops.

The length of the bus stop is

$$L_{stop} = N_{\max} \times \bar{L}_{bus} \tag{14}$$

where

$N_{\max}$ = The maximum number of vehicles that can be parked at the bus station at a common station,

$\bar{L}_{bus}$ = Length of parking required for a single bus.

5) The planning of bus depots is mainly based on the overall dispatch of the urban bus line network, because this article mainly studies the passenger flow of rail transit. The research on the current bus

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network is not focused on description. Therefore, the preliminary planning study of the bus station is omitted. It is only based on the existing bus station facilities and considers the subway connecting passenger flow to expand the scale of the bus station. The expansion plan of the yard refers to the planning model of bus stops.

6) The scale prediction model of the taxi parking lot is based on the research premise of the taxi connecting passenger flow at the station, and comprehensively considering factors such as taxi turnover efficiency, the area of the taxi parking lot is

$$S_t = N_t \times \overline{S}_t \times (1+\alpha_t) = \frac{N_4}{\beta_t \times \tau_t} \times S_t \times (1+\alpha_t) \tag{15}$$

where

N_t = Demand for taxis per hour during peak hours,

$\overline{S}_t$ = Parking area required for a single taxi,

α_t = The ratio coefficient of the area required for the turnover of a single taxi (in and out of parking lot),

N_4 = Hourly taxi passenger flow during peak hours,

β_t = Average number of taxi riders (except drivers),

τ_t = Average turnover rate of taxi parking lot.

7) Taking into account the special situation that the subway connecting passenger flow (except the staff) cannot drive the private car alone, we found that the subway connecting passenger flow's demand for cars is mainly reflected in two aspects: one is the connection of private cars to and from the station Passenger flow, the second is that there is a demand for online car-hailing to pick up and drop off passengers. The former has relatively flexible demands, while the latter has relatively fixed stops. The operation of the two methods is similar to that of taxis, and the drivers are not within the scope of the subway connecting passenger flow. The scale prediction model of the car parking lot is based on the research premise of the passenger flow of car connections at the station, and comprehensively considering factors such as car turnover efficiency, the area of the car parking lot is

$$S_c = N_c \times \overline{S}_c \times (1+\alpha_c) = \frac{N_5}{\beta_c \times \tau_c} \times S_c \times (1+\alpha_c) \tag{16}$$

where

N_c = Hourly demand for cars during peak hours,

$\overline{S}_c$ = Parking area required for a single car,

α_c = The ratio coefficient of the area required for the turnover of a single car (in and out of parking lot),

N_5 = Hourly car passenger flow during peak hours,

β_c = Average number of car riders (except drivers),

τ_c = Average turnover rate of car parking lot.

Because the factors that affect the scale of various access facilities are not the same, the overall model involves many parameters, some of which can be directly determined by experience or obtained from existing research results, and the remaining parameters are combined with specific urban rail transit stations and Obtained through field investigation. The specific parameter values are summarized in the following table.

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Table 1. Some parameter values for the scale demand forecast of connection facilities

Parameter	Value	Parameter	Value
γ_w	10.0	τ_t	1.5
$\bar{S}_b$	1.5	$\bar{S}_c$	11.25
α_b	0.2	β_c	1.15
β_b	1.0	τ_c	1.0
τ_b	1.5	α_c	0.6
$\bar{S}_t$	11.25	γ_{wait}	0.8
α_t	0.6	$N_{\max}$	2.0
β_t	1.45	$\bar{L}_{bus}$	10.0

3. Planning Scheme of Connecting Facilities of Dongfang Square Station in Changchun City

Dongfang Square Station is located underneath the circular Dongfang Square in Erdao District, Changchun City. It has five exits A, B, C1, C2, and D. The west side is the intersection of Jilin Road and Yangpu Street, and the east and southeast sides are connected respectively. Jilin Road and Changji Highway. There are many large commercial buildings and municipal buildings in the surrounding area. It is one of the most prosperous areas in Changchun City. The area is characterized by mature or aging built-up areas. Satellite pictures around the site are placed below.

Figure 1. Location and surrounding plan

3.1 Forecast of passenger flow

From the passenger flow data obtained, it can be seen that the peak hour of Dongfang Square Station is from 7 to 8 in the morning, and the peak hour passenger flow is 1220 people. At Dongfang Square Station, 50 questionnaires were issued to passengers entering and exiting Metro Line 2 to obtain Passengers' personal attributes: gender, age, occupation, monthly income, whether they own a car, whether they own a private bicycle, and whether they own a private electric car. Analyze the results of the questionnaire, and use the multiple logistics regression model constructed in Chapter 3 in combination with the survey data to obtain the connection sharing rate of each method at Dongfang Square Station as follows.

Table 2 Forecast of share rate and passenger flow

Travel mode	Predicted share ratio/%	The passenger flow forecast value of each connection method during peak hours/Person times
Walk	64.29	784
Non-motor vehicle	1.9	23
Car	4.29	52
Taxi	7.14	87
Bus	22.38	273

3.2 Forecast of facility scale demand

The total area of the square in front of the Oriental Plaza Station is about 305 m^2 , and the total area of non-motorized vehicles is about 27.6 m^2 (including approximately 15 parking spaces for non-motorized vehicles). The width of the stop is about 20m, the total area of the taxi parking lot is about 720 m^2 (including about 40 parking spaces), and the total area of the car parking lot is about 814 m^2 (It contains approximately 45 parking spaces).

3.3 Layout planning of connection facilities

Since the area near the Dongfang Square Station is a mature or aging built-up area, there was a large number of passenger flows around the subway station before the construction of the subway station. Therefore, the existing bus stop, motor vehicle parking lot and other facilities are relatively complete. On this basis, try to use the existing Connecting facilities are based and supplemented accordingly.

According to field observations, the land use at entrances C1, C2 and D of Dongfang Square Station is complex, and the distance between entrance C1 and the road is relatively short, which does not meet the construction conditions of the square in front of the station, while the conditions near the entrances A and B are relatively good. Set up a crosswalk in front of the entrance and exit of C1 with a length of 15m and a width of 3m. According to the conclusions of the scale demand forecast, the station squares were set up at the entrances and exits of A and B, each with a scale of 15m in length and 10m in width.

According to field observations, the settings of bus stops near the entrances and exits of Dongfang Square Station are as follows. Here are two Oriental Plazas (bus stations) on the north and south sides of the road near entrance A; Jingkai Building (bus station) and Oriental Plaza (bus station) are located on the north and south sides of entrance B; National Highway 302 between C1 and D With the Oriental Plaza (bus station), it can be seen that the existing bus stops can basically meet the bus transfer needs of the Oriental Plaza.

According to field observations, there is a Marriott International Parking Lot on the southwest side of the intersection of Jilin Road and National Highway 302, located near the entrance of Dongfang Square Station A, a distance of about 100m. Therefore, the taxi and car parking spaces were merged, and based on the conclusion of the scale demand forecast, the original parking lot was expanded on the existing basis. Specifically, about 85 motor vehicle parking spaces were added, with an area of about 1550 m^2 .

4. Conclusion

Based on the summary and analysis of domestic and foreign scholars' research on rail transit connection facilities, this article has reached certain conclusions. Through the investigation and analysis of passenger connections, it can be found that the choices of different connection methods

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by subway passengers are related to their own age and personal income. In the process of rail transit demand forecasting, multiple logistics regressions can provide a good feedback of a certain proportion of various connection methods to a certain extent. In the process of forecasting the scale of rail transit connection facilities, we can refer to the construction cases of related infrastructure to analyze the important factors that affect the scale of connection facilities. For the layout of rail transit connection facilities, not only are they laid out in accordance with relevant standards, but the actual situation around the site is also an important factor that needs to be considered.

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