Research on the scale of transportation connecting facilities in comprehensive transportation hubs

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Abstract. In the context of designing integrated transportation hubs, scientifically determining the appropriate scale of diverse transportation connecting facilities holds a pivotal role. Utilizing the instance of Shengzhou Xinchang Station, we delineate the traffic functionalities and interconnectivity principles of the various connecting facilities encompassed within the plaza preceding the high-speed railway station. By leveraging pertinent design data pertaining to the high-speed railway station, we forecast the anticipated demand for diverse transportation connections. Furthermore, we introduce layout norms and methods for calculating the scale of transportation connecting facilities. Upon calculating the scale of various transportation facilities, we integrate considerations of the layout configuration and traffic flow to optimize and refine the scale, ultimately arriving at an optimized plan.

Keywords: Comprehensive transportation hub; Station square; Passenger flow prediction; Facility scale

1 INTRODUCTION

An urban transportation hub serves as a nodal point where diverse modes of transportation converge, facilitating transfers both externally and internally, as well as among various internal transportation systems[1-3]. Establishing a rational scale for the various transportation connecting facilities within a comprehensive transportation hub is crucial for devising its spatial layout, enhancing operational efficiency, and promoting seamless travel experiences for the public.

This study employs the case of Shengzhou Xinchang Station to propose methodological frameworks and innovative design concepts for estimating the scale of transportation connecting facilities within the plaza adjacent to the high-speed railway station. This exploration aims to offer insights and guidelines for analogous projects.

Located at the convergence of two pivotal comprehensive transportation arteries in Shengzhou city, Shengzhou Xinchang Station serves as a public hub for the Hangzhou-Taiwan High Speed Railway and the Jinyong Railway, as illustrated in Figure 1.

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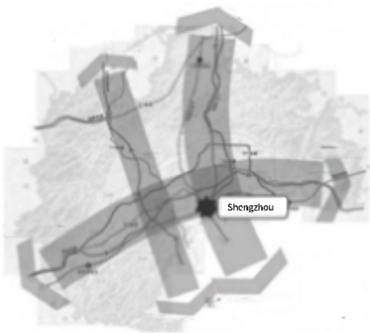

Fig. 1. Project area map.

2 PASSENGER FLOW PREDICTION

2.1 Railway Passenger Flow Prediction

Drawing upon pertinent design data pertaining to the high-speed railway station, it is anticipated that Shengzhou Xinchang Station will accommodate an annual passenger volume of 3.5 million by the year 2030, with a peak hour passenger volume reaching 1092 individuals. Furthermore, projections indicate that by 2040, the annual transmission volume will increase to 4.5 million people, accompanied by a peak hour transmission volume of 1404 individuals. Additionally, the maximum anticipated number of individuals congregating at the station in the future is estimated to be 2000.

2.2 Prediction of the Proportion of Travel Modes

The categorization of transportation modes pertains to the selection of diverse modes of travel during a journey. This categorization employs a probabilistic framework, presupposing that the choice of transportation modes is grounded on impedance factors specific to each mode, including time and cost, and occurs with a defined probabilistic relationship[4]. The Logit model stands as a widely employed predictive tool, which suggests that the utilization rate of a particular transportation mode among OD (origin-destination) pairs can be mathematically expressed as follows[5,6]:

$$P_i = \frac{\exp(-U_i)}{\sum_{j=1}^{j} \exp(-U_j)}$$

$$U_i = \sum_k a_k X_{ik}$$

The prediction of transportation mode division incorporates the travel time of each mode as the utility function, while also incorporating comprehensive costs as additional pertinent variables influencing travel within the utility function.

By taking into account various factors such as the travel habits of Shengzhou residents, the standard of public transportation services, travel time expenditure, and travel distance, the anticipated proportion of transportation modes in Shengzhou is derived, as presented in Table 1.

Table 1. Prediction of the proportion of travel modes in the urban area of Shengzhou.

Proportion of travel modes/%	2020	2030	2040
Walk	22	19	15
Non-motorized vehicle	28	24	14
Motorcycle	3.5	0	0
Mass transit	16	23	29
Taxi	1.5	2	7
Private car	27	30	33
Corporate vehicles	1	1	1
Other	1	1	1

2.3 Estimation of Passenger Flow for Transportation Connecting Facilities

The predicted transportation connection structure of the Shengzhou New High Speed Railway Station in 2040 are shown in Table 2.

Table 2. Planned long-term (2040) peak hour connecting passenger flow.

	Transit	Passenger transport	Taxi	Car	Other
Peak hour sending volume/ (person $\cdot h^{-1}$)	394	169	211	548	84
Full day sending volume /(person $\cdot d^{-1}$)	3577	1357	1918	4981	763
Method ratio	28%	12%	15%	39%	6%

3 STANDARD FOR LAYOUT OF TRANSPORTATION CONNECTION FACILITIES

3.1 Passenger Station

In establishing a passenger station on the piazza preceding, it is imperative to consider the necessary amenities for a bus passenger station. These amenities typically encompass a station piazza, parking facilities, and departure bays. Given the station's proximity to the piazza in front of the high-speed railway station, the piazza area of the bus station is deemed unnecessary for separate consideration.

Drawing from the "Classification and Construction Requirements for Bus Terminals" (JT/T 200-2004), the methodologies for calculating the scales of parking areas and departure bays at bus stations are outlined as follows:

(1) The maximum passenger aggregation is determined by multiplying the daily shipment volume by the calculated percentage.

(2) The number of departures is calculated by multiplying the maximum passenger aggregation by a coefficient of addition (taken as 1.2) and dividing the result by the average number of departures per hour per parking space, assuming a passenger capacity of 30.

(3) The parking area is computed by multiplying the number of departures by 28 and the projected area of passenger vehicles, typically estimated as 30 square meters per vehicle.

3.2 Bus Terminals

The design regulations outlined in CJJ/T 15-2011 for urban road public transportation stations, yards, and factories specify the following:

(1) The allocation of operating vehicles to a particular line must take into account the anticipated development requirements of that line.

(2) The entrance and exit points of the initial and terminal stations must be separated and clearly indicated. The recommended width for the entrance and exit ranges from 7.5 to 10 meters. In cases where the lane width outside the station measures less than 14 meters, the width of the entrance and exit should be increased by a factor of 20% to 25%.

3.3 Taxi

The average pick-up and drop off time for taxis is 30 seconds. Considering the unevenness of taxi arrivals, multiply the correction factor of 1.3 when calculating the taxi alighting space, and do not correct the boarding space. In addition, according to Japanese regulations, the pick-up and drop off ratio is set at 0.9, which means the arrival volume is calculated based on 0.9 of the sending volume.

3.4 Motor Vehicle Parking Lot

Vehicles accessing the departure level directly for passenger drop-off purposes typically spend approximately 50 seconds at the designated zone. Incoming vehicles to the parking lot are categorized into three distinct groups, each with its specific parking duration: (1) Vehicles servicing commuting passengers typically park for about 10 hours; (2) Delivery vehicles spend approximately 20 minutes; and (3) Vehicles intended for multi-day storage are parked for one day or longer, with a parking space calculation factoring in a 1.3 unevenness coefficient. Additionally, when determining the necessary pick-up parking spaces.

4 ESTIMATION OF THE SCALE OF TRANSPORTATION CONNECTING FACILITIES

The scale of various transportation facilities is determined by the passenger flow of each facility. The full load rate is calculated based on 40 people/vehicle for buses, 30 people/vehicle for long-distance buses, 2 people/vehicle for taxis, and 2.5 people/vehicle for social vehicles. Based on this, the scale of various parking facilities is shown below:

4.1 Passenger Station

The scale calculation of passenger stations is shown in Table 3.

Table 3. Calculation of passenger station scale.

Passenger flow categories	Peak hour sending volume/(person $\cdot h^{-1}$)	Parking/unit	Parking area/m^2	Departure area/m^2	Station area/m^2
Passenger station	153	3	2520	360	2880

4.2 Calculation of the Scale of Initial and Final Bus Stops

The scale prediction of the first and last bus stops is shown in Table 4.

Table 4. Prediction of the scale of bus terminals.

Passenger flow categories	Number of lines/piece	Parking area/ m^2
Transit	6	2400

4.3 Underground Garage

(1) Scale of pick-up section (see Table 5)

Table 5. Calculation of underground garage scale - station connection.

Passenger flow categories		Passenger flow	Parking/unit	Parking area/m^2	Drop off seat/unit
Delivery vehicles		308(person $\cdot h^{-1}$)	-	-	3
Parking lot vehicles	Bus delivery flow	110(person $\cdot h^{-1}$)	32	1280	
	Commuting passenger flow	697(person $\cdot h^{-1}$)	251	10040	
	Multi day storage	260(person $\cdot h^{-1}$)	299	11960	

(2) Scale of delivery station (see Table 6)

Table 6. Calculation of underground garage scale - delivery station.

Passenger flow categories	Peak hour sending volume/(person ·h^{-1})	Parking/unit	Parking area/ m^2
Parking lot	548	238	9520

(3) Overall scale

The surface area allocated for social parking facilities is detailed in Table 7.

Table 7. Calculation of Underground Garage Scale.

Passenger flow categories	Calculate parking spaces/unit	Consider reserving/parking space	Parking area/m^2
Parking lot	820	1120～1520	44800～60800

4.4 Summary of Scale of Connecting Facilities

Calculate that the required area for stations related to high-speed rail stations should not be less than 50000 square meters, and sufficient underground space should be set up; In actual layout, appropriate adjustments should be made based on factors such as the land occupation of future new energy car supporting facilities, the popularity of ride hailing services, shared cars, and the occupation of employee parking lots. The final scale is shown in Table 8.

Table 8. Summary of Connection Facilities.

Passenger flow composition	Peak hour demand scale/(person ·h^{-1})	Facility scale/m^2	Optimization	Notes
Tourist bus	51	1000	1000	The average occupant capacity stands at 40 passengers per vehicle, with a departure space turnover rate of 2 vehicles per hour.
Coach	153	2880	3000	The average passenger capacity per vehicle is 30 individuals, and the turnover rate for departure spaces averages at 2 vehicles per hour.
Bus	663	2400	2400	The departure interval is 15 minutes per trip, with a passenger capacity of 40 people per train, and a station area of 400 m^2 per line.

Taxi	211	1533	1600	Passenger capacity of 1.5 people per vehicle, waiting for an average of 20 minutes in the storage area.
Car	548	44800~ 60800	45000~61000	Consider hub connecting passenger flow and reserved parking needs; When calculating, consider the passenger flow characteristics of the passenger transfer station and calculate separately

5 CONCLUSION

The cornerstone of predicting the scale of transportation connecting facilities within comprehensive transportation hubs lies in passenger flow prediction. However, passenger flow prediction is an intricate task, and currently, there is no standardized analytical or calculation method. The theories and methodologies of prediction analysis are continuously evolving and improving. Additionally, the accuracy of passenger flow predictions cannot be guaranteed to align precisely with future scenarios. Over the years, various unpredictable factors may significantly influence passenger flow. Consequently, once the scale prediction results of transportation connecting facilities are obtained, further contemplation must be accorded to the hub's layout, the rationality of various traffic flow lines, and the overall configuration of comprehensive transportation hubs.

After the completion and operation of the hub, the internal passenger flow environment will further become more complex. In the future, on-site research parameters can be supplemented, and rolling tracking and evaluation can be carried out regularly to smooth out the micro cycle of passenger flow operation.

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