УДК 654.6.4

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STOP FEATURE ANALYSIS OF GUANGZHOU − ZHUHAI INTERCITY RAILWAY BASED ON PASSENGER FLOW

This paper analyzes the dwelling regulation of Chinese representative intercity railway, Guangzhou − Zhuhai Intercity Railway. In order to study the needs of stop schedule plan, the cluster analysis method is used to calibrate the class of stations according to passenger flow. Combined with a given passenger flow demand, the relationship between the class and stopping trains of station, originating-ending passenger trains, and the train dwelling regulation of different grade trains, such as the number of stops, stop ratio and stop distance, association between station class and service trains were analyzed systematically. It is show that there are obvious hierarchy features in current intercity railway stop schedule: The distribution of Guangzhou − Zhuhai train passages is provided with a master- more deputy structure, the train service amount successively decreases according to station grade and the originating-destination passenger trains focus on the stations of high class. Train service frequency between the stations is closely relate to OD passenger flow, the long-distance trains operate in the Guangzhou − Zhuhai Intercity Railway between Guangzhou and Zhuhai makes the passenger flow along the way obtains higher train service to Guangzhou South.

Operating trains according to passenger flow is the basic principle for formulating a railway passenger train plan, and the distribution of passenger flow is a decisive factor in determining the operation and stops of trains [1]. The relationship between passenger flow distribution and the number of service trains is more complicated, due to the huge number of combinations of departure and destination stations and stations and stops of trains. In western Europe and Japan, generally the number of stop stations is regard as an important feature of high-speed trains. It is a commonly used method to determine the starting and ending points and stops of trains according to the distribution law of OD passenger flow.

In China, it has a rich practical experience in passenger station classification for existing railway, and the division criteria have been scientifically tested and tested to be of high scientificity and rationality. There are many classification and types of trains, and there is a relatively clear corresponding relationship between train level and stop station level.

In contrast, the high-speed railway station ranks are generally higher, the discrimination is not obvious, and the train types are relatively single. Therefore, the correspondence between the high-speed railway train service frequency and the passenger flow distribution needs to be further clarified.

Domestic and foreign scholars have conducted a lot of research on the laws of railway passenger flow, the operation plan of high-speed railway trains and the setting of train stops. In terms of passenger flow analysis, Suh SD [2] studied the Korean high-speed railway (KTX) to verify that the quality of transport services has a great impact on passenger travel behavior; Bingyu Feng [3] used gray neural network technology to study the trend of passenger flow. Ma Yanxiang [4] studied the periodicity, trend and stability of short-term passenger flow in railways, and obtained the rule that the short-term passenger flow of the railway is generally stable and cyclically changes in units of weeks.

In the high-speed railway train operation plan and parking station setting optimization, Chang Yh., Niu Hm. studied the train operation plan and map problem under the preset stop station scheme respectively [5, 6]. Xu Ruihua [7] combined the determination of the stop station with the passenger flow of the train. The method determines the train stop plan adopted the passenger flow merger and according to the passenger flow. Li Dewei [8] established the optimization model of the high-speed railway train stop plan based on the station train service. Deng Lianbo [9] constructed a two-level planning model for the passenger train stops based on the relationship between the number of service trains and passenger flow choices.

It has become the consensus of researchers to formulate the train operation plan based on the passenger flow law. However, in general, the relationship between the train service frequency and passenger flow of China's high-speed railways needs to be further discussed. The research on the high-speed railway train operation plan and stop station setting optimization needs to be supported by relevant operation practice laws. The intercity railway has facilitated interconnection and commuting due to its ″public transit″ operating mode.

This paper takes the actual train operation plan of Guangzhou − Zhuhai intercity railway, a most representative intercity railway in China, as the research object, and research on the train dwelling regulation. Using the agglomeration clustering method, the Guangzhou − Zhuhai Intercity Railway station is classified according to the passenger flow. The analysis of the train dwelling regulation mainly includes the matching relationship between the number of parked trains, station class, the number of train stops, the train level, the number of trains per passenger flow OD and the OD passenger flow demand. Based on the above analysis, this paper summarizes the stop station setting regular intercity railway.

Guangzhou − Zhuhai Intercity Railway is an inter-city railway connecting Guangzhou and Zhuhai in Guangdong Province of China. It runs from north to south. It is the south end of Beijing Harbin − Beijing Hong Kong Macao channel of China's ″eight vertical and eight horizontal″ high-speed railway network. It is also one of the main lines of the inter-city rapid rail transit in the Pearl River Delta. Guangzhou − Zhuhai intercity railway is distributed in the shape of Chinese characters ″human″ (figure 1).

The total length of Guangzhou South Railway Station to Zhuhai Station is 116 km, it is the main line. And the length of branch line, Xiaolan Station to Xinhui Station, is 27 km, also it connects the Jiangmen − Maoming high-speed railway. So, cross-line passenger flow is considered in the passenger flow analysis.

This article selects the train operation diagram on 5th November, 2019 as an example. There are 222 trains run in Guangzhou − Zhuhai Intercity Railway, including 126 trains on this line, all of which are intercity trains (speed 250 km/h) starting with ″C″; and 96 trains across the line. Among them, there are 82 Medium-speed trains (250 km/h) starting with ″D″, and 14 high-speed trains (350 km/h) starting with ″G″. The Guangzhou − Zhuhai Intercity Railway has a total of 22 stations and 20 have been opened. There are 17 stations in the main line (Guangzhou South − Zhuhai) and 3 stations in the branch line (Xiaolan − Xinhui). Among them, there are 3 departure stations namely Guangzhou South Station, Zhuhai Railway Station and Xinhui Station, and the other 17 stations are intermediate stations.

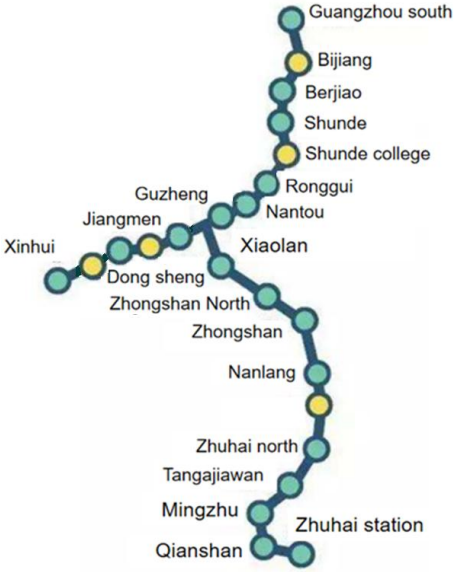

Figure 1 – The map of Guangzhou − Zhuhai Intercity Railway

According to the passenger volume, freight volume and technical operation volume, the existing railway stations in China are divided into six grades: special grade, first to fifth grade. But the grades and discrimination of high-speed railway stations are not obvious. Therefore, the cluster analysis method is used to calibrate the station class according to the passenger flow demand situation, and the station passenger traffic is selected as the clustering index, and the passenger traffic Q_k of the station ″k″ is the sum of the sending and arriving passenger traffic:

$$Q_k = \sum_{i=1}^{H} f(i,k) + \sum_{j=1}^{H} f(k,j), \quad (1)$$

where $f(i, k)$, $f(k, j)$ are the passenger flow from station ″i″ to station ″k″ and from station ″k″ to station ″j″ respectively $i, j = 1, 2, \cdots, H$, H is the number of stations. Taking the average daily passenger flow as the reference data, the average daily passenger flow of the stations of Guangzhou − Zhuhai intercity railway from October 15 to November 15, 2019 is shown in figure 2.

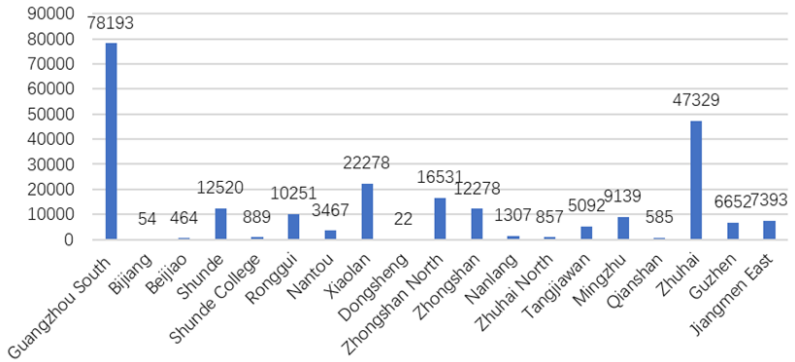

Figure 2 – The average daily passenger flow of stations

Using software ″SPSS″ to classify stations by agglomerative clustering Analysis (CA). The idea is to first cluster each station as a single cluster, and then merge the two closest data objects each time to cluster until all objects are merged into one class or stop clustering when a certain termination condition is reached. The similarity is calculated using the square Euclidian distance, and the distance between the classes is converted to a value between 1 and 25. The clustering process tree diagram of the Guangzhou − Zhuhai Intercity Railway Station is shown in figure 3.

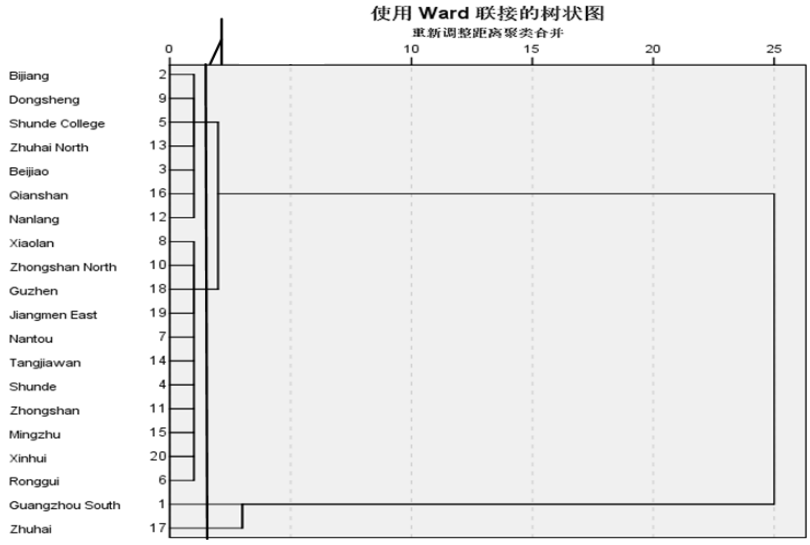

Figure 3 – The clustering process tree diagram

Setting the termination condition as group distance ≥ 1,56, and divide 20 stations of the whole line into 4 classes, as shown in table 1.

Table 1 – **Station class division table**

Station class	Stations
First class	Guangzhou south
Second class	Zhuhai
Third class	Ronggui, Xinhui, Mingzhu, Zhongshan, Shunde, Tangjiawan, Nantou, Jiangmen-east, Guzhen, Zhongshanbei, Xiaolan
Fourth class	Nanlang, Qianshan, Beijiao, Zhuhai north, Shunde college, Dongshen, Bijiang

Table 2 shows the average daily passenger flow of all classes of stations of Guangzhou-Zhuhai intercity railway. It can be seen that the passenger flow of each level has obvious differences, which shows the effectiveness of station clustering.

Table 2 – **The average daily passenger flow of each stations class**

Unit: person. time

Station class	First class	Second class	Third class	Fourth class
Average Passenger flow	78193	47329	3947	360

The trains of the station providing boarding and landing for passengers include the departure and arrival trains and parking trains. The number of service trains in the station reflects the passenger flow service level of the station. The train service status of each station of the Guangzhou − Zhuhai Intercity Railway is shown in figure 4.

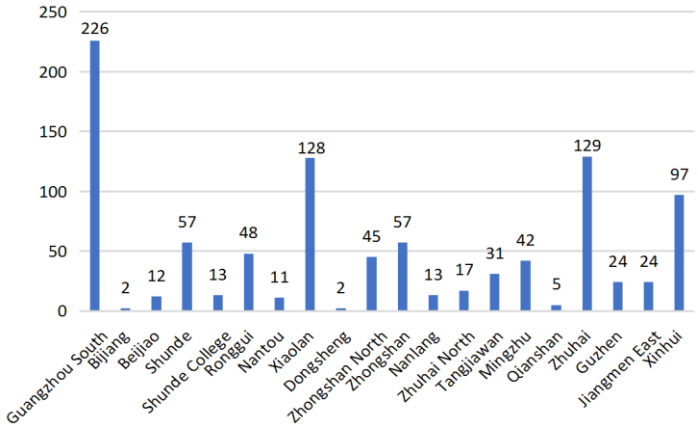

Figure 4 – Train service frequency of each station

As can be seen from the figure, the "C" prefix trains at each station are far more than the "D" and "G" prefix trains. The total number of train services at each station is also significantly different and has a significant hierarchy.

The distribution of departure and arrival trains of Guangzhou-Zhuhai intercity railway is shown in figure 5.

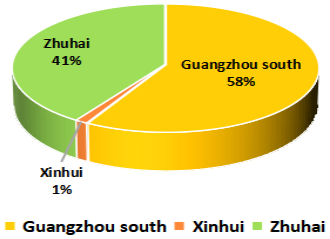

Figure 5 – Frequency of departure trains

There are only three stations, Guangzhou South, Zhuhai and Xinhui, which have set up departure and arrival trains. Among which 58 % are from Guangzhou south, 41 % are from Zhuhai and only 1 % are from Xinhui. It can be seen that the starting trains of Guangzhou Zhuhai intercity are mainly set in Guangzhou south railway station, and the branch line from Guangzhou south railway station to Xinhui railway station is extended to Yangjiang station of Jiangmen − Maoming High Speed Railway, so most of the trains start and end at Yangjiang station, where the starting and end ratio of Xinhui station is low.

The relationship between the passenger flow of the Guangzhou − Zhuhai intercity railway and the train service frequency is shown in figure 6.

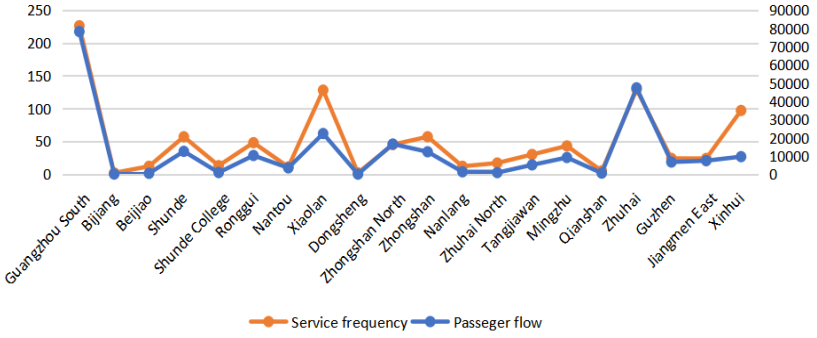

Figure 6 – Combination diagram of train frequency and passenger flow

From the figure, it can be seen that the train service frequency is closely related to the station passenger flow, the station with a large number of passenger flow volume has a large service frequency. For example, the train service frequencies of Guangzhou South and Zhuhai are more prominent, which classified in first class and second class, while the service frequencies of the third class stations Xiaolan and Xinhui Station are similar, closely following Zhuhai Station. The remaining third class stations are significantly lower than the above-mentioned high-grade stations, but higher than the fourth-class stations.

The station service frequency shows the busy degree of the station, and

also reflects the grade of the station to a certain extent. Based on the above classification of each station on Guangzhou − Zhuhai Intercity Railway, the average service frequency and passenger flow of nodes at different levels are compared, as shown in table 3.

Table 3 – **Comparison of passenger flow and train service frequency**

Station Class	Passenger flow of node	"C" train	"D" train	"G" train	Originating train
First class	78193	127	83	16	93
Second class	47329	96	23	10	65
Third class	10474	40	17	4	2
Fourth lass	597	9	1	1	0
Sum	136593	272	124	31	160

Furthermore, the analysis of the average service frequency, originating trains frequency and stopping trains frequency of the different grade trains of each class station, is shown in figure 7.

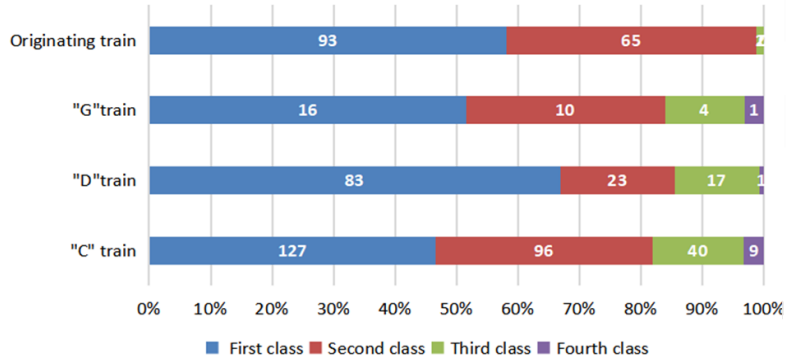

Figure 7 − The structure of the service trains for all station classes

As we can see ″C″-rank trains services mainly in the stations of first class and second class , which service frequency are respectively account for 46,64 % and 35,26 % of all ″C″-rank trains; ″D″-rank trains mainly service the stations of first class, reached 66,94 %; ″G″-rank trains also mainly service the stations of first class, reached 51,61 %. At the same time, the highest frequency of the originating train is the trains of first class and second class, respectively accounted for 58,13 % and 40,63 % of all departing train, however the lower nodes such as fourth class without originating train, which is corresponding to station status of passenger demand.

Through figure 8, ″C″- rank trains in the station at all classes occupy the main body status, the proportion of the ″C″-rank trains to the total number of trains are over 56,19 %, the fourth class is even reached 81,82 %. It shows that Guangzhou

– Zhuhai Intercity Railway mainly operates intercity trains starting with ″C″, ″D″ medium-speed trains and ″G″ high-speed trains are cross line trains with few stops.

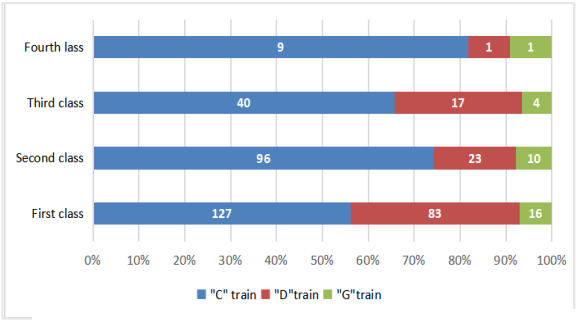

Figure 8 – The structure of service trains for all classes stations

Figure 9 is a pie chart of the distribution of departure trains at each station's class. The first class account for 58 %, the second class account for 41 %, and the fourth class have no departure trains. It can be seen that the departure and terminal stations are basically set at high-level nodes.

Train stop is mainly to meet the needs of Midway passengers. Intermediate stations with less passenger flow mainly rely on the parking trains to transport passengers. The greater the number of train stops, the more convenient it is for passengers to board and land. However, stoping too many stations on the way will reduce the travel speed and lose the significance of high-speed for high-speed train, even extend the travel time of passengers who not to get on the train. Therefore, the setting of train stops should not only consider the convenience of passengers' travel, but also must not reduce the travel speed of the train too much, so as to avoid increasing the travel time of passengers. In addition, different train stopping schemes will attract different passenger flows, which will affect the congestion and comfort of passengers on the train.

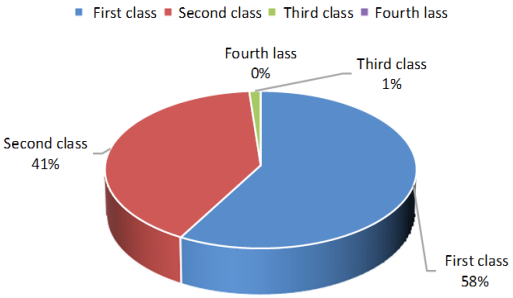

Figure 9 – The pie chart of the distribution of originating trains

Every level train dwelling regulation are analyzed below from two aspects: the number and the distance of stopping stations.

Guangzhou Zhuhai Intercity Railway operates 222 trains a day, including 14 high-speed (″G″) trains, 82 medium speed (″D″) trains and 126 intercity (″C″) trains. The statistics of the number of stops of three classes of trains are shown in table 4.

Due to the ″G″ and ″D″ trains are cross line trains, they are run a short section

of the Guangzhou − Zhuhai Intercity Railway. As can be seen in table 4, the number of stops for medium-speed ″D″ trains at 250 km/h and high-speed ″G″ trains at 300 km/h is concentrated at 2−3 stations, and there is no case of stopping at more than 6. And the stops are all in the overlapping section of the line.

Table 4 – **Operated trains distributing in different stop stations**

Number of stops	2	3	4	5	6	7	8	9	Total trains
″C″train	0	2	14	40	42	18	8	2	126
″D″train	42	34	6	0	0	0	0	0	82
″G″train	5	9	0	1	0	0	0	0	14

Therefore, only ″C″ trains of Guangzhou − Zhuhai Intercity Railway are examined here. As can be seen from the table 4, the maximum number of stops is 9 stops. The Guangzhou − Zhuhai Intercity Railway has 17 stations on the main line and 11stations on the branch line. 8 stations of them overlap. It can be seen that there are no stop-stop trains, and the trains are in skip-stop mode.

Due to the differences in starting points, further analysis of the stoppage ratio. The distribution chart of the stoppage ratio of ″C″ trains is shown in figure 10.

The stoppage ratio is between 18 % and 64 %. There are 61 trains, accounting for 48,5 % of the total number of trains in operation, whose stoppage ratio in the 29−35 % section. There are 14 trains whose stoppage ratio between 50 % and 65 %.

It shows that there are still different service ranges in train ″C″, and the coordination of various stop modes ensures the boarding and descending of each station and optimizes the resource allocation. The average stop distance of the train can be expressed as the ratio of the train running mileage and number of stopping stations. The average distance between stop stations is distributed as figure 11.

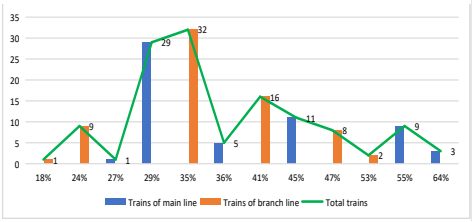

Figure 10 – The distribution of train stop ratio

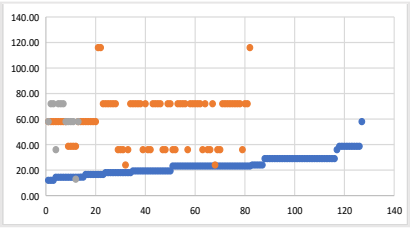

Figure11 – The distribution of average stop distance

The stations are densely distributed with a distance of about 8 km on Guangzhou − Zhuhai Intercity Railway. It can be seen from the figure that the average operating mileage between stations of ″C″ trains is between 12−58 km,

among which 101 trains are in the section with an average stopping mileage of 15−30 km, accounting for 79,5 % of the total trains. It can be seen that most of the ″C″ trains have shorter stopping distance and larger stopping frequency, which is convenient for short distance passengers, but it still reflects the mode of station selection and skip-stop of intercity trains.

The service frequency of OD refers to the number of train services that can arrive directly between od without transfer, which reflects the direct situation between each two stations, and also reflects the transfer demand of the scheme. According to the division of station class as the above, the train service frequency between various classes and OD passenger were calculated, shown in table 5.

Table 5 – **OD train service frequency between stations of each class**

Classes	Average OD passenger flow	Average service trains	Average originating-destination trains	Originating-destination trains ratio (%)
First to second class	2016	67	55	82
First to third class	1532	25		
First to fourth class	89	5		
Second to first class	2217	68	54	80
Second to third class	472	11		
Second to fourth class	136	4		
Third to first class	1389	16	1	6
Third to second class	694	11		
Between Third class	274	5		
Third to fourth class	68	2		
Fourth to first class	56	2		
Fourth to second class	163	3		
Fourth to third class	56	2		
Between Fourth class	15	1		

It can be seen that the train mainly serves between high-level stations. The average service frequency of OD decreases with the decrease of station level. The train service frequency between the first-class stations and the second and third class stations is higher, and the originating train is also set between them. The setting of the originating train from the first class station to the second and third level stations reaches 82 % and 80 % respectively. However, the frequency of passenger flow and OD train service between other level nodes is obviously low.

Based on the analysis of all aspects of Guangzhou − Zhuhai intercity railway stop, the following regulation are obtained.

1 Passenger flow and train distribution characteristics. Guangzhou − Zhuhai

Intercity Railway has the largest passenger flow in Guangzhou south station, followed by Zhuhai, Xiaolan and Xinhui. From the distribution of train operation, the train only starts and ends at the three major nodes of Guangzhou south, Zhuhai and Xinhui.

2 The service frequency of trains with different speed levels has hierarchical characteristics. In terms of the train service frequency of the station, the number of service trains will be reduced step by step according to the node level. High-speed train (G) and medium-speed train (D) mainly serve the first and secondary stations, while intercity-train "C" serves the first, secondary and third stations, and also realizes the coverage of the fourth nodes.

3 The number of train stops has a direct relationship with passenger flow demand and line characteristics, showing a multi-level distribution in terms of number. The number of stops for the main line of Guangzhou − Zhuhai Intercity Railway is mostly distributed in 5−7 stations, and the number of stops for the branch line is mainly concentrated in 3−6 stations, but the overall proportion of stops is concentrated in 29–35 %, which shows that the intercity trains mostly adopt the mode of station selection. In terms of stopping distance, the average stopping distance of trains is concentrated in 15−30 km, which corresponds to the operation speed of 200 km/h and the characteristics of intercity passenger flow.

4 The train service frequency is closely related to OD passenger flow. Most of the trains running on Guangzhou − Zhuhai intercity railway are connected with Guangzhou south railway station. Guangzhou south railway station has achieved high od with each station of the main and auxiliary lines. Therefore, the passenger flow is diverging from Guangzhou south railway station to the main and branch lines. Through the trains between Guangzhou south railway station, Zhuhai and Xinhui, the passenger flow service along the way can be realized. At the intersection of the main and branch lines, Xiaolan station has a higher train service frequency. The OD of passenger flow between small stations along the line is relatively low, and there is no train running between some small stations, which is related to the station spacing between small stations and other traffic modes.

Guangzhou − Zhuhai Intercity Railway is a representative intercity railway in China. On the one hand, the stop rule analyzed in this paper has its own characteristics, and also reflects the current situation of most intercity railways. In the follow-up research, the passenger flow characteristics will be further studied, and it is expected to put forward optimization suggestions for the stop scheme of intercity trains.

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Л. КАННИ

АНАЛИЗ ПАССАЖИРОПОТОКОВ НА УЧАСТКЕ ЖЕЛЕЗНОЙ ДОРОГИ ГУАНЧЖОУ – ДЖУХАЙ

Приведены статистические данные по объемам пассажирского движения на участке Гуанчжоу – Джухай. На основе кластерного анализа проведена калибровка класса железнодорожных станций участка, позволяющая оптимизировать расписание следования поездов и их остановки с учетом потребностей пассажиров. Предлагается выделять классы станций, для которых в зависимости от станции зарождения пассажиропотока и его размеров определяются типы пассажирских поездов и их параметры. Установлено, что максимальная интенсивность следования поездов должна быть определена со станции Гуанчжоу-Южный как раздельного пункта, являющегося станцией зарождения пассажиропотока по маршруту Гуанчжоу – Джухай.

Получено 27.10.2022