Network Assembly Schedule Bus Travel Demand Thermodynamic Diagram Analysis Model Based on Bus Station Ensembles

Jingfeng Yang¹,²,⁴, Ji Yang¹, Nanfeng Zhang³,⁴, Yong Li¹, Handong Zhou¹,², Feng Yang¹, Fei Luo⁴*

¹Open Laboratory of Geo-spatial Information Technology and Application of Guangdong Province, Guangzhou Institute of Geography, Guangzhou 510070, China;

²Guangzhou Yuntu Information Technology CO, LTD, Guangzhou 510650, China;

³Guangdong Entry-Exit Inspection And Quarantine Bureau, Guangzhou 510623, China;

⁴School of Automation Science and Engineering, South China University of Technology, Guangzhou 510641, China

Abstract

With the development of intelligent terminal technology, mobile Internet public transportation mode will be put forward higher requirements on the service industry based on personalized, network assembly schedule bus is a new mode of experience bus service. With the continuous development of the new model, traditional travel demand analysis method of traditional bus lines and the site has been difficult to meet the demand, based on the concept of bus station ensembles, combining with the network assembly schedule bus operation mode, network assembly schedule bus thermodynamic diagram analysis method is constructed, and applied in the city of Guangzhou. The test results show that, through the construction of working days, weekends, holidays and other public transportation demand thermodynamic diagram, which is conducive to the bus company operating the main custom line planning, enhance the personalized public service attendance and revenue, and provide an important reference to the decision-making departments.

Keywords: Network Assembly Schedule Bus, Bus Station Ensembles, Travel Demand, Thermodynamic Diagram.

1. INTRODUCTION

In general, the traditional public transport lines are planned according to the access rate of public transport, repetition rate, economy and so on. These indicators are usually used in the opening and management of the line. At the same time, the traditional bus ticket system can only through the data of IC card equipment to estimate the time and number of the bus, based on the information of GPS and transit station, bus passenger flow is derived. Although the accuracy of this method is insufficient, unless used to get segmented charging mode require credit card, otherwise it is difficult to estimate the distribution of passenger flow, but the researchers still become the focus of the study. The analysis of public transit passenger flow in a visual way has become one of the key research.

Beijing traffic development research center with Beijing IC card data as the basis, the establishment of the bus line passenger flow diagram and the Beijing city public transport passenger flow thermodynamic diagram, focusing on the analysis of the passenger car position distribution (Chen, 2013); Through the distribution of thermal
contrast traffic thermodynamic diagram and hot area, Xuet al., (2016) identify previously forecast based on the analysis of public opinion of network experiment by the analysis of trajectory visualization, visualization and visualization of density properties of water transport of visualization, Xuet al., (2015) summarized the challenge and development direction of the water traffic information visualization is facing, to provide a new technical means for marine supervisors to master the characteristics of the traffic flow, analyze the behavior of the ship and assess the risk of navigation; An interactive visual mining method based on the user behavior data is used as the research position by Sun (2015), and a case analysis is completed based on the real social media big data and large urban traffic data; ASCDT clustering algorithm is used for the analysis of highway traffic capacity data, combined with the clustering result description parameters by Zhang (2013), implemented the military highway transportation system in traffic situation display; Heet al., (2016) introduced the traffic congestion index to determine temporal and spatial accumulation and quantitative analysis on the regional traffic state, establishing the relationship between the source and the function of congestion evaluation positions to construct visualization model, analysis of the traffic state data for feature extraction by using gradient direction histogram and principal component and clustering, the feature data using the Gauss mixture clustering mode of traffic congestion in the area of spatial distribution. In the study of visualization of mathematical model of transportation, the main methods proposed by the researchers are, based on first-order differential equations describing the evolution of a LWR model in road traffic flow in terms of time(Lighthill and Whitham, 1955;Richards, 1956) and space and consider the vehicle acceleration and deceleration of the two order model(Aw and Rascle, 2000), the road traffic state discrete of cellular transmission model(Daganzo, 1995;Daganzo, 1996), the spatial and temporal pattern of gathering travel(Beecham and Wood, 2014), Image two order characteristic and road traffic state model(Kotha, 2003).In addition, some methods have been applied in similar areas, such as GA(Gayatri Devi et al., 2015;Khwaja et al., 2015), Robust Analysis(Nougrara, 2015),PSO Algorithm(Deng and Chen, 2016),Time Sequence Encoding Algorithm(Zhang, 2015),Geographic Routing(Huang et al., 2016).However, these methods are difficult to be applied in the construction of thermodynamic diagram.

In transit demand visualization, according to the current traditional bus line mode of operation, the same bus station, passengers are not a destination, the same line also have different positions and off when the passengers get off, does not require swing card or do any operation, it is often difficult to estimate the flow direction. With the rapid development of the mobile Internet, a new type of traffic is emerging, which leads to a great change in the means of collecting travel demand and the way of travel. Network assembly schedule bus lines of the current opening caused a certain impact on the traditional model, as the business model changes caused by the original access rate, repetition rate and other indicators in the role of bus route planning gradually reduced, the demand and reservation way to collect basic needs and prepaid ticket decision line opened or not, so the analysis of network assembly schedule bus travel route planning demand has become the key to the opening line. At present, the demand of thermodynamic diagram is only considering the requirements of the bus getting on area, which can meet the planning and scheduling of vehicles, but this is based on the line is not fixed. For network assembly schedule bus lines, due to the fixed line, planning only getting on area is often difficult to analyze bus lines relative to the fixed line planning, it is difficult to be used as a reference for the line. Network assembly schedule bus operating mode to one person a seat of the high-end approach based, and its vehicles are mostly used by the relatively high-grade bus as an operating tool. Network assembly schedule bus operations to the needs of the mobile phone APP registration and collection, on the position of getting on and getting off position is usually very clear. Get on and off position, operation time and other conditions for sample statistics usually can obtain the demand from the statistical significance, but also can be used as the opening of the conditions, but in this way the electronic map can be expressed. As to the same bus station as the starting position of the line number, in the traditional thermodynamic
diagram it usually will position to different destinations demand statistics, the directivity is unknown, only express that the current regional travel demand. This pattern of thermodynamic diagram consistent with taxi, rental car, special car for their applications, does not conform to the bus industry application, more do not apply network assembly schedule bus applications, but at present, there is no way to express a kind of travel thermodynamic diagram, which can be expressed on and off for the bus on the plane electronic map. Therefore, this paper puts forward the construction method of the travel demand thermodynamic diagram based on the combination of the network assembly schedule public transit position of getting on and getting off the bus, which provides the decision-making reference for the planning and the opening of the network assembly schedule bus routes (Zhang, 2015; Wang et al., 2015; Li et al., 2016; Bejan, 2016; Giannetti et al., 2016; Biserni and Garai, 2016; Trancossi et al., 2016; Cascetta et al., 2016).

2. CONSTRUCTION METHOD OF NETWORK ASSEMBLY SCHEDULE BUS THERMODYNAMIC DIAGRAM

The application of thermodynamic diagram in public transportation industry mainly focuses on the analysis on the demand, is used widely in the taxi, rental car, special car and other fields. Demand thermodynamic diagram is basically designed around the getting on area. The usual way, the demand thermodynamic diagram is on the electronic map using the way of contour mapping, and in the closed graphics inside with different colors to represent different levels of demand. As the deeper color that demand more brisk, usually in red said the greatest demand for the yellow area, relatively strong demand for the green area, not strong regional demand.

The traditional travel thermodynamic diagram only on the expression of starting position on the electronic map, effectively guide the taxi, rental car, special car drivers to demand about hot spots to improve attendance, and it only can apply to the number of travel of the few. However, the demand for the area of getting off is ignored, and the demand of the application of the bus for a larger number of passengers can not be satisfied. In order to meet the needs of a large number of passengers when the route planning and vehicle scheduling requirements, fully consider the demand of different area of getting off by the fixed line, it need to establish network assembly schedule bus public transit planning travel demand thermodynamic diagram. The construction steps are as follows:

(1) All bus stations have been built in the city as a potential starting position and get off position, that all the city's bus station can be regarded as the starting position or get off position.

(2) Application system development after the completion of the support of mobile phones, tablet PCs, desktop computers and other terminal equipment applications, and open to all users. All registered users can initiate the demand for collection, the most convenient to choose the user travel needs of the starting position or get off position.

(3) Take the starting position time, starting position, get off position three factors constitute a travel sample, the application background of all the user needs in accordance with the time, starting position, get off position and other statistics. At the same time, the statistical results are arranged, and the highest value of the statistics may also exist at the same time.

(4) The concept of bus station ensembles, randomly select one of the highest value of the statistical results of the bus station, which is circular, outside the circular area with radius of 500 meters square (length direction by East, South, West, North) within the
scope of the bus station included in the statistical range, the formation of a bus station ensembles.

(5) A process of forming the above bus station ensembles square based, with copy to the East, South, West, North four directions, all regions in accordance with the city bus station ensembles square division.

(6) Registered users choose any bus station will be all included in the travel needs of group demand statistics covered by bus station ensembles. Through the bus station ensembles square area of travel demand, to solve the last 1 kilometers around the public transport to get off the road within the scope of the walk as the guiding principle, the bus station ensembles square group as a statistical basis, on time, to the starting position, the get off position of three factors: a sample application background will travel, all the user needs in accordance with the starting time, the starting position, get off position statistics.

(7) In order to solve the problem of the bus station at the junction of the square group statistical requirements, i.e. two or more bus stations at the junction of the passengers can choose different bus station ensembles as the starting position of the "sharp boundary" problem, the algorithm and the graph of smooth transition in the actual application, the circular area of external square four sides are expanding 100 meters in the actual statistics, the statistical range is one of the highest value of the statistical results of the bus station, which is circular, outside the circular area of radius of 600 meters of the ground bus station ensembles’ formed square.

(8) The public transit network electric map as the base map, network assembly schedule bus route planning travel demand thermal graph has two layers in the electronic map, which is needed in the public transportation network map loading three layers, including starting demand layers, arrival demand layer and traveling demand layer (including two ways).Starting demand layers is to describe the demand thermodynamic diagram for the starting position, arrival demand layer is to describe the demand thermodynamic diagram for the arrival position, travel demand layer is to describe the demand thermodynamic diagram for position of view of the overall requirements.

(9) The departure time for this property to set the time period (e.g. 10 or 15 minutes) division, each set time period needs to be loaded at the same time three layers, when set in different time periods, will switch and load the corresponding time layer.

(10) The whole set a period of time of the demand for the number of N bus station ensembles the number of M, starting data of a bus station ensembles for K, in the following way of a transit station square inscribed area color mark:

<table>
<thead>
<tr>
<th>Ordinal</th>
<th>Number Range</th>
<th>Color Representation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K ≥ (4N/5M)</td>
<td>Deep red</td>
</tr>
<tr>
<td>2</td>
<td>(3N/5M) &gt; K ≥ (4N/5M)</td>
<td>Red</td>
</tr>
<tr>
<td>3</td>
<td>(2N/5M) &gt; K ≥ (3N/5M)</td>
<td>yellow</td>
</tr>
<tr>
<td>4</td>
<td>(1N/5M) &gt; K ≥ (2N/5M)</td>
<td>Light green</td>
</tr>
<tr>
<td>5</td>
<td>K &lt; (1N/5M)</td>
<td>Dark green</td>
</tr>
</tbody>
</table>

(11) In addition to the inscribed circle outside the square in other areas, in accordance with the surrounding area marked in accordance with the principle of color, color mixing of the color area fill color. For example, if two near the encircle colors were dark red and
yellow, in addition to other regions outside the inscribed square marked pinkish red, filling and so on.

(12) In the calculation of the buffer (for a given object A, its buffer can be defined as: \( P = \{ x | d(x, A) \leq r \} \) (d generally refers to the Euclidean distance, can also be other distance, where R is the radius of neighborhood or buffer established conditions) in different regions of color all the way on Regional map, in order to solve the problem of the fill color mutation, smooth color expression over. Complete 10, 11, 12 steps, you can form the starting demand for thermodynamic diagram.

(13) It is similar to the construction method of the thermodynamic diagram of starting demand for the construction of the thermodynamic diagram to arrival demand, in the same way, the difference between the algorithm and the expression is the choice of time period. The time period of the starting demand thermodynamic diagram is collected by mobile phone, tablet PC, desktop computer and so on, the time data is completed by the passengers themselves. And for the arrival demand thermodynamic diagram, when the demand for the collection does not need to fill in the specific time, the arrival time of the acquisition in general through the line planning to estimate travel time acquisition. The relative departure time, arrival time of bus station ensembles is the time starting demand of bus station ensembles needs, plus the estimated time travel to reach the bus station ensembles in the form of demand group time, calculation method of time of arrival of the demand of thermodynamic diagram is the starting time and duration of demand upward formation. The same departure time of starting demand thermodynamic diagram can be displayed in the same thermal layer to display in different layers of arrival demand thermodynamic diagram.

(14) Network assembly schedule bus public transportation planning line travel demand thermodynamic diagram is composed of the starting demand thermodynamic diagram and arrival demand thermodynamic diagram. According to the demand of the passengers to collect the corresponding relationship, the bus station ensembles statistics of starting demand are needed to matching bus station ensembles statistics of arrival demand. The bus station ensembles of starting demand is marked as A1, A2, ......, AX; the bus station ensembles of arrival demand is labeled as B1, B2, ......, BY. For a certain time period, the A1 bus station ensembles starting demand the corresponding relations includes A1B1, A1B2, ......, A1BY. If you use 11 seats light as a means of transport, you can choose 11 or more high value as a line of statistical filter, which is greater than the corresponding relationship between the selected set values, as the content of expression of thermodynamic diagram layer. If you use other means of transport, you can adjust to other screening conditions.

(15) Put the statistics of the pie chart as marking method for bus station ensembles public transportation planning line starting demand thermodynamic diagram, the corresponding relationship between the steps of the last step is to express the proportion of different arrival sites according to the percentage of pie chart. That is, in view of the starting demand on the basis of thermodynamic diagram mark after screening the corresponding relationship between the pie chart to indicate that the transit station travel demand thermodynamic diagram. Analogy, it can complete all the bus station ensembles marking travel demand pie chart, thus forming bus station ensembles public transportation planning line starting demand thermodynamic diagram.

(16) As to bus station ensembles public transportation planning line arrival demand thermodynamic diagram, it only need to adjust the corresponding relations. Set starting demand for bus station ensembles marked as A1, A2, ......, AX; arrival demand for bus station ensembles labeled as B1, B2, ......, BY. For a certain time period B1 bus station ensembles starting demand the corresponding relations includes B1A1, B1A2, ......, B1AX. If you use 11 seats light as a means of transport, you can choose 11 or more high
value as a line of statistical filter, which is greater than the corresponding relationship between the selected set values, as the content of expression of thermodynamic diagram layer. If you use other means of transport, you can adjust to other screening conditions.

(17) Put the statistics of the pie chart as marking method for bus station ensembles public transportation planning line arrival demand thermodynamic diagram, the corresponding relationship between the steps of the last step is to express the proportion of different arrival sites according to the percentage of pie chart. That is, in view of the arrival demand on the basis of thermodynamic diagram mark after screening the corresponding relationship between the pie chart to indicate that the transit station travel demand thermodynamic diagram. Analogy, it can complete all the bus station ensembles marking travel demand pie chart, thus forming bus station ensembles public transportation planning line starting demand thermodynamic diagram.

(18) Bus station ensembles public transportation planning line starting demand thermodynamic diagram marked and formed on the basis of starting demand thermodynamic diagram, so as to bus station ensembles public transportation planning line arrival demand thermodynamic diagram. If it is necessary to carry out a comprehensive period of time for the screening conditions, while the two pie chart at the same time marked on the starting demand thermodynamic diagram or arrival demand thermodynamic diagram, and travel demand thermodynamic diagram is done. Route planners can choose different demand objects using bus station ensembles public transportation planning line travel demand thermodynamic diagram to analyze passenger demand and thus more reasonable planning of line according to the actual demand, to enhance the overall planning level, improve line transportation service economic benefit.

3. EXPERIMENT AND RESULT

3.1 Test data description

Based on the business data generated by the network assembly schedule bus lines in Guangzhou city in July 2015, the data base of the network assembly schedule bus travel demand thermodynamic diagram is formed. July 2015 only less than 20 lines opened, to November 2016 has more than 450 lines. At present, mobile Internet applications have been registered users more than 300 thousand, more than 360 thousand travel demand data, the actual opening of the line and the daily average daily passenger travel more than 5400 (October 2016). In this paper, from July 2015 to November 2016, demand collection line planning and operation, passenger travel data as the basis will be done for the establishment of network assembly schedule bus travel demand thermodynamic diagram. It needs to be explained that, through the mobile internet terminal launched passenger travel demand including departure, destination, departure time, departure frequency (day tickets, ticket etc.) etc.. The line opened and operated, the passenger terminal data including passengers arriving time at the station, getting on time, time of reaching the destination, the driver terminal data including the starting position, arrival position, operated line, real-time traffic state, the number of passengers users and passenger information, and not getting on passengers information, arrival time, operated time, the driver starting time etc.. Operating background in addition to the passenger side and the driver side of the data, but also includes location information, time, line and mileage, station, road congestion index data etc..

3.2 Test data processing method, result and analysis

In accordance with the requirements of the bus station ensembles and the distribution of the demand for travel, the first will be divided into grid computing. After the formation of the grid, according to the travel demand, the evaluation value of travel demand is given
to the corresponding grid (The results including the passengers self initiated solicitation, the public transportation company line collection and transit station travel demand model calculation results of bus station ensembles). Finally, the visualization method, the travel demand to assess the value of discrete into a color corresponding color sequence, according to the assessment value of the division rules are filled with a color to each grid, and can complete the visual rendering. Visual modeling based on the value of travel demand assessment can form a network assembly schedule bus travel demand thermodynamic diagram. In general, the directional gradient histogram method is used to extract the characteristics of the influence factors of the travel demand evaluation model (such as working travel characteristics, age distribution, etc.), at the same time, the principal component analysis is used to eliminate the redundancy of image feature data and reduce the dimension of data, and the processed data are clustered by the clustering algorithm (supervised or unsupervised). Take the distance of the nearest cluster center of the thermodynamic diagram sample extraction, combined with the traffic geographic information, such as the location of the regional travel demand, the impact of the scope of analysis and evaluation. After this process, the general contours will appear obvious edge features, and from the center to the edge of the image color with different gain.

The demand data of the working days, weekends and holidays (Labors' Day) were selected as the data source of the demand data of the bus travel demand in May 2016. Rendering includes travel demand thermodynamic diagram and arrival demand thermodynamic diagram, and with strong regularity work as the key analysis object, play an important role in the detailed description of the custom bus travel demand thermodynamic diagram in route planning etc.

The working day in the traditional mode of public transport mode to build the starting demand thermodynamic diagram, starting demand thermodynamic diagram based on bus station ensembles, travel demand thermodynamic diagram combined with the arrival demand are shown as Fig. 1-3, respectively.

**Figure 1.** Working day travel demand thermodynamic diagram (Traditional mode) (Left)
**Figure 2.** Working day travel demand thermodynamic diagram (Based on bus station ensembles) (Right)

**Figure 3.** Working day travel demand thermodynamic diagram (Combined with the arrival demand)

It can be seen from the above, the demand collection analysis result of starting demand thermodynamic diagram by traditional way to build mostly based on the traditional bus station as core analysis object. Based on the demand of the bus station ensembles, the starting demand thermodynamic diagram is fully considered in the actual situation, such as the demand of the surrounding and more concentrated model to express the demand of passengers. According to the arrival demand of travel demand, the thermodynamic diagram is constructed on the basis of the starting demand thermodynamic diagram of the bus station ensembles. The expression of passenger travel demand by the way of visualization, it has the reference value for planning and operation of the main line. It should be explained that, due to the limited area of the map display, the display of the selected area in the display area can be displayed, the specific statistical data can be exported through the background statistics.

Similar to the above, Fig. 4-6 were in the traditional way to build a model of the traditional way of building the starting demand thermodynamic diagram for the weekend, starting demand thermodynamic diagram based on bus station ensembles, travel demand thermodynamic diagram combined with arrival demand, respectively. Fig. 7-9 were in the bus station ensembles way to build a model of the traditional way of building the starting demand thermodynamic diagram for the weekend, starting demand thermodynamic diagram based on bus station ensembles, travel demand thermodynamic diagram combined with arrival demand, respectively.
Figure 4. Weekend travel demand thermodynamic diagram (Traditional mode) (Left)

Figure 5. Weekend travel demand thermodynamic diagram (Based on bus station ensembles) (Right)

Figure 6. Weekend travel demand thermodynamic diagram (Combined with the arrival demand)
Figure 7. Festival and holiday travel demand thermodynamic diagram (Traditional mode) (Left)

Figure 8. Festival and holiday travel demand thermodynamic diagram (based on bus station ensembles) (Right)

Figure 9. Festival and holiday travel demand thermodynamic diagram (Combined with the arrival demand)

From the travel demand analysis of Fig. 1-9 visualization results can be seen, travel demand thermodynamic diagram combined with the arrival demand can effectively
express passenger travel demand. In practical applications, excluding promotion due to operating and the new passenger considerations, network assembly schedule bus lines in the initial operation, from a few lines in the center of city suburb, demand planning for starting demand thermodynamic diagram by traditional constructing methods, the attendance was 58.57% weekly average; the starting position was adjusted by bus station ensembles starting demand thermodynamic diagram, the occupancy rate rose to 67.42% weekly average; according to application combined with arrival demand for travel demand thermodynamic diagram, then to adjust the starting position and the get off position, the whole line is basically unchanged, at the beginning of May week occupancy rate rose to 78.49% weekly average, until the beginning of June without changing the starting position and the get off position, the occupancy rate increased to 84.27% weekly average.

Test results show that in the more able to reflect the passenger travel demand analysis model to carry out the adjustment of the operation line, will be conducive to the operation of the main line to open and adjust the operation, and it will improve the efficiency of bus operations and attendance, but also conducive to public transit network adjustment from the macro scope, to enhance the management level and convenient passenger travel.

4. CONCLUSION

By building travel demand thermodynamic diagram based on the network assembly schedule bus, it can provide to meet the upgrade attendance and personalized line planning and decision support for the bus company and other public transport operators. Provide services based on mobile Internet technology by means of the personalized service demand monthly, weekly, chartered, which provides a feasible technology and management for the establishment to break the traditional management mode and new personalized management mode.

From the angle of technology, the construction of network assembly schedule bus travel demand thermodynamic diagram achieves a breakthrough to the traditional analysis method based on the bus station, especially made great breakthrough to break the constraints on the bus station bus line planning, but also for passengers near the centralized travel provides a convenient conditions. Combined with the characteristics of passenger mobility, this method is more effective than the way to organize the passenger travel through the construction of large public transport hub. The test results show that, through the construction of working days, weekends, holidays and other public travel demand thermodynamic diagram, is conducive to the bus company operating the main custom line planning, enhance the personalized public service rises rate and revenue, and provide an important reference for the decision-making department.

5. ACKNOWLEDGMENTS

6. REFERENCES


Chen F. (2015). Big data for IC card smart bus IC card based on data of Beijing city transit network evaluation and optimization technology research and demonstration, China Highway, 7, 102-103.


Zhang Y. (2013).Research on Situation Visualization of Road Transport Capacity Based on Spatial Clustering, Master Degree Dissertation of National University of Defense Technology.