

Research on Survey and Calculation of Load Factor in Urban Public Transportation

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Abstract. In order to solve the problems of unclear definition, unclear scope and unsuitable methods in the survey and calculation of urban public transportation load factor, this paper combines with other scholars' definition and calculation methods of load factor. From the purpose of load factor statistics and the sense of evaluation, the survey method of load factor is used to redefine the calculation method of the load factor index value in the morning and evening peak hours, and the index value of load factor can be calculated through actual survey, which reflects the passenger flow of the urban public transportation in the morning and evening peak hours. Through the analysis of passenger flow in different directions, distribution analysis of regional passenger flow, and trend analysis of passenger flow in a single line, the characteristics of urban bus passenger flow are learned. Finally, based on the actual survey cases of urban public transportation load factor index, the feasibility, reliability and adaptability of the index calculation method are verified, which lays a foundation for the urban public transportation load factor survey and calculation.

1. Introduction

In 2012, the State Council published "Guiding Opinions on Priority Development of Urban Public Transportation", government started to implement the priority development strategy of urban public transportation and promoted the construction and development of the national urban public transportation system. In 2013, for the development of urban public transportation becoming more powerful and comprehensive, the Ministry of Transport launched the National Transit Metropolis Demonstration Project. Three batches of projects were launched as of July 2018, and a total of 37 cities have joined in the project.

At the same time, the Ministry of Transport also published the "Transit Metropolis Assessment and Evaluation Index System", as an evaluation basis of the National Transit Metropolis Demonstration Project. The index system consists of 20 assessment indexes and 10 reference indexes in which the load factor index in the morning and evening peak hours is one of the assessment indexes, so that the city joined the project must carry out the survey of urban public transportation load factor index, to obtain the basic data of survey for calculating the value of urban public transportation load factor index.

Since the 20th century, scholars have begun to study the definition and calculation methods of urban public transportation load factor. Shen Lu[1] proposed the calculation method of the bus line section load factor and the bus line load factor. The bus line section load factor is the ratio of the bus



line cross-section passenger flow to bus line vehicle rated passenger capacity multiplied by vehicle numbers. The bus line load factor is the ratio of the bus line section load factor multiplied by section length to the sum of section lengths. Sha Huang et al[2] defined the average load factor and the peak load factor with reference to the definition of American passenger load factor. The peak load factor is the ratio of the total passenger flow during peak hours to the number of seats for all shifts during peak hours. At the same time, the value range of the peak load factor index is given. The calculation method of the average load factor remains unchanged with 24 hours survey data range. Liu Huan et al[3] combined with the actual situation of China urban population, the number of seats is often less than the number of passengers. According to the calculation method of the American passenger load factor, the load factor of Chinese city is usually greater than 1. The article proposes definitions of the total load factor, vehicle load factor and bus line load factor, and the bus line load factor is calculated combined with an example analysis. The Ministry of Transport[4] defined the load factor index in morning and evening peak hours as the average value of bus line and rail line load factor in Transit Metropolis Assessment and Evaluation Index System; bus line load factor index in morning and evening peak hours is the ratio of the maximum cross-section passenger flow to the maximum cross-section vehicle rated passenger capacity. The traffic industry standard[5] defined the peak load factor in the service quality evaluation of public transport enterprises as the ratio of the maximum cross-section passenger flow to the vehicle rated passenger capacity in peak hours.

Therefore, because of the imbalance of passenger flow at each station or each bus line, the calculation method of the load factor based on the maximum passenger flow section is more meaningful, which is more conducive to the purpose and significance of the load factor index. However, the calculation method of the load factor based on the maximum passenger flow section is different from the previous calculation methods, mainly reflected in the following four aspects.

- The time ranges in calculation are different. The urban public transportation load factor index is the evaluation index of the time period, and evaluates the overall passengers in the morning and evening peak hours. In the load factor survey and calculation, it is generally only considering the highest load factor index in the morning and evening peak hours which means the maximum value of this period is taken as the index value, and the imbalance of passenger flow during the peak time period is not concerned. Since the highest load factor at a certain moment does not fully reflect the matching degree of urban public transportation vehicle supply capacity, the calculation result of load factor index will mislead the judgment of the supply situation of urban passenger flow.

- The basis for the calculation of index is different. The maximum passenger flow section should be the largest section of a single bus line. The calculation of the total load factor is based on the calculation of the load factor of a single bus line. If the calculation method of the total load factor depends on the maximum load factor of the road section or the maximum single vehicle load factor, the total load factor will be affected by the layout and model of the urban public transportation network. According to the maximum load factor of a single bus line, it will not be affected by the layout and model of the urban public transportation network, making the calculation results of different load factor comparable.

- The judgment of the maximum passenger flow section is different. The largest passenger flow section is where the largest ratio of urban public transportation passenger flow to rated passenger capacity, rather than the site with the largest urban public transportation passenger flow. In the vehicle load factor survey, because the rated passenger capacity of the vehicle is constant, the maximum passenger flow section is both the maximum load factor and the largest passenger flow. However, in investigating process of the bus line load factor, the investigators will inevitably miss the record of the vehicles. Therefore, compared with other large passenger traffic places, where the bus line has the largest passenger flow, the transport capacity is not same and the load factor is not the largest, so the place where the ratio of passenger flow to passenger capacity as largest can be selected as the maximum passenger flow section.

- The judgment of the transit peak hour is different. Through the load factor survey, the hour that passenger flow is highest is the morning and evening peak hours. Based on the load factor survey

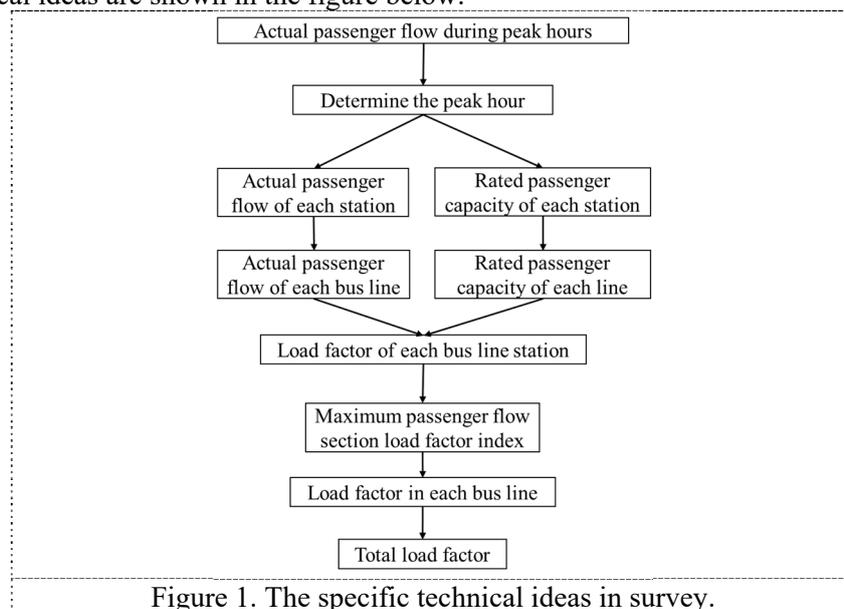
data during peak hours, the bus line load factor index is concluded and peak hour range of load factor index cannot be determined before the load factor survey.

2. Evaluation method in survey

2.1. Survey method

The bus line load factor reflects the relative value of the vehicle capacity and passenger demand on the bus line within a certain period of time. Generally, the ratio between the bus line maximum cross-section passenger flow and the vehicle rated passenger capacity is used as the calculation basis. The calculation of load factor index is usually designed by arranging personnel at the main bus station in the city to investigate and count the vehicle passenger loaded. The specific survey statistics are as follows.

- Selecting the bus stations with more bus lines and larger passenger flow in the main urban area, and collecting the basic conditions of all the vehicles passing through each bus station by the peak hours, including the survey station, survey time, vehicle code, line code, vehicle load factor, etc.
- Calculating the load factor of each bus line station, determining the maximum passenger flow section of each bus line, and calculating the bus line load factor of the largest passenger flow section.
- Summarizing the calculated results of all bus line load factor index, and the average value of all bus line load factor index is the total load factor of urban public transportation network. The specific technical ideas are shown in the figure below.



The calculation formula for the total load factor during the morning and evening peak hours is as follows:

$$Q = \frac{\sum_{k=1}^w L_k}{w} \quad k \in [1, w] \quad (1)$$

Q is the total load factor during the morning and evening peak hours.

L_k is the load factor of the bus line k in the morning and evening peak hours.

w is the number of bus lines.

$$L_k = \text{Max}(S_{1k}, S_{2k}, S_{3k}, \dots, S_{jk}, \dots, S_{mk}) \quad j \in [1, m] \quad (2)$$

S_{jk} is the load factor of the bus line k and station j in the morning and evening peak hours.

m is the number of bus station in survey.

$$S_{jk} = \frac{\sum_{i=1}^n P_{ijk}}{\sum_{i=1}^n E_{ijk}} \quad i \in [1, n] \quad (3)$$

P_{ijk} is the actual passenger flow of the bus line k and station j and vehicle i in the morning and evening peak hours.

E_{ijk} is the rated passenger capacity of the bus line k and vehicle i .

n is the number of each line bus shift in the morning and evening peak hours.

2.2. Evaluation method

After the total load factor survey, based on the relevant data of the survey, the characteristics of bus line passenger flow and regional passenger flow are analysed.

2.2.1. Analysis of passenger flow direction. Through the analysis of the passenger flow in the up-and-down directions of each line, the imbalance coefficient of the passenger flow in the different directions of a single line is obtained. The imbalance coefficient is the ratio of the maximum one-way passenger flow during peak hours to the two-way average passenger flow during peak hours, showing whether the bus line passenger flow has one-way travel characteristics.

- *imbalance coefficient* = $\frac{\text{the maximum one-way passenger flow during peak hours}}{\text{the two-way average passenger flow during peak hours}}$

When the imbalance coefficient is lower than or equal to 1.2, the passenger flow in each direction of the bus line is balanced, when the imbalance coefficient is higher than 1.2, the passenger flow in the peak period has a large difference in different directions.

2.2.2. Analysis of regional passenger flow. Through the analysis of the bus station load factor in morning and evening peak hours, the bus stations average load factor in various regions is obtained. The bus stations average load factor is the average load factor of all vehicles passing through the station, showing the travel characteristics of the area where the bus station is located.

- *bus stations average load factor* = $\frac{\text{The sum of the load factor of all vehicles passing through the stations}}{\text{Number of vehicles passing through the station}}$

2.2.3. Analysis of passenger flow trend. Through the analysis of the vehicle load factor in the morning and evening peak hours of a single line bus station, the vehicle load factor fluctuation of the bus station in each morning and evening peak hours is obtained. The comparison of load factor of different stations on one side at the peak hours in the morning and evening is made in order to obtain the trend and rule of each site.

3. Case analysis

3.1. Survey

In February of 2018, 20 bus stations were selected as survey points in Baoji City, Shaanxi Province, and 40 investigators were arranged to conduct a load factor survey in morning peak hours (7:20-8:30) and evening peak hours (17:30-19:00) from which 6,527 valid survey data were obtained.

3.2. Calculation method

Firstly, according to the relevant information investigated by different investigators, the vehicle information and line information are to be verified, the wrong bus line and vehicle number as modified, the missing survey data as supplemented, and the evaluation, correction and data cleaning of the survey data as completed.

Secondly, through the data of load factor survey, the city passenger flow is estimated, and the passenger flow of each time period is counted by one hour. The peak hour of the passenger flow

distribution in the morning and evening is determined. The relevant information of the peak hour is used as the basic data for calculating the total load factor.

Finally, according to the previous load factor calculation method, the each bus line load factor is calculated, and the average value of all bus line load factor is taken as the total load factor of urban public transportation network.

Through the vehicles load factor survey of bus station in the morning and evening peak hours, the total load factor in Baoji City during the morning and evening peak hours was 66.6%.

3.3. Analysis of results

3.3.1. Bus line load factor analysis. A total of 32 lines more than three bus stations surveyed in all bus lines are calculated, together with the bus line load factor of these line. The number of survey station and the each line load factor are shown in the following table.

Table 1. Urban bus lines load factor survey.

Line Name	Station Num	Line Load Factor	Line Name	Station Num	Line Load Factor
Route 1	7	67.9%	Route 33	6	66.6%
Route 2	3	64.7%	Route 34	6	63.3%
Route 4	7	64.9%	Route 36	10	73.3%
Route 5	8	81.2%	Route 37	6	51.2%
Route 6	7	56.6%	Route 38	4	67.0%
Route 7	10	70.9%	Route 39	4	46.8%
Route 8	8	57.7%	Route 40	3	65.8%
Route 9	6	54.8%	Route 41	4	63.5%
Route 10	5	68.9%	Route 43	3	64.2%
Route 15	10	76.3%	Route 46	9	80.2%
Route 17	4	55.0%	Route 48	3	65.5%
Route 20	7	70.5%	Route 51	8	81.7%
Route 21	7	79.9%	Route 53	3	58.8%
Route 22	8	84.8%	Route 61	3	69.6%
Route 28	6	64.0%	Route 71	6	65.6%
Route 31	7	76.8%	Route 81	5	54.2%

The total load factor of 14 bus lines is concentrated between 60% and 70%, accounting for 43.7% of the total number of bus lines, and the rest is between 40% and 80%. The farther the load factor index is from 60%, the fewer the number of lines. The number of bus lines which load factor is above 60%, accounts for 75% of the total lines. The overall urban public transportation network operates efficiently.

Table 2. Distribution of bus line load factor in different intervals.

Load Factor	Line Num	the proportion of line
0.4-0.5	1	3.1%
0.5-0.6	7	21.9%
0.6-0.7	14	43.7%
0.7-0.8	6	18.8%
0.8-0.9	4	12.5%

3.3.2. Analysis of passenger flow direction. Through the up-and-down passenger flow of each line in peak hour, the imbalanced coefficient of passenger flow of most bus lines in morning and evening peak hours are generally closed to 1, and there are 9 bus lines with an imbalance coefficient of 1.2 or

above in the morning and evening peak hours, 23 bus lines below. It can be seen that the passenger flow of Baoji City has a good balance.

Thereinto, there are 3 bus lines in the morning peak period with the imbalance coefficient above 1.2, which are route 4, 7 and 20 respectively. There are 6 bus lines in the evening peak period with the imbalance coefficient above 1.2, which are route 4, 8, 9, 15, 34 and 33.

Table 3. Imbalance coefficient in morning and evening peak hour.

Line Name	Peak Hour	direction	Actual passenger	Imbalance coefficient
Route 7	Morning peak	From west to east	1684	1.25
Route 4	Morning peak	From west to east	1907	1.25
Route 20	Morning peak	From west to east	1455	1.23
Route 8	Evening peak	From west to east	1227	1.39
Route 33	Evening peak	From east to west	975	1.37
Route 34	Evening peak	From east to west	1471	1.27
Route 9	Evening peak	From west to east	1996	1.23
Route 4	Evening peak	From east to west	2338	1.23
Route 15	Evening peak	From west to east	6461	1.22

3.3.3. *Analysis of regional passenger flow.* By calculating the average load factor of different stations in morning and evening peak hours, the characteristics of passenger flow in various regions are obtained. It can be seen from the figure that the average load factor of the bus station is related to the location of bus station, the number of bus lines, whether it is an intermediate station, etc., The closer the bus station is to the commercial core area of the city, the higher the average load factor. The closer the bus station is to the periphery of the city, the less bus lines, the closer to the first and last stations, the lower the average load factor. It has been shown in normal distribution analysis of bus station average load factor that the significance of normality test comes to 0.2, higher than 0.05, which means following normal distribution.

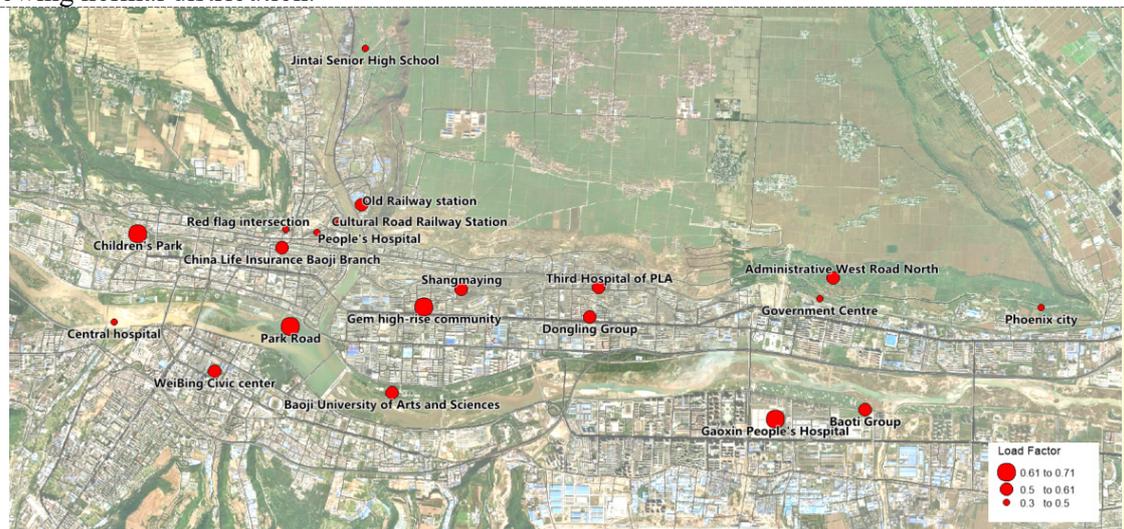


Figure 2. Average load factor of bus stations.

3.3.4. *Analysis of passenger flow trend.* By analyzing the changes of different lines load factor in the morning and evening peak hours, it can be seen that the majority of bus lines load factor is stable, and the load factors in the morning and evening peak hours are not much different. A few bus lines of which load factor in the morning and evening peak hours is quite different, and the trend of station load factor of a single bus line is similar.

For example, from the 6 bus stations' load factor of the Route 4, it can be seen that the north station load factor in the morning peak hour is generally lower than that in the evening peak hour, and the south station load factor is within the north station load factor for the morning and evening peak hour. It means that the passenger flow from the west to the east in morning peak hour is relatively large, and the passenger flow from the east to the west in evening hour is relatively large. Because of the urban land utilization and population distribution of Baoji City, some routes have obvious tidal passenger flow in morning and evening peak hours.



Figure 3. The load factor change of route 4 bus line station in morning and evening peak hour.

4. conclusion

According to the purpose and significance of the load factor survey, this paper analyses the problems in the urban public transportation load factor survey. Based on the adaptability of the manual load factor survey of urban public transportation networks, the new ideas and survey methods of urban public transportation load factor calculation are proposed. The new calculation method and results of load factor are more in line with the comparative analysis of urban passenger flow demand and vehicle capacity. It is of great significance for other cities of the same type to carry out the investigation of the load factor of public transport and to calculate and analyze the comparable load factor of the city in the future. At the same time, through the load factor survey case in Baoji City, the feasibility and operability of the new calculation method were tested, and the problems of the previous load factor survey and low calculation accuracy were improved. This paper makes full use of the load factor survey data and analyzes the characteristics of urban traffic and the travel environment, through the

analysis of bus line load factor, passenger flow direction, regional passenger flow, passenger flow trend, etc..

In the next step, the analysis of urban public passenger flow in the city needs to be combined with IC card data, vehicle GPS data, passenger flow statistics, etc., to carry out more accurate, convenient and comprehensive calculation and analysis, to receive an analysis that is more in line with urban planning, land use, and population characteristics, etc.

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