Analysis on Influencing Factors of Traffic Congestion in Chongqing and Study on Countermeasures

Empirical Analysis Based on Principal Component Analysis

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Abstract. Serious traffic congestion not only affects people's quality of life, but also increases the economic cost of the city and reduces the efficiency of urban operation. As a typical representative of mountain cities and big cities, Chongqing has a serious traffic congestion problem. Through qualitative analysis of the causes of traffic congestion in Chongqing from 2004 to 2019, 15 relevant indicators are extracted and the influencing factors are analyzed by using SPSS principal component analysis. The research shows that the degree of traffic congestion is positively correlated with urban population density, GDP and other social and economic factors, and the amount of public transport supply and the number of taxis significantly affect the degree of traffic congestion. Finally, from urban development, public transport supply and other aspects, put forward the corresponding countermeasures and suggestions.

Keywords: Chongqing · traffic congestion · influence factor · principal component analysis · management strategy

1 Introduction

In the process of urban development, a large number of labor force into the city, the size of the population continues to increase, traffic demand rises, but due to the limited traffic supply, and the traffic safety awareness and legal concept of the public weak reasons, resulting in traffic congestion. Chongqing Municipality, as one of the four municipalities directly under the Central Government in our country, has inevitably encountered traffic congestion with the rapid economic development. With the continuous improvement of residents' living standards and the increasing number of private cars, but traffic planning and construction has not met the needs of city development and residents' living standards, leading to great traffic pressure during the peak period of traffic congestion. It directly affects people's quality of life. In addition, compared with other areas, Chongqing has a unique topography, known as "mountain city", is a typical representative of mountain cities, but also one of the reasons for the serious traffic congestion in Chongqing.

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In the "2020 China Urban Traffic Report" published by Baidu Map, Chongqing ranks first among the TOP10 cities in the list of 100 congested cities in China with the commuter peak congestion index[1] of 2.260, and the actual commuter peak speed is 24.06 km/h [3]. In the report of China's urban traffic in the first quarter of 2021 released by Baidu Map, the commuter congestion index of Chongqing is 1.866 during peak hours and 1.551 during weekends[2], both ranking the second [4]. In the China Urban Traffic report of the second quarter of 2021, Chongqing ranked the third with 2.057 commuter peak congestion index, and the average vehicle speed was only 24.95 km/h [5]. In the Traffic Analysis Report of Major Cities in China in the Third Quarter of 2021 published by Amap, Chongqing's traffic health index[3] ranks the second from the bottom, only better than Changchun [6]. All the above data show that Chongqing is facing a serious traffic congestion problem, and the traffic congestion has not improved significantly in recent years.

2 Literature Review

For the urban traffic congestion problem, scholars mainly from its influencing factors and solutions and other aspects of research. Specifically, in terms of influencing factors of traffic congestion, most of them are analyzed mainly from the perspectives of vehicles, roads, people and policies. Zhang Zeyu (2019) [7] made use of 14 traffic-congestion related data of Chongqing City from 1995 to 2017, including urban development, traffic demand and traffic supply, and find that annual bus passenger volume, per capita GDP and annual rail transit passenger volume are the main factors affecting traffic congestion. Li Aixuan (2019) [8] studied the traffic situation in Chongqing's main urban area and concluded that there were three major factors affecting traffic congestion in Chongqing's main urban area by using principal component analysis method: population quality, public transport planning and public transport supply. Li Kangning and Yu Lijing (2021) [9] adopted the grey correlation model to sort the influencing factors of urban traffic congestion and found that public transport, GDP, population and other factors were the key factors of urban traffic congestion. Wang Liyan et al. (2018) [10] finded that city size and economic level were positively correlated with traffic congestion level.

In terms of traffic congestion control measures, Chen Wei (2020) [11] proposed a travel mode based on "public transportation + walking", and vigorously promoted the construction of smart cities to alleviate traffic congestion. Tu Yu, Li Hao (2020) [12] analyzed the formation mechanism of traffic congestion in the three major business districts of Chongqing, and proposed a new governance concept of using shared cars to

[1] Commuting peak congestion index = the ratio of actual travel time to unimpeded travel time in morning and evening peak hours on weekdays. The morning peak is 07:00–09:00, and the evening peak is 17:00–19:00.

[2] Weekend congestion index = the ratio of actual travel time to unblocked travel time from 8:00 to 20:00 on weekends.

[3] Traffic health index is a comprehensive evaluation index for urban traffic diagnosis initiated by Amap and multiple research teams. It includes 9 data from three dimensions of time, space and efficiency, such as road network travel delay index, road network distance ratio of peak congestion, and road network running time ratio of high delay.

control traffic congestion. Chen Li (2020) [13] studied the traffic congestion problem in Chongqing's main urban area and proposed solutions such as strengthening government management, building big data management platform and public infrastructure construction.

In the existing researches on traffic congestion, most of them study the causes of congestion from the single aspects such as the imbalance between demand and supply, and lack the quantitative analysis and calculation of the impact degree of urban traffic congestion. Based on the existing results, this paper uses the principal component analysis method to study the influence of social economy, traffic demand, traffic supply, environment and other factors on traffic congestion in Chongqing, and finds out the key factors of traffic congestion in Chongqing according to the principal component score, in order to provide feasible directions for the control of traffic congestion in Chongqing.

3 Theoretical Methods

3.1 Principal Component Analysis

Principal component analysis is a multivariate statistical analysis method that uses the idea of dimensionality reduction to transform multiple indicators into several indicators on the premise of losing little information. The indicators generated by transformation are called principal components. Each principal component is a linear combination of the original variables, and the principal components are not correlated with each other, so that the principal components have better performance than the original variables.

3.2 Basic Steps

1. Bartlett sphericity test to determine whether there is a strong correlation between indicators.
2. Standardize raw variables to eliminate dimensional effects. Suppose there are m index variables for principal component analysis: $x_1, x_2, \cdots, x_m$, there are n evaluation objects in total. The j index of the i evaluation object is x_{ij}, and each index value x_{ij} is converted into standard index $\tilde{x}_{ij}$. $\tilde{x}_{ij}=\frac{x_{ij}-\overline{x}_{ij}}{s_j}$, $(i = 1, 2, \cdots, n; j = 1, 2, \cdots, m)$, Where $\overline{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}$, $s_j = \frac{1}{n-1}\sum_{i=1}^{n}(x_{ij} - \overline{x}_j)^2$, $(j = 1, 2, \cdots, m)$, $\overline{x}_{ij}$, s_j is the sample mean and sample standard deviation of the fourth index.
3. Establish the correlation coefficient matrix R among variables. Correlation coefficient matrix $R = (r_{ij})_{m\times n}$, in Formula $r_{ij} = \frac{\sum_{i=1}^{n}\tilde{x}_{ki}\cdot\tilde{x}_{kj}}{n-1}$, $(i, j = 1, 2, \cdots, m)$, $r_{ii} = 1$, $r_{ij} = r_{ji}$, r_{ij} is the correlation coefficient between the i and j indexes.
4. Calculate the eigenvalues and eigenvectors of the correlation coefficient matrix R.Calculate the eigenvalues of the correlation coefficient of $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_m$ matrix R and the corresponding eigenvectors $u_1, u_2, \cdots, u_m$, and $u_j =$

$(u_{1j}, u_{2j}, \cdots, u_{mj})^T$ consists of the eigenvectors into m new standard variables.

$$\begin{cases} y_1 = u_{11}\tilde{x}_1 + u_{21}\tilde{x}_2 + \cdots + u_{m1}\tilde{x}_m \\ y_2 = u_{12}\tilde{x}_1 + u_{22}\tilde{x}_2 + \cdots + u_{m2}\tilde{x}_m \\ \cdots \\ y_m = u_{1m}\tilde{x}_1 + u_{2m}\tilde{x}_2 + \cdots + u_{mm}\tilde{x}_m \end{cases}$$

5. Write down the principal components and calculate the composite score. The information contribution rate and cumulative contribution rate of characteristic value $\lambda_i (j = 1, 2, \cdots, m)$ are calculated, which is called the information contribution rate of principal component y_j of $b_j = \frac{\lambda_i}{\sum_{k=1}^{m} \lambda_k}$; $\alpha_p = \frac{\sum_{k=1}^{p} \lambda_k}{\sum_{k=1}^{m} \lambda_k}$ cumulative contribution rate of principal component $y_1, y_2, \ldots y_m$; When α_p is close to 1, the first p indicators are selected as p principal components to replace the original m index variables. Calculate the combined score $Z = \sum_{j=1}^{p} b_j y_j$.

4 Empirical Study on Urban Traffic Congestion in Chongqing

4.1 Sample Data and Sources

The data selected in this paper are from Chongqing Statistical Yearbook of Chongqing Bureau of Statistics and China Statistical Yearbook of National Bureau of Statistics from 2005 to 2020.

4.2 Variable Design

Based on the current situation of traffic congestion in Chongqing and previous studies on factors affecting traffic congestion in Chongqing, this paper selects 15 indicators from 2004 to 2019 to carry out principal component analysis on factors affecting traffic congestion in Chongqing. The specific indicators are shown in Table 1.

4.3 Principal Component Analysis

According to the need of empirical analysis, principal component analysis in SPSS21.0 is used to analyze the main influencing factors of traffic congestion in Chongqing. First, Bartlett sphericity test was conducted to judge Sig values and KMO values, and the results were shown in Table 2.

As can be seen from Table 2, KMO value is 0.780, larger than the critical value 0.6, which is suitable for principal component analysis. Bartlett sphericity test results show that P value is 0.000, less than 0.05, indicating that the selected index is suitable for principal component analysis.

The results of principal component analysis are shown in Table 3. It can be seen from Table 2 that the first two principal components explain 97.974% of the total variance,

Table 1. Index system of influencing factors of traffic congestion

Index class	variable name	Variable code
Economic and social factors	GDP (hundred million yuan)	X_1
	Urban permanent population (ten thousand)	X_2
	per capita GDP (ten thousand yuan/person)	X_3
	Urban population density (person/square kilometer)	X_4
	built-up area (square kilometer)	X_5
Transportation supply factors	Taxi (vehicle)	X_6
	Passenger volume (ten thousand)	X_7
	Passenger volume (ten thousand)	X_8
	Road area (10,000 square meters)	X_9
	Number of public transport vehicles in operation (units)	X_{10}
	Light rail length (km)	X_{11}
Traffic demand factors	Private automobile ownership (10,000 units)	X_{12}
Environmental factors	Annual Daily Mean of sulfur dioxide in Main urban Areas (mg/m^3)	X_{13}
	Annual Daily Mean of nitrogen dioxide in main urban areas (mg/m^3)	X_{14}
	Environmental noise equivalent Sound level dB(A)(decibels)	X_{15}

Table 2. Index system of influencing factors of traffic congestion

The Kaiser-Meyer-Olkin measure of sample adequacy		0.780
Bartlett's sphericity test	Approximate chi-square	488.055
	df	45
	Sig.	0.000

indicating that the extracted two principal components can represent 97.974% of the original 15 factors affecting traffic congestion. The extracted principal components have a high degree of confidence in evaluating the influencing factors of traffic congestion and play a role in dimension reduction. The extracted two principal components are Y_1 and Y_2. The coefficient of each index is solved according to the principal component score and component matrix coefficient, and the linear combination of Y_1 and Y_2 is obtained:

$$Y_1 = 0.337X_1 + 0.337X_2 + 0.338X_3 + 0.336X_5 + 0.332X_6 - 0.105X_7 + 0.335X_8 + 0.337X_9 + 0.332X_{10}$$

Table 3. Principal component analysis results

Total variance of interpretation						
component	Initial eigenvalue			Extract sum of squares and load		
	total	Percentage of variance	cumulative percentage	total	Percentage of variance	cumulative percentage
1	8.703	87.032	87.032	8.703	87.032	87.032
2	1.094	10.942	97.974	1.094	10.942	97.974
3	0.120	1.199	99.173			
4	0.039	0.394	99.567			
5	0.035	0.348	99.915			
6	0.005	0.047	99.962			
7	0.003	0.026	99.988			
8	0.001	0.010	99.998			
9	0.000	0.002	100.000			
10	6.073E-006	6.073E-005	100.000			

$$Y_2 = 0.011X_1 - 0.012X_2 + 0.033X_3 + 0.080X_5 - 0.009X_6 + 0.903X_7 - 0.172X_8 + 0.009X_9 - 0.158X_{10}$$

The variance contribution rate of Y_1 is 87.032%, which is mainly related to GDP, urban resident population, per capita GDP, urban population density, taxi, passenger volume, road area and the number of public transport vehicles operated.

The variance contribution rate of Y_2 is 10.942%, which is mainly related to passenger volume. According to the component matrix coefficient and factor load value, the scores of each principal component, Y_1 and Y_2, were calculated. Then, the variance contribution rate of each principal component was taken as the weight to construct Chongqing traffic congestion comprehensive evaluation system, and the comprehensive scores were calculated, as shown in Table 4.

As can be seen from the comprehensive scores in Table 4, traffic congestion in Chongqing has been serious year by year during the urban development process from 2004 to 2019, but there is no easing trend.

5 Management Countermeasures and Suggestions

5.1 Improving Urban Management and Improving the Efficiency of Urban Operation

According to the first principal component, traffic congestion in Chongqing is positively correlated with socio-economic factors such as GDP, urban resident population, per capita GDP and urban population density.

Table 4. Principal component scores and comprehensive scores

index	Y_1	Y_2	synthesis score	rank	index	Y_1	Y_2	synthesis score	rank
2004	-3.39	-0.38	-2.99	16	2012	-0.44	2.07	-0.16	8
2005	-3.17	-0.35	-2.8	15	2013	0.61	-0.5	0.48	7
2006	-2.78	-0.37	-2.46	14	2014	1.58	-0.64	1.3	6
2007	-2.49	-0.02	-2.17	13	2015	2.2	-0.77	1.83	5
2008	-2.23	0.79	-1.86	12	2016	2.78	-0.86	2.32	4
2009	-1.94	0.98	-1.58	11	2017	3.46	-0.97	2.91	3
2010	-1.54	1.3	-1.2	10	2018	3.83	-0.95	3.23	2
2011	-0.87	1.69	-0.57	9	2019	4.39	-1.02	3.71	1

The higher the level of economic development, the more permanent urban population, the greater the population density, the more serious traffic congestion. From the perspective of economics, it is unreasonable to control economic development, so the population density can only be controlled within a reasonable range. As the extensive urban development mode will lead to urban low-density expansion, urban population density keeps rising. Therefore, in the process of urban development, the spatial layout of urban function points should be reasonably designed according to the characteristics of residents' distribution and demands, and the distribution of urban function points should be reasonably arranged according to the changing trend of population distribution. Refined urban traffic management, promote the agglomeration of heterogeneous functional points, and establish the urban complex centered on the rail station.

5.2 Increase the Supply of Public Transport and Advocate Green Travel

According to the first principal component, traffic congestion in Chongqing is closely related to the quantity of public transport supply. The quantity of public transport supply is one of the important factors affecting traffic congestion in Chongqing.

First of all, the government should scientifically plan the supply of public transport, make full use of big data platforms for traffic management, such as Amap and Baidu Map, and strive to achieve fine traffic management, accurately calculate the travel demand at various time periods, reasonably set the operating routes and time of public transport, and accurately and effectively meet the travel needs of residents. Secondly, due to the unique topography of Chongqing, a green travel mode dominated by "public transportation + walking" can be developed.

5.3 Standardize the Taxi Market and Control the Number Reasonably

According to the first principal component, the number of taxis is one of the important factors affecting traffic congestion in Chongqing.

Taxi is one of the essential means of transportation in the city. Since the departure time of public transport has a fixed train schedule and time interval, for the groups with

urgent time or special needs, taxi has become the choice of some groups with high opportunity cost of time due to its flexibility of travel time. With the development of cities, the taxi market continues to expand, and private cars travel the same traffic routes, causing a certain amount of traffic congestion. Therefore, the government should issue relevant laws and regulations to regulate the taxi market and control the number of taxis. For example, the number of taxis should be controlled within a reasonable range by taxi business license and granting taxi license.

5.4 Strengthen the Publicity of Traffic Culture and Improve Citizens' Transportation Literacy

According to the second principal component, traffic congestion in Chongqing is closely related to passenger volume, that is, passenger volume is an important factor affecting traffic congestion in Chongqing.

The passenger volume reflects the transportation capacity of the transportation system and the transportation demand of passengers. The larger the passenger volume, that is, the travel demand is more vigorous, the transport capacity is more developed. In addition, citizens' traffic behaviors will also affect traffic congestion, such as slow driving, frequent lane changes and other bad driving behaviors. However, as specific behavioral indicators cannot be quantified, they are not included in the model. However, according to experience, improving residents' awareness of laws and regulations is crucial to easing traffic congestion. Therefore, advocating civilized driving and traveling, encouraging residents to choose appropriate transportation modes according to travel purpose and travel distance, advocating "low-carbon travel" from the perspective of realizing the goal of "double carbon", and improving citizens' transportation literacy are helpful to alleviate traffic congestion in Chongqing.

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