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Research on Beijing Urban Traffic Operation Efficiency

--Based on Entropy Weight and Fuzzy Comprehensive Evaluation

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Abstract

With the development of China's urbanization process, the efficiency of urban traffic operation often becomes the bottleneck of urban economic development. Solving the problems of traffic efficiency in cluster cities has become an important problem in urban development. Considering the availability of indicator data and the scientificity of the evaluation, based on the 2014-2018 Beijing Statistical Yearbook data and the Beijing Transportation Development Annual Report, a fuzzy comprehensive evaluation model based on entropy weight was established. An empirical study on the efficiency of traffic operations was conducted. The results show that Beijing's urban traffic operation efficiency is on the rise. To improve urban traffic operation efficiency, it is necessary to increase the per capita road area, increase traffic supervision equipment, and reduce the traffic congestion coefficient.

Keywords

Urban transportation, Traffic operation efficiency, Fuzzy comprehensive evaluation.

1. Introduction

China's urbanization process is accelerating. A large number of people are pouring in to form an aggregate of urban transportation. Traffic efficiency often affects the operation of the entire city. Efficient urban transportation operation efficiency can drive the sustainable development of urban economy and environment. In the current situation, urban traffic circulation often attracts people's attention. The research objects include the efficiency of urban transportation, road network, highway network, and track network. At this stage, the analysis of urban traffic efficiency is mainly based on DEA data envelopment analysis, fuzzy comprehensive evaluation, complex networks, and big data processing. There is also a combination of positive and negative investment in road network construction to propose overall efficiency, establish a multi-objective model, and optimize land and transportation modes. There are also many scholars who take environmental factors into consideration for urban transportation efficiency and conduct a diversified analysis. As the capital of China, Beijing has attracted attention for its development. According to the Tom Tom Transportation Index, Beijing, China's 2016 traffic congestion index was 46%, ranking tenth in the world. This requires us to study Beijing's transportation development objectively. By reading relevant literature, this paper selects a fuzzy comprehensive evaluation model based on entropy weight through qualitative and quantitative analysis, establishes evaluation indicators according to the specific situation of Beijing and related factors, and uses the objectivity of entropy weight to evaluate the urban traffic operation in Beijing from 2014 to 2018. The efficiency is calculated and evaluated to provide a reference for the relevant departments in Beijing to further improve the efficiency of urban transportation operations.

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2. Beijing Traffic Operation Efficiency Evaluation Index

Through reading various domestic and foreign articles, finally determines the Beijing transportation efficiency evaluation index. The indicator data in the article is mainly from the "Beijing Transportation Development Annual Report" and "Beijing Statistical Yearbook" released by the Beijing Institute of Transportation Development. Due to the systemic and complexity of urban transportation, this article mainly uses two indicator levels to calculate urban transportation analysis. The selection of evaluation indicators often directly affects the results of the final analysis. This paper selects indicators comprehensively referring to domestic and foreign research, and selects the evaluation indicator system as shown in the figure below.

First, the urban spatial structure index. Generally speaking, the urban spatial structure is different from city to city. So there is a big uncertainty in the choice of composition. The article selects Beijing urban population density, urban per capita road area, rail transit network density, and urban passenger transportation volume to describe.

Second, the travel structure of urban residents. The structure of urban residents' travel often affects the operation of urban transportation efficiency. The article selects the number of private cars in society, the average daily travel volume of residents, the density of the road network, and the proportion of public transport travel.

Third, urban transportation infrastructure. The transportation infrastructure of a city often determines the efficiency of its internal operation. Generally speaking, the more complete the urban transportation infrastructure is, the faster the urban transportation circulation speed is, and the higher the efficiency is. Therefore, this article mainly chooses the number of buses, the length of rail transit lines, traffic monitoring equipment, urban transportation construction investment and other indicators to start.

Fourth, the level of urban traffic management. Urban traffic management refers to the use of various means to make people and traffic coordinate with each other. As various policy options are difficult to quantify, the road traffic congestion index, the duration of congestion, and the urban traffic environment have been established based on the above analysis as affecting urban traffic management.

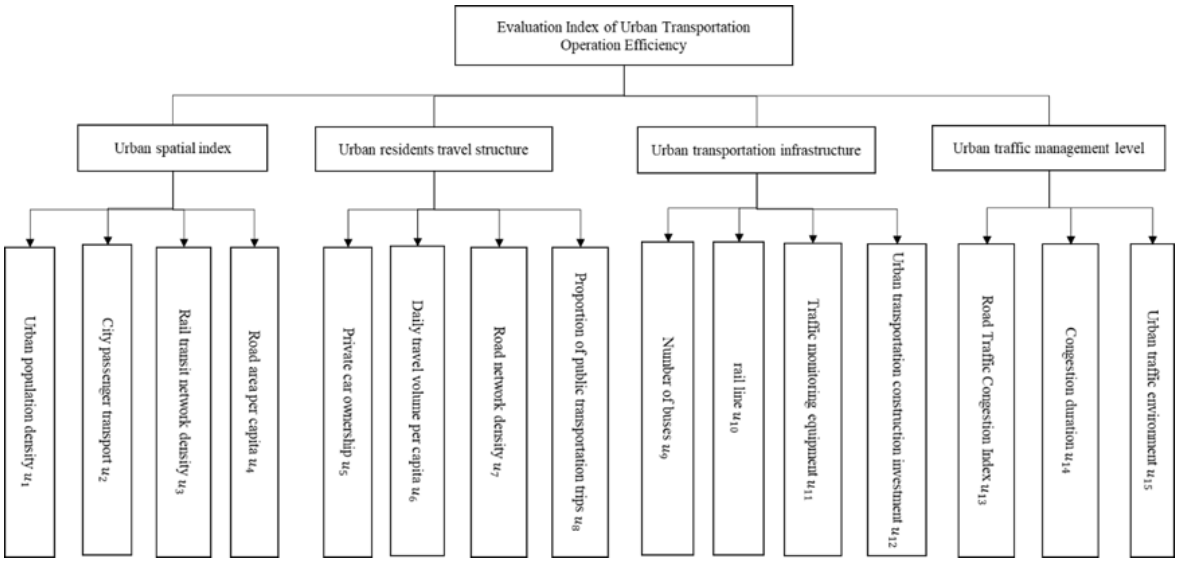

Figure 1. Beijing City Traffic Operation Efficiency Index

3. Construction based on entropy weight fuzzy evaluation model

According to the current situation and characteristics of urban transportation development in Beijing, this article uses the entropy weight method and fuzzy comprehensive evaluation method to evaluate the advantages of urban transportation operation efficiency. Through the establishment of the index

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system, the entropy weight method is used to evaluate the objectiveness and fuzzy evaluation of the quantitative index system, and objectively evaluate the urban transportation operation efficiency of Beijing, and it is expected to provide reference for the future planning of the corresponding departments. Specific steps are as follows:

Step 1:Establish the factor level of Beijing urban traffic operation efficiency$\mathrm{U} = \{u_1, u_2, \dots u_n\}$, n is the number of evaluation indicators.

Step 2: Determine the rating of Beijing urban traffic operation efficiency$\mathrm{V} = \{v_1, v_2, \dots v_m\}$. This article divides the level into 5 levels$\mathrm{V} = \{\mathrm{High}, \mathrm{higher}, \mathrm{medium}, \mathrm{lower}, \mathrm{low}\}$.

Step 3: Perform a single factor evaluation on each evaluation index to obtain a membership vector $r_t = \{r_{i1}, r_{i2}, \dots r_{im}\}$, The membership matrix R forming the fuzzy relationship, the fuzzy judgment matrix is shown below.

$$\mathrm{R} = \begin{pmatrix} r_{11}, r_{12}, \dots r_{1m} \\ r_{21}, r_{22}, \dots r_{2m} \\ \dots \dots \\ r_{i1}, r_{i2}, \dots r_{im} \end{pmatrix} \tag{1}$$

Step 4: determine the weight of each index, and use the entropy weight method to calculate each index and the overall comprehensive entropy weight and perform normalization processing.

Step 5: calculate the comprehensive efficiency evaluation result of Beijing according to the above steps, $B = \mathrm{W}_i * \mathrm{R}$. And judge it accordingly.

In determining Beijing's urban traffic operation efficiency index, the standard value of the index is brought into the fuzzy membership matrix. To promote the efficiency of urban transportation, carry out$r_{im} = \frac{u_{im} - u_{min}}{u_{max} - u_{min}}$; To impede the efficiency of urban transportation, carry out$r_{im} = \frac{u_{max} - u_{im}}{u_{max} - u_{min}}$, Determine the degree of membership. Among them u_{min}, u_{max} upper and lower limits of this indicator.

4. Empirical analysis

4.1 Beijing traffic operation overview and data collection

According to the "Beijing Transportation Development Annual Report" and "Beijing Statistical Yearbook" released by the Beijing Institute of Transportation Development, Beijing's urban passenger traffic in 2018 reached 7.78 billion passengers, and rail transit accounted for 47.6%. The external passenger traffic reached 306 million times, and the urban freight transport volume reached 25.241 million tons, an increase of 5.7% year-on-year. The total volume of business in the urban express industry was 2.21 billion, a year-on-year decrease of 2.9%. At the end of 2018, the number of motor vehicles was 6.084 million, an increase of 3.0% year-on-year. The average daily travel volume of private cars is 2.81 times per day. The mileage of special roads for ground buses reaches 952 kilometers, and the total mileage of rail transit reaches 637 kilometers. The total number of work trips per capita of the center was 39.24 million person-times, an increase of 0.8% over 2017. The average traffic index of the center during the morning peak is 5.1 (the road network is divided into 5 levels, and 5.5 is at a light congestion level), and the evening peak is 6.0. The average congestion time is up to 2 hours and 50 minutes, an increase of 10 minutes from last year. The specific indicators of Beijing in 2014-2018 are shown in the table below.

4.2 Calculation of Beijing City Traffic Operation Efficiency

According to the above method, the urban traffic operation efficiency of Beijing is calculated, the specific steps are as follows:

Step 1: construct the fuzzy factor level U for the index evaluation in the following table.

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Table 1. 2014-2018 Beijing urban traffic operation efficiency data

First-level indicators	Secondary indicators	2014	2015	2016	2017	2018
Urban spatial index	Urban population density u_1	1311	1323	1324	1323	1375.8
	City passenger transport u_2	86.26	78.3	77.76	75.47	74.39
	Rail transit network density u_3	0.244	0.255	0.264	0.280	0.296
	Road area per capita u_4	0.13	0.132	0.129	0.129	0.133
Urban residents travel structure	Private car ownership u_5	2854	2729	2666	2765	2779
	Daily travel volume per capita u_6	450	452	461	476	489
	Road network density u_7	0.642	0.640	0.620	0.619	0.601
	Proportion of public transportation trips u_8	0.7	0.707	0.71	0.721	0.73
Urban transportation infrastructure	Number of buses u_9	23667	23287	22688	25624	24076
	rail line u_{10}	527	554	574	608	637
	Traffic monitoring equipment u_{11}	238211	233461	254925	260998	277994
	Urban transportation construction investment u_{12}	884	1122.3	988	1217.3	1282.7
Urban traffic management level	Road Traffic Congestion Index u_{13}	5.5	5.7	5.6	5.6	5.5
	Congestion duration u_{14}	65	180	195	180	190
	Urban traffic environment u_{15}	85.9	80.6	73	58	51

Data source: Beijing Traffic Operation Report

Step 2: According to various indicators$u_1, u_2, u_5, u_6, u_{14}, u_{15}$,The larger the index value, the higher the urban traffic operation efficiency, and the larger the remaining index value, the lower the urban traffic efficiency. According to the above calculation steps, a single factor evaluation matrix is obtainedR_1, R_2, R_3, R_4,comprehensive fuzzy judgment matrix$\mathrm{R} = \{R_1, R_2, R_3, R_4\}^T$,the calculation results are as follows.

$$R_1 = \begin{bmatrix} 1 & 0.815 & 0.799 & 0.814 & 0 \\ 0 & 0.671 & 0.716 & 0.909 & 1 \\ 0 & 0.203 & 0.379 & 0.693 & 1 \\ 0.519 & 0.709 & 0.022 & 0 & 1 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0 & 0.665 & 1 & 0.473 & 0.399 \\ 1 & 0.946 & 0.716 & 0.332 & 0 \\ 1 & 0.952 & 0.471 & 0.437 & 0 \\ 0 & 0.233 & 0.333 & 0.700 & 1 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0.333 & 0.204 & 0 & 1 & 0.473 \\ 0 & 0.245 & 0.716 & 0.909 & 1 \\ 0.107 & 0 & 0.379 & 0.693 & 1 \\ 0 & 0.598 & 0.261 & 0.836 & 1 \end{bmatrix}$$

$$R_4 = \begin{bmatrix} 1 & 0 & 0.5 & 0.5 & 1 \\ 0 & 0.885 & 1 & 0.885 & 0.962 \\ 0 & 0.152 & 0.370 & 0.799 & 1 \end{bmatrix}$$

Step 4: Calculate a single factor weight matrix separately $\mathrm{W}_1, \mathrm{W}_2, \mathrm{W}_3, \mathrm{W}_4$, the comprehensive entropy weights are shown in the table below.

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$$W_1=\{0.1703\ 0.1770\ \ 0.2779\ \ 0.3748\}$$
$$W_2=\{0.2311\ 0.2362\ \ 0.2352\ \ 0.2975\}$$
$$W_3=\{0.2008\ 0.3527\ \ 0.1972\ \ 0.2493\}$$
$$W_4=\{0.3065\ 0.2461\ \ 0.4474\}$$

Table 2 Weights of Beijing urban traffic operation efficiency indicators

w1	w2	w3	w4	w5	w6	w7	w8
0.046	0.048	0.075	0.101	0.058	0.059	0.059	0.074
w9	w10	w11	w12	w13	w14	w15	
0.079	0.069	0.084	0.064	0.056	0.045	0.082	

Step 5: According to the above steps, the fuzzy comprehensive evaluation of the urban traffic operation efficiency of Beijing was calculated and the following results were obtained:

$$B_1=W_1*R_1=[0.3652\ \ 0.5798\ \ 0.3765\ \ 0.4922\ \ 0.8297]$$
$$B_2=W_2*R_2=[0.4715\ \ 0.6706\ \ 0.6101\ \ 0.4989\ \ 0.3896]$$
$$B_3=W_3*R_3=[0.0880\ \ 0.2766\ \ 0.3108\ \ 0.7909\ \ 0.8941]$$
$$B_4=W_4*R_4=[0.3065\ \ 0.2857\ \ 0.5647\ \ 0.7286\ \ 0.9905]$$
$$B_4=W*R=w_i*\{R_1,R_2,R_3,R_4\}^T=[0.308\ \ 0.448\ \ 0.445\ \ 0.627\ \ 0.758]$$

4.3 Analysis of Beijing City Traffic Operation Efficiency

4.3.1 Analysis of single factor evaluation results

Based on the calculation results of the above calculation steps, each weight index is analyzed. In the urban spatial structure, the weight of urban per capita road area and rail transit network density is larger. In the travel of residents, the weight of public transport travel is greater. In the urban transportation infrastructure and urban traffic management level, the traffic monitoring equipment, road traffic congestion index and urban traffic environment are heavily weighted. According to the nature of the entropy method, the greater the entropy value of this indicator, the greater the effect on the final evaluation. The improvement of Beijing urban traffic operation efficiency can be improved by the above-mentioned weighted indicators.

4.3.2 Analysis on Evaluation Results of Comprehensive Efficiency of Beijing Urban Transportation

Based on the above-calculated evaluation matrix, the urban traffic operation efficiency of Beijing in each year from 2014 to 2018 is determined, as shown in Table 3.

Table 3 Beijing city efficiency values 2014-2018

year	2014	2015	2016	2017	2018
Efficiency value	0.308	0.448	0.445	0.627	0.705
Evaluation	Lower	Lower	Lower	medium	Higher

It can be drawn from Table 3 that the overall city of Beijing's traffic operation in 2014-2018 showed an upward trend. The efficiency increased from the original lower level of 0.308 to a higher level of 0.705. It is consistent with the actual situation in Beijing. The decline in the road congestion index, the construction of multiple urban rails, and the government's promotion of green and public travel. It has brought tangible improvements to Beijing's urban traffic operation. At the same time, with the improvement of various advanced smart devices of big data and the improvement of various

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emergency handling capabilities, Beijing transportation efficiency has been greatly improved. However, the growth of private cars and the increase in people's travel have also put tremendous pressure on urban transportation operations. It is necessary to continuously increase transportation infrastructure, strengthen big data and intelligent construction, and effectively divert traffic travel to reduce congestion.

5. Conclusion

Urban transportation operation is related to the operation of the entire city. Efficient urban efficiency not only brings economic development, but also reduces urban carbon dioxide emissions and achieves the purpose of green transportation. Based on this, this paper builds a fuzzy comprehensive evaluation model of entropy weight, and scientifically evaluates 15 indicators. The results show that from 2014 to 2018, the efficiency of Beijing's urban traffic operation has increased significantly, and the efficiency has reached a relatively high level. However, as a super-large city, how Beijing can further improve the efficiency of urban traffic operation must be considered from various aspects. In this paper, due to the availability of data, only 15 indicators are selected for research. Therefore, there are certain limitations in evaluating the efficiency of Beijing's transportation operation. It is necessary to obtain a more complete efficiency evaluation through more comprehensive construction of indicators.

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References

[1] J.C. Wei, W Xia, X.M. Guo: Urban transportation in Chinese cities: An efficiency assessment, Transportation Research Part D, vol. 23 (2013), 20-24.

[2] Abbas Sheikh Mohammad Zadeh, Mohammad Ali Rajabi: Analyzing the effect of the street network configuration on the efficiency of an urban transportation system, Cities, vol. 31 (2013), 285-297.

[3] Tetsuya T, Hiroki N, Hidemichi F: Efficiency and emissions from urban transport: Application to world city-level public transportation, Economic Analysis and Policy, vol. 61 (2019), 55-63.

[4] W.D Zhang, J. Lu and Y. Zhang: Comprehensive Evaluation Index System of Low Carbon Road Transport Based on Fuzzy Evaluation Method, Procedia Engineering, Vol. 137 (2016), 659 - 668.

[5] Hana F, Marketa M: Comparison of urban public transport systems in the Czech Republic and Slovakia: Factors underpinning efficiency, Vol. 81 (2020), (02).

[6] Information on http://tjj.beijing.gov.cn/.