Study on Evaluation Index System of Urban Traffic Improvement Based on Analytic Hierarchy Process

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Abstract. The double development of urbanization and motorization has made the traffic demand of our country grow rapidly and diversified. the improvement of urban traffic has become an important condition for the sustainable development of the city. Based on the analytic hierarchy process (AHP), this paper establishes the evaluation index system of urban traffic improvement by comparing the importance of indexing by experts. It is found that improvement of road network, optimization of public traffic and improvement of intersection are the most important in urban traffic improvement. the intersection of the most important level of service. By using qualitative and quantitative methods, the Likert scale was used to classify the results and the four-quadrant method was used to analyze the urban traffic improvement evaluation index system.

1 Introduction

The pace of urbanization in China is accelerating and the economy is developing rapidly. The traffic demand is also growing rapidly. At the same time, traffic congestion has become a prominent problem in most cities in China^[1]. At present, China is in the stage of rapid motorization, which makes it difficult to achieve a fundamental relief of traffic congestion in the central city, seriously restricting the healthy development of the city and reducing the quality of life of the residents.

Urban traffic improvement has become an important issue for sustainable urban development. Causes of urban traffic congestion: On the one hand, the increase is in traffic demand, on the other hand, the shortage of supply is caused by the limited urban land. Therefore, the improvement of urban traffic is a systematic issue^{[2]-[3]}.

The establishment of a scientific and objective evaluation system for urban traffic improvement results can help us better understand the causes of urban congestion and provide more diversified and intuitive methods for solving problems. In this paper, the evaluation index system for urban traffic improvement is established based on the principle of analytic hierarchy process (AHP) by experts, and the evaluation system is tested according to the Fuling District of Chongqing, China.

2 Construction of evaluation index system for urban traffic improvement

2.1 Principles of establishment of indicator system

The urban traffic evaluation index system should be able to represent the current status of various aspects of the urban transport system, and it can reflect the changing trends of various aspects of the urban transport system, and should be able to reflect the degree of coordination of the various subsystems of urban transport^[4]. When constructing the urban traffic evaluation index system, it should meet the following principles:

Systematic: Urban traffic itself is a complex system project, and it should be evaluated from the perspective of system engineering. The subsystems should be divided into different levels according to the basic principles of system engineering. At the same time, we should pay attention to the correlation between the indicators to avoid partiality.

Scientific and objective: The selected indicators and the evaluation criteria must be scientific, objective, and consistent with the facts.

Reliable and independent: The selected indicators should reflect the idea of system and maintain independence between the indicators.

Combinations of qualitative and quantitative analysis: on the basis of qualitative index analysis, the method of combining qualitative and quantitative analysis can carry out quantitative treatment of indicators, so as to make them better measurable.

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2.2 Selection of evaluation indicators

This paper adopts AHP to select the index of evaluation system^[5]. The entire evaluation index system consists of three levels: evaluation target level A, criterion level C, and indicator level P. The target layer A is an evaluation of urban traffic improvement. According to the composition of the urban traffic system, the criteria layer C is composed of six subsystems: road network improvement, public traffic optimization, intersection improvement, parking facility improvement, slow-motion system optimization, and traffic management optimization. The first-level indicator layer P contains a total of 18 first-level evaluation indicators. The structure of each evaluation indicator is shown in the table:

Table 1. Indicator system for urban traffic improvement.

The target layer A	The criterion level C	The indicator level P	Remark	Evaluation method	coding
Urban Traffic Improvement Evaluation System	Road network improvement	Road network structure	road network layout, grade is reasonable	Combine	P11
		Road network accessibility	cut - off ratio	Quantitative	P12
		Road network density	road network density has improved	Quantitative	P13
	Public transportation optimization	Bus network structure	line network level, layout optimization	Combine	P21
		Road and bus facilities	Optimization of bus lanes, stations, etc	Combine	P22
		Public transport hub construction	, transfer system construction	Qualitative	P23
	Intersection improvement	Intersection spacing		Combined	P31
		Intersection control mode	Whether the type of control method is reasonable	Qualitative	P32
		Intersection service level		Quantitative	P33
	Improvement of parking facilities	Parking facilities supply and demand ratio		Quantitative	P41
		Parking guidance system		Combined	P42
		Parking policy and management	Whether or not there are different control strategies for partitions	Qualitative	P43
	Slow system optimization	Slow - running system network	network layout and hierarchical structure optimization	Combine	P51
		Street crossing facilities		Combine	P52
		Slow space facilities	non - separation and environment optimization	Combine	P53
	Traffic Management Optimization	Traffic information modernization		Combine	P61
		Traffic system management	traffic demand and supply management	Qualitative	P62
		Transportation policy guarantee	project implementation completion estimated	Qualitative	P63

3 Standards for the evaluation model system of urban traffic improvement

This paper uses the method of questionnaire survey on the Internet platform to take an anonymous survey of experts, so that they are ranked according to the importance of indicators, and then use the principle of the analytic hierarchy process as the principle of urban traffic improvement evaluation index system model calibration.

3.1 Principles of AHP Model

American Operations Research Specialist T. L. Saaty proposed AHP in the mid-1970s to decompose complex problems into hierarchical structures, and then juxtapose each factor in the next level with each factor in the previous level to construct a judgment matrix^[6-7]. Through the calculation and analysis of the judgment matrix, the importance of each factor is ranked, so as to achieve the purpose of solving the problem. General AHP is carried out according to four steps, namely, establishing hierarchical structure, constructing judgment matrix, calculating relative weight of elements under a single criterion, and carrying out consistency test, total hierarchy sort and consistency test. This section is limited to space and will not be introduced in detail.

3.2 Standards for indicator weights

This is limited to space, only the criteria layer C calculation process of a questionnaire is displayed. First, a comparison proof C of the criterion layer for the target layer A is constructed.

$$U = \begin{bmatrix} 1 & 2 & 3 & 5 & 5 & 7 \\ \frac{1}{2} & 1 & 2 & 4 & 4 & 6 \\ \frac{1}{3} & \frac{1}{2} & 1 & 4 & 5 & 6 \\ \frac{1}{5} & \frac{1}{4} & \frac{1}{4} & 1 & 3 & 5 \\ \frac{1}{5} & \frac{1}{4} & \frac{1}{5} & \frac{1}{3} & 1 & 5 \\ \frac{1}{7} & \frac{1}{6} & \frac{1}{6} & \frac{1}{5} & \frac{1}{5} & 1 \end{bmatrix}$$

The normalized matrix of matrix U is:

$$U = \begin{bmatrix} 0.421 & 0.480 & 0.453 & 0.344 & 0.275 & 0.233 \\ 0.210 & 0.240 & 0.302 & 0.275 & 0.220 & 0.200 \\ 0.140 & 0.120 & 0.151 & 0.275 & 0.275 & 0.200 \\ 0.084 & 0.060 & 0.038 & 0.069 & 0.165 & 0.167 \\ 0.084 & 0.060 & 0.030 & 0.023 & 0.055 & 0.167 \\ 0.060 & 0.040 & 0.025 & 0.014 & 0.011 & 0.013 \end{bmatrix}$$

Determine the weight $\omega = (0.368 \ 0.241 \ 0.194 \ 0.097 \ 0.070 \ 0.031)$ CR is 0.0076, it meet the consistency test requirements.

3.3 Model calibration results

Matlab was used to calibrate the index system, and after obtaining the weight of the judgment matrix of each class of the questionnaire, the arithmetic average method was used to calculate the value. The weight of each index of each layer is shown in table 2.

It can be seen from table 2 that in the urban traffic improvement evaluation system, the road network improvement plays the biggest role in the criterion layer, while the public transportation optimization and the intersection improvement play the biggest role.

Table 2. The weight of each index.

The target layer A	The criterion level C	Criterion layer weight	The indicator level P	The indicator level weight	The total weight	The sorting
Urban Traffic Improvement Evaluation System	Road network improvement	0.405	P11	0.473	0.191	1
			P12	0.129	0.052	7
			P13	0.398	0.161	2
	Public transportation optimization	0.203	P21	0.553	0.112	4
			P22	0.261	0.053	5
			P23	0.186	0.038	9
	Intersection improvement	0.195	P31	0.587	0.114	3
			P32	0.232	0.045	8
			P33	0.181	0.035	10
	Improvement of parking facilities	0.092	P41	0.575	0.053	6
			P42	0.157	0.014	17
			P43	0.268	0.025	12
	Slow system optimization	0.057	P51	0.547	0.031	11
			P52	0.197	0.011	18
			P53	0.256	0.015	15
	Traffic Management Optimization	0.048	P61	0.340	0.016	14
			P62	0.301	0.014	16
			P63	0.359	0.017	13

Improvements in parking facilities, optimization of urban slow-motion systems, and optimization of traffic management have played a minor role. Among the 18 index layers, only the road network structure, road network density, bus line network structure, and intersection service level weight values are greater than the average value, indicating that the weight distributions of the indicators in the indicator layer are more dispersed and the variance is larger.

4 Application of Evaluation Index System for Urban Traffic Improvement

Based on the results of model calibration and the results of the "Fengling District Jiangnan District Traffic Improvement Plan" (hereinafter referred to as the "planning"), this paper applies the urban traffic improvement evaluation index system. By inviting the digital experts to take an anonymous form and using the

planning results as a reference, the Likert scale is used as a principle to combine the qualitative and quantitative methods to score the indicator items^[8].

4.1 Introduction to the traffic improvement plan in Jiangnan District, Fuling District

The Jiangnan District of Fuling District is surrounded by the Yangtze River and Wujiang River and covers an area of about 17 square kilometers. It is the core urban area of Fuling District and has a planned population of about 400,000.

Based on the full investigation of the current situation, this plan has systematically planned the road network, public transportation, intersections, parking, slow moving systems, and traffic management.

The plan will adjust the grade and layout of the trunk line network in Fuling District, adjust the local road network, open up the broken road, and encrypt the entire road network. The planned density will be increased from 5.9km/km² to 6.555.9km/km²; The network has undergone major adjustments to alleviate the problem of serious overlapping of the original line network and a small radiation area. A total of 5 bus stations and 7 bus terminals have been arranged; reasonable improvements have been made to the important blocked intersections of the current situation. Its service level can reach Class C; a differentiated control strategy for parking is adopted, and parking spaces are added according to the needs of different communities; and the urban green space system, urban road traffic, and public service facility systems are combined to adjust the slow-moving system in Fuling. Optimize the slow space environment; traffic management is centered on "relaxation and diversion" to improve the efficiency and role of traffic management.

Fig. 1. The road network improvement scheme.

4.2 Results of traffic improvement evaluation in Fuling District

According to the Likert Scale, five divisions are very good, four divisions are better, three divisions are general, two divisions are worse, and one point is not good. The expert scores the average value, and then calculates the score of the criterion layer C and the score

of the target layer A according to the index layer score.

Table 3 Each index score.

The target layer A	The criterion level C	Criterion score	The indicator level P	Index score
Urban Traffic Improvement Evaluation System	Road network improvement	4.5	P11	4.2
			P12	4
			P13	5
	Public transportation optimization	4.0	P21	4.1
			P22	3.5
			P23	4.2
	Intersection improvement	3.7	P31	4
			P32	3.7
			P33	2.6
	Improvement of parking facilities	4.5	P41	5
			P42	3.5
			P43	4.1
	Slow system optimization	3.6	P51	4.5
			P52	2.6
			P53	2.4
	Traffic Management Optimization	3.4	P61	2.5
			P62	4.1
			P63	3.6

From the table, the criterion level A score is 4.1, indicating that the results of the “Fengling District Jiangnan District Traffic Improvement Plan” are between good and excellent.

However, in the plan's forecast of the transportation plan, when the traffic demand increases by 80%, the road network service level of the improvement plan is not significantly reduced, and the various subsystems of the urban traffic can operate well.

Fig. 2. Network operation analysis diagram.

Fig. 3. Planning road network operation analysis diagram.

From this point of view, the improvement effect of the evaluation service system for this plan is 4.1, which is between good and excellent. This reflects the effect of the urban traffic improvement more accurately and the evaluation service system has higher reliability.

5 Conclusion

This paper establishes a comprehensive evaluation index system for urban traffic improvement through AHP and expert scoring. According to the principle of AHP, target layer A, criterion layer C, and indicator layer P are provided. Taking the urban traffic improvement evaluation system as the core, and using the six subsystems of roads, buses, intersections, parking, running, and management of the urban transportation system as the guideline, 18 evaluation indicators have been established. Through expert scoring, the importance of 22 evaluation indicators and 6 criteria subsystems is compared at the level of two or nine, and the weight of each index is obtained according to the principle of the analytic hierarchy process, so as to establish an urban traffic improvement evaluation system. It is found that road network optimization, optimization of public transportation, and improvement of intersections are the three most important indicators of urban traffic improvement, and they should also be the first issues to be noticed in the process of urban traffic improvement.

This paper uses the case of "Traffic Improvement Plan for Jiangnan Area of Fuling District" as a case to apply the evaluation system of urban traffic improvement. Through the combination of quantitative and qualitative methods, various indicators of each layer were scored according to the fifth scale of the Likert scale, and the overall evaluation of the plan was between good and excellent, which reflected this fact more realistically. The effect of urban traffic improvement and evaluation service system have high reliability.

Through the establishment and application of the urban traffic improvement evaluation index system, we can decompose the complex and diversified urban transportation problems and quickly find the advantages and disadvantages of the current traffic improvement programs. We have found positive solutions to our urban traffic problems. The role played a guiding role in the evaluation and optimization of urban transport improvement programs.

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