Satisfaction Evaluation of Urban Public transportation based on AHP-Matter-Element Model

Yugang Wang [a], Jichun Kang [b] and Jingcheng Wu [c]

School of Energy and Engineering, Henan Polytechnic University, Jiaozuo, Henan, 454000, China;

[a]wangyugang@hpu.edu.cn, [b]kjc3980336@126.com, [c]jackwujingcheng@icloud.com

Abstract

This paper constructs an urban public transport satisfaction evaluation system that covers safety, convenience, rapidity, punctuality, comfort and economy. The hierarchy of analytic hierarchy process (AHP) is used to establish index hierarchy of evaluation system, and the weights of indicators are determined by expert consultation. The index hierarchy of evaluation system is established based on the framework of AHP, and the weight of indexes are determined by Delphi method. Based on the extensible set theory, we establish the evaluation model of urban public transportation satisfaction, and get the weight and correlation function of each evaluation factor, so as to realize the quantitative evaluation of urban public transportation satisfaction. Finally, according to the data from the questionnaire survey of public transportation passenger satisfaction, we analyzed the satisfaction in Jiaozuo City, Henan Province, and the final evaluation result was general satisfaction.

Keywords

Urban public transportation satisfaction; analytic hierarchy process; extension set theory; matter element evaluation model.

1. Introduction

Urban public transportation is an important infrastructure closely related to people's life, and also an important way to solve traffic jams in cities. Whether public transportation is preferred by the public is mainly dependent on the level of public transport services. Only based on the needs of the passengers can the public transport system be constantly improved, better services are provided, and more public transportation is attracted by the public, thus effectively alleviating traffic congestion. Therefore, the evaluation of residents' satisfaction with public transport is not only more and more important for the implementation of public transport priority plans, but also provides a decision basis for improving the service quality of public transportation services.

Since 1970s, scholars have put forward a more systematic view from the aspects of theoretical research and practical research in the field of urban public transportation evaluation. Alter[1] evaluated the level of passenger satisfaction by accessibility, reliability, travel time and other indicators; David[2] constructs a public transportation preference model based on five variables, such as waiting satisfaction, travel satisfaction, car satisfaction, information satisfaction and comfort; Friman[3] proposed a public transport passenger satisfaction evaluation model, and concluded that the overall satisfaction and cumulative satisfaction showed a positive correlation. In the field of urban public transport evaluation, Chinese scholars mainly focus on two indicators of public transport system service level and passenger satisfaction. Wei Wang[4] put forward a fuzzy clustering analysis method based on the service level of public transport system. Jing-jin Yuan[4] uses the AHP to evaluate the running state of the city public transportation system; Ying-hong Li[5] demonstrated the grey clustering evaluation model of China's public transportation rapid transit service level by line 1 of Ji'nan city BRT; Xing Kuang[6] evaluated the satisfaction of passenger transportation level and public transportation line network in Changchun from walking distance, ticket price, vehicle safety,. etc. In the study of public transportation passenger satisfaction, scholars mainly focus on the development model of public transportation system, public transportation station [7], public transportation network optimization [8], public transportation safety and convenience [9], economy and comfort.

Most of the researches are focus on public transportation construction and the statistical data of facilities to evaluate the development level of public transportation. The evaluation methods mainly adopt fuzzy comprehensive evaluation method, grey theory evaluation and BP neural network evaluation. But the urban public transportation satisfaction is a comprehensive problem that covers the participation of many parties. The comprehensive concept of operation management and service characteristics should be analyzed qualitatively when evaluating the satisfaction. From the point of view of the system, this paper constructs the evaluation system of urban public transportation satisfaction, and builds the evaluation model of urban public transportation satisfaction based on the theory of matter element extension and the analytic hierarchy process. It aims to achieve comprehensive quantitative evaluation of public transportation satisfaction, and provide some reference for urban public transport management department.

2. Urban public transportation satisfaction evaluation system

At present, China has not set up a unified evaluation index system of public transportation passenger satisfaction, and the evaluation indexes of public transportation passenger satisfaction are different in all regions. The paper mainly draws on the evaluation index system of public transportation passenger satisfaction established at home and abroad, fully considers the present situation of the development level of urban public transportation service, and combines the appendix and appendix to the survey questionnaire of passengers, and has screened out six major indicators which are more close to the public and easy to accept, that is, safety, convenience, punctuality, rapidity, economy and comfort.

Safety refers to the safety awareness of public transportation service to passengers, which is mainly reflected by the safe driving of the public transportation. Convenience refers to the convenience for the public taking the public transportation, mainly reflected by the average walking distance to the public public transportation, the public transportation operation time and the use of the public transportation card. Rapidity refers to the rapid delivery of public transportation to the destination, mainly reflected by the speed index of the public transportation; punctuality refers to whether the public transportation can arrive at the public transportation station on time, mainly reflected by the average waiting time of the passengers, and the comfort refers to the public transportation travel time. Comfort refers to the comfort of the passengers when the public transportation travels. The public transportation enterprises should try to reduce the weary sense of the public transportation passengers on the way, and reflect the public health service status of the public transportation, the change of the public transportation speed, the ventilation of the public transportation, the noise status in the public transportation and the damaged status of the public transportation seats. Economic refers to the cost of passengers traveling by public transportation, which is mainly reflected by the public transportation fare. On the basis of these, the basic indexes of Changsha public transportation passenger satisfaction evaluation model are selected, and the hierarchical structure of the evaluation index of public transportation passenger satisfaction is finally established as shown in Table 1.

Table 1 Public transportation satisfaction evaluation system

	Index level 1	Index level 1
Public transportation satisfaction	Safety	Accident rate
	Convenience	Walking distance, Operation time, The use of public transportation cards

	Rapidity	Public transportation running speed
	Punctuality	Average waiting time
	Comfort	Public transportation internal environment, Public transportation platform environment, Public transportation congestion degree, Service attitude of driver and passengers
	Economy	fare

3. AHP-matter-element model of urban public transportation satisfaction

Matter element analysis is an important mathematical tool by introducing the concept of "matter element" and using the extension set theory to analyze things. It has been widely used in creative thinking, artificial intelligence, decision making, recognition and evaluation. In matter element analysis, the three elements are organically combined by the objects, the features of objects and the values of features, and a ordered tuple is formed in a certain order, which is called the matter element [10] as the basic element of the objects. The main idea of matter-element analysis is to replace the feature vectors of various evaluation indexes, and to carry out the transformation of matter element by reference to its corresponding evaluation set, so as to get the degrees of correlation between the subject element and each evaluation set. Finally we select the maximum corresponding level in the maximum correlation degree as the membership grade of the matter element.

3.1 Weight determination by AHP.

First, we arrange each index into several levels according to the affiliation and category (as shown in Figure 1), and then compare the importance of each index in the lowest level, so as to quantify the relative importance of each index, and the judgment matrix for constructing the quantized value of the relative importance of the index is as follows.

$$A=\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \tag{1}$$

The element a_{ij} in the Judgment matrix represents the value of the index i relative to the index j, and a_{ij} and a_{ji} are reciprocal. According to the judgment matrix A, the maximum eigenvalue $\lambda_{\max}$ and the corresponding eigenvector $\omega=(\omega_1,\omega_2,...,\omega_n)$ are obtained. At the same time, the consistency index CR is calculated to determine the consistency rate, $CR=CI/RC$, $CI=(\lambda_{\max}-n)/(n-1)$, in which RC is a random consistency index, and its value can be obtained by literature[11]. When $CR<0.1$, the consistency is acceptable. After passing the conformance test, the final feature vector ω is the weight coefficient of the evaluation index.

3.2 Matter element of urban public transportation satisfaction.

Taking the object N as the urban public transport, the value of characteristic C is V, and the ordered triple $R=(N,C,V)$ is the basic unit of the object, that is, the satisfaction of urban public transportation. The matter-element R has n characteristics (evaluation index) expressed by $c_i(i=1,2,...,n)$ respectively, and the corresponding value is $v_i(i=1,2,...,n)$. The satisfaction degree of urban public transport can be expressed as:

$$R=\begin{bmatrix} N & c_1 & v_1 \\ & c_2 & v_2 \\ & \dots & \dots \\ & c_n & v_n \end{bmatrix} \tag{2}$$

For the matter element of urban public transportation satisfaction, it is assumed that each characteristic $c_i(i=1,2,...,n)$ has several levels to describe the level and quality of the development of each characteristic (evaluation index). It is called the classical field matter element R_B, that is:

$$R_B=(N_B,C,V_B)=\begin{bmatrix} N_B & c_1 & (a_{B_1},b_{B_1}) \\ & c_2 & (a_{B_2},b_{B_2}) \\ & ... & ... \\ & c_n & (a_{B_n},b_{B_n}) \end{bmatrix} \quad (3)$$

Each characteristic of matter element has a range of value to describe the range of the development of each characteristic (evaluation index), which is called the segment field matter element, that is:

$$R_p=(N_p,C,V_p)=\begin{bmatrix} N_p & c_1 & (a_{p_1},b_{p_1}) \\ & c_2 & (a_{p_2},b_{p_2}) \\ & ... & ... \\ & c_n & (a_{p_n},b_{p_n}) \end{bmatrix} \quad (3)$$

3.3 Correlation function and comprehensive correlation degree.

According to the basic characteristics of the extension set theory and urban public transportation, the following correlation function is used to express the degree of membership of the degree of urban public transportation satisfaction and the level of evaluation in advance. The correlation function $k_j(x_i)$ of evaluation index i can be expressed in the following way:

$$k_j(x_i)=\begin{cases} \dfrac{\rho(x_i,x_{ji})}{|\rho(x_i,x_{pi})-\rho(x_i,x_{ji})|}, x_i \notin x_{ji} \\ \dfrac{-\rho(x_i,x_{ji})}{|x_{ji}|}, x_i \in x_{ji} \end{cases} \quad (5)$$

$$\rho(x_i,x_{ji})=|x_i-(a_{ji}+b_{ji})/2|-(b_{ji}-a_{ji})/2 \quad (6)$$

$$\rho(x_i,x_{pi})=|x_i-(a_{pi}+b_{pi})/2|-(b_{pi}-a_{pi})/2 \quad (7)$$

We set the corresponding weight of each feature c_i as ω_i, and the multi index comprehensive association degree $k_j(R)$ of R can be expressed as:

$$k_j(R)=\sum_{i=1}^{n}\omega_i \cdot k_j(x_i) \quad (8)$$

$$K(R)=\max k_j(R) \quad (9)$$

For urban public transport satisfaction element R, the greater the $k_j(R)$ of the comprehensive correlation degree, the higher the correlation degree of urban public traffic satisfaction belongs to the grade j, and $K(R)$ indicates that the satisfaction of urban public transportation is subordinate to the grade j.

4. Example analysis

Taking the public transport system in Jiaozuo city of Henan Province as an example of comprehensive evaluation, the evaluation model built before is analyzed and explained. The total population of Jiaozuo is 3 million 539 thousand and 800, the number of urban population is 1 million 433 thousand and 600, and the rate of urbanization is 49%. Up to now, there are 702 buses in Jiaozuo bus company, including 78 commuters, 4 robbing cars, 9 stopping cars, and a total of 38 bus routes in Jiaozuo.

4.1 The weights of indexes.

In the construction of the judgment matrix, 1~9 and its reciprocal are used as the relative importance scale of the two indexes in the urban public transportation satisfaction evaluation system. The weight coefficients of each index are obtained by the calculation method described before, as shown in Table 2.

Table 2 calculation results of index weight

<table>
<tr><th></th><th>Index level 1</th><th>weight</th><th>Index level 2</th><th>weight</th></tr>
<tr><td rowspan="12">Evaluation system of public transportation satisfaction</td><td>Safety</td><td>0.15</td><td>Accident rate</td><td>1.00</td></tr>
<tr><td rowspan="3">Convenience</td><td rowspan="3">0.20</td><td>Walking distance</td><td>0.32</td></tr>
<tr><td>Operation time</td><td>0.44</td></tr>
<tr><td>The use of public transportation cards</td><td>0.24</td></tr>
<tr><td>Rapidity</td><td>0.18</td><td>Public transportation running speed</td><td>1.00</td></tr>
<tr><td>Punctuality</td><td>0.15</td><td>Average waiting time</td><td>1.00</td></tr>
<tr><td rowspan="4">Comfort</td><td rowspan="4">0.12</td><td>Public transportation internal environment</td><td>0.24</td></tr>
<tr><td>Public transportation platform environment</td><td>0.20</td></tr>
<tr><td>Public transportation congestion degree</td><td>0.36</td></tr>
<tr><td>Service attitude of driver and passengers</td><td>0.20</td></tr>
<tr><td>Economy</td><td>0.20</td><td>fare</td><td>1.00</td></tr>
</table>

The consistency index $CI = 0.139$, random consistency index $RI = 1.45$, and we obtain $RC = 0.096 < 0.1$. Therefore, the weight is satisfied with the consistency test.

4.2 Correlation function and comprehensive correlation degree.

In view of every index in the evaluation system of urban public transportation satisfaction, 5 levels of expectations are set: satisfaction, basically satisfaction, general, dissatisfaction, disappointment. The correlation function of each index is calculated according to the questionnaire results and formula (5) ~ (7), and the calculation results are shown in Table 3. Then the 5 levels of relevance are calculated as shown in Table 4. Finally, the comprehensive correlation degree each scheme is shown in Table 4. Due to length limit, only part of the data is listed in Table 4.

Table 3 Correlation degree of each index

	Safety	Convenience	Rapidity	Punctuality	Comfort	Economy
satisfaction	0.17	-0.14	-0.06	0.02	0.12	0.29
basically satisfaction	0.01	0.11	0.11	0.27	0.39	0.16
general	-0.03	0.13	0.03	0.13	0.07	-0.08
dissatisfaction	-0.20	-0.37	-0.37	-0.13	-0.35	-0.50
disappointment	-0.38	-0.45	-0.58	-0.76	-0.77	-0.47

Table 4 Comprehensive correlation degree of public transportation satisfaction in Jiaozuo

satisfaction	basically satisfaction	general	dissatisfaction	disappointment
-0.04	0.18	0.02	-0.37	-0.41

4.3 Scheme comprehensive evaluation.

In the evaluation of urban public transportation satisfaction, the value of $K(R)$ reflects different situations:

(1) when $0 \le K(R) \le 1$, it indicates that the evaluation index accords with the quantification degree of a certain level. The larger the value, the closer the standard is to the standard upper limit.

(2) when $-1 \le K(R) \le 0$, it is indicated that the index of the modified evaluation does not conform to the degree of a certain grade, but it is transformed into the condition of this level, and the greater the value, the more easily the index is converted.

From the correlation degree of Table 4, we can see that the city's public transport satisfaction evaluation results are basically satisfactory. Besides, the evaluation results of safety and economic indicators are "very satisfied". The evaluation results of rapidity, punctuality and comfort are "basically satisfaction", and the evaluation result of the convenience index is "general". Therefore, in order to improve the satisfaction degree of urban public transportation in Jiaozuo, we should start with the operation time index under the convenience index, and put forward the corresponding improvement plan.

5. Conclusion

In this paper, matter element analysis is applied to evaluate the satisfaction degree of urban public transport. Through the analysis of the influencing factors of urban public transport, we select the relevant indicators to construct the evaluation system, and establish the evaluation model of urban public transport satisfaction. Finally, an example is made to analyze the results of Jiaozuo public transportation related parameters. The results show that the AHP- matter-element evaluation model is feasible in the urban public transportation satisfaction, and the method is easy to calculate and clear in steps. In addition, the results of the comprehensive evaluation of urban public transportation satisfaction are obtained, and the evaluation results of all kinds of indicators in the evaluation system are reacted with specific numerical values, so as to provide reasonable suggestions for improving the service quality of urban public transportation.

Acknowledgements

The Youth Science Foundation of Henan Polytechnic University (Natural Science) (Q2017-4) .

References

[1] Alter C.H. Evaluation of public transit service: the level-of-service concept [R]. Transportation research record, 1976,(606):323-330.

[2] David A. Hierarchical stated response designs: an application to bus user preference [J]. Logistics and Transportation Review, 1990,(26):299-321.

[3] Margareta Friman, Bo Edvadsson, Tommy Garling. Frequency of negative critical incidents and satisfaction with public transport services [J]. Journal of Retailing and Customer Services, 2001,(8):95-104.

[4] Wei Wang. Urban public transport system planning method and management technology [M]. Beijing: Science Press, 2002. (In Chinese)

[5] JinG-jin Yuan. Evaluation of operation status of urban road traffic system based on reliability analysis [D]. Beijing: Beijing Jiaotong University, 2006. (In Chinese)
[6] Ying-hong Li, Hui-juan Sun. BRT service level evaluation research [J]. Journal of Chongqing Jiaotong University (NATURAL SCIENCE EDITION), 2010, (2): 285-289. (In Chinese)
[7] Xing Kuang. Evaluation of urban conventional public transport service level [D]. Changchun: Jilin University, 2004. (In Chinese)
[8] Yu-long Pei, Da-wei Xu. Prediction of public traffic sharing rate based on fuzzy reasoning [J]. Journal of Harbin Institute of Technology, 2003, (7): 22-26. (In Chinese)
[9] Ai-di Zhou. The analysis and evaluation index of the conventional bus fairy king and its recent adjustment and optimization method [D]. Nanjing: Southeast University, 2004. (In Chinese)
[10] Cai Wen. Matter-element model and application [M]. Beijing: Science and Technology Press, 1994. (In Chinese)
[11] Dong Du, Qing-hua Pang, Yan Wu. Selection of modern comprehensive evaluation methods and cases [M]. Beijing: Tsinghua University press, 2008. (In Chinese)