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Research on Fuzzy Comprehensive Evaluation of Passenger Satisfaction in Urban Public Transport

Di Yin

School of Economics and Management, Xidian University, Xi'an, China
Email: yd_yindi@163.com

Abstract

Bus has become an integral traffic mode for urban residents along with the development of public transport system; and as a kind of public service, urban public transport is the basic infrastructure closely related to people, and is also required to constantly improve its service levels to better serve people. Therefore, how to evaluate its service level has become one of the important projects that need to be studied. Based on establishing the mathematical model of fuzzy comprehensive evaluation and illustrated by the case of Xi'an, this paper verifies the model rationality, assesses the bus development level in Xi'an, and further puts forward countermeasures for its bus services according to the results.

Keywords

Public Transport, Passenger Satisfaction, Fuzzy Comprehensive Evaluation

1. Introduction

Urban public transport is not only the key to the modernization construction, but also an indispensable part of urban infrastructure construction, as well as an important link to build a harmonious society and improve the living standard of residents. As a kind of public service, public transport is also required to conduct marketing for most consumers under the background of continuously improved transport facilities. More importantly, the quality of bus service not only reflects the travel condition, social style, urban and spiritual civilization construction level, but also becomes the main indicator to measure the urban public transport marketing competitiveness.

The service level of urban public transport has been greatly improved in recent years, but the traditional increase in the number of buses and control of

passenger fares still cannot solve the problems of low safety, poor comfort and environmental health of the bus. The improved people's living standard and the reduced costs of cars have made more and more people choose private cars, thus exacerbating the urban traffic congestion, air pollution, noise and safety. As the service level of urban public transport directly affects its sustainable development goals, the research on the passenger satisfaction evaluation can effectively find problems in the process of public transport services from the perspective of "customers", in order to improve the bus passenger satisfaction and public transport service level.

2. Selection of Evaluation Index of Passenger Satisfaction in Public Transport

There is no complete, unified and effective evaluation index system of public transport passenger satisfaction in China, making different evaluation indicators in various regions. Therefore, based on the foreign evaluation indexes and the actual situation in China, the paper adopts the expert investigation to screen more suitable six major indicators (see Table 1), including safety [1], convenience [1], punctuality, rapidity, comfort [1] and economy.

In the process of index selection, this article follows the scientific principle, objectivity principle, operability principle, measurability principle and Importance guarantee principle.

1) Scientific principle: The choice of indicators and the determination of index weights, data selection, calculation and synthesis must be based on accepted scientific theories.

Table 1. Passenger satisfaction evaluation index.

First-class targets	Second-class targets
Safety	Security configuration
	Property loss rate
	Personal safety
Convenience	Reasonable site settings
	Frequency of starting
	Traffic jam situation
Quasi-point	The condition of the dedicated lane
	On time arrival rate
	Average waiting time
Rapidity	Transfer routes
	The speed of the vehicle
	Seat damaged
Comfort	The steady state of vehicle operation
	Hygiene in the car
	The degree of congestion in the car
Economic	Transportation fee rates
	Bus card benefits

2) Objectivity principle: Ensure the objective and fairness of the evaluation index system, ensure the accuracy of the data sources and the scientificity of the assessment methods.

3) Operability principle: The indicators should try to select daily statistical indicators or easy available indicators so as to provide an intuitive and easy understanding of the stage of public transport and help improve the service level.

4) Measurability principle: Customer Satisfaction Evaluation results must be quantifiable, so the selected indicators must be able to carry out statistical analysis.

5) Importance guarantee principle [2]: Need to grasp the needs of customers accurately, the selected indicators must be considered important by customers.

3. Establishment of the Fuzzy Comprehensive Evaluation Model

Fuzzy comprehensive evaluation method is to regard the fuzzy object and fuzzy concept as the certain fuzzy set, then establish a fuzzy membership function, and conduct the quantitative analysis on fuzzy object through the relevant operations [3].

1) Determine the factor set of fuzzy comprehensive evaluation object

The set of factors that affects the scores of evaluation objects is called the factor set, which is usually expressed by the letter U, $U = \{u_1, u_2, \cdots, u_m\}$.

2) Determine the weight set of each influencing factor

The influencing degree of each factor on the value of evaluation object is different, so different factors $u_i (i = 1, 2, \cdots)$ should be given the corresponding weight coefficient $\alpha_i (i = 1, 2, \cdots m)$, thus forming the weight set $A = \{\alpha_1, \alpha_2, \cdots, \alpha_m\}$.

And the weight coefficient should be normalized before synthesis, which means

$$\sum_{i=1}^{m} \alpha_i = 1, \alpha_i \geq 0 (i = 1, 2, \cdots, m)$$

As the weight set is a fuzzy set, in order to clearly represent the correspondence between weight coefficient and various factors, it can be expressed as

$$A = \frac{\alpha_1}{u_1} + \frac{\alpha_2}{u_2} + \cdots + \frac{\alpha_m}{u_m}$$

3) Determine the evaluation set of the evaluation object

The evaluation set is a collection of various evaluation results that reviewers may make on the evaluation objects, and usually expressed as capital letter V, then $V = \{V_1, V_2, \cdots, V_n\}$, and each level corresponds to a fuzzy subset.

The evaluation set is desirable as V = {very satisfied, more satisfied, general, not very satisfied, very dissatisfied} in the passenger satisfaction evaluation in public transport.

4) Establish the fuzzy membership matrix

The single-factor fuzzy evaluation is to evaluate separately from a factor, and

determine the elements membership of evaluation objects in the evaluation set.

Generally, the i-th element u_i should be evaluated in the factor set, and if the membership degree of the j-th element v_j is given as γ_{ip} the result can be expressed as a fuzzy set:

$$R_i = \frac{\gamma_{i1}}{v_1} + \frac{\gamma_{i2}}{v_2} + \cdots + \frac{\gamma_{in}}{v_n} (i = 1, 2, \cdots, m)$$

R_i is a single-factor evaluation set, and the fuzzy matrix R formed by its membership is the single-factor evaluation matrix,

$$R = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1n} \\ \gamma_{21} & \gamma_{22} & \cdots & \gamma_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \gamma_{m1} & \gamma_{m2} & \cdots & \gamma_{mn} \end{bmatrix}$$

5) Synthetic fuzzy comprehensive evaluation result vector

The evaluation result vector can be obtained by synthesizing the membership matrix of each subject with the appropriate weight set.

$$B = A * R = (\alpha_1, \alpha_2, \cdots, \alpha_m) \begin{bmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1n} \\ \gamma_{21} & \gamma_{22} & \cdots & \gamma_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \gamma_{m1} & \gamma_{m2} & \cdots & \gamma_{mn} \end{bmatrix}$$

The matrix B can obtain the results according to the fuzzy evaluation method after the normalized process.

4. Evaluation of Passenger Satisfaction in Public Transport-Illustrated by the Case of Xi'an

With the accelerating process of urbanization, economic development has stimulated the development of urban transport and brought tremendous pressure on urban transport. As a result, traffic congestion has become increasingly serious and the contradiction between supply and demand on roads has become increasingly acute. As a political, economic and cultural center of Shanxi Province, Xi'an has such characteristics as dense population, frequent activities, centralized facilities and tight land. It is reflected in the fact that Xi'an has less people and less traffic and fewer cars, these basic contradictions are prominent [4].

In the process of public transportation development, there is a single public transport system structure, an unreasonable layout of the line network, a low service rate of the site, and a poor service level of the system, which does not fully reflect the idea of "bus priority" and can no longer fully satisfy people's travel needs. Quality requirements, the downward trend in the attraction of the travel crowd, resulting in the structure of the entire city traffic to the bad direction, reducing the utilization of urban roads.

In order to verify the rationality of the mathematical model, at the same time,

put forward reasonable suggestions for the development of public transport in Xi'an. In this paper, Xi'an city as an example, Xi'an city bus passenger satisfaction survey were conducted, a total of 570 questionnaires were distributed, a total of 500 valid questionnaires were obtained, the statistical results in Table 2.

Then makes the quantitative evaluation of its overall level of the according to the fuzzy evaluation method.

1) Factor set

The factor set of the fuzzy comprehensive evaluation can be obtained according to the evaluation index determined above.

U = {safety (u_1), convenience (u_2), punctuality (u_3), rapidity (u_4), economy (u_5), comfort (u_6)}

2) Weight set

Based on the results of the calculation, we can give the evaluation weight set of the six components of bus passenger satisfaction: A = {a_1, a_2, a_3, a_4, a_5, a_6} = {0.03, 0.25, 0.04, 0.15, 0.44, 0.09}

3) Evaluation set

The evaluation set V = {V_1, V_2, V_3, V_4, V_5} = {very satisfied, more satisfied, general, not satisfied, very dissatisfied}

The corresponding numerical set of the evaluation set is N = {N_1, N_2, N_3, N_4, N_5} = {95, 85, 75, 65, 55}

4) Single-factor fuzzy evaluation

It can be obtained from the data,

$$R_1 = \frac{0.4}{V_1} + \frac{0.3}{V_2} + \frac{0.21}{V_3} + \frac{0.05}{V_4} + \frac{0.04}{V_5}$$

$$R_2 = \frac{0.24}{V_1} + \frac{0.17}{V_2} + \frac{0.27}{V_3} + \frac{0.21}{V_4} + \frac{0.11}{V_5}$$

$$R_3 = \frac{0.17}{V_1} + \frac{0.3}{V_2} + \frac{0.31}{V_3} + \frac{0.14}{V_4} + \frac{0.08}{V_5}$$

$$R_4 = \frac{0.04}{V_1} + \frac{0.12}{V_2} + \frac{0.32}{V_3} + \frac{0.42}{V_4} + \frac{0.10}{V_5}$$

$$R_5 = \frac{0.05}{V_1} + \frac{0.25}{V_2} + \frac{0.48}{V_3} + \frac{0.17}{V_4} + \frac{0.05}{V_5}$$

$$R_6 = \frac{0.09}{V_1} + \frac{0.31}{V_2} + \frac{0.39}{V_3} + \frac{0.17}{V_4} + \frac{0.04}{V_5}$$

Table 2. The percentage Xi'an citizen's satisfaction with public transit evaluation results.

Index Percentage Satisfaction	Very satisfied v_1	More satisfied v_2	General v_3	Not so satisfied v_4	Not satisfied v_5
Safety	40	30	21	5	4
Convenience	24	17	27	21	11
Quasi-point	17	30	31	14	8
Rapidity	4	12	32	42	10
Comfort	5	25	48	17	5
Economic	9	31	39	17	4

The single-factor evaluation matrix is:

$$R = \begin{bmatrix} 0.4 & 0.3 & 0.21 & 0.05 & 0.04 \\ 0.24 & 0.17 & 0.27 & 0.21 & 0.11 \\ 0.17 & 0.3 & 0.31 & 0.14 & 0.08 \\ 0.04 & 0.12 & 0.32 & 0.42 & 0.10 \\ 0.05 & 0.25 & 0.48 & 0.17 & 0.05 \\ 0.09 & 0.31 & 0.39 & 0.17 & 0.04 \end{bmatrix}$$

And then the complex operation of fuzzy matrix is

$$B = A*R = (0.03, 0.15, 0.04, 0.15, 0.44, 0.09) \begin{bmatrix} 0.4 & 0.3 & 0.21 & 0.05 & 0.04 \\ 0.24 & 0.17 & 0.27 & 0.21 & 0.11 \\ 0.17 & 0.3 & 0.31 & 0.14 & 0.08 \\ 0.04 & 0.12 & 0.32 & 0.42 & 0.10 \\ 0.05 & 0.25 & 0.48 & 0.17 & 0.05 \\ 0.09 & 0.31 & 0.39 & 0.17 & 0.04 \end{bmatrix}$$

$$= (0.19, 0.2, 0.35, 0.19, 0.07)$$

5) Fuzzy comprehensive evaluation

We can calculate specific scores in safety, convenience, punctuality, rapidity, economy and comfort of public transport in Xi'an according to the obtained weight and the corresponding numerical set of the evaluation set.

The score of safety

$$B_1 * N = \begin{bmatrix} 0.4 & 0.3 & 0.21 & 0.05 & 0.04 \end{bmatrix} \begin{bmatrix} 95 \\ 85 \\ 75 \\ 65 \\ 55 \end{bmatrix} = 84.7$$

The score of convenience

$$B_2 * N = \begin{bmatrix} 0.24 & 0.17 & 0.27 & 0.21 & 0.11 \end{bmatrix} \begin{bmatrix} 95 \\ 85 \\ 75 \\ 65 \\ 55 \end{bmatrix} = 77.2$$

The score of punctuality

$$B_3 * N = \begin{bmatrix} 0.17 & 0.3 & 0.31 & 0.14 & 0.08 \end{bmatrix} \begin{bmatrix} 95 \\ 85 \\ 75 \\ 65 \\ 55 \end{bmatrix} = 78.4$$

The score of rapidity

$$B_4 * N = \begin{bmatrix} 0.04 & 0.12 & 0.32 & 0.42 & 0.10 \end{bmatrix} \begin{bmatrix} 95 \\ 85 \\ 75 \\ 65 \\ 55 \end{bmatrix} = 70.8$$

The score of economy

$$B_5 * N = \begin{bmatrix} 0.05 & 0.25 & 0.48 & 0.17 & 0.05 \end{bmatrix} \begin{bmatrix} 95 \\ 85 \\ 75 \\ 65 \\ 55 \end{bmatrix} = 75.8$$

The score of comfort

$$B_6 * N = \begin{bmatrix} 0.09 & 0.31 & 0.39 & 0.17 & 0.04 \end{bmatrix} \begin{bmatrix} 95 \\ 85 \\ 75 \\ 65 \\ 55 \end{bmatrix} = 77.4$$

The comprehensive score

$$B * N = \begin{bmatrix} 0.19 & 0.2 & 0.35 & 0.19 & 0.07 \end{bmatrix} \begin{bmatrix} 95 \\ 85 \\ 75 \\ 65 \\ 55 \end{bmatrix} = 77.5$$

The above calculation results show that the comprehensive score of bus passenger satisfaction in Xi'an is 77.5 and in the intermediate level, so many public transport services still need to be adjusted. And the scores of safety, convenience, punctuality, economy and comfort index are 84.7, 77.2, 78.4, 75.8 and 77.4, which are basically between the general and the satisfaction, belong to the intermediate level, and still require to be further improved. While the score of rapidity index is 70.8, and between not satisfied and the general, which is very urgent to be improved. Only in this way, we can improve the bus passenger satisfaction level in Xi'an, and make the overall level show a relatively stable upward trend.

5. Conclusions

As a scientific, accurate and intuitive research method, the quantitative research of fuzzy comprehensive evaluation is widely applied under the background of the continuous developed society and science.

Based on the establishment of the fuzzy comprehensive evaluation model, this paper mainly measures the bus passenger satisfaction in service level of Xi'an, verifies the reason and applicability of the model, and further puts forward sug-

gestions on public transport services according to the results.

1) To strengthen the investment of government in public transport infrastructure, and take measures to ensure its preferential development.

2) To improve the hardware facilities of bus services, strengthen the construction of junction and interchange station.

3) To conduct humanistic bus services, and improve the soft power of public transport.

4) To establish and improve the bus service operation mechanism and enhance the social benefits.

At the same time, there are still some deficiencies in this study:

1) The evaluation lacks consideration of regional environmental issues. This paper did not consider the influence of weather, seasons and urban culture when doing evaluation studies. In particular, Xi'an City, as a world-famous cultural city, has a very limited plan for bus routes. At the same time, due to different weather and seasons, people's physiological experience is different [5], which may also have an impact on ride satisfaction.

2) Bus collinear problem evaluation does not consider the problem that how many buses the passengers can choose to the same place. In the case of collinearity, ride satisfaction will affect passengers' decision-making on line selection. This is also a direction of future research.

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