

Analysis of Shanghai Metro Passenger Satisfaction Based on Fuzzy Comprehensive Evaluation Method

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Abstract

As an urban infrastructure construction, metro is a symbol of the city's economic strength and a mode of urban rail transportation with the advantages of high delivery capacity, punctuality, speed, ease of ride, low energy consumption and less pollution. In recent years, the rapid development of metro transportation mode plays an increasingly important role in urban public transportation. As people's demand for a better life grows, people's concern and demand for the quality of subway operation services is also increasing. The evaluation of metro passenger satisfaction is of great significance to the development of metro companies and the overall operation of the urban rail transit service industry. The concept of customer satisfaction, a relatively mature management concept in modern enterprise management system, has been very widely applied to various industries. This thesis combines the actual situation of Shanghai Metro and the theory of customer satisfaction, conducts research on passenger satisfaction, and uses the evaluation method combining hierarchical analysis and fuzzy comprehensive evaluation method to construct the evaluation index system of passenger satisfaction of Shanghai Metro Line 16. The index weights were calculated by the consistency test, and the results were combined with the results of 126 passenger questionnaires of Shanghai Metro Line 16, and the evaluation results were obtained by using the principle of weighted average to find the subordinate rank. The results show that Shanghai Metro Line 16 should pay more attention to the service facilities and service quality, and improve the indicators of both, so as to continuously improve the quality of service of Shanghai Metro operating company and the business standard of service personnel.

Keywords

Metro passenger satisfaction; hierarchical analysis method; fuzzy integrated evaluation method; Shanghai Metro Line 16.

1. Introduction

Along with the continuous development of China's national economy, the pace of urbanization in China has been maintained at a high level since the reform and opening up of China. The ground surface is under pressure and needs to adjust its role and management to accommodate the continuous growth of ground traffic. As a key measure of the quality of services provided by metro operators to the traveling public, metro passenger satisfaction plays an important role in the transformation and development of metro companies to continuously improve operational efficiency and achieve intelligent transportation.

Customer satisfaction is different from customer satisfaction in that it is a quantitative indicator. In other words, "satisfaction" is not a subjective concept, but it is a visualization of customer satisfaction [10]. It can be expressed as the degree of difference between the actual utility of the product or service

purchased by the customer and the expected one. The process of measuring customer satisfaction is to analyze the factors affecting customer satisfaction, then use specific statistical tools to filter out the main indicators, quantitatively describe the products and services experienced by customers, and mathematically express them as a function of the difference between the actual utility value and the expected value. It directly and effectively reflects the degree of satisfaction of customer consumption experience, and at the same time indirectly indicates the customer's opinion on the product and the service demand that they wish to be satisfied at the side, providing a reference for enterprises.

Metro Passenger Satisfaction Degree (MPSD) refers to the state of passengers' perceptions of subway service expectations compared to the actual situation. Passenger satisfaction is influenced by multidimensional psychological factors, which are subjective and vague, and difficult to observe directly. In order to make a scientific evaluation, a hierarchical index structure system is proposed based on hierarchical analysis for each general index. The fuzzy comprehensive evaluation method is used to evaluate the Shanghai Metro Line 16, and the overall evaluation of the criterion level indexes and target level indexes, which are subject to multiple factors, is based on the weighted average and subordinate rank principle of fuzzy mathematics.

2. The subway passenger satisfaction assessment model

2.1 Build a hierarchical model

The metro passenger satisfaction is modeled in a hierarchical structure according to the passenger-oriented principle. The problems to be solved, factors and criteria to be considered, apply the hierarchical analysis, build alternatives and draw the hierarchical structure.

2.2 Construction of judgment matrix and consistency

Test A scale of proportional scales proposed by American operations researcher Thomas Sethi was used by the expert group to score the two factors of the two comparisons, and the weights W_i of each indicator of the judgment matrix S and the maximum eigenvalues λ_{max} , and the consistency ratio CI of the judgment matrix were calculated.

To confirm the hierarchical single ordering and reduce the possibility of random deviations in consistency, the consistency ratio CR of the matrix is calculated.

$$CR = \frac{CI}{RI}$$

In general, if $CR < 0.1$, the judgment matrix is considered to pass the hierarchical single-sort consistency test; otherwise, the index values of the matrix need to be readjusted to obtain consistency.

The total hierarchical ranking is the ranking weight value of each hierarchical indicator relative to the relative importance of the highest hierarchical indicator. Assuming that there are K levels with n elements, the overall judgment matrix is considered to pass the consistency test when $CR(k) < 0.1$.

2.3 Fuzzy comprehensive evaluation of subway passenger satisfaction

2.3.1 Build fuzzy sets

Determine the set of evaluation indicators $Q = \{Q_1, Q_2, \dots, Q_n\}$. The Likert scale method was chosen as a quantitative method to classify the evaluation criteria of each indicator into 5 levels and assign values to these level options, the set of evaluation levels $V = \{V_1, V_2, V_3, V_4, V_5\} = \{\text{very satisfied, more satisfied, average, dissatisfied, very dissatisfied}\} = \{5 \text{ points, } 4 \text{ points, } 3 \text{ points, } 2 \text{ points, } 1 \text{ point}\}$.

Let the weight assignment set Q_i to Q be a_i , then the set of indicator weights for each level is $A = \{a_1, a_2, \dots, a_n\}$.

2.3.2 Build fuzzy relationship matrix.

A single factor evaluation is made for the single factor in the indicator set Q . The single factor evaluation set $ri = (ri1, ri2, \Lambda, rim)$ for the i th factor is then obtained based on the ratio of the number of people who select the rank to the total number of people, thus obtains the evaluation affiliation matrix R :

$$R = \begin{matrix} r11 & r12 & \Lambda & r1m \\ r21 & r22 & \Lambda & r2m \\ rn1 & rn2 & \Lambda & rnm \end{matrix}$$

Take the affiliation vector B of the evaluation index set to the evaluation level set, which is the total evaluation result.

$$B = A \cdot R = (a1, a2, \Lambda, an) \cdot \begin{matrix} r11 & r12 & \Lambda & r1m \\ r21 & r22 & \Lambda & r2m \\ rn1 & rn2 & \Lambda & rnm \end{matrix} = (b1, b2, \Lambda, bm)$$

2.3.3 Score analysis of the judgment result vector

Using the principle of weighted average to find the subordinate rank, the corresponding scores were calculated for each index of metro passenger satisfaction after ranking according to the rank position. The evaluation rank set V is divided into five different scales on a percentage basis, respectively $V = \{V1, V2, V3, V4, V5\} = \{95, 85, 75, 65, 55\}$.

3. Shanghai Metro Line 16 Empirical Study

3.1 Shanghai Metro Line 16 Subway Passenger Satisfaction

For Shanghai Metro Line 16, a metro passenger satisfaction model is established from people, vehicles, environment, facilities and equipment that passengers reflect more problems and use most frequently. The total evaluation object $A = \{\text{metro passenger satisfaction}\}$, the three-level hierarchy model in the criterion level $B = \{\text{service safety } B1, \text{service quality } B2, \text{service facilities } B3, \text{service environment } B4\}$ as the first level indicators, $C = \{C1 \text{ train operation control, } C2 \text{ security and monitoring, } C3 \text{ station lobby and platform, } C4 \text{ subway fare, } C5 \text{ fare discount system, } C6 \text{ departure interval, } C7 \text{ first and last train settings, } C8 \text{ on-time and fast, } C9 \text{ guidance signs, } C10 \text{ gate passage rate, } C11 \text{ number of self-service ticket machines, } C12 \text{ entrance/exit settings, } C13 \text{ station environment, } C14 \text{ train environment, } C15 \text{ train crowding, } C16 \text{ passenger behavior, } C17 \text{ service order}\}$ are secondary indicators to determine the comprehensive index system of metro passenger satisfaction.

3.2 Hierarchical single ranking with consistency test

The steps of hierarchical analysis modeling mainly include: establishing the structural model of hierarchical order; constructing the judgment matrix of indicators at all levels; single ranking and consistency test of indicator levels; total ranking and consistency test of indicator levels.

Let the index of consistency be CI (**ConsistencyIndex**), there is:

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

and the corresponding consistency index RI (**RandomIndex**) was found, as shown in Table 1.

Table 1. Random consistency index taking values

Matrix Order	1	2	3	4	5	6	7	8	9	10
Ir	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The results of the consistency test of the hierarchical single ranking of the judgment matrix of each layer of indicators were tallied (see Table 2) through the expert scoring of each indicator in the judgment matrix by the professionals of Shanghai Metro Line 16, and the consensus was obtained after several iterations.

Table 2. Attributes of judgment matrix at all levels

Properties	Judgment Matrix				
	A	B1	B2	B3	B4
λ_{max}	4.086 8	3.053 6	5.116 8	4.121 3	5.384 3
CI	0.032 5	0.051 6	0.026 1	0.045 4	0.085 8
RI	0.9	0.58	1.12	0.9	1.1200
CR	0.036 1	0.088 9	0.023 3	0.050 4	0.076 6

Finally,
calculate its consistency ratio:

$$CR = \frac{CI}{RI}$$

Generally, if $CR < 0.1$, we consider the judgment matrix as the consistency matrix, and the consistency value calculated according to it is acceptable, otherwise the judgment matrix should be reworked.

3.3 Hierarchical total ranking and consistency test

The results of the hierarchical ranking of the factors influencing passenger satisfaction on Shanghai Metro Line 16 were calculated (see Table 3).

The combined test index for the total ranking is :

$$\begin{aligned}
 CR &= \\
 &0.0516 \times 0.3294 + 0.3625 \times 0.0261 + 0.2215 \times 0.0454 + 0.0866 \times 0.0858 \\
 &0.3294 \times 0.58 + 0.3625 \times 1.12 + 0.2215 \times 0.9 + 0.0866 \times 1.12 \\
 &= 0.049 < 0.1
 \end{aligned}$$

Therefore, the overall ranking of passenger satisfaction level of Hangzhou Metro Line 1 by .

Table 3. Overall ranking and weighting calculation

Weights	B1	B2	B3	B4	Portfolio weights	Sort by
	0.3294	0.3625	0.2215	0.0866		
C1	0.1956				0.0644	1
C2	0.0821				0.0270	4
C3	0.0517				0.0170	8
C4		0.0894			0.0324	3
C5		0.1185			0.0430	2
C6		0.0505			0.0183	7
C7		0.0593			0.0215	5
C8		0.0447			0.0162	9
C9			0.0865		0.0192	6
C10			0.0612		0.0136	10
C11			0.0433		0.0096	11
C12			0.0306		0.0068	12
C13				0.0120	0.0010	16
C14				0.0176	0.0015	15
C15				0.0342	0.0030	13
C16				0.0048	0.0004	17
C17				0.0179	0.0016	14

4. Fuzzy integrated evaluation analysis

4.1 Questionnaire

The survey was conducted at Ding Lingang Avenue Station, Huinan Station and Longyang Road Station on Line 16 of the Shanghai Metro. A total of 130 questionnaires were distributed, and 126 valid questionnaires were selected. The questionnaires were processed and counted, and the details are shown in Table 4.

Table 4. Passenger satisfaction rating of each indicator of Shanghai Metro Line 16

Tier1 Indicators	Secondary indicators	Very satisfied (5)	More satisfied (4)	General (3)	Dissatisfaction (2)	Very dissatisfied (1)
B1	C1	39	68	10	7	2
	C2	56	62	3	3	1
	C3	48	38	23	13	4
B2	C4	28	65	20	10	3
	C5	67	31	18	10	0
	C6	5	18	12	66	25
	C7	24	38	28	32	4
	C8	45	40	32	8	1
B3	C9	49	43	17	17	0
	C10	50	48	19	4	5
	C11	18	34	38	23	13
	C12	21	45	39	17	4
B4	C13	35	57	30	2	2
	C14	34	52	32	6	2
	C15	8	23	29	34	32
	C16	5	31	34	30	26
	C17	33	39	29	23	2

4.2 Fuzzy integrated evaluation

4.2.1 Fuzzy comprehensive evaluation

(1) First-level fuzzy comprehensive evaluation. According to the analysis of the train operation control in Table 4, 39 passengers out of 126 are very satisfied with the train operation control with the probability of $39/126 = 0.31$; 68 passengers are satisfied with the train operation control with the probability of $68/126 = 0.54$; 10 passengers are satisfied with the train operation control with the probability of $10/126 = 0.08$; 7 passengers are dissatisfied with the train operation control with the probability of $7/126 = 0.06$;

(2) Passengers are dissatisfied with the train operation control with the probability of $2/126 = 0.01$. The fuzzy vectors are $(0.31, 0.54, 0.08, 0.06, 0.01)$. Similarly, the fuzzy vectors of the other three levels of indicators are obtained by the same data processing, and the affiliation matrices **R 1**, **R 2**, **R 3**, **R 4** of the first-level fuzzy comprehensive evaluation.

5. Analysis of evaluation results

From the results, it can be seen that the final score of passenger satisfaction evaluation of Shanghai Metro Line 16 is 83.02, At the level of general satisfaction.

The scores of each indicator in the criterion level of the passenger satisfaction index system of Shanghai Metro Line 16 are 86.13, 80.97, 82.89 and 80.10 respectively, and the service safety indicators are between very satisfied and relatively satisfied, which means that Shanghai Metro Line 16 takes ensuring the personal safety of passengers as the basic criterion and ensures the smooth and safe operation of trains. For the service facilities, service quality and service environment, the satisfaction level of passengers is between average and relatively satisfied, and the service facilities

and service quality have a greater weight in the overall ranking, which has a greater impact on the results.

6. Recommendation

6.1 Convenience and speed

According to the results of the previous analysis, convenience and speed are the items that need to be improved immediately, including specific problems such as setting the first and last train times, transferring to other modes of transportation, parking lots at subway entrances, and congestion in the cars during peak hours. The following solutions are proposed for specific problems:

(1) For the first and last train time setting, the last train departure time can be extended. In order to meet the travel demand of passengers and considering the operating cost of the subway, the last train departure time can be extended to 23:30. In addition, different train times can be set in summer and winter according to the seasonal pattern.

(2) For the interchange problem, rational planning should be done. Traffic management departments should work together to rationalize the location of subway stations and bus stops seamlessly to achieve convenient conversion between the two modes of public transportation. In the future construction of other routes, the metro traffic management department should reasonably plan the interchange hubs, design passenger interchange routes, and improve the density of the transportation network to facilitate passenger travel.

(3) For the subway entrance parking problem, can be equipped with subway supporting parking. In accordance with the proportion of bicycle travel can be set up at the subway entrance bicycle canopy, in the suburbs with conditions to allocate non-motorized parking lots. At present, the motor vehicle parking stations along Line 16 for passengers are not perfect. Therefore, it is recommended to cooperate with the Shanghai Municipal Planning Bureau to consider sacrificing part of the green land around the station to be converted into motor vehicle parking lots, and later the metro company will be responsible for arranging relevant personnel to guide or set up prompt signs to maintain the parking order.

6.2 For ticketing services

According to the analysis results, the ticketing service is in the secondary improvement area. The main problems under the improvement items are: the current fare and fare calculation methods are not reasonable and the customer service center is not convenient to recharge the metro card. The following solutions are proposed for specific problems:

(1) The current fares and counting methods are being improved by diversifying ticket types. The number of low-income riders in the subway is high. In view of this situation, different stored-value tickets can be set for frequent riders, student tickets and discounts for low-income people can be increased, end-ride discounts and group purchase discounts for single-ride tickets can be added, and weekly tickets, monthly tickets and special tickets can be added. In addition, increase the diversity of ticket publicity. Through **microblogging, weibo**, newspapers, station display, car built-in TV, so that passengers understand the preferential ticket information, so that they can choose the right ticket for themselves.

(2) For the customer service center metro card recharge is not convenient, optimize the recharge process and system, open multi-channel recharge mode. Customer service center recharge passengers more manual recharge is not fast enough, you can configure automatic recharge machine, reduce human resources waste while improving efficiency. You can also cooperate with major banks to open telephone banking, online banking, WeChat, Alipay, etc. to transfer funds for recharge. We can also provide multiple channels to check the balance and open SMS.

6.3 Information dissemination

The results of the analysis show that the information campaign is in the secondary area of improvement. The problems of information promotion are divided into three areas: promotion of subway information platform, promotion of subway culture, and promotion of subway safety. These three areas are discussed below:

- (1) Publicity of metro information platform. Improve the attractiveness of information, update speed as well as increase the information of complaint service, and increase the content of public service advertisement. Public service type activities can be advertised, and the participation of passengers can be enhanced by collecting Shanghai Metro mascots.
- (2) The promotion of subway culture. The subway is a window to show the culture of the city, through the station decoration, personalized service, subway cartoon image, etc. you can feel the rhythm of a city's life, folk customs. At present, Shanghai's subway culture does not highlight local characteristics, and there is a lot of room for improvement. It is suggested that Shanghai metro set up art walls in stations or transfer channels, the content of which can show Shanghai's red history, famous monuments, special snacks, etc.
- (3) Dissemination of metro safety knowledge. The Shanghai Metro has not yet conducted emergency drills for operational emergencies since it began operations, and there has been little publicity about emergency measures for passengers facing accidents. Therefore, a combination of extensive publicity and actual drills can be adopted. Specific measures include: arranging regular safety knowledge and emergency response training for metro staff, setting up a metro emergency command center, establishing emergency plans, and periodically conducting emergency drills; for passengers, the metro company produces manuals, videos and other media to publicize safety escape knowledge, such as passenger norms and safety knowledge. At the same time, reminders on the use of facilities and equipment and safety and civilized slogans are posted at stations to give passengers humanized instructions to improve customers' self-help ability and safety knowledge level, so that they can make timely and effective self-help when necessary; for equipment safety, the subway should be regularly maintained and overhauled. The reminder function is convenient for passengers to recharge in time to prevent inconvenience caused by temporary recharge.

6.4 Other aspects

- (1) Since order and safety, guidance and riding environment are the aspects of Nanchang metro service that perform better and have fewer problems, they are combined into one part. The following is an analysis of these two aspects in turn:
- (2) The problems in order and safety are waiting and riding order. It is suggested that the subway company advocate passengers to ride civilized by posting civilized slogans, ground signs, warm tips, voice prompts, etc.; it can also organize experience days to let people understand the importance of civilized riding; in addition, it can reasonably deploy guiding staff according to the passenger flow to ensure good riding order.
- (3) The problem of riding environment is that the service facilities for special people in the station are not perfect. It is suggested that Nanchang Metro should open a green channel for special people at the entrance and exit of the station, and set up special seats for people with disabilities in the restrooms.

7. Conclusion

In the future, the metro is bound to become the first choice of the majority of the public, and it is a matter of concern for the metro authorities to continuously improve the satisfaction of the metro passengers and achieve win-win development between the metro operating companies and the passengers. This evaluation method is a quantitative method to study the satisfaction of metro passengers, which has certain application value and aims to provide a certain reference basis for the

relevant metro operating companies, so that the operation of metro companies can move forward towards the concept of "operation service for passengers".

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