

Chapter 78

The Application of Fuzzy Analytic Hierarchy Process and Grey Relational Analysis in the Taxi Passenger Satisfaction Evaluation

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Abstract Taxis are an important supplementary and complementary tool of public transport and analysis of passenger satisfaction aims to identify existing problems in the process of taxi service, then to propose improvements. By fuzzy analytic hierarchy process and grey relational analysis, to calculate the weight and correlation degree of the impact factors, then to obtain the key factors. The data analysis shows that the range of between dissatisfaction and the general, it is in the lower level. The waiting time, refusing to take passengers, service attitude and complaints handling are the most dissatisfied factors. The government should improve the overall satisfaction of the taxi passengers from three strategies about raising the price of the taxi, developing the public transport, strengthening management.

Keywords Evaluation • F-AHP • GRA • Satisfaction

78.1 Introduction

78.1.1 Research Background

The existing taxi number is 14120 in Wuhan City, this number was far from satisfying the needs of passengers, strong demand is an important reason, in addition to the increase of passengers, mainly taxi driving is difficult, the root cause is that road congestion increased year by year. The survey shows a substantial increase

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in car ownership in Wuhan City. In urban areas, the vehicle speed is showing a declining trend, lower than the average speed in some of the congested road, and road congestion caused the decline in turnover efficiency of taxi operations.

The passengers pay attention to the time efficiency, when public transport which is urban transport aorta were blocked, it prompted the explosive development of private transport, so road blocking was harder than before. For taxi drivers, they will consider cost accounting, some sections which the efficiency is not high will not travel, so that makes congestion sections of very few taxi trips, which is exacerbated by a “take a taxi is hard” phenomenon.

78.1.2 Research Contents

From the perspective of the passengers, this paper analyzes the taxi passenger satisfaction evaluation factors firstly, through questionnaires, randomly selected passengers to score the 17 indicators of the impact on passenger satisfaction evaluation, and then calculated the satisfaction evaluation data, to analyze the problems of the taxi service process, then to propose improvements for increasing passenger satisfaction and easing “take a taxi is hard” phenomenon.

78.1.3 Research Methods

In this paper, fuzzy analytic hierarchy process (F-AHP) and grey relational analysis (GRA) combined to increase the reliability and accuracy of the satisfaction evaluation.

F-AHP combines the advantages of the AHP and fuzzy comprehensive evaluation method, in a fuzzy environment, to take into account many factors, and use the fuzzy membership theory quantitative to quantify the qualitative indicators reasonably. This method solves the question that evaluation process is too subjective, and to effectively compensate for the lack of establishing the weight. Come to the scientific, objective results of evaluation (Zheng Xin et al. 2010; Xu Ge-ning and Jiang Fan 2010).

GRA is an important method in grey system theory that the objective things have a wide range of grey, according to similar or different degree of the development trend between factors, to measure the correlation degree, which reflect the merit order of evaluation indicators (Wu Qi-bing et al. 2008). GRA has obvious advantage of the theoretical analysis for inaccurate information and the uncertainty of small sample system (Hu Da-li 2003).

78.2 F-AHP and GRA Model of Taxi Passenger Satisfaction Evaluation

78.2.1 Index System

Index system of taxi passenger satisfaction evaluation is the premise and foundation to build satisfaction evaluation model. Whether index system is reasonable and accurate, directly impact on the scientific, reliability and accuracy of the evaluation results. The evaluation index system can be divided into three layers: target layer, rule layer and indicator layer (Wang En-xu and Wu Chun-you 2009) (Fig. 78.1, Li Hong-ji 2005).

78.2.2 Determining the Weights of the Index System

To establish weight layer $W = \{W_1, W_2, \dots, W_n\}$, W_i is the weight of the i -th indicator in the rule layer, $W_i = \{W_{i1}, W_{i2}, \dots, W_{ij}\}$, W_{ij} is the weight of the j -th indicator in the i -th indicator (Lu Yue-jin 2002).

A number of experts judge the importance of n indicators on the same layer by Delphi method (Table 78.1), then to establish the judgment matrix, and check the consistency. Consistency index is $CI = \frac{\lambda_{\max} - n}{n - 1}$, according the mean random consistency index RI (Table 78.2), obtains relative consistency index CR, $CR = \frac{CI}{RI}$, if $CI < 0.1$, the weight order meets the requirements, the results are satisfied, or to adjust the judgment matrix, and to obtain the weights again by the above steps (Morash 2001).

1. Judgment matrix $O-U$:

$$A = \begin{pmatrix} 1 & 3 & 1/2 & 2 & 1/3 \\ 1/3 & 1 & 1/4 & 1/5 & 1/5 \\ 2 & 4 & 1 & 1/2 & 1/2 \\ 1/2 & 5 & 2 & 1 & 1/2 \\ 3 & 5 & 2 & 2 & 1 \end{pmatrix}, \lambda_{\max} = 5.374, CI = 0.094, CR = 0.084$$

< 0.1 , the judgment matrix $O-U$ has consistency. $W = (0.168, 0.055, 0.193, 0.202, 0.382)^T$.

2. Judgment matrix U_1-U_{1j} :

$$A_1 = \begin{pmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 3 \\ 1/3 & 1/3 & 1 \end{pmatrix}, \lambda_{\max} = 3.054, CI = 0.027, CR = 0.046 < 0.1, \text{ the}$$

judgment matrix U_1-U_{1j} has consistency. $W_1 = (0.527, 0.333, 0.140)^T$.

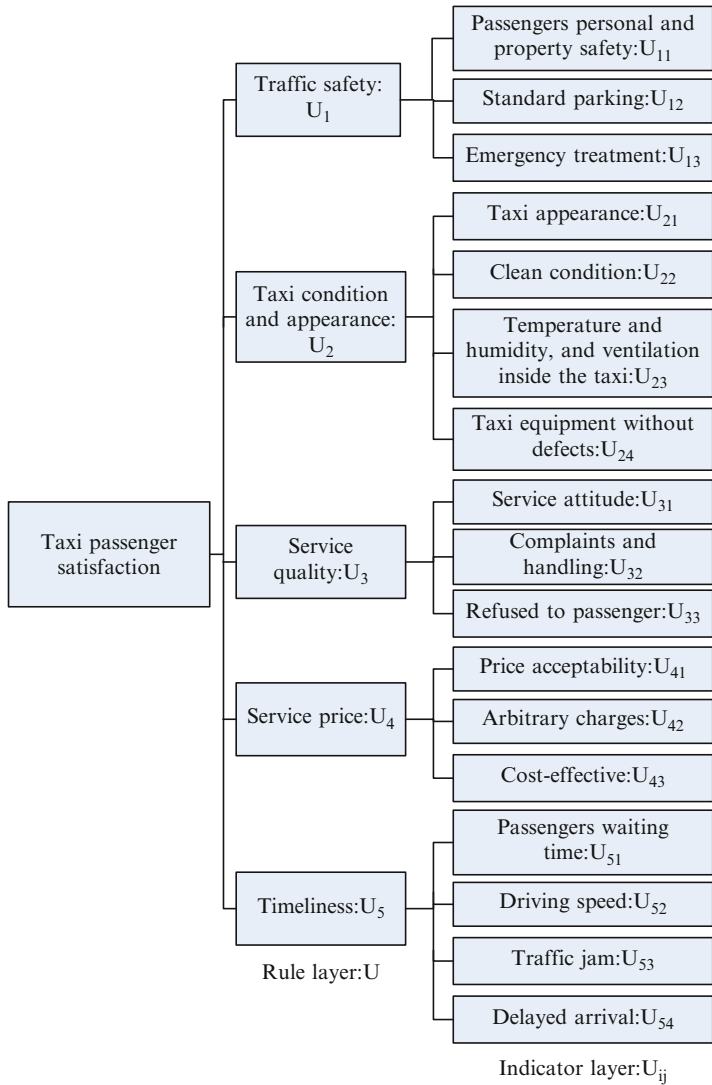


Fig. 78.1 Index system of taxi passenger satisfaction evaluation

Table 78.1 RI value

Size(n)	1	2	3	4	5	6	7
RI	0	0	0.58	0.9	1.12	1.24	1.32

Table 78.2 Evaluation results of various indicators

Rule layer	Indicator layer	Very satisfactory	Satisfactory	General	Dissatisfactory	Very dissatisfactory
R ₁	R ₁₁	0.1	0.3	0.4	0.2	0
	R ₁₂	0.2	0.4	0.3	0.1	0
	R ₁₃	0.1	0.3	0.4	0.2	0.1
R ₂	R ₂₁	0.2	0.4	0.3	0.1	0
	R ₂₂	0.3	0.4	0.3	0	0
	R ₂₃	0.1	0.3	0.4	0.2	0
	R ₂₄	0.3	0.4	0.3	0	0
R ₃	R ₃₁	0	0.1	0.4	0.4	0.1
	R ₃₂	0	0.1	0.5	0.3	0.1
	R ₃₃	0	0.1	0.4	0.4	0.1
R ₄	R ₄₁	0.3	0.4	0.2	0.1	0
	R ₄₂	0.1	0.2	0.5	0.1	0.1
	R ₄₃	0.1	0.2	0.4	0.2	0.1
R ₅	R ₅₁	0	0.1	0.4	0.4	0.1
	R ₅₂	0.2	0.4	0.3	0.1	0
	R ₅₃	0.1	0.2	0.4	0.2	0.1
	R ₅₄	0.1	0.2	0.3	0.3	0.1

3. Judgment matrix U_2-U_{2j} :

$$A_2 = \begin{pmatrix} 1 & 1/2 & 1/3 & 1 \\ 2 & 1 & 1 & 2 \\ 3 & 1 & 1 & 4 \\ 1 & 1/2 & 1/4 & 1 \end{pmatrix}, \lambda_{\max} = 4.046, CI = 0.015, CR = 0.017 < 0.1, \text{ the}$$

judgment matrix U_2-U_{2j} has consistency. $W_2 = (0.141, 0.314, 0.413, 0.132)^T$.

4. Judgment matrix U_3-U_{3j} :

$$A_3 = \begin{pmatrix} 1 & 5 & 3 \\ 1/5 & 1 & 1/3 \\ 1/3 & 3 & 1 \end{pmatrix}, \lambda_{\max} = 3.039, CI = 0.019, CR = 0.033 < 0.1, \text{ the}$$

judgment matrix U_3-U_{3j} has consistency. $W_3 = (0.637, 0.105, 0.258)^T$.

5. Judgment matrix U_4-U_{4j} :

$$A_4 = \begin{pmatrix} 1 & 1/4 & 2 \\ 4 & 1 & 3 \\ 1/2 & 1/3 & 1 \end{pmatrix}, \lambda_{\max} = 3.108, CI = 0.054, CR = 0.093 < 0.1, \text{ the}$$

judgment matrix U_4-U_{4j} has consistency. $W_4 = (0.218, 0.630, 0.152)^T$.

6. Judgment matrix U_5-U_{5j} :

$$A_5 = \begin{pmatrix} 1 & 5 & 2 & 2 \\ 1/5 & 1 & 1/5 & 1/3 \\ 1/2 & 5 & 1 & 1/2 \\ 1/2 & 3 & 2 & 1 \end{pmatrix}, \lambda_{\max} = 4.155, CI = 0.052, CR = 0.057 < 0.1,$$

the judgment matrix U_5-U_{5j} has consistency. $W_5 = (0.438, 0.070, 0.219, 0.273)^T$.

78.2.3 *Establishing the Evaluation Set and Comprehensive Evaluation Matrix*

The data were collected by the questionnaires. Issued 500 copies of the questionnaire, the recovered questionnaires were 387, effective rate was 77.4 %. The age of investigators divided into 4 ranges, under 18, 18–30, 30–40 and over 40 years old. Each indicator divided into 5 levels of evaluation, to establish the evaluation set V , $V = \{V_1, V_2, V_3, V_4, V_5\} = \{\text{very satisfactory, quite satisfactory, general, dissatisfactory, very dissatisfactory}\}$, score range is from 0 to 100 points, and score range for each grade are: very satisfactory (over 90 points), quite satisfactory (70–90 points), general (50–70 points), dissatisfactory (30–50 points), very dissatisfactory (under 30 points). Except “very satisfactory” grade rating, each grade ratings can choose the lower limit as parameters, namely: $C = (1, 0.7, 0.5, 0.3, 0)$, then obtained the results of comprehensive evaluation (Table 78.2), finally to build the total evaluation matrix (Miao Zhi-guo and Zheng Quan-cheng 2010; Niu Hui-yong 2005).

Then to combine two fuzzy subset W_i and R_i to the total evaluation matrix, namely $B_i = W_i * R_i$ (Wang Gui-cheng 2008).

$$\begin{aligned}
 B_1 &= W_1 R_1 = (0.527 \ 0.333 \ 0.140) \begin{pmatrix} 0.1 & 0.3 & 0.4 & 0.2 & 0 \\ 0.2 & 0.4 & 0.3 & 0.1 & 0 \\ 0.1 & 0.3 & 0.4 & 0.2 & 0.1 \end{pmatrix} \\
 &= (0.133, 0.333, 0.367, 0.167, 0.014)
 \end{aligned}$$

Similarly calculate the B_2, B_3, B_4 and B_5 , obtained a total evaluation matrix R . Then,

$$\begin{aligned}
 B &= W * R = (0.168 \ 0.055 \ 0.193 \ 0.202 \ 0.382)^* \\
 &\begin{pmatrix} 0.133 & 0.333 & 0.367 & 0.167 & 0.014 \\ 0.203 & 0.359 & 0.341 & 0.097 & 0 \\ 0 & 0.100 & 0.411 & 0.390 & 0.100 \\ 0.144 & 0.244 & 0.419 & 0.115 & 0.078 \\ 0.063 & 0.170 & 0.366 & 0.308 & 0.093 \end{pmatrix} \\
 &= (0.087, 0.209, 0.384, 0.250, 0.073)
 \end{aligned}$$

Grade calculation result is as follows:

$$\begin{aligned}
 F &= B * C = (0.087, 0.209, 0.384, 0.250, 0.073)^* (1, 0.7, 0.5, 0.3, 0) \\
 &= 0.5003.
 \end{aligned}$$

According to the previous evaluation set shows that the satisfaction of the taxi passengers is between general and dissatisfaction. Then using GRA to get the

Table 78.3 The average score of each indicator

Indicator	Passengers (ages)				Comparative sequence X_{ij}
	Under 18	18–30	30–40	Over 40	
U ₁₁	65.5	65.2	61.7	72.0	72.0
U ₁₂	72.9	65.9	76.3	62.5	76.3
U ₁₃	61.1	56.3	57.4	64.0	64.0
U ₂₁	64.2	74.4	60.8	71.0	74.4
U ₂₂	71.4	82.7	67.7	79.0	82.7
U ₂₃	73.4	70.4	66.0	70.0	73.4
U ₂₄	74.3	72.1	79.7	80.5	80.5
U ₃₁	50.9	48.3	45.7	51.3	55.9
U ₃₂	53.6	52.0	50.8	55.2	62.0
U ₃₃	50.1	46.7	44.3	51.7	54.1
U ₄₁	71.9	79.5	83.3	68.1	83.3
U ₄₂	65.0	58.8	68.1	55.7	68.1
U ₄₃	57.6	66.7	63.6	54.5	66.7
U ₅₁	55.8	48.4	45.0	48.4	56.0
U ₅₂	77.6	67.0	74.0	63.5	77.6
U ₅₃	58.2	52.6	49.9	60.9	60.9
U ₅₄	60.3	52.1	49.3	57.5	60.3

satisfaction evaluation value of each factor and identify the key factors of the taxi passenger satisfaction (Li Juan-fang and Liu Xing 2011).

78.2.4 Getting the Satisfaction Evaluation Value of Each Factor by GRA

1. *Determining the analysis sequence:*

GRA must be sure the reference sequence X_0 (the evaluation indicator of n), $X_0 = \{X_0(1), X_0(2), \dots, X_0(n)\}$, then select the maximum value of satisfaction evaluation of the m -class passengers record as the comparative sequence X_i , $X_i = \{X_i(1), X_i(2), \dots, X_i(n)\}$ (Zhou Yan-fang and Zhou Leishan 2007; Yang Ya and Qi Xiao-yu 2011). The average score of each indicator are shown in Table 78.3.

2. *Calculating the correlation coefficient $\xi_i(k)$* (Dai Yi et al. 2008):

$$\xi_i(k) = \frac{\min_i \min_k |X_0(k) - X_1(k)| + \zeta \max_i \max_k |X_0(k) - X_1(k)|}{|X_0(k) - X_1(k)| + \zeta \max_i \max_k |X_0(k) - X_1(k)|}$$

$(i = 1, 2, \dots, m; k = 1, 2, \dots, n);$ (78.1)

$\xi_i(k)$: the relative difference between X_i and X_0 of the k th factor;
 ζ : distinguishing coefficient, $\zeta \in [0, 1]$, in order to reduce the influence of extreme values on the calculation (Miller 1992).

According to Table 78.3, $\min_i \min_k |X_0(k) - X_1(k)| = 0$, $\max_i \max_k |X_0(k) - X_1(k)| = 15.1$, take $\zeta = 0.5$, coefficient matrix E as follows:

$$E = \xi_i(k)_{m \times n} = \begin{pmatrix} \xi_1(1) & \xi_1(2) & \cdots & \xi_1(n) \\ \xi_2(1) & \xi_2(2) & \cdots & \xi_2(n) \\ \vdots & \vdots & \ddots & \vdots \\ \xi_m(1) & \xi_m(2) & \cdots & \xi_m(n) \end{pmatrix}$$

$$= \begin{pmatrix} 0.54 & 0.53 & 0.42 & 1.00 \\ 0.69 & 0.42 & 1.00 & 0.35 \\ 0.72 & 0.49 & 0.53 & 1.00 \\ 0.43 & 1.00 & 0.36 & 0.69 \\ 0.40 & 1.00 & 0.33 & 0.67 \\ 1.00 & 0.72 & 0.51 & 0.69 \\ 0.55 & 0.47 & 0.90 & 1.00 \\ 0.60 & 0.50 & 0.43 & 0.62 \\ 0.47 & 0.43 & 0.40 & 0.53 \\ 0.65 & 0.51 & 0.43 & 0.75 \\ 0.40 & 0.67 & 1.00 & 0.33 \\ 0.71 & 0.45 & 1.00 & 0.38 \\ 0.45 & 1.00 & 0.71 & 0.38 \\ 0.98 & 0.50 & 0.41 & 0.50 \\ 1.00 & 0.42 & 0.68 & 0.35 \\ 0.73 & 0.48 & 0.41 & 1.00 \\ 1.00 & 0.48 & 0.41 & 0.73 \end{pmatrix}$$

3. Calculating the correlation degree r_i :

$$r_i = \sum_{k=1}^n W(k)\xi_i(k) \tag{78.2}$$

then $r_{11} = 0.55$, $r_{12} = 0.64$, $r_{13} = 0.60$, $r_{21} = 0.68$, $r_{22} = 0.66$, $r_{23} = 0.67$, $r_{24} = 0.70$, $r_{31} = 0.50$, $r_{32} = 0.44$, $r_{33} = 0.53$, $r_{41} = 0.71$, $r_{42} = 0.66$, $r_{43} = 0.76$, $r_{51} = 0.52$, $r_{52} = 0.56$, $r_{53} = 0.55$, $r_{54} = 0.55$; the order is $r_{43} > r_{41} > r_{24} > r_{21} > r_{23} > r_{22} > r_{42} > r_{12} > r_{13} > r_{52} > r_{11} > r_{53} > r_{54} > r_{33} > r_{51} > r_{31} > r_{32}$ (Qin Peng et al. 2011).

According to the sort of correlation degree r_i , in all the factors, taxi passengers satisfied with taxi cost-price, price and taxi equipment without defects. They dissatisfied with taxi refusing to take passengers, waiting time, the attitude of taxi drivers, complains handling (Li Li 2012). To find out the factors that taxi passengers are less satisfied, in order to propose the measures to improve the overall satisfaction (Lin Xiao-yan et al. 2005).

78.3 Improvements

78.3.1 Raising the Price

Bus and subway are the most important public transport, taxis as a supplementary mode of transport service for the relatively small number of people and special population. The start-price of Wuhan taxi is 6 yuan, 1.4 yuan per kilometer after 2 km, the lower price and underdeveloped public transport make a large number of passengers to choose a taxi trip, to take up the limited resources of the community. If the taxi price are raised, not only can improve the ability of taxi operators, increase drivers' income, but also balance taxis demand by the price leverage.

78.3.2 Developing Public Transport

Public transport is underdeveloped, causing passengers to travel difficulties, and part of the bus passengers diverted to the taxi. Government needs to increase public transport investment to improve the public transport grade, reduce price, raise the service quality of public transport, and avoid the loss of bus passengers on the taxi.

78.3.3 Strengthening Government Management

To install the GPS system for taxi, and establish a taxi dispatch center, form a comprehensive supervision; to increase the on-call service for improving the utilization of the taxi; strengthen the service of handling the passengers complaints for increasing satisfaction rate; severely crack down on a small number of taxi refuse to take passengers; increase the intensity of traffic congestion management; speed up the road widening maintenance and new construction, to fundamentally solve taxi passenger waiting time, traffic jam and raising the turnover rate of a taxi.

78.4 Conclusion

Through F-AHP and GRA, establish evaluation model of taxi passenger satisfaction, then analyze the main factors of the impact on passenger satisfaction (Chen Kai et al. 2011). And propose improvements for increasing satisfaction. Combination of two methods, simple and easy to operate practical, and the conclusion was reasonable and scientific (Yan Zhi-heng et al. 2010).

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