Evaluation Model of Automobile Users Satisfaction Based on AHP

Lanyou Li, Jingui Lu*

School of Mechanical and Power Engineering, Nanjing Tech University, Nanjing Jiangsu 211800, China

*Corresponding author’s e-mail: lujinguin@163.com

Abstract. Aiming at the uncertainty problem of obtaining automobile users satisfaction, evaluation models which combine the objective evaluation methods such as entropy weight method (EWM) and the subjective evaluation methods such as analytic hierarchy process (AHP) are given. With power, fuel consumption, space, control, comfort, appearance, automotive interior and cost performance as the performance evaluation indicators, the comprehensive coefficient weight for each indicator is determined with both AHP and other objective evaluation methods. Taking the SUV users satisfaction as an example, the satisfaction corresponding to each model is given. The results show that the satisfaction evaluation model based on the combination of AHP and objective evaluation method is more effective, which provides a reference evaluation model for the automobile enterprises that make decisions or seek for design innovation.

1. Introduction

In the face of the huge automobile sales market, consumers are influenced by many factors such as appearance, control, interior decoration, space, comfort, power, cost performance and fuel consumption. They are faced with a variety of difficulties in car purchase decision-making, which leads to the reduction of car purchase satisfaction. On the other hand, automobile enterprises urgently need to listen to the voice of users, track the customer satisfaction of sold models, so as to decide whether to carry out targeted improvement design for the sold models in the next generation products, so as to carry forward the advantages and improve the deficiencies, and then enhance the competitiveness of products. However, there are complex factors such as strong subjectivity and many uncertain factors in the evaluation of user satisfaction. It is of practical significance to construct an evaluation model with high accuracy. Domestic and foreign scholars have conducted extensive and in-depth research on the concept of user satisfaction.

Kathleen seiders [1] analyzed the relationship between purchase decision and customer satisfaction through empirical method. Huiying Wen et al. [2] proposed a fuzzy comprehensive evaluation method for Guangzhou Foshan intercity bus satisfaction by using improved AHP. Hongxiang Xu et al. [3] proposed a family car purchase decision-making model based on AHP. However, the domestic research on automobile customer satisfaction mostly focuses on the selection and formulation of indicators, and lacks a variety of fusion methods for the comparative analysis of the same case.

In this paper, based on the application of analytic hierarchy process (AHP), a variety of objective evaluation methods are combined with it, and the evaluation model system of automobile customer
satisfaction is constructed, and these models are compared and analyzed to study the effectiveness and usability of each fusion model. The research results can provide a reference solution for ordinary users to purchase cars or improve the design of automobile enterprises.

2. Background and related work

2.1. AHP

Analytic hierarchy process (AHP) was proposed by American professor T.L.Saaty in the 1970s. It makes decisions according to the thinking mode of decomposition, comparison, judgment and synthesis. It is a multi criteria and multi-objective decision analysis method for complex problems [4,5]. It is mainly analyzed by establishing hierarchical structure model, constructing judgment matrix, determining eigenvalue and eigenvector, and checking consistency.

(1) The hierarchical structure model is established by constructing target layer, benchmark layer and scheme layer.

(2) According to the 1-9 scaling method, if \( C_i \) is the importance index of element \( A_i \) and \( C_j \) is the importance index of element \( A_j \), then the relative importance index of \( A_i \) and \( A_j \), can be quantified as \( a_{ij} = C_i / C_j \). The judgment matrix constructed by \( a_{ij} \) is shown in formula (1).

\[
A = \begin{bmatrix}
a_{11} & a_{12} & \cdots & a_{1n} \\
a_{21} & a_{22} & \cdots & a_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
a_{n1} & a_{n2} & \cdots & a_{nn}
\end{bmatrix}, \quad a_{ij} = 1/a_{ji} \tag{1}
\]

(3) The square root method [6] is used to obtain the maximum eigenvalue \( \lambda_{\text{max}} \) and eigenvector \( W \) of judgment matrix \( A \). The calculation formula is as follows:

\[
w_i = \frac{\prod_{j=1}^{n} a_{ij}}{\sum_{i=1}^{n} \prod_{j=1}^{n} a_{ij}} , \quad i=1,2,\ldots,n \tag{2}
\]

where \( w_i \) in formula (2) has been normalized, the eigenvector is:

\[
W = (w_1, w_2, \ldots, w_n)^T \tag{3}
\]

The maximum eigenvalue \( \lambda_{\text{max}} \) can be obtained as follows:

\[
\lambda_{\text{max}} = \frac{1}{n} \sum_{i=1}^{n} (Aw)_i / w_i \tag{4}
\]

Where \((Aw)_i\) is the \( i \) component of the vector \( Aw \).

(4) The consistency test was carried out, and the index calculation formula was as follows:

\[
\text{CI} = \frac{\lambda_{\text{max}} - n}{n-1} \tag{5}
\]

The random consistency index RI can be obtained by looking up the table, then the random consistency ratio CR was as follows:

\[
\text{CR} = \frac{\text{CI}}{\text{RI}} \tag{6}
\]

If CR\( \leq 0.1 \) holds, it is considered that the calculation results have satisfactory consistency. Otherwise, it is necessary to adjust the judgment matrix \( A \) until the consistency test meets the requirements.
2.2. Entropy weight method (EWM)
The weight of each index can be calculated by using entropy, which provides the basis for the comprehensive evaluation of multiple indicators. If \( m \) evaluation schemes are given and the number of indicators of each evaluation scheme is \( n \), then \( x_{ij} \) represents the original data of the \( j \)-th evaluation scheme of the \( i \)-th index [7].

(1) The standardization formula is as follows, in which the positive index is as follows:
\[
y_{ij} = \frac{x_{ij} - \min(x_i)}{\max(x_i) - \min(x_i)}
\]  \hspace{0.5cm} (7)

The negative indicators were as follows:
\[
y_{ij} = \frac{\max(x_i) - x_{ij}}{\max(x_i) - \min(x_i)}
\]  \hspace{0.5cm} (8)

The normalization formula is as follows:
\[
p_{ij} = \frac{y_{ij}}{\sum_{j=1}^{m} y_{ij}}
\]  \hspace{0.5cm} (9)

where \( i \) is the index ordinal number, \( i=1,2,\ldots,n \), \( j \) is ordinal numbers of evaluation scheme, \( j=1,2,\ldots,m \), \( y_{ij} \) is the standardized value of \( x_{ij} \), \( p_{ij} \) is the normalized value of \( y_{ij} \), and \( \max(x_i), \min(x_i) \) are the maximum and minimum value of the \( i \)-th index respectively.

(2) The formula of information entropy is as follows:
\[
E_i = -\frac{1}{\ln m} \sum_{j=1}^{m} p_{ij} \ln p_{ij}
\]  \hspace{0.5cm} (10)
in formula (10), \( E_i \) represents the entropy of the \( i \)-th index.

(3) The calculation formula of entropy weight is as follows:
\[
\omega_i = \frac{1 - E_i}{\sum_{i=1}^{n} (1 - E_i)}
\]  \hspace{0.5cm} (11)
in Eq.(11), \( i=1,2, \ldots, n \), \( \omega_i \) is the entropy weight of the \( i \)-th index.

3. Construction of satisfaction evaluation model

3.1. Construction of evaluation model based on AHP-EWM
The construction steps of the evaluation model of the integration of AHP and entropy weight method are as follows [8,9,10]:

(1) According to formula (3) of analytic hierarchy process, the weight of subjective evaluation index \( w \) is obtained.

(2) According to formula (10) and (11) of entropy weight method, the objective weight is obtained, and then the two weights are fused to construct the comprehensive weight formula as follows:
\[
F_i = \frac{w_i \omega_i}{\sum_{i=1}^{n} w_i \omega_i}
\]  \hspace{0.5cm} (12)

(3) The result of satisfaction evaluation is given

The evaluation value of customer satisfaction can be obtained by multiplying the comprehensive weight of each index with its corresponding index value. The calculation formula is as follows:
where $G$ is the satisfaction evaluation value, $F_i$ is the weight value of the $i$-th index, and $x_{ij}$ is the score of the $i$-th index of the $j$-th evaluation object.

4. Numerical experiments

4.1. Construction of evaluation index system

The evaluation of SUV users satisfaction is a comprehensive evaluation process involving many aspects and indexes. Through literature discussion [11,12], expert consultation and consulting the mainstream automobile portals, the hierarchical structure model of SUV satisfaction is shown in Figure 1.

![Hierarchical model of SUV user satisfaction](image)

Figure 1. Hierarchical model of SUV user satisfaction.

The criteria layer judgment matrix obtained by formulas (1) to (6) is shown in Table 1. It can be seen from table 1 that CR=0.0531<0.1, which meets the consistency condition, then the weight matrix of subjective evaluation index $\begin{pmatrix} 0.1756 & 0.0800 & 0.0390 & 0.1107 & 0.1573 & 0.1281 & 0.2904 & 0.0189 \end{pmatrix}^T$ is obtained.

4.2. Comprehensive evaluation of AHP-EWM

According to the domestic SUV sales ranking list and comprehensive expert opinions, 16 SUV models are selected and numbered with model 1 ($C_1$) to model 16 ($C_{16}$), and the corresponding indicators $A_1$ to $A_8$ are obtained through the word-of-mouth evaluation information page of mainstream automobile portal websites to obtain the evaluation data under the corresponding indicators. Five degree method is used to quantify the evaluation grade, namely \{5,4,3,2,1\} is used to describe \{'very good', 'good', 'general', 'poor', 'very poor'\}. All the evaluation data of a certain vehicle model are summarized, and then the data validity is preprocessed.

| Table 1. The judgment matrix and weight vector. |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ | $A_7$ | $A_8$ | $w$   |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| $A_1$ | 1     | 3     | 5     | 2     | 1     | 1/2   | 9     | $w_1=0.1756$  |
| $A_2$ | 1/3   | 1     | 3     | 1/3   | 1     | 1/2   | 3     | $w_2=0.0800$  |
| $A_3$ | 1/5   | 1/3   | 1     | 1/3   | 1/4   | 1/3   | 1/7   | 3     | $w_3=0.0390$  |


The processed data are averaged as the final evaluation value of the vehicle model. Similarly, other models are processed in turn. Finally, the evaluation data under 8 indexes corresponding to all 16 vehicle models can be obtained, as shown in Table 2.

The data in Table 2 are normalized by formulas (7) and (9). Entropy $E$ can be obtained by formula (10), entropy weight $\omega$ can be obtained by formula (11), and comprehensive weight $F$ can be obtained by formula (12), as shown in Table 3.

Through formula (13) combined with the data in table 2 and table 3, the satisfaction evaluation value based on AHP and entropy weight method can be obtained, as shown in Table 4.

5. Conclusion
In order to verify the rationality of AHP entropy weight method, the comprehensive score (word-of-mouth) about an automobile portal website of the selected vehicle model is selected as the reference ranking result of user satisfaction, as shown in Table 8.
The ranking results calculated by entropy weight method combined with AHP: the data in Table 4 are compared with the data in Table 5 of reference satisfaction ranking result, and the test results are shown in Fig. 2:

As can be seen from the above figure, the ranking results of the evaluation models namely AHP entropy weight method, which gives better satisfaction evaluation results, and also shows overall consistency with the word-of-mouth ranking of vehicle evaluation websites. However, there are two problems in the ranking jump of C9 models: one is that the satisfaction value of the word-of-mouth of the car review website may have data defects; the other is that under the current evaluation index system, the ranking of user satisfaction given by the evaluation model is higher, but the ranking of word-of-mouth of car review website is low, which indicates whether the automobile enterprises has some problems needed to be solved, it is helpful for automobile enterprises to find out the short board of model index.

![Figure 2. Comparison chart of satisfaction ranking of different evaluation models.](image)

**Acknowledgments**

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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