

# Intelligent Calculation of Automobile Brand Power Score based on Analytic Hierarchy Process and Entropy Weight Method

Tie Wang<sup>a</sup>, Jing Yang<sup>b</sup>, Junlei Wang<sup>c</sup>, Fan Zhang<sup>d,\*</sup>

China Automotive Technology&Research Center Co., Ltd., China

<sup>a</sup> wangtie@catarc.ac.cn, <sup>b</sup> Yangjing2012@catarc.ac.cn, <sup>c</sup> wangjunlei@catarc.ac.cn, <sup>d,\*</sup> m13502037247\_3@163.com

\* Corresponding author: Fan Zhang (Email: m13502037247\_3@163.com)

**Abstract:** In order to improve the brand power of national auto brands and build a strong country for national auto brands, based on the research of this paper, the use of analytic hierarchy process and entropy weight method is used to calculate the score of auto brand power. First, consult a large amount of information to determine the relevant indicator factors. Here, eight indicators are selected, respectively from market research data and sales-related market-side data. Then, the AHP + entropy weight method is used to calculate the first-level index score of the user terminal according to the questionnaire questions of the second-level index. Secondly, on the basis of eight index scores, the entropy weight method is used to calculate the first-level index weight, and the weighted sum method is used to calculate the brand power. Finally, four brands are used for experimental verification, and the results meet the actual situation. Therefore, the method studied in this paper can be used as a reference for promoting brand power.

**Keywords:** Brand Power; AHP; EWM; National Automobile.

## 1. Background Introduction

On the afternoon of July 23, 2020, General Secretary Xi Jinping, who was inspecting in Jilin Province, came to China FAW Group Research and Development Institute, walked into the laboratory and inspected the latest styles of vehicle products of independent brands such as "Hongqi". Xi Jinping said: "At present, the international automobile manufacturing industry is very competitive, and trends such as informatization and intelligence are constantly developing. For us, there are opportunities in danger, and opportunities in danger. In our own hands, we should establish this ambition and promote the national automobile brand ". After that. Various automobile enterprises, research institutes, automobile related associations and other institutions formulate relevant policies and research methods according to the call of the general secretary, so as to help the upward development of national automobile brands. As a state-owned central enterprise, China Automobile Center (China Automobile Technology Research Center Co., Ltd., referred to as: CATARC) and the second-level unit China Automobile Information Technology Co., Ltd. (China Automobile Information Technology Co., Ltd.) invested nearly 10 million funds as major special projects to study national automobile brands. It aims to help self-owned brand cars improve their core competitiveness and build a world auto power.

The current competition between enterprises is mainly the competition of their brand power, and this has even become the core competitiveness of enterprises to survive, develop and win the business sea. Brand power varies in form and size because of its different entities. Brands can generate a "force", and the role of this "force" is unparalleled. It can create value and wealth, improve efficiency, and is a crucial "productivity" that enterprises must rely on for competition. Therefore, we vividly call it "brand power". Therefore, there is an urgent need for a breakthrough in the research of brand power:

objectively, rationally and practically integrating the related elements and their operating mechanism of brand power from the perspectives of strategy and tactics, so as to inject new blood and strength into brand practice. Therefore, we should establish a model and method to measure automobile brand power.

To calculate the size of brand power, first determine the influencing factors affecting brand power, then calculate the weight of each influencing factor, and finally calculate the weighted sum to obtain the score of brand power. Brand power is related to two parts of data sources. The first is related to the user's mind; The second is related to the data of market sources, such as brand market share, brand circulation rate and brand premium. Therefore, this paper uses analytic hierarchy process combined with entropy weight method to calculate the weight of indicators.

Analytic hierarchy process set entropy weight method has been successfully applied in many fields to comprehensively calculate the weight of complex system indicators; For example, Wang Yang [1] and others lack operability and pertinence to expressway, so they study and establish a set of scientific, reasonable and operable environmental risk assessment methods suitable for expressway. The main research is to select the analytic hierarchy process to layer the relevant factors affecting the transportation risk of dangerous chemicals on the expressway, then determine the weight of different factors according to the entropy weight method, quantitatively evaluate the risk by using the fuzzy comprehensive evaluation method, and finally form an evaluation model for the environmental risk of the expressway. Wang benqiang [1-2] and others constructed the evaluation index system of interregional scientific and technological innovation ability from the aspects of environment, input, output, efficiency and performance, and comprehensively evaluated the development level of scientific and technological innovation ability in various

regions of Anhui Province by using analytic hierarchy process entropy weight method (ahp-ewm). The results show that there are huge differences in the ability of scientific and technological innovation between regions within the province, but the regions with similar resource endowments show a certain degree of similarity. The radiation capacity is still weak. Hefei, Wuhu, Chuzhou and Maanshan contribute the most to the province's scientific and technological innovation achievements. Basic service facilities are an important factor in attracting scientific and technological innovation talents. In view of this, it is proposed that Anhui Province should establish a platform for co-construction, sharing, cooperation and exchange of scientific and technological innovation resources and a comprehensive evaluation mechanism for scientific and technological innovation efficiency, and implement the "three-pronged" strategy of attracting and training scientific and technological innovation talents, in order to solve the problem of low scientific and technological innovation output and regional areas. The problem of unbalanced development between countries will be solved, so as to promote the high-quality and coordinated economic development of various regions in the province. Xiong Hanwu [3] and others proposed a power cable quality evaluation method based on entropy weight-analytic hierarchy process fusion, which fully mines a large amount of data in the supervision process such as sampling and testing, and calculates the quality of power cables by means of test item assignment weight and detection level division. The quality weighted score of the inspection products, combined with the mathematical statistical analysis method, realizes the ranking of the supply quality of the qualified suppliers. Selected 500 product sampling reports from 10 qualified suppliers, and carried out quality analysis and ranking. The research results suggest that this method can better distinguish the quality level of different qualified suppliers, and evaluate the consistency and continuity of the product quality of qualified suppliers, which is of great significance to the improvement of power cable product quality and the optimization of supplier product performance.

To sum up, this paper proposes an analytic hierarchy process+entropy weight method to calculate the score of automobile brand power, aiming at helping self-owned brand cars to improve their brand power, not forgetting the general secretary's entrustment, and striving to promote national automobile brands.

## 2. Method Research

The research method of this paper is shown in Figure 1, which mainly includes five parts: data source, data preprocessing, calculation weight, and calculation of car brand power. Among them, the data source is the user data obtained by market research and the market data obtained from the car website, at the same time, there is an introduction of data indicators; data preprocessing includes the search and processing of missing data, the missing and processing of outliers; the calculation weight is obtained by the comprehensive calculation method of the analytic hierarchy process and the entropy weight method, and the accuracy of the calculation weight is obtained. The accuracy rate is higher than that of a single and unique algorithm; the calculation of car brand power is calculated by the method of weighted summation, and finally the national cars are ranked according to the score of brand power.

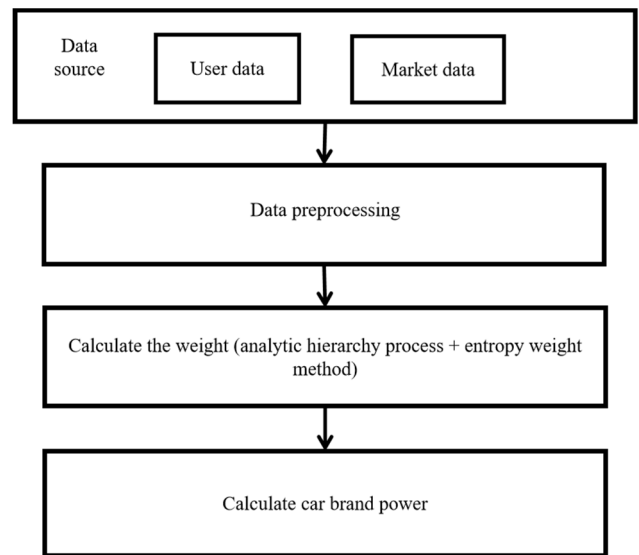


Fig 1. Research method of this paper

### 2.1. Data Source

The data source is composed of two parts, the first: user data (subjective data), and the second: market-side data (objective data). Therefore, the data source uses a combination of subjective and objective methods to calculate car brand power. Each data module will be introduced one by one below.

#### 2.1.1. User Data

The acquisition method of user data is obtained by means of questionnaire scoring. The value range of each index and corresponding score of questionnaire survey user data are shown in Table 1 below.

Table 1. Each indicator of user data and its corresponding value range

Primary index	Secondary index	Score range
Brand awareness	Popularity	Integer between 1 and 5
	Familiarity	Integer between 1 and 5
Brand association	Associative intensity	Integer between 1 and 5
	Positive tropism	Integer between 1 and 5
	Uniqueness	Integer between 1 and 5
Brand attitude	Positivity	Integer between 1 and 5
	Consideration degree	Integer between 1 and 5
	Preference degree	Integer between 1 and 5
Brand resonance	Consistency	Integer between 1 and 5
	Attachment	Integer between 1 and 5
	Reputation	Integer between 1 and 5
	Recommendation degree	Integer between 1 and 5

#### 2.1.2. Market Data

The data on the market side are obtained from various auto portals, such as auto home, Pacific Auto Network, e-Car network, vehicle quality network and other platforms. The

value range of each index and corresponding score on the market side are shown in Table 2 below.

**Table 2.** Each indicator on the field side and the corresponding score range

First-level indicator	Calculation	Score range
Market share	Sales of a brand divided by sales of all brands in the same market	0-100% (With two decimal places)
Hedging rate	The selling price of a car of a certain brand is divided by the price at the time of purchase, generally based on the 3-year value retention rate	0-100% (With two decimal places)
User flow potential difference	In a given year, the sales that bought the brand minus the sales that lost the brand	
Brand premium	All brands of cars in the same market segment are arranged in descending order of transaction price, and the gap between each car and the car with the lowest transaction price is calculated	

## 2.2. Data Preprocessing

Data preprocessing includes the missing value search and processing of data, and the missing and processing of abnormal values; Each part is described below.

### 2.2.1. Missing Outliers

There are two kinds of abnormal data: (1) The abnormal value does not belong to this population, and the sampling is wrong. One (some) data is extracted from another population, and its value is quite different from the average of the population; (2) Although the abnormal value belongs to the population, it may be the extreme expression of the inherent random variability of the population, for example, the data exceeding  $3\sigma$  has a small probability of occurrence.

The methods of judging outliers are as follows: first, physical discrimination method: according to people's existing understanding of objective things, judge that the measured data deviate from the normal results due to external interference, human error and other reasons, and judge and eliminate them at any time during the experiment; Second, statistical discrimination method: give a confidence probability and determine a confidence limit. If the error exceeds this limit, it is considered that it does not belong to the range of random error, and it is eliminated as abnormal data. It is sometimes difficult to judge abnormal data by physical discrimination method. At this time, statistical discrimination method can only be used to judge the distinction of abnormal data [4-5].

This paper adopts the  $3\sigma$  principle to detect outliers. The  $3\sigma$  criterion is also known as the Laida criterion. It first assumes that a set of test data only contains random errors, calculates and processes them to obtain the standard deviation, and determines an interval according to a certain probability. It is considered that any error exceeding this interval does not belong to the Random error is a gross error, and the data containing this error should be eliminated, and  $3\sigma$  is applicable when there are many sets of data. In a normal distribution,  $\sigma$  represents the standard deviation and  $\mu$

represents the mean.  $x=\mu$  is the symmetry of the image. The  $3\sigma$  principle is: the probability of numerical distribution in  $(\mu-\sigma, \mu+\sigma)$  is 0.6827, the probability of numerical distribution in  $(\mu-2\sigma, \mu+2\sigma)$  is 0.9545, and the probability of numerical distribution in  $(\mu-3\sigma, \mu+3\sigma)$  with a probability of 0.9973. Therefore, it can be considered that the value of Y is almost all concentrated in the interval  $(\mu-3\sigma, \mu+3\sigma)$ , and the possibility of exceeding this range is less than 0.3%.

### 2.2.2. Handling of Abnormal Values

In this paper, outliers are treated as missing values. The processing of missing values is shown in the following sections.

### 2.2.3. Detection of Missing Values

In practice, data is often missing for some reasons, and only a part of data can be observed, which is commonly called missing data in statistics [6].

Causes of missing value: information cannot be obtained temporarily, information is missing, one or some attributes are unavailable, some information (considered) is unimportant, the cost of obtaining this information is too high, and the real-time performance requirements of the system are high, that is, it is required to make judgments or decisions quickly before obtaining this information.

In this paper, the method of mathematical statistics is used to detect missing values.

### 2.2.4. Handling of Missing Values

General processing methods for missing values: (1) retain missing data (do not do any processing for missing data); (2) Discard the samples containing missing data (that is, delete the objects (tuples and records) with missing information attribute values, so as to obtain a complete information table); (3) Filling method: treat missing values as a special attribute value, mainly in the following ways: (a) replace all missing data with average or mode; (B) Using machine learning methods, such as regression or decision tree induction, these methods directly deal with the estimation of model parameters rather than the vacancy value prediction itself.

In this paper, the hot card method is used to fill in missing values: that is, to find a sample with the most similar and complete data in the database, and then use the value of this similar object to fill in. For example: (variable Y is similar to variable X, all cases are sorted according to the value of Y, then the missing value of variable X can be replaced by the data of the case before the missing value), use hot card to fill. After the data is imputed by the method, the standard deviation of the variable is close to that before the imputation.

## 3. Calculate Weights

Weight refers to the importance of a factor or index relative to something, which is different from the general proportion. It reflects not only the percentage of a factor or index, but also the relative importance of a factor or index, which tends to contribute or be important. Generally, weight can be judged and calculated by dividing multiple hierarchical indicators. Commonly used methods include single methods for calculating weight, such as analytic hierarchy process, entropy weight method, CRITIC method, fuzzy method, fuzzy analytic hierarchy process, expert evaluation method, etc. At the same time, there are mixed calculation methods combining them. Because the data source of this paper is composed of subjective evaluation data scored by investigation and some objective data on the market side, such as sales volume, the analytic hierarchy process and entropy

weight method are used to comprehensively calculate the weight.

### 3.1. Analytic Hierarchy Process

Using AHP to analyze the problem generally goes through the following five steps, as shown in Figure 2 below.

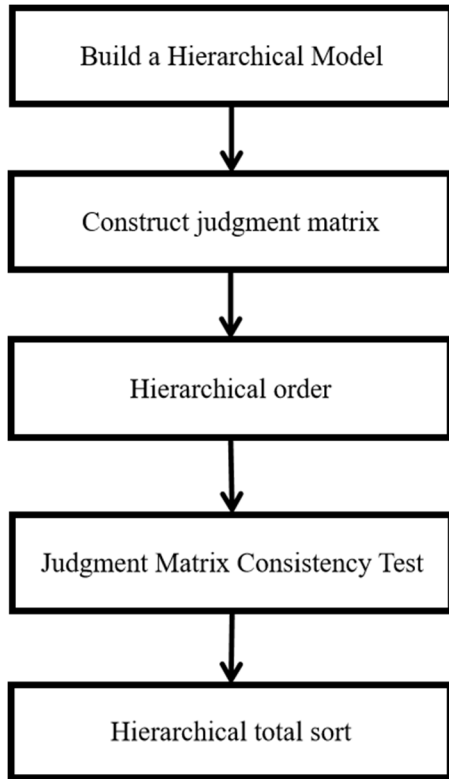


Fig 2. Five steps of AHP analysis

#### (1) Establish hierarchical model structure

Methods: divide the decision objectives, factors to be considered (decision criteria) and decision objects into the highest level, middle level and lowest level according to the relationship between them, and draw the hierarchical structure diagram, as shown in Figure 3 below

Decision making level (the highest level): brand strength score;

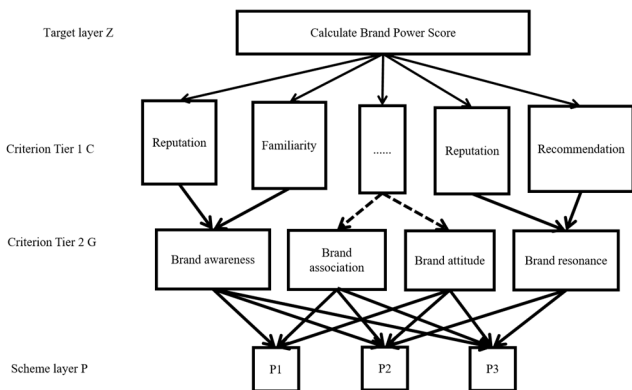


Fig 3. Hierarchy diagram of this paper

Middle layer 1 (criterion layer): the factors considered include 12 secondary index factors, such as popularity, familiarity, association strength, positivity, uniqueness, enthusiasm, consideration, preference, consistency, attachment, reputation and recommendation;

Middle layer 2 (criterion layer): the factors considered

include four primary indicators: brand awareness, brand association, brand attitude and brand resonance;

Solution layer: P1: the market share of the product increased, P2: the guide price and transaction price of the product increased, and P3: the word-of-mouth satisfaction of the increased word-of-mouth.

#### (2) Construct judgment matrix

The consistent matrix method proposed by Saaty et al. is adopted, that is, all factors are not compared as a whole, but pairwise comparisons are made. When comparing, the relative scale is used to minimize the difficulty of comparing different factors and improve the accuracy.

For example, criterion level 1 contains 12 criterion factors, C1: popularity, C2: familiarity, ..., C11: reputation, C12: recommendation; P1: market share of improved products, P2: guide price and transaction price of improved products, P3: word-of-mouth satisfaction of improved word-of-mouth. Compare this with the score of the car brand power of the target level, that is, the constructed judgment matrix A is shown in the following formula (1), where the number represents the scale, and the meaning of each scale is shown in Table 3 below, and the same can be obtained for the criterion level 2.

$$A = \begin{matrix} & C_1 & C_2 & \dots & C_{11} & C_{12} \\ \begin{matrix} 1 \\ 2 \\ \dots \\ 1/3 \\ 1/3 \end{matrix} & \begin{matrix} 1 \\ 1/2 \\ \dots \\ 1/5 \\ 1/5 \end{matrix} & \begin{matrix} \dots \\ 1 \\ \dots \\ 2 \\ 3 \end{matrix} & \dots & \begin{matrix} 3 \\ 5 \\ \dots \\ 1 \\ 1 \end{matrix} & \begin{matrix} 5 \\ 5 \\ \dots \\ 1 \\ 1 \end{matrix} \end{matrix} \quad (1)$$

Table 3. Meaning of digital scale

Scale	Meaning
1	Of equal importance
3	Pairwise, one factor is slightly more important than the other
5	Pairwise, one factor is significantly more important than the other
7	Pairwise, one factor is strongly more important than the other
9	Pairs are compared, one factor is extremely important than the other
2, 4, 6, 8	The median of the above consecutive judgment values
Reciprocal	The judgment $a_{i,j}$ for the comparison of factors i and j, then the judgment $a_{j,i} = 1/a_{i,j}$ for the comparison of factors j and i

#### (3) Hierarchical order

The so-called single-level ordering refers to the ordering of the importance of each factor in this level for a certain factor in the previous level. The method adopted is to solve the maximum eigen root of the judgment matrix and its corresponding eigenvector. The steps are as follows:

1) Each column of the matrix is normalized as shown in the following formula (2):

$$g_{i,j} = \frac{a_{i,j}}{\sum_{i=1}^m a_{i,j}} \quad (2)$$

2) The normalized judgment matrix is  $g$ , as shown in the following formula (3);

$$G = [g_{i,j}] \quad (3)$$

3) The matrix normalized by columns is summed by rows as shown in the following formula (4).

$$\bar{W} = (\bar{W}_1, \bar{W}_2, \dots, \bar{W}_n)^T \quad (4)$$

Normalize the vector  $\bar{W}$  as shown in formula (5) below,

$$W_i = \frac{\bar{W}_i}{\sum_{i=1}^m \bar{W}_i} \quad (5)$$

**Table 4.** Stochastic consistency index RI value

N	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

3) Define the consistency ratio CR, and the calculation method of CR is as follows (8):

$$CR = \frac{CI}{RI} \quad (8)$$

Generally, when the consistency ratio Cr is less than 0.1, it is considered that the inconsistency degree of a is within the allowable range and has satisfactory consistency. Through the consistency test, its normalized eigenvector can be used as the weight vector, otherwise, the pair comparison matrix A shall be reconstructed and adjusted.

(5) Hierarchical Total Ranking and Its Consistency Test

The ranking weight process of determining the relative importance of all factors in a certain level to the overall goal is called hierarchical general ranking. This process is carried out sequentially from the top to the bottom. For the highest level, the result of the hierarchical single sort is also the result of the total sort.

### 3.2. Entropy Weight Method

The main steps of calculating the weight by entropy method are: (1) data standardization, (2) calculating the information entropy of each index, (3) calculating the redundancy of information entropy, and (4) determining the weight of each index; Let's explain each step step by step.

(1) Data standardization:

Normalization of data is to scale the data so that it falls into a small specific interval. It is often used in some comparison and evaluation index processing to remove the unit limitation of the data and convert it into a dimensionless pure value, so that indicators of different units or magnitudes can be compared and weighted. The most typical one is the normalization of data, that is, the data is uniformly mapped to the [0,1] interval. Common data normalization methods are: min-max normalization, log function conversion, Z-score normalization (zero-mean normalization), fuzzy quantization method, etc. The text is normalized by min-max.

Assume that data set D has m sample data, namely  $D = [X_1, X_2, \dots, X_m]^T$ ; In which, it is assumed that each

4) Calculate the maximum characteristic root  $AW = \lambda W$  to obtain W and  $\lambda$

(4) Consistency Check of Judgment Matrix

1) Define the consistency index with the following formula (6):

$$CI = \frac{\lambda - m}{m - 1} \quad (6)$$

2) Define RI:

In order to measure the size of CI, the random consistency index RI is introduced, and the calculation formula of RI is shown in the following formula (7):

$$RI = \frac{CI_1 + CI_2 + \dots + CI_{500}}{500} = \frac{\lambda_1 + \lambda_2 + \dots + \lambda_{500} - m}{m - 1} \quad (7)$$

The value of random consistency index RI is shown in Table 4 below:

sample has n features, namely  $X_m = [x_{m,1}, x_{m,2}, \dots, x_{m,n}]$ .

The min-max standardized formula is shown in the following formula (9):

$$Y_{i,j} = \frac{x_{i,j} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (9)$$

Where  $Y_{i,j}$  represents the data after the standardization of the j-th index of the i-th sample,  $x_{i,j}$  represents the data before the standardization of the j-th index of the i-th sample,  $\min(x_j)$  represents the minimum value of the j-th column index, and  $\max(x_j)$  represents the maximum value of the j-th column index.

(2) Find the information entropy of each indicator:

According to the definition of information entropy in information theory, the formula for calculating the information entropy of a group of data is shown in the following formula (10).

$$E_j = -\ln(n)^{-1} \sum_{i=1}^n p_{i,j} \ln p_{i,j} \quad (10)$$

Where  $p_{i,j} = \frac{Y_{ij}}{\sum_{i=1}^n Y_{ij}}$ , if  $p_{i,j} = 0$ , defines

$$\lim_{p_{i,j} \rightarrow 0} p_{i,j} \ln p_{i,j} = 0.$$

(3) Calculate the information entropy redundancy (difference), the redundancy calculation formula is shown in formula (11):

$$d_j = 1 - e_j \quad (11)$$

(4) Calculate the weight of each index, as shown in formula (12):

$$\omega_j = \frac{d_j}{\sum_{j=1}^m d_j} \quad (12)$$

### 3.3. Comprehensive Calculation Method

Assuming that  $b$  is the weight calculated by the AHP, and  $c$  is the weight calculated by the entropy weight method, this paper uses the average method to calculate the weight, as shown in the following formula (13), and  $w$  is the result of comprehensive calculation of the weight.

$$w_j = \frac{1}{2}(a_j + b_j) \quad (13)$$

## 4. Example Analysis

Because it is necessary to calculate all the weights of the

**Table 5.** The weight of the first-level index of the test brand

Indicator name	Brand awareness	Brand association	Brand attitude	Brand resonance	Market share	Rate of maintaining value	User circulation	Brand premium
Weight	0.11	0.11	0.12	0.11	0.11	0.09	0.17	0.20

The brand power scores and rankings of the four automobile brands are shown in Table 6 below.

**Table 6.** Brand Power Scores and Rankings of Four Automobile Brands

Brand name	Score	Ranking
A	79.9	1
B	62.7	2
C	46.3	3
D	40.9	4

## 5. Conclusion

This paper uses eight indicators to calculate the calculation of automobile brand power, which are four user indicators and four market-side data sources. The simulation results are consistent with the actual situation and have a certain reference function. Enterprises can use the scores and weights of various indicators to analyze the areas for improvement of products and promote the upward development of new energy vehicles. In the future, the text will consider more indicators, and the calculation results will be more accurate.

secondary indicators under each primary indicator, and the sum of the weights of the secondary indicators under each primary indicator is 1.

Therefore, to calculate the first-level indicators of the user survey data, we should use the (AHP+EWM) comprehensive calculation method to calculate the weights four times, and then calculate the first-level indicators of each user.

For the market source data terminal, the normalization method is used to remove the dimension, and then it is combined with the four first-level indicators of user research to form 8 first-level indicators for weight calculation. At this time, the EWM method is used alone to calculate the weight.

In this paper, 4 car brands are used as experimental data, namely A, B, C and D. The weights of the 8 first-level indicators of the test brands are shown in Table 5 below.

## References

- [1] Wang Yang, Li Hengjun, Chen Lanfang. Highway environmental risk assessment method based on AHP-entropy weight method and fuzzy comprehensive evaluation [J]. Traffic World, 2022 (Z1): 11-13. DOI:10.16248/j. cnki.11-3723/u. 2022. z1.050.
- [2] Wang Benqiang, Chen Meng, Zheng Shanshan. A Comprehensive Evaluation of Inter-regional Science and Technology Innovation Capability in Anhui Province Based on AHP-Entropy Weight Method [J]. Science and Technology Management Research, 2022, 42(02): 75-83.
- [3] Xiong Hanwu, Fan Wei, Niu Yanzhao, Zeng Sicheng, Gong Hui, Liang Zhengbo. Quality Evaluation Method of Power Cable Based on Entropy Weight-Analytic Hierarchy Process [J]. High Voltage Electrical Appliances, 2022,58(02):185-192. DOI: 10.13296/j. 1001-1609.hva.2022.02.025.
- [4] [https://blog.csdn.net/weixin\\_41521681/article/details/90377445](https://blog.csdn.net/weixin_41521681/article/details/90377445).
- [5] <https://baike.so.com/doc/3753267-3942946.html>.
- [6] <https://www.jianshu.com/p/fa73a07cd750>.