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Group-Buying Websites Evaluation Model Based on AHP-TOPSIS under the Environment of Multi-Attribute Decision-Making

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Abstract

As time went by, the convenience derived from information technology and the popularity of shopping online make consumers adapt to online group buying or even addicted in it. However, the explosive growth of group buying market brought problems because of information asymmetry. The group buying websites emerge as bamboo shoots after a spring rain while the numerous group buying websites confused consumers. Therefore, proper evaluation of group buying websites is necessary. The paper proposed AHP-TOPSIS method, a combination of AHP and TOPSIS, to solve this problem under multi-attribute decision-making background. This method takes experts' opinions into account, both subjective and objective. And the method performs well in solving evaluating problems under multiple attribute decision background. Finally, the experimental results of this method on three group buying websites evaluation proved its good effectiveness and feasibility.

Keywords: *Group-buying websites evaluation; O2O; Multi-attribute decision-making; AHP-TOPSIS*

1. Introduction

From the perspective of consumption, online group buying consists simple online mode and O2O mode (combined with online and offline mode). Sincerely speaking, the O2O mode is new to China which has been adopted by most consumers almost in a minute, owing to the development of information technology and the shopping online habit. Furthermore, the popularity of network consumption increased the consumption proportion in offline service industry, such as food, beverage, movie, photography and beauty etc. The trend predicts a brighter prospect of O2O mode and its great development opportunity.

The first online group buying website is GROUPON in USA, Chicago. By the end of 2011, the market valuation was nearly billion dollars after a new round of financing. The success of this mode attracted imitators in China. In 2010, the first domestic group buying website emerged. Then numerous group buying websites appeared as bamboo shoots after spring and the irrational prosperity called out extremely confusion to consumers.

He Lefei took DIANPING website as an example of studying O2O business model [1]. By evaluating its business mode, typical "O2O+SOLOMO", through nine elements of business model and Potter five competitive forces analysis method, he discussed existing issues in group website running mode and proposed corresponding countermeasures.

Shi Chunjia studied O2O marketing model and proved its significance in company development [2]. He proposed that to ensure effectively implement of O2O mode,

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complementary conditions (products, the upstream supply chain, service management and logistics support *etc.*) should keep pace. In addition, potential risk could not be ignored.

Wang Yanpeng studied competitive strategy of GROUON [3]. Based on the principle of competitive intelligence triangulation analysis, he expounded the competitive situation of GROUPON from three angles, competitive environment, competitors and competitive power. According to research results, he constructed a SWOT analysis to sum up the advantages of GROUPON and set up a fruitful competitive strategy.

Chi Kunpeng considered online group buying as typical industry with two-side market characteristics, a bilateral cross network effect platform between buyer and seller [4]. He established a pricing model of network group buying, including monopoly mode, competition model under the condition of bilateral users and multi-homing of bilateral users. He calculated the pricing formula in monopoly mode and competition mode equilibrium condition, analyzing key factors changing effect and summarizing industrial characteristics.

Wang Lin studied the influence factors of online group buying customer satisfaction [5]. According to factor analysis, reliability analysis and validity analysis, he summarized three offline links, namely business service quality, business environment quality and after-sale service business. Furthermore, he proposed five online links, such as group buying website quality, website communication service, marketing characteristics, network payment and website design. Through an analysis of satisfaction influence factors, he revised and improved the satisfaction evaluation model and concluded that offline link was more important than online link.

AHP aims to analyze qualitative problem through quantitative method, which has developed rapidly in various fields [6-9]. In addition, scholars improved AHP method by combining with ANP, SWOT and fuzzy theory *etc.* They get a lot of new hybrid algorithms [10-13], which help AHP method keeping pace with times. TOPSIS, proposed by C. L. Hwang and K. Yoon in 1981, links valuation objects through calculating distance between evaluation objects and idealization objects. The basic theory of TOPSIS aims to order targets through detecting distance between evaluated objects and optimal solutions. If the evaluated object is near to the optimal solution and far away from the poor solution, it is the best. The method is very important in evaluation theoretical system [14-17]. By combining with other evaluated method, it brings innovative methods [18-21], such as AHP-TOPSIS method, another very important innovation through that [22-25].

Based on the research papers mentioned above, evaluation of group buying websites is a multiple attribute decision problems. However, the traditional AHP and the TOPSIS method cannot solve the multiple attribute decision problems very well. Based on this, we propose AHP-TOPSIS method under the environment of multi-attribute decision-making. This method combines the AHP method with TOPSIS method and we improve this mixed method to solve multiple attribute decision problems. The structure of this paper is as follows. The first part is the introduction. The second part is the basic knowledge. In this part, we introduce the traditional TOPSIS, AHP and AHP-TOPSIS. The third part is the AHP-TOPSIS under the environment of multi-attribute group decision-making. In this part, we proposed a new AHP-TOPSIS method which is under the environment of multi-attribute group decision-making. The fourth part is the numerical analysis and the last part is conclusion.

2. Basic Knowledge

2.1 Traditional TOPSIS

Assuming the scheme sets of the multi-attribute problem is $A=\{A_1,A_2,\cdots,A_m\}$. The attribute sets is $F=\{f_1,f_2,\cdots,f_n\}$. The decision matrix is $B=\{b_{ij}\}_{m\times n}$. Among them, b_{ij} is the attribute value of the j attribute in the scheme i, $i=1,2,\cdots,m$, $j=1,2,\cdots,n$. The scheme A_i is written as $A_i = (b_{i1}, b_{i2}, \cdots, b_{in})$, $i = 1, 2, \cdots, m$, $b_{ij} \geq 0$. The weight vector of the attribute is $W = (\omega_1, \omega_2, \cdots, \omega)^T$.

Among them, $\sum_{j=1}^{n} \omega_j = 1, \omega_j \geq 0, j = 1, 2, \cdots, n$. The traditional TOPSIS method can deal with the problem for the multi-attribute decision. And the basic steps are as follows.

The first step is to construct the standardized decision matrix $C = (c_{ij})_{m \times n}$ by using the vector standardized method.

For the benefit attribute,

$$c_{ij} = \frac{b_{ij}}{\sqrt{\sum_{i=1}^{m} b_{ij}^2}} \tag{1}$$

For the cost attribute,

$$c_{ij} = \frac{1/b_{ij}}{\sqrt{\sum_{i=1}^{m} (1/b_{ij})^2}} \tag{2}$$

Where $i = 1, 2, \cdots, m$, $j = 1, 2, \cdots, n$.

The second step to construct the weighted standardization decision matrix $Z = (z_{ij})_{m \times n}$. Where

$$z_{ij} = \omega_{ij} c_{ij} , \ i = 1, 2, \cdots, m , \ j = 1, 2, \cdots, n .$$

The third step is to determine the positive ideal solution A^+ and the negative ideal solution A^- . There are two artificial schemes, positive ideal scheme $A^+ = (z_1^+, z_2^+, \cdots, z_n^+)$ and negative ideal scheme $A^- = (z_1^-, z_2^-, \cdots, z_n^-)$. They express as the most preference scheme and the least preference scheme. For the benefit attribute, $z_j^+ = \max_i z_{ij}, z_j^- = \min_i z_{ij}$. For the cost attribute, $z_j^+ = \min_i z_{ij}, z_j^- = \max_i z_{ij}$.

The fourth step is to calculate the Euclid distance d_i^+ and d_i^- . d_i^+ is the distance from each scheme to the positive ideal solution. And d_i^- is the distance from each scheme to the negative ideal solution.

$$d_i^+ = \|z_i - A^+\| = \sqrt{\sum_{j=1}^{n} (z_{ij} - z_j^+)^2} \tag{3}$$

$$d_i^- = \|z_i - A^-\| = \sqrt{\sum_{j=1}^{n} (z_{ij} - z_j^-)^2} \tag{4}$$

Where $i = 1, 2, \cdots, m$, $j = 1, 2, \cdots, n$, $z_i = (z_{i1}, z_{i2}, \cdots, z_{in})$

The fifth step is to calculate the relative degree C_i^+ for each scheme and the positive ideal solution.

$$C_i^+ = \frac{d_i^-}{d_i^+ + d_i^-} \tag{5}$$

Where $i = 1, 2, \cdots, m$

It can be seen if $z_i = A^+$, $C_i^+ = 1$. And if $z_i = A^-$, $C_i^+ = 0$. $0 \leq C_i^+ \leq 1$. When $C_i^+ \to 1$,scheme $A_i \to A^+$.

The sixth step is to prioritize each scheme according to the descending order for C_i^+ .

2.2 The Traditional AHP

AHP is a decision and evaluation method. The main steps are as follows.

(1) Constructing the hierarchical structure model and establishing the criterion layer and the index layer

(2) Structural comparison matrix

$$A=(a_{ij})_{n\times n} \quad (i=1,2,\cdots,n), a_{ij}=1, a_{ij}=1/a_{ji} \tag{6}$$

A is the judgment matrix. We set a_{ij} which shows the relative comparison value of a_i index and a_j index.

Among them,

$$a_{ij}>0, \frac{1}{a_{ij}}=a_{ji}, a_{ii}=1.\ a_{ii}=1$$

(3) Judgment matrix A is normalized:

$$a_{ij}=a_{ij}\Big/\sum_{k=1}^{n}a_{kj} \quad (i=1,2,\cdots,n) \tag{7}$$

(4) Sum the row of judgment matrix A:

$$\omega_i=\sum_{j=1}^{n}a_{ij} \quad (i=1,2,\cdots,n) \tag{8}$$

(5) ω_i is normalized:

$$\omega_i=\omega_i\Big/\sum_{i=1}^{n}\omega_i \quad (i=1,2,\cdots,n) \tag{9}$$

(6)To derive the maximum eigenvalue and its eigenvector according to

$$A\omega=\lambda_{\max}\omega. \tag{10}$$

(7)Consistency check

We define

$$CI=\frac{\lambda_{\max}-n}{n-1} \tag{11}$$

CI is the index of consistency.

When the Judgment matrix has the character of consistency, $CI=0$

If $\lambda_{\max}-n$ is large, CI is large. And the consistency is worse.

2.3 Traditional AHP-TOPSIS

The traditional AHP-TOPSIS is a mixed method which combines the AHP and TOPSIS. The concrete solving steps are as follows.

The first step is to standardize the decision matrix by using the vector normalization method. Then we get the standard matrix $Y=\left(y_{ij}\right)_{m\times n}$.

Among them,

$$y_{ij}=\frac{x_{ij}}{\sqrt{\sum_{i=1}^{m}x_{ij}^{2}}},\ \left(i=1,2,\cdots,m; j=1,2,\cdots,\mathrm{n}\right).$$

The second step is to calculate the weights ω_{ij} of the first level indexes and the second level indexes by using the AHP method. Then we calculate the weighted normalized matrix.

$$V=\left(v_{ij}\right)_{m\times n}=\left(\omega_{ij}y_{ij}\right)_{m\times n}.$$

The third step is to determine the ideal solution and the non-ideal solution according to the weight of each index which is obtained in step (2).

The ideal step is

$$V^* = \left\{ \left(\min_{1 \le i \le m} v_{ij} \mid j \in J^+ \right), \left(\min_{1 \le i \le m} v_{ij} \mid j \in J^- \right) \right\} = \left(v_1^*, v_2^*, \cdots, v_n^* \right). \tag{12}$$

The non-ideal step is

$$V^- = \left\{ \left(\min_{1 \le i \le m} v_{ij} \mid j \in J^+ \right), \left(\max_{1 \le i \le m} v_{ij} \mid j \in J^- \right) \right\} = \left(v_1^-, v_2^-, \cdots, v_n^- \right). \tag{13}$$

Among them,

$J^+ = \{\text{benefit index}\}$, $J^+ = \{\text{cost index}\}$.

The fourth step is to calculate the distance between each scheme and the ideal solution. And it also calculates the distance between each scheme and the non-ideal solution according to the formula (14).

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^* \right)^2}, (i = 1, 2, \cdots, m), \quad S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^- \right)^2}, (i = 1, 2, \cdots, m) \tag{14}$$

Finally, we calculate the relative closeness degree among each scheme. And we order all of the schemes according to the size of the relative closeness degree. That is, the relative closeness degree is bigger, the scheme is better.

The flow of AHP-TOPSIS is as follows.

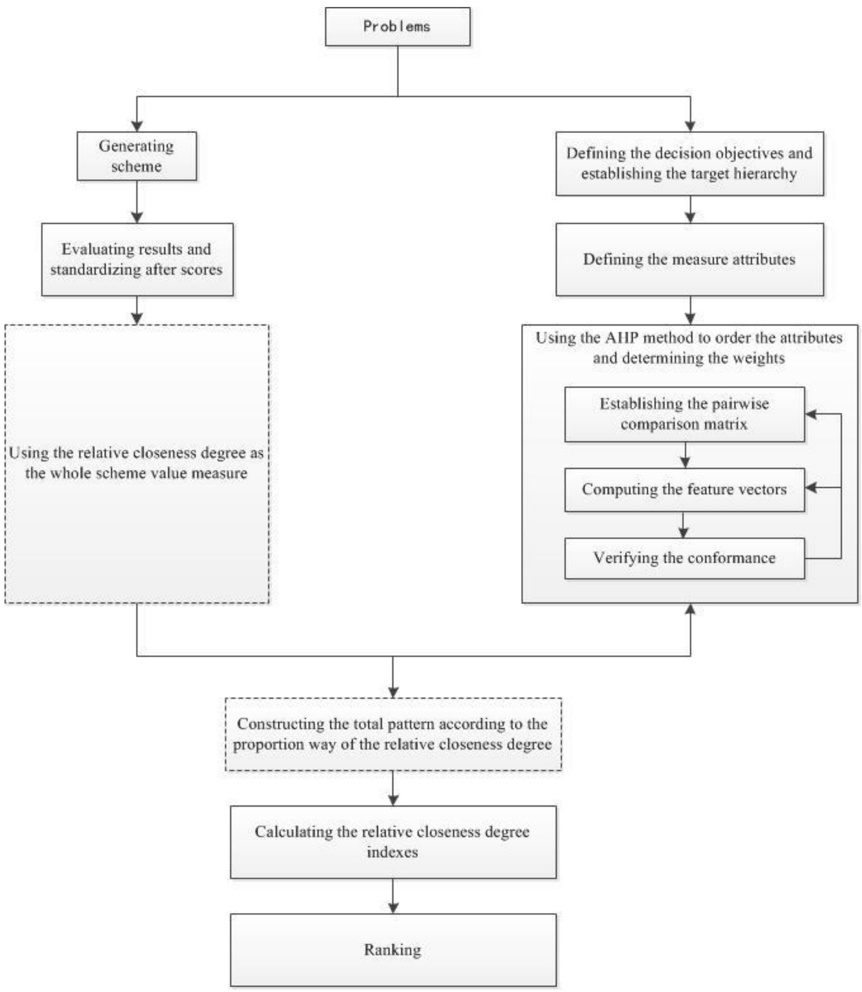

Figure 1. The flow of AHP-TOPSIS

3. AHP-TOPSIS under the Environment of Multi-Attribute Group Decision-Making Acquaintance

We introduce the expert weight ideal which relay on the attribute evaluation and the similarity of expert advice. Based on this ideal, we proposed on the AHP-TOPSIS method under the environment of multi-attribute group decision-making. The main steps of this method are as follows.

The first step is to use the qualitative analysis method to find out the values of the different attribute in each scheme. Then we get the decision matrix $\tilde{A}_i = (\tilde{a}_{kj}^i)_{m\times l}$ of the scheme. $\tilde{a}_{kj}^i$ is the fuzzy evaluation value which is given by the expert c_k of the attribute u_j for the scheme x_i

The second step is to divide the attribute problem. In the decision question, the type of the attribute can divide into the benefit and the cost. For the benefit attribute, the bigger evaluated value is better. For the cost attribute, the smaller evaluated value is better. In order to eliminate the effects of the different physical dimension on the decision results, firstly, according to the type of the attribute, we process standardly the evaluation matrix $\tilde{A}_i = (\tilde{a}_{kj}^i)_{m\times l}$.

Then we get the standardized appraisal matrix $\tilde{R}_i = (\tilde{r}_{kj}^i)_{m\times l}$ and $\tilde{r}_{kj}^i = ((\tilde{r}_{kj}^L)^i, (\tilde{r}_{kj}^M)^i, (\tilde{r}_{kj}^U)^i), 1 \le k \le m, 1 \le j \le l$.

For the attribute u_j ,

(1) If u_j is the benefit,

$$\tilde{r}_{kj}^i = ((\tilde{r}_{kj}^L)^i, (\tilde{r}_{kj}^M)^i, (\tilde{r}_{kj}^U)^i) = \left[\frac{(a_{kj}^L)^i}{\sum_{k=1}^{m}(a_{kj}^U)^i}, \frac{(a_{kj}^M)^i}{\sum_{k=1}^{m}(a_{kj}^M)^i}, \frac{(a_{kj}^U)^i}{\sum_{k=1}^{m}(a_{kj}^L)^i} \right] \tag{15}$$

(2) If u_j is the benefit

$$\tilde{r}_{kj}^i = ((\tilde{r}_{kj}^L)^i, (\tilde{r}_{kj}^M)^i, (\tilde{r}_{kj}^U)^i) = \left[\frac{\frac{1}{(a_{kj}^L)^i}}{\frac{1}{\sum_{k=1}^{m}(a_{kj}^U)^i}}, \frac{\frac{1}{(a_{kj}^M)^i}}{\frac{1}{\sum_{k=1}^{m}(a_{kj}^M)^i}}, \frac{\frac{1}{(a_{kj}^U)^i}}{\frac{1}{\sum_{k=1}^{m}(a_{kj}^L)^i}} \right] \tag{16}$$

The third step is to get the weight value according to the AHP method. Then we combine the weight value with the normalized evaluation information. Then we get

$$\tilde{E}_i = (\tilde{e}_{kj}^i)_{m\times l}, i = 1, 2, \cdots, n$$

Among them,

$$\tilde{e}_{kj}^i = \tilde{\omega}_{kj} \otimes \tilde{r}_{kj}^i \tag{17}$$

$\tilde{\omega}_{kj}$ is the weight of attribute.

The fourth step is to determine the important degree of the sum of the experts. In addition to considering the expert individual important degree, the similarity between the expert opinion and other experts opinion should be as an aspect to evaluate the importance degree of the decision. The different experts c_k and c_z evaluate the same scheme x_i .

The evaluated values are $\tilde{e}_{kj}^i = ((\tilde{e}_{kj}^L)^i, (\tilde{e}_{kj}^M)^i, (\tilde{e}_{kj}^U)^i)$ and $\tilde{e}_{zj}^i = ((\tilde{e}_{zj}^L)^i, (\tilde{e}_{zj}^M)^i, (\tilde{e}_{zj}^U)^i)$. Their similarity is

$$s(\tilde{e}^i_{kj},\tilde{e}^i_{zj}) = 1 - \frac{\left|(\tilde{e}^L_{kj})^i - (\tilde{e}^L_{zj})^i\right| + \left|(\tilde{e}^M_{kj})^i - (\tilde{e}^M_{zj})^i\right| + \left|(\tilde{e}^U_{kj})^i - (\tilde{e}^U_{zj})^i)\right|}{3} \quad (18)$$

We compute the average similarity of the evaluated value of the expert c_k about the scheme x_i in expert group.

$$AS(\tilde{e}^i_{kj}) = \frac{1}{m-1}\sum_{z=1,z\neq k}^{m} s(\tilde{e}^i_{kj},\tilde{e}^i_{zj}) \quad (19)$$

Then, we compute the relative similarity of the evaluated value of the expert c_k about the scheme x_i in expert group c_k .

$$RS(\tilde{e}^i_{kj}) = \frac{AS(\tilde{e}^i_{kj})}{\sum_{z=1}^{m} AS(\tilde{e}^i_{zj})} \quad (20)$$

Combining the average similarity and the relative similarity, we can get the comprehensive important degree of the expert c_k about the scheme x_i in expert group.

$$\beta_{ij}(c_k) = \sigma\beta^j_k + (1-\sigma)\cdot RS(\tilde{e}^i_{kj}) \quad (21)$$

The fifth step is to get the standardized comprehensive fuzzy decision matrix.

$$\tilde{E}_i = (\tilde{e}^i_{ij})_{n\times j} \quad (22)$$

Among them,

$$\tilde{e}^i_{ij} = \sum_{k=1}^{m}\beta_{ij}(c_k)\cdot\tilde{e}^i_{kj}$$

The sixth is to ensure the positive and negative ideal solution.

The distance between the scheme x_i and the positive ideal solution can be expressed as follows.

$$D^+_i = \sqrt{(d(\tilde{e}^i_{i1},\tilde{e}^+_1))^2 + (d(\tilde{e}^i_{i2},\tilde{e}^+_2))^2 + \cdots + (d(\tilde{e}^i_{i2},\tilde{e}^+_2))^2} \quad (23)$$

Among them,

$$d(\tilde{e}^i_{i1},\tilde{e}^+_1) = \sqrt{\frac{(\tilde{e}^L_{ij} - \tilde{e}^{L+}_j)^2 + (\tilde{e}^M_{ij} - \tilde{e}^{M+}_j)^2 + (\tilde{e}^U_{ij} - \tilde{e}^{U+}_j)^2}{3}} \quad (24)$$

The distance between the scheme x_i and the negative ideal solution can be expressed as follows.

$$D^-_i = \sqrt{(d(\tilde{e}^i_{i1},\tilde{e}^-_1))^2 + (d(\tilde{e}^i_{i2},\tilde{e}^-_2))^2 + \cdots + (d(\tilde{e}^i_{i2},\tilde{e}^-_2))^2} \quad (25)$$

Among them,

$$d(\tilde{e}^i_{i1},\tilde{e}^+_1) = \sqrt{\frac{(\tilde{e}^L_{ij} - \tilde{e}^{L-}_j)^2 + (\tilde{e}^M_{ij} - \tilde{e}^{M-}_j)^2 + (\tilde{e}^U_{ij} - \tilde{e}^{U-}_j)^2}{3}} \quad (26)$$

The eighth step is to calculate the relative closeness degree between each scheme and the ideal scheme.

We use the formula (27) to express the closeness degree. If the closeness degree is bigger, the scheme is better.

$$L(x_i) = \frac{D^-_i}{D^+_i + D^-_i} \quad (27)$$

The ninth step is to order according to the closeness degree. If scheme of relative degree is biggest, t is the best scheme.

4. Numerical Analysis

We select three websites to evaluate, MEITUAN, 55tuan and LASHOU and invited experts to conduct the evaluation. The three evaluation indexes are website attribute, product attribute and safety attribute. The field and the experience of the experts are different. Therefore, we got different evaluation matrixes for one website from different

angles. We use AHP-TOPSIS method under multi-attribute decision-making situation. The specific steps are as follows.
Firstly, we get the solution evaluation matrixes of the experts. They are

$$\tilde{A}_1 = \begin{bmatrix} (0.75,1,1) & (0.75,1,1) & (0.5,0.75,1) \\ (0.83,1,1) & (0.83,1,1) & (0.67,83,1) \\ (0.88,1,1) & (0.75,0.88,1) & (0.63,0.75,0.88) \end{bmatrix}$$

$$\tilde{A}_2 = \begin{bmatrix} (0.75,1,1) & (0.5,0.75,1) & (0.5,0.75,1) \\ (0.83,1,1) & (0.67,0.83,1) & (0.5,0.67,0.83) \\ (0.75,0.88,1) & (0.63,0.75,0.88) & (0.63,0.75,0.88) \end{bmatrix}$$

$$\tilde{A}_3 = \begin{bmatrix} (0.5,0.75,1) & (0.25,0.5,0.75) & (0.25,0.5,0.75) \\ (0.67,0.83,1) & (0.5,0.67,0.83) & (0.33,0.5,0.67) \\ (0.63,0.75,0.88) & (0.5,0.63,0.75) & (0.38,0.5,0.63) \end{bmatrix}$$

Secondly, according to the formula, we can get the normalized evaluation matrix.

$$\tilde{R}_1 = \begin{bmatrix} (0.27,0.33,0.44) & (0.27,0.33,0.44) & (0.18,0.33,0.67) \\ (0.27,0.33,0.33) & (0.27,0.33,0.33) & (0.28,0.45,0.77) \\ (0.27,0.33,0.38) & (0.24,0.33,0.5) & (0.63,0.75,0.88) \end{bmatrix}$$

$$\tilde{R}_2 = \begin{bmatrix} (0.27,0.33,0.44) & (0.18,0.33,0.67) & (0.18,0.33,0.67) \\ (0.27,0.33,0.33) & (0.28,0.45,0.77) & (0.5,0.67,0.83) \\ (0.24,0.33,0.5) & (0.23,0.35,0.48) & (0.23,0.35,0.48) \end{bmatrix}$$

$$\tilde{R}_3 = \begin{bmatrix} (0.18,0.33,0.67) & (0.1,0.27,0.58) & (0.1,0.27,0.58) \\ (0.28,0.45,0.77) & (0.24,0.29,0.6) & (0.17,0.34,0.67) \\ (0.23,0.35,0.48) & (0.25,0.28,0.5) & (0.16,0.27,0.48) \end{bmatrix}$$

Thirdly, according to AHP method, we get attribute weight vectors c_1, c_2, c_3 , given by experts.

$$\beta_1 = (0.28, 0.36, 0.36)$$
$$\beta_2 = (0.25, 0.45, 0.30)$$
$$\beta_3 = (0.40, 0.20, 0.40)$$

Fourthly, according to the formula 19, we get the comprehensive evaluation matrix.
Among them,

$$\sigma = 0.5\,.$$

$$\tilde{E} = \begin{bmatrix} (0.21,0.35,0.47) & (0.15,0.32,0.68) & (0.35,0.41,0.45) \\ (0.18,0.33,0.51) & (0.19,0.37,0.49) & (0.30,0.33,0.45) \\ (0.16,0.36,0.78) & (0.09,0.25,0.34) & (0.15,0.35,0.49) \end{bmatrix}$$

Fifthly, we solve the positive and negative ideal solution.

$$\tilde{E}^{+} = \left[(0.15,0.23,0.58),(0.12,0.22,0.51),(0.23,0.20,0.49)\right]$$
$$\tilde{E}^{-} = [(0.08.0.21,0.30),(0.09,0.23,0.31),(0.11,0.24,0.35)]$$

Sixthly, we solve the relative approximation degree between the scheme and the ideal solutions. Then we can get the relative approximation degree.

$$L(x_1) = 0.7600, L(x_2) = 0.6887, L(x_3) = 0.6125$$

The order of the three websites is MEITUAN, 55tuan and LASHOU, which is the same to the market ratio.

5. Conclusion

The rapid development of electronic commerce promotes the formation of O2O industry. More and more consumers accept this new consumption mode. This paper evaluates group buying websites market under current business background, the popularity of O2O mode. In this paper, we do the following works. Firstly, we analyze the research status of the group buying market and find out that the evaluation of group buying market is blank topic. Secondly, aiming to the characteristic of the group buying market, we propose AHP-TOPSIS method under the environment of multi-attribute decision-making. Thirdly, we apply this method to evaluate group buying websites. In addition, we evaluate three typical group buying market websites. The experimental results show that the AHP-TOPSIS method is effective and feasible.

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