Research on Supplier Selection Decision-making Based on Dual hesitation Fuzzy Linguistic Set TOPSIS

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Abstract

In order to solve the problem of multi-attribute decision making which needs to deal with linguistic evaluation information. In this paper, we proposed the TOPSIS model of dual hesitant fuzzy linguistic term set. First of all, in the case of the dual hesitant fuzzy defines a new method of calculating the distance between the dual hesitant fuzzy linguistic elements. Then we utilized trust function to determine the weights of decision makers, and TOPSIS method to get the optimal decision scheme. This is a good expression of the decision maker in the evaluation of uncertainty and uncertainty in the evaluation linguistic. Finally, experiments are conducted on the problem of supplier selection in retail enterprises. Results show that our method is effective significantly.

Keywords

Dual hesitant fuzzy linguistic term set; TOPSIS; Supplier selection.

1. Introduction

Supplier selection decisions are a very important part of supply chain management. Walmart provides consumers with a wide range of high-quality goods at low prices and unique services, and effectively supervises suppliers to reduce operating costs. Walmart, a large retailer, the selection of suppliers should not only focus on cost, but also consider its service level and responsiveness. For an enterprise, a reasonable selection of suppliers can not only quickly respond to customer needs, improve customer service satisfaction, thus conforming to market demand, but also reduce costs to a certain extent, improve product quality and the core competitiveness of the enterprise. However, enterprises tend to be perceptual in the process of selecting suppliers, and many qualitative linguistic evaluation indicators are difficult to be converted into quantitative indicators for calculation. Therefore, how to choose suppliers reasonably and scientifically is an important problem faced by enterprises in this consumer-oriented market environment.

The evaluation index of supplier should be determined in the problem of supplier selection. At present, many scholars have conducted in-depth research on the evaluation indicators of supplier selection. For example, Dickson[1] sorted out 23 key indicators of supplier selection and surveyed 273 purchasing agents. According to the survey, the top three most important indicators were quality, just-in-time delivery and historical performance. Ma Shihua[2] et al. proposed to take business structure and production capacity, enterprise environment, quality system and enterprise performance as the indicators of supplier selection. Yuan Yu[3] et al. analyzed the papers on supplier selection indicators and concluded that there are many indicators of just-in-time delivery rate, product quality and enterprise comprehensive capacity. In this paper, we proposed six supplier evaluation indexes including price, quality, service level, innovation ability, market response ability and industry reputation according to the problem of supplier selection of retail enterprises.

Supplier selection is a kind of fuzzy multi attribute decision making problem. The core problem of supplier selection is to develop appropriate selection decision method according to evaluation indicators. To solve this problem, TOPSIS method can be used. TOPSIS was proposed by C.L.Hwang in 1981[4]. The method is a method for sorting the distance between the positive ideal point and the negative ideal point for evaluation object and the relative progress. Wang Lin[5] et al. solved the multi-objective inventory control decision with minimization of cost, shortage rate and backorder by the hybrid TOPSIS method with mixed DE algorithm and entropy weight method. Wang Lei[6] applied the improved TOPSIS method to the supplier selection decision. The traditional TOPSIS method cannot take into account the hesitation and ambiguity in the evaluation indicators. The common quantitative method may lose the important information of the evaluator to a certain index.

The fuzzy set theory was proposed by Zadeh[7] in 1965, which used membership degree to express the fuzziness of things. Herrera[8] et al. proposed the method of linguistic evaluation to express the uncertainty of evaluation information. Rodriguez[9], putting forward the hesitant fuzzy linguistic set (HFLTS), the evaluation information in natural linguistic into hesitation fuzzy linguistic term set, makes the linguistic information can be calculated and more close to people's cognition. Zhu Bin[10] et al. put forward the dual hesitation fuzzy linguistic term set (DHFS) which membership degree and non-membership degree are both sets of Numbers on the interval of [0,1]. It accurately described the hesitation and expressed the hesitation property of evaluators. Li Liying[11] studied the multi attribute decision making method based on the dual hesitation fuzzy set and proposed the Hamming distance measurement method of the dual hesitation fuzzy set and the correlation coefficient between the two double hesitation fuzzy information. It made the calculation process more simple and effective. Yang Shanghong[12] et al. proposed a multi attribute decision making method based on DHFLS and defined the operation rules of the variables of DHFLS. The linguistic evaluation set qualitatively expresses the degree to which a certain indicator is superior or inferior when the decision maker evaluates suppliers. However, It lacks quantitative evaluation. The dual hesitation fuzzy linguistic term set contains membership degree, non-membership degree and linguistic evaluation elements. How to convert these elements into quantitative data is very important.

In this paper, we proposed a new method to calculate the normalized Euclidean distance of the elements of dual hesitant fuzzy linguistic. It is a new method to solve the problem of supplier selection for dual hesitant fuzzy linguistic variables. We analyzed the actual case of supplier selection of a retail enterprise. The validity of the proposed vendor selection method for TOPSIS is verified. It provided enterprises with reasonable and feasible supplier selection decision scheme.

2. Preliminaries

2.1 Dual hesitation fuzzy set

Definition 1. Suppose X be a reference set, the dual hesitant fuzzy set (DHFS) on X was shown as follows:.

$$D=\left\{\left\langle x,h_{(x)},g_{(x)}\right\rangle \middle| x\in X\right\} \tag{1}$$

$h(x)$ is the hesitant membership degrees and $g(x)$ is the hesitant non-membership degrees.

2.2 Dual hesitation fuzzy linguistic term set and definition

Dual hesitation fuzzy linguistic set is a concept that combines dual hesitation fuzzy linguistic term set, including three parts: membership degree, non-membership degree and linguistic evaluation phrase. At the same time, we put forward a new method to measure the distance between the variables of dual hesitation fuzzy linguistic term set, and turns the abstract data of the variables into quantitative data. The definition of dual hesitation fuzzy linguistic term set is as follows:

Definition 2. Suppose X be a reference set, a dual hesitant fuzzy linguistic set (DHFLS) on X was shown as follows:

$$H=\left\{\left\langle x,s_{\theta(x)},h_{(x)},g_{(x)}\right\rangle \middle| x\in X\right\} \tag{2}$$

Where $s_{\theta(x)}$ is the linguistic variable, $h(x)$ denotes the hesitant membership degrees to the $s_{\theta(x)}$ and $g(x)$ is the hesitant non-membership degrees to $s_{\theta(x)}$. In this paper, the expression $\vartheta=\langle s_\theta,h,g\rangle$ is used to simplify the 3-tuples $\vartheta(x)=\langle s_{\theta(x)},h_{(x)},g_{(x)}\rangle$, in which ϑ is named a DHFL element (DHFLE) in this paper.

2.3 Distance measures

As we know, the existing method [3-5] first compares the number of elements in a hesitant fuzzy set. If the numbers are different, then add the minimum or maximum membership or non-membership degrees several times into the one to make the two sets have the same number. However, this method has two problems: (1) Adding the minimum or maximum evaluation value extremely emphasizes the subjectivity of the decision maker; (2) Judgement and determination of the decision makers' risk attitude is a hard work.

For the purpose of computing the distance between two DHFL variables, a new distance measure for DHFL information is introduced and is suitable for overcoming the irrational traditional methodology upon the well-known distance measure and basic probability concepts, which are computed directly from DHFL variables and there is not need to add any max/min value into the evaluation set with fewer number of elements. The method to calculate the distance of dual hesitation fuzzy linguistic term variables is as follows:

Definition 3. Suppose two DHFLEs $\vartheta_k = \langle s_{\theta_k}, h_k, g_k \rangle$ and $\vartheta_l = \langle s_{\theta_l}, h_l, g_l \rangle$, the normalized Euclidean distance for DHFLEs is given as follows:

$$d(\vartheta_k,\vartheta_l) = \frac{1}{2\xi}\left(\sum_{k=1}^{\#h_k}\sum_{l=1}^{\#h_l}\left|\frac{\theta_k\gamma_k - \theta_l\gamma_l}{\#h_k\#h_l}\right|^2 + \sum_{k=1}^{\#g_k}\sum_{l=1}^{\#g_l}\left|\frac{\theta_k\eta_k - \theta_l\eta_l}{\#g_k\#g_l}\right|^2\right)^{1/2} \quad (3)$$

Where $\#h_k$, $\#h_l$, $\#g_k$ and $\#g_l$ respectively denote the numbers of values in h_k, h_l, g_k and g_l, where $\gamma_k \in h_k, \gamma_l \in h_l, \eta_k \in g_k, \eta_l \in g_l$. The distance $d(\vartheta_k,\vartheta_l)$ between ϑ_k and ϑ_l satisfies the following properties: (1) $0 \le d(\vartheta_k,\vartheta_l) \le 1$; (2) $d(\vartheta_k,\vartheta_l) = 0$, if only if $\vartheta_k = \vartheta_l = \langle s_\theta, \{\gamma\}, \{\eta\} \rangle$; (3) $d(\vartheta_k,\vartheta_l) = d(\vartheta_l,\vartheta_k)$.

3. Establish supplier selection model

According to the above analysis of the definition of dual hesitant fuzzy linguistic term set and TOPSIS method, the following supplier selection evaluation model is established.

3.1 Dual hesitation fuzzy linguistic evaluation matrix

In the selection and evaluation of suppliers, a total of 4 suppliers and 4 evaluation indicators including price, service level, quality and industry reputation were selected.

3.2 Determine the weight of decision makers

In the face of supplier selection decision problems, decision-makers will hesitate and be uncertain, which contains the evaluation information of hesitation degree. Because determining weights is a difficult task, we used the deterministic weight ω.

3.3 Determining positive and negative ideal point

We defined the positive ideal point is p^+. The Negative ideal point is p^-. On the positive ideal point linguistic variable and hesitant membership degrees are maximum, hesitant non-membership degrees is minimum. On the negative ideal point linguistic variable and hesitant membership degrees are minimum, hesitant non-membership degrees is maximum. The p^+ and the p^- can be described as follows:

$$p^+ = (s^+_{\theta_k}, h^+_k, g^-_k) \quad (4)$$

$$p^- = (s^-_{\theta_k}, h^-_k, g^+_k) \quad (5)$$

Where $s^+_{\theta_k}$ is maximum of all linguistic variables, and the $s^-_{\theta_k}$ is minimum of all linguistic variables. Where h^+_k is maximum of all linguistic variables, and the h^-_k is minimum of all linguistic variables. Where g^+_k is maximum of all linguistic variables, and the g^-_k is minimum of all linguistic variables.

The above is for the benefit-based indicators. If indicators are cost-based, the positive ideal point is $p^+ = (s_{\theta_k}^-, h_k^-, g_k^+)$ and the negative ideal point is $p^- = (s_{\theta_k}^+, h_k^+, g_k^-)$

3.4 Calculating the distance

In the case of the dual hesitation fuzzy evaluation matrix R. Then, calculated the normalized Euclidean distance by equation (3) between the positive and negative ideal points of each double hesitation fuzzy linguistic element, respectively d_{ij}^+ and. d_{ij}^-

Suppose the distance between each supplier and the positive and negative ideal points be respectively d_i^+ and d_i^-.

$$d_i^+ = \sqrt{\sum_{i=1}^{m} d_{ij}^{+2}}\,,\ d_i^- = \sqrt{\sum_{i=1}^{m} d_{ij}^{-2}}\,,\ i = 1, 2, \cdots m \tag{6}$$

3.5 Calculating the optimal membership

The optimal evaluation scheme is the scheme which is closest to the positive ideal point and furthest from the negative ideal point at the same time, but such an ideal scheme does not usually exist in the actual situation, so we use the optimal genus degree to evaluate the quality of suppliers.

Superiority degree refers to the proportion of the distance from the negative ideal point to the sum of the distance from the positive ideal point and the negative ideal point. The greater the superiority degree is, the better the scheme will be and the better the supplier will be.

$$c_i = \frac{d_i^-}{d_i^- + d_i^+} (0 \le c_i \le 1) \tag{7}$$

3.6 Sorting by the optimal membership

According to the optimal membership calculated by each supplier, the higher the optimal membership is, the better the scheme is. Then, select the supplier with the highest priority.

Table 1 Three Scheme comparing

Numble	Scheme 1	Scheme 2	Scheme 3
1	456	456	123
2	789	213	644
3	213	654	649

4. Numerical Example

If you follow the “checklist” your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

After comprehensively considering the various factors, the enterprise decision makers ranked the four suppliers according to four indicators of price dimension (c_1), service level dimension (c_2), quality dimension (c_3), industry reputation dimension (c_4). The evaluation indicators were marked as $C = \{c_1, c_2, c_3, c_4\}$. The linguistic term set was given as follows:

$S = \{s_0$: *Extremely low*, s_1: *very low*, s_2: *low*, s_3: *medium*, s_4: *high*, s_5: *very high*, s_6: *extremely high*$\}$

Step1. According to the evaluation rules of four indicators, each alternative supplier was evaluated in each suppliers selection indicators. The original evaluation information was shown in Table 2.

Table 2. Original Assessment Information

	c_1	c_2	c_3	c_4
a_1	$\langle s_4, \{0.4, 0.5, 0.6\}, \{0.3, 0.4\} \rangle$	$\langle s_4, \{0.4, 0.5\}, \{0.2, 0.3\} \rangle$	$\langle s_3, \{0.2, 0.3, 0.4\}, \{0.4, 0.5\} \rangle$	$\langle s_1, \{0.5, 0.7\}, \{0.2, 0.3\} \rangle$

a_2	$\langle s_5,\{0.5,0.6,0.7\},\{0.3,0.4\}\rangle$	$\langle s_3,\{0.2,0.3,0.6\},\{0.4,0.6\}\rangle$	$\langle s_6,\{0.6,0.7\},\{0.3,0.4\}\rangle$	$\langle s_5,\{0.4,0.5\},\{0.5,0.6\}\rangle$
a_3	$\langle s_2,\{0.5,0.6\},\{0.4,0.5\}\rangle$	$\langle s_1,\{0.3,0.4,0.5\},\{0.3,0.4\}\rangle$	$\langle s_3,\{0.4,0.5\},\{0.2,0.4\}\rangle$	$\langle s_4,\{0.2,0.3,0.5\},\{0.4,0.5\}\rangle$
a_4	$\langle s_3,\{0.6,0.7\},\{0.2,0.3\}\rangle$	$\langle s_4,\{0.5,0.6,0.7\},\{0.4,0.5\}\rangle$	$\langle s_5,\{0.5,0.6,0.7\},\{0.3,0.4\}\rangle$	$\langle s_2,\{0.4,0.6\},\{0.3,0.4\}\rangle$

Step2. In this paper, we focused on supplier selection with known weight situation. The decision makers determined the weight vector of four indicators as $\omega=\{0.12,0.27,0.23,0.38\}$.

The method of multiplying the weights of dual hesitant fuzzy linguistic elements is as follows.

$$\omega\vartheta(x)=\left\langle s_{\omega\theta(x)},\bigcup_{\gamma\in h_{(x)},\eta\in g_{(x)}}\{\{1-(1-\gamma)^{\omega}\},\{(\eta)^{\omega}\}\}\right\rangle \tag{8}$$

Step3. Determine the positive and negative ideal points by equation (3). The positive and negative ideal point was shown in Table 3.

Table 3. Positive and Negative Ideal Point

	c_1	c_2	c_3	c_4
Pos	$\langle 0.1,\{0.1345\},\{0.8244\}\rangle$	$\langle 0.18,\{0.2775\},\{0.6476\}\rangle$	$\langle 0.23,\{0.2419\},\{0.6906\}\rangle$	$\langle 0.3167,\{0.3671\},\{0.5425\}\rangle$
Neg	$\langle 0.04,\{0.0595\},\{0.9201\}\rangle$	$\langle 0.045,\{0.0585\},\{0.8712\}\rangle$	$\langle 0.115,\{0.0788\},\{0.8526\}\rangle$	$\langle 0.063,\{0.0813\},\{0.8236\}\rangle$

Step4. According to the characteristics of dual hesitation fuzzy linguistic, the normalized Euclidean distance could be calculated by equations (3) and (6). The dual hesitation fuzzy linguistic elements' normalized Euclidean distance was shown in Table 4 and Table 5.

Table 4. Distance of Positive Ideal Points

	c_1	c_2	c_3	c_4
a_1	0.0047	0.0089	0.0258	0.0587
a_2	0.0023	0.0104	0.0118	0.034
a_3	0.0167	0.0319	0.0295	0.0241
a_4	0.0115	0.0108	0.0068	0.0435

Table 5. Distance of Negative Ideal Points

	c_1	c_2	c_3	c_4
a_1	0.012	0.0311	0.004	0.0074
a_2	0.0183	0.0261	0.0296	0.0739
a_3	0.0005	0.0022	0.0053	0.0488
a_4	0.0052	0.039	0.0203	0.0148

Step5. After the normalized Euclidean distance is obtained, the optimal membership is calculated. The optimal membership was $[0.4817,0.3922,0.5319,0.483]$

Finally, the optimum rank was $a_3 \succ a_1 \succ a_4 \succ a_2$. Thus, the optimal choice was also a_3.

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