Research on Supplier Evaluation about Delivery Ability Based on Hesitant Fuzzy Linguistic Term Set and Linear Assignment

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Abstract

Concerning to the current "mismatch" problem between the supplier ability to deliver and the company ability to respond to consumer needs, the aim of this paper is to develop an approach for supplier selection based on hesitant fuzzy language evaluation and incomplete weight information. Firstly, original language evaluation information is transformed into hesitant fuzzy linguistic term set (HFLTS). By using the generalized normalized distance of hesitant fuzzy linguistic term set to measure the distance between two linguistic variables, the relative closeness coefficient in regard to the positive ideal point and the negative ideal point is obtained. Then, the priority order of alternative suppliers is acquired by establishing a linear assignment decision making model with incomplete weight. Finally, a numerical example is given to illustrate the rationality of the proposed method, and the sensitivity analysis shows that decision results are stable.

Keywords

Hesitant fuzzy linguistic term set (HFLTS); incomplete weight; linear assignment; delivery ability; supplier selection.

1. Introduction

Delivery ability refers to the ability of a supplier to provide a company products or services as agreed. The stronger supplier delivery ability, the faster the company can make decisions to respond to consumer demand and increase consumer satisfaction, so supplier delivery ability impacts directly the company ability to respond to customer demand[1]. However, in recent years, it has been common to see that companies are unable to provide consumers products or services in time because of insufficient supplier supply capacity. For example, in 2017, after the sale of Xiaomi 6, due to insufficient supplier supply about mobile phone accessory processors, the company could not send Xiaomi 6 to consumers in time. Consumers expressed strong dissatisfaction with this situation and even abandoned phones, which resulted in a sharp drop in phone sale and company profit. It can be seen that supplier delivery ability plays a decisive role in meeting consumer needs. If the company cannot provide high quality delivery services, it will lose customer benefits. Therefore, it is especially important for companies to use a reasonable approach to select the supplier with best delivery ability to respond quickly to consumer demand.

In the process of evaluating supplier delivery ability, on the one hand, decision makers are more inclined to use fuzzy language rather than precise numbers to express their views, and often hesitate between several evaluation values. On the other hand, the importance of each evaluation criterion is different, which is reflected in different values of attribute weights. Usually, the obtained weight information is incomplete because of limited conditions, just only including weight relationship and value range.

Evaluation criteria on supplier selection have been focus at home and abroad. Some scholars have studied them from different aspects. For example, based on the performance-elasticity perspective, Ma et al. [2] performed a comprehensive analysis of relevant domestic and foreign supplier evaluation criteria, and used several criteria such as delivery time, after-sale service, and information sharing to elaborate supplier evaluation criterion system. Zhou et al. [3] constructed an evaluation criterion framework from product qualification rate, on-time delivery rate and service level, and evaluated suppliers in various stages. Pan et al. [4] selected seven evaluation criteria such as quality, price, production delivery, service and more, then conducted a more detailed evaluation analysis of supplier selection. Dey et al. [5] considered traditional performance evaluation criteria such as quality, delivery time cost and other factors such as risk, business, social, environment for supplier performance comprehensive assessment. The above indicates that supplier evaluation criteria have been gradually improved, but delivery ability is often included in other supplier evaluation criteria system. Therefore, in order to evaluate supplier delivery ability better, it is necessary to establish evaluation criteria about it.

Decision makers tend to use fuzzy language rather than precise numbers to express evaluation opinions, and usually hesitate between several evaluation values [6]. The language evaluation is hesitant and fuzzy. Some scholars have conducted relevant research on this situation. Based on fuzzy set [7], Torra [8] defined hesitant fuzzy set and proposed that element membership could be composed of several possible values, then scholars introduced the set into various evaluation decision making fields. For example, making all evaluation experts satisfied with decision results, Wei et al. [9] proposed a consensus model based on hesitant fuzzy linguistic decision matrix to select the best production place. It showed that this method could make full use of original information to obtain expert consensus by correcting information. Liu [10] used an interval hesitant fuzzy PROMETHEE multiple attribute decision making method to obtain the priority index of alternatives. The results showed that hesitant fuzzy language improved information aggregation effect. Zhao et al. [11] established a hesitant fuzzy multiple attribute decision making model for supplier selection based on VIKOR. The model maintained original information integrity by directly processing language. It can be seen that hesitant fuzzy language reserves original linguistic information value so that it improves the effectiveness of realistic decision- making results about supplier with best delivery ability.

Another issue related to supplier delivery ability evaluation is about attribute weights of evaluation criteria. At present, most researches are based on the known weights. However, due to some limited conditions, weight information obtained by decision makers is incomplete. Some scholars have conducted related research on weight solving. For example, based on weight constraint set, Ye et al. [12] designed a single-objective optimization model to determine attribute weights by the weighted average operator of preference degree and TOPSIS. Zhao et al. [13] established an attribute weight target planning model based on interval intuitionistic fuzzy cross entropy to obtain a set of objective weight values. Shao et al. [14] proposed a nonlinear programming attribute weight solution model based on Jaynes maximum entropy principle and fair alternative competition. Although traditional weight solution methods can obtain a set of reasonable weight values, these methods need to optimize results continually. In this process, too much information will be generated, which may affect the effectiveness of decision results. Therefore, it is very important to adopt a weight solution method that can fully utilize weight information and simplify solving process. The objective weight can be obtained by criterion weight relationship and its value range through linear assignment method. The method can not only solve incomplete weight information, but also simplify calculation process to obtain the ranking of the alternatives.

In view of above analysis, as for the “mismatch” problem between supplier delivery ability and company response to consumer demand, the linear assignment method can obtain the ranking of the alternatives to determine the optimal supplier [15] with incomplete weight information. However, it cannot directly deal with hesitant fuzzy language. This paper proposes a new linear assignment decision making method based on HFLTS. The remainder of this paper is organized as follows: In

Section 2, we make a problem description. In Section 3, HFLTS is briefly reviewed, and the generalized normalized distance of the set is defined. In Section 4, we develop a linear assignment method with incomplete weight information based on HFLTS and propose detailed solutions. In Section 5, a numerical example and its sensitivity analysis are given to illustrate the proposed method. The paper is concluded in Section 6.

2. Problem Description

As consumer demands for company response increase, supplier delivery ability becomes the focus. However, in recent years, suppliers have failed to provide consumers products or services in time according to their agreement, which makes companies lose consumers and reduce business profits. For this situation, the paper focused on solving supplier delivery ability evaluation and selection problem. Considering hesitant fuzzy language evaluation and incomplete weight information, a new linear assignment method based on HFLTS was proposed to choose the best supplier.

Supposing that a company had m alternative suppliers, recorded as $\mathbf{A}=\{a_1,a_2,\cdots,a_m\}$. Let $\mathbf{C}=\{c_1,c_2,\cdots,c_n\}$ be delivery ability evaluation criteria set. The evaluation values of the alternative $a_i\left(i=1,2,...,m\right)$ satisfying criterion $c_j\left(j=1,2,...,n\right)$ were expressed by hesitant fuzzy linguistic variables (HFLVs) $H_S^{ij}=H_S{}^{a_i}\left(c_j\right)=\left\{s\middle|s\in H_S{}^{a_i}\left(c_j\right),s\in S\right\}$. Since evaluation criteria weight information is usually incomplete [16-17], let $\mathbf{W}=\left(w_1,w_2,\cdots,w_n\right)^T\in\Delta$ be the attribute weight vector, in which $w_j\geq 0\left(j=1,2...n\right)$, $\sum_{j=1}^{n}w_j=1$,and Δ was a set of weight information. For $i\neq j$,

$$\left\{\begin{array}{l} w_i\geq w_k;\ w_i-w_k\geq\alpha_i,\ \alpha_i>0;\ w_i-w_{k_1}\geq w_{k_2}-w_l,\\ k_1\neq k_2\neq l; w_i\geq\beta_i w_k,\ 0\leq\beta_i\leq 1;\ \delta_i\leq w_i\leq\delta_i+\varepsilon_i,\\ 0\leq\delta_i<\delta_i+\varepsilon_i\leq 1 \end{array}\right\}$$

Where $i=1,2,\cdots,m$, $k_1=1,2,\cdots,m$, $k_2=1,2,\cdots,m$, $j=1,2,\cdots,n$.

The core of the selection problem was how to solve hesitant fuzzy language evaluation and incomplete weight information, and then to obtain the ranking of the alternative suppliers to determine the supplier with best delivery ability.

3. Preliminaries

Definition 1[18] Let $S=\left\{s_0,\cdots,s_g\right\}$ be a set of linguistic evaluation set on a given domain, based on hesitant fuzzy set [8], HFLTS is expressed as follows:

$$H=\left\{<\vartheta,H_S\left(\vartheta\right)>\middle|\vartheta\in S,S=\left\{s_0,\cdots,s_g\right\}\right\}\tag{1}$$

Where $H_S\left(\vartheta\right)$ is a set of linguistic variables in HFLTS, and describes possible linguistic value of variable $\vartheta\in S$. For convenience, $H_S\left(\vartheta\right)$ is named a HFLV.

Based on the general idea Yager[19] first proposed and used for decision making, the generalized normalized distance measure of HFLTS was used to measure the distance between two HFLVs.

Definition 2 Let H_S^1 and H_S^2 be two HFLVs. The generalized normalized distance of HFLTS between two variables is defined as:

$$D_\lambda\left(H_S^1, H_S^2\right)=\left(\frac{\sum_{\gamma_1 \in H_S^1} \sum_{\gamma_2 \in H_S^2}\left|\gamma_1-\gamma_2\right|^\lambda}{l\left(H_S^1\right) \times l\left(H_S^2\right)}\right)^{1/\lambda} \tag{2}$$

Where $S=\{s_0,\cdots,s_g\}$, $l\left(H_S^1\right)$ and $l\left(H_S^2\right)$ are the number of the factors in the H_S^1 and H_S^2, respectively. And $\lambda>0$, if $\lambda=1$, the distance $D_\lambda\left(H_S^1, H_S^2\right)$ transforms into the hesitant standardized Hamming distance; if $\lambda=2$, the distance $D_\lambda\left(H_S^1, H_S^2\right)$ transforms into the hesitant standardized Euclidean distance.

4. Linear Assignment Decision Making Model for Supplier Delivery Ability

4.1 Evaluation Criteria of Supplier Delivery Ability

Before selecting the supplier with best delivery ability, appropriate evaluation criteria must be determined. However, most delivery ability evaluation criteria are included in terms of service, production, and quality. For example, Han et al. [20] comprehensively evaluated alternative suppliers based on 12 criteria such as quality, demand response capacity, delivery punctuality rate, and production flexibility. Wang et al. [21] selected supplier by four aspects from development, procurement, production and quality. The production dimension included two evaluation criteria, delivery timeliness and supply capacity. Based on comprehensive principle and typical principle, Wu et al. [22] established a supplier evaluation criterion system about 18 secondary criteria by five dimensions from company qualification, service level, stability and more. The first-level criterion service level included second-level criteria such as order response speed and on-time arrival rate. In a word, it is necessary to develop detailed supplier delivery ability evaluation criteria. Based on relevant literatures, suppliers were evaluated through product complete delivery rate, document information accuracy, procurement processing efficiency, and market adjustment flexibility, as shown in Table 1.

Table 1. Supplier delivery ability evaluation criteria

Criteria	Description
product complete delivery rate	Completion about that the right product was delivered to the right person in the right way, at the right time and place.
document information accuracy	The integrity of information related to the product, such as outbound information and delivery information.
procurement processing efficiency	Completion about operational task such as order processing and cargo picking during this period from receiving orders to shipping.
market adjustment flexibility	Adaptability in terms of goods, personnel, funds and more under changing market.

4.2 Linear Assignment Decision Making Model

Linear assignment method was extended to decision making process with hesitant fuzzy language evaluation information and incomplete weight information for the optimal supplier selection problem about delivery ability. Firstly, Original linguistic evaluation information was transformed into HFLV. Then, by the relative closeness coefficient of each alternative in regard to the positive ideal point and the negative ideal point, the superiority as well as inferior relationship of each alternative in each evaluation criterion and the adding-weight rank frequency matrix were obtained. Finally, linear assignment model was built to get a set of weight values and the ranking of alternative suppliers. The specific decision steps were as follows.

Step1. Obtain original assessments provided for this decision making problem. According to four delivery ability evaluation rules, original evaluation information was obtained.

Step2. Convert original evaluation information into HFLVs. The language evaluation expression was compared with the linguistic evaluation set, then original evaluation information was converted into HFLTS H_S^{ij} of an alternative a_i in the criterion c_j.

Step3. Determine relative closeness coefficient. The distance between two HFLVs was measured by the generalized normalized distance of HFLTS. Then relative closeness coefficient ξ_{ij} in regard to the positive ideal point and the negative ideal point under hesitant fuzzy environment was calculated by Equation (3) [23-24].

$$\xi_{ij} = \frac{D_\lambda\left(H_S^{ij}, H_S^{j-}\right)}{D_\lambda\left(H_S^{ij}, H_S^{j-}\right) + D_\lambda\left(H_S^{ij}, H_S^{j+}\right)} \tag{3}$$

Where $H_S^{j+} = \max\left\{\cup_{i=1}^{m} H_S^{ij}\right\}$ and $H_S^{j-} = \min\left\{\cup_{i=1}^{m} H_S^{ij}\right\}$ were the positive ideal point and the negative ideal point, respectively. Obviously, we knew that $0 \le \xi_{ij} \le 1$ for every $a_i \in A$ and $c_j \in C$, and if $\xi_{ij} \to 1$, then $H_S^{ij} \to H_S^{j+}$, if $\xi_{ij} \to 0$, then $H_S^{ij} \to H_S^{j-}$. As the relative closeness coefficient ξ_{ij} grows higher, the evaluation value H_S^{ij} becomes better [25].

Step4. Get the ranking of alternatives under each evaluation criterion. According to relative closeness coefficient ξ_{ij} value in different criteria, the alternatives were sorted in descending order of ξ_{ij} values.

Step5. Build the rank frequency matrix. According to the above ranking of the alternatives in each evaluation criterion, the rank frequency matrix π was obtained.

$$\pi = \begin{array}{c} \\ a_1 \\ a_2 \\ \vdots \\ a_m \end{array} \begin{array}{c} \begin{array}{cccc} 1st & 2nd & \cdots & mth \end{array} \\ \begin{bmatrix} \pi_{11} & \pi_{12} & \cdots & \pi_{1m} \\ \pi_{21} & \pi_{22} & \cdots & \pi_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \pi_{m1} & \pi_{m2} & \cdots & \pi_{mm} \end{bmatrix} \end{array}$$

Where the element π_{ik} ($i = 1, 2, \cdots, m$; $k = 1, 2, \cdots, m$) represented the frequency that a_i was listed as the k th standard ranking by ranking m alternatives regarding to each criterion $c_j \in C$ in the light of descending order of ξ_{ij} values (If the ρ alternatives had something to do with a criterion, then $\rho!$ balanced rankings were made a list separately).

Step6. Construct the adding-weight rank frequency matrix. Based on the above rank frequency matrix, the adding-weight rank frequency matrix Π was acquired.

$$\Pi = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} 1st & 2nd & \cdots & mth \end{array} \\ \begin{bmatrix} \Pi_{11} & \Pi_{12} & \cdots & \Pi_{1m} \\ \Pi_{21} & \Pi_{22} & \cdots & \Pi_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \Pi_{m1} & \Pi_{m2} & \cdots & \Pi_{mm} \end{bmatrix} \end{array}$$

Where $\Pi_{ik} = w_{j_1} + w_{j_2} + \cdots + w_{j_{\pi_{ik}}}$. Each entry Π_{ik} of the adding-weight rank frequency matrix Π measured the consistency within all criteria in ranking the i th alternative k th. The greater the assignment pointed by Π_{ik}, the larger consistency that would root in assigning a_i to the k th overall rank.

Step7. Establish the linear assignment decision making model.

$$Max\sum_{i=1}^{m}\sum_{k=1}^{m}\Pi_{ik}\bullet p_{ik}$$

$$Subject\ to\begin{cases}\sum_{k=1}^{m}p_{ik}=1,i=1,2,\cdots,m;\\ \sum_{i=1}^{m}p_{ik}=1,k=1,2,\cdots,m;\\ \mathbf{W}=\left(w_1,w_2,\cdots,w_n\right)^T\in\Delta;\\ \sum_{j=1}^{n}w_j=1,p_{ik}=0\ or\ 1\ ,for\ all\ i\ and\ k.\end{cases}$$

Where the permutation matrix $\mathbf{P}$ was a square ($m\times m$) matrix. Note that the Π_{ik} value was the result of standard ranking, and p_{ik} was unknown and was undecided by the model.

Step8. Solve the above model, and get the attribute weight $\mathbf{W}$ as well as the optimal permutation matrix $\mathbf{P}^*$.

Step9. Choose the supplier with best delivery ability. The optimal ranking of alternatives was acquired by $\mathbf{A}\bullet\mathbf{P}^*$, then the optimal supplier was chosen.

5. A Numerical Example

In order to gain a competitive advantage in an economically globalized market, a company intended to select a supplier with strong delivery ability for long-term cooperation. After preliminary selection, there were five alternative suppliers, called as $\mathbf{A}=\{a_1,a_2,a_3,a_4,a_5\}$. The five alternatives agreed that the company would select the best one by four delivery ability evaluation criteria, they were product complete delivery rate (c_1), document information accuracy (c_2), procurement processing efficiency (c_3), and market adjustment flexibility (c_4), called as $\mathbf{C}=\{c_1,c_2,c_3,c_4\}$. Some information about attribute weight was given as follows:

$$\Delta=\left\{\begin{array}{l}w_1\ge w_3,w_2\ge w_3,w_4\ge w_3,w_4-w_2\ge 0.1,w_1-w_4\ge 0.05,w_4-\\ w_2\ge w_2-w_3,w_1-w_3\ge w_3-w_2,0.1\le w_2\le 0.3,0.2\le w_4\le 0.5,\\ w_1\ge 0.7w4,w_2\ge 0.5w_1,\sum_{j=1}^{n}w_j=1,w_j\ge 0,j=1,2,3,4,5.\end{array}\right\}$$

Let $X=\{x_0:extremely\ low,\ x_1:very\ low,\ x_2:low,\ x_3:medium,\ x_4:high,\ x_5:very\ high,\ x_6:perfect\}$ be the linguistic evaluation set. Specific steps were as follows:

Step1. According to evaluation rules of four delivery ability criteria, alternative suppliers were evaluated. The original evaluation information was shown in Table 2.

Table 2. The original evaluation information

	c_1	c_2	c_3	c_4
a_1	{*High, Medium, Low*}	{*High, Medium, Low*}	{*Low, Very Low*}	{*Very High, Low,Very Low*}
a_2	{*Low, Very Low*}	{*High, Very Low*}	{*High, Medium, Low*}	{*High, Low*}
a_3	{*Very High, High, Medium*}	{*High, Medium, Very Low*}	{*High, Low*}	{*Perfect, Low*}
a_4	{*Perfect, Very High, High*}	{*Very High, Low,Very Low*}	{*Perfect, Low,Very Low*}	{*High, Medium,Very Low*}
a_5	{*Perfect, Medium, Low*}	{*Very Low*}	{*Medium, Very Low*}	{*High, Medium,Very Low*}

Step2. The language evaluation expression was compared with the linguistic evaluation set, and was converted into HFLV, as shown in Table 3.

Table 3. Convert original evaluation information into HFLVs

	c_1	c_2	c_3	c_4
a_1	$\{s_4, s_3, s_2\}$	$\{s_4, s_3, s_2\}$	$\{s_2, s_1\}$	$\{s_5, s_2, s_1\}$
a_2	$\{s_2, s_1\}$	$\{s_4, s_1\}$	$\{s_4, s_3, s_2\}$	$\{s_4, s_2\}$
a_3	$\{s_5, s_4, s_3\}$	$\{s_4, s_3, s_1\}$	$\{s_4, s_2\}$	$\{s_6, s_2\}$
a_4	$\{s_6, s_5, s_4\}$	$\{s_5, s_2, s_1\}$	$\{s_6, s_2, s_1\}$	$\{s_4, s_3, s_1\}$
a_5	$\{s_6, s_3, s_2\}$	$\{s_1\}$	$\{s_3, s_1\}$	$\{s_4, s_3, s_1\}$

Step3. The relative closeness coefficient ξ_{ij} in regard to the positive ideal point and the negative ideal point was calculated by Equations 错误!未找到引用源。 and 错误!未找到引用源。, as indicated in Table 4.

For instance, let $\lambda = 2$, take ξ_{21} for an example:

$$\xi_{21} = \frac{D_\lambda\left(H_S^{21}, H_S^{1-}\right)}{D_\lambda\left(H_S^{21}, H_S^{1-}\right) + D_\lambda\left(H_S^{21}, H_S^{1+}\right)} = \frac{s_{0.707}}{s_{0.707} + s_{4.528}} = 0.135$$

$$D_\lambda\left(H_S^{21}, H_S^{1+}\right) = D_\lambda\left(\{s_2, s_1\}, \{s_6\}\right) = \sqrt{\frac{\left(s_2 - s_6\right)^2 + \left(s_1 - s_6\right)^2}{2}} = s_{4.528}$$

$$D_\lambda\left(H_S^{21}, H_S^{1-}\right) = D_\lambda\left(\{s_2, s_1\}, \{s_1\}\right) = \sqrt{\frac{\left(s_2 - s_1\right)^2 + \left(s_1 - s_1\right)^2}{2}} = s_{0.707}$$

Table 4. The relative closeness coefficient ξ_{ij}

	c_1	c_2	c_3	c_4
a_1	0.410	0.500	0.135	0.389
a_2	0.135	0.421	0.410	0.414
a_3	0.590	0.440	0.414	0.560
a_4	0.760	0.452	0.443	0.369
a_5	0.523	0.000	0.255	0.369

Step4. The alternative suppliers were sorted in descending order of ξ_{ij} value under the same criterion. The results were shown in Table 5.

Table 5. Ordering of the alternatives in each criterion

Criterion	Ordering
c_1	$\xi_{41} \succ \xi_{31} \succ \xi_{51} \succ \xi_{11} \succ \xi_{21}$
c_2	$\xi_{12} \succ \xi_{42} \succ \xi_{32} \succ \xi_{22} \succ \xi_{52}$
c_3	$\xi_{43} \succ \xi_{33} \succ \xi_{23} \succ \xi_{53} \succ \xi_{13}$
c_4	$\xi_{34} \succ \xi_{24} \succ \xi_{14} \succ \xi_{44} = \xi_{54}$

Step5. Establishing the rank frequency matrix π was indicated in Table 6. For instance, note that a_4 had a first rank twice (on c_1 and c_3), a second rank once (on c_2), a fourth rank once (on $c_{4(1)}$) and a fifth rank once (on $c_{4(2)}$). Thus, $\pi_{41}=2$, $\pi_{42}=1$, $\pi_{43}=0$, $\pi_{44}=1$, and $\pi_{45}=1$.

Table 6. The rank frequency matrix π

	1st	2nd	3rd	4th	5th
a_1	1	0	1	1	1
a_2	0	1	1	1	1
a_3	1	2	1	0	0
a_4	2	1	0	1	1
a_5	0	0	1	2	2

Step6. Based on the above rank frequency matrix, computing Π_{ik} and establishing the adding-weight rank frequency matrix Π were indicated in Table 7. For instance, $\Pi_{54}=w(G_3)+\frac{w(G_{4(2)})}{2}$.

Table 7. The adding-weight rank frequency matrix Π

	1st	2nd	3rd	4th	5th
a_1	$w(G_2)$	0	$w(G_4)$	$w(G_1)$	$w(G_3)$
a_2	0	$w(G_4)$	$w(G_3)$	$w(G_2)$	$w(G_1)$
a_3	$w(G_4)$	$w(G_1)+w(G_3)$	$w(G_2)$	0	0
a_4	$w(G_1)+w(G_3)$	$w(G_3)$	0	$\frac{w(G_{4(1)})}{2}$	$\frac{w(G_{4(2)})}{2}$
a_5	0	0	$w(G_1)$	$w(G_1)$	$w(G_2)+\frac{w(G_{4(1)})}{2}$

Step7. Construct the linear assignment decision making model with $\Pi_{ik}\bullet p_{ik}$, as follows:

$$Max \quad Z=\sum_{k=1}^{5}\sum_{i=1}^{5}\Pi_{ik}\cdot P_{ik}$$

$$Subject\ to\begin{cases}\sum_{i=1}^{5}p_{ik}=1, k=1,2,3,4,5;\\ \sum_{k=1}^{5}p_{ik}=1, i=1,2,3,4,5;\\ w\in\Delta, \sum_{j=1}^{n}w_j=1;\\ p_{ik}=1\ or\ 0,\ for\ \text{i=1,2,3,4,5}; k=1,2,3,4,5.\end{cases}$$

Step8. Solve the above model, and acquire the attribute weight vector $\mathbf{W}=(0.36,0.18,0.18,0.28)^T$ as well as the optimal permutation matrix $\mathbf{P}^*$.

$$\mathbf{P}^* = \begin{array}{c} \\ a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{array} \begin{array}{c} \begin{array}{ccccc} 1st & 2nd & 3rd & 4th & 5th \end{array} \\ \begin{bmatrix} 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix} \end{array}$$

Step9. The optimal supplier was determined by the ranking of alternatives acquired by $\mathbf{A}\bullet\mathbf{P}^*$.

$$A\bullet\mathbf{P}^* = (a_1, a_2, a_3, a_4, a_5)\bullet\begin{bmatrix} 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix} = (a_4, a_3, a_5, a_1, a_2)$$

Finally, the optimum ranking sequence was $a_4 \succ a_3 \succ a_5 \succ a_1 \succ a_2$. Thus, the best choice was a_4.

To demonstrate the impact of decision maker preferences in this case, different values λ were utilized to rank the alternatives. In Table 8, the ranking sequences were presented. The result was different because the sequence of the alternatives were different according to different values λ. Therefore, companies could choose desirable alternative in accordance with its interest and actual need. However, it was noted that the best alternative was a_4 all the time in this example, which illustrated the decision result stability of the proposed method.

Table 8. The rankings of alternatives by the different distance measure

λ	Ranking
$\lambda = 1$	$a_4 \succ a_3 \succ a_5 \succ a_1 \succ a_2$
$\lambda = 2$	$a_4 \succ a_3 \succ a_5 \succ a_1 \succ a_2$
$\lambda = 5$	$a_4 \succ a_3 \succ a_2 \succ a_1 \succ a_5$
$\lambda = 10$	$a_4 \succ a_3 \succ a_2 \succ a_1 \succ a_5$
$\lambda = 20$	$a_4 \succ a_3 \succ a_2 \succ a_1 \succ a_5$

6. Conclusion

For supplier delivery ability evaluation problem, evaluation criteria were established from four aspects including product complete delivery rate, document information accuracy, procurement processing efficiency, and market adjustment flexibility. Considering hesitant fuzzy language evaluation and incomplete weight information, a new linear assignment decision making model based on HFLTS was developed. Firstly, the original language assessment information was transformed into HFLVs. The generalized normalized distance of HFLTS was utilized to measure the distance between two HFLVs, and the relative closeness coefficient in regard to the positive ideal point and the negative ideal point was acquired. Then, based on the rank frequency matrix and incomplete weight constraint conditions, a linear assignment model was established. Finally, a set of attribute weight values and the ranking of the alternatives were obtained by solving the model, so that the supplier with best delivery ability was determined.

The research shows that the proposed method deals with hesitant fuzzy language well to preserve original information value. In the simple process, redundant information is not generated, and the error caused by evaluation information subjectivity is effectively reduced, which makes decision result more stable. The method also provides reference value for various linguistic management decision making problems.

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