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Supplier Selection Based on Intuitionistic Fuzzy Sets Group Decision Making

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Abstract: The selection of suppliers had always been a key point of the supply chain management, directly impact the operation of supply chain. In this context, firstly introduced the study situation of supplier selection, established the evaluation index system based on the research and then puts forward a new method for supplier selection based on intuitionistic fuzzy sets. Finally, using an example to illustrate the application of indicators and the method provides a new method for supplier selection.

Keywords: Intuitionistic fuzzy sets, similarity, supplier selection, TOPSIS method

INTRODUCTION

With the development of global economic integration, the relationship among enterprises is closer; competition among enterprises is gradually transformed into competition between chain and chain. Enterprises want to survive in the fierce competition, it must adapt to the new environment, mutual cooperation and the implementation of complementary advantages and all companies are to coordinate, so that supply chain management came into being. In supply chain management, how to choose the right supplier is a key link of the entire supply chain operations, directly impact the production, continuity and coordination of the enterprise, thereby affecting their competitiveness.

The research of supplier selection is currently focused in two aspects: on the one hand, the selection of supplier evaluation indicators; on the other hand, methods and models of supplier selection.

The earliest study of supplier selection is Dickson. Dickson (1966) through surveying of purchasing managers and procurement agents identified 23 attributes that decision-makers could use when choosing suppliers. Shipley (1985) suggested that supplier selection involve three criteria, namely, quality, price and delivery lead time. Ellram (1990) suggested that in the supplier selection process, firms must to consider whether product quality, offering price, delivery time and total service quality meet organizational demand. Patton (1996) proposed seven criteria; price, Delivery time, quality, order situation, equipment and technology, financial condition, sale support.

Weber *et al*. (1991) reviewed the literature from 1967 to 1990 about supplier selection; divide the supplier selection methods into three categories: linear weighting method, mathematical programming models, statistical and probabilistic methods. Lorange *et al*. (1992) developed a 2-stage supplier selection approach: first evaluating the degree of match with a candidate supplier and then analyzing the market potential and main competitors and simulating worst case scenarios after the formation of the relationship. Ghodsypour and O'Brien (1997) utilized AHP with Linear Programming (LP) model which consider both qualitative and quantitative factors in a systematic approach. Choy *et al*. (2005) propounded a knowledge-based model to select suppliers. Sha and Che (2006) proposed an approach, which is based on the Genetic Algorithm (GA), the analytic hierarchy process and multi-attribute utility theory to satisfy simultaneously the preferences of the suppliers and the customers at each level in the network. Sarkis *et al*. (2007) built a strategic model for supplier selection by using Analytic Network Process (ANP) methodology. This effectively overcomes the problem of rank reversal, which is also a limitation of AHP.

As can be seen from the research of scholars, the supplier evaluation criteria is mostly concentrated in the cost, price, quality, delivery time and so on. But as the development of market, this appears to be too incomplete, some scholars began to focus on other aspects, such as innovate ability, information acceptance ability and production flexibility and so on, the supplier evaluation criteria become increasingly comprehensive and systematic. However, different industries are facing different situation, enterprises should accord to their own situation find own supplier evaluation criteria. The method of supplier selection include: expert systems, direct classification, data envelopment analysis, group analysis, the linear weighted model, the total cost of ownership model,

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mathematical programming models, statistical models, artificial intelligence model *et al*.

In this study, we introduce a new supplier selection methods based on intuitionistic fuzzy sets group decision making.

THE EVALUATION INDEX SYSTEM OF SUPPLIER SELECTION

Index system: There are 5 level indicators: quality (B1), technology (B2), delivery ability (B3), financial situation (B4) and service level (B5). Quality include: the rate of qualified products (C1), quality management system (C2) and environment management system (C3). Technology include: the advanced nature of equipment (C4), the ability of master new technologies (C5), the ability of design and development new product (C6). Delivery ability include: the Tate of on-time provide products (C7) and flexible production (C8). Financial situation include: cost advantages (C9), the asset-liability ratio (C10) and sales profit margins (C11).Service level include: the ability and attitude of coordinate with customer (C12), after-sales service (C13).

The description of indexes:
The rate of qualified products (C1): The higher the better, not only can meet customers' pursuit of high quality, but also can achieve the low cost of quality, thereby reducing the entire supply chain costs and improve competitive advantage.

Quality management system (C2): Evaluated whether the quality system of supplier is perfect, only to establish a complete quality management system, suppliers can be organized, planned, targeted to carry out production and business activities can be sustained and stable to provide qualified products.

Environment management system (C3): Mainly on whether the supplier established a sound environmental management system and can correctly implement and maintain; whether it passed the ISO14001 certification; the environmental assessment of the suppliers; waste disposal; resource utilization; cleaner production and the friendliness to environment.

The advanced nature of equipment (C4): Whether the equipment is correctly used and maintain, whether meet the needs of customers, whether in a leading position of the industry, whether the supplier has the ability to invest in new equipment to meet customer requirements of the development of future products.

The ability of master new technologies (C5): Mainly used to examine the supplier mastery of new technologies in the current industry, the ability to absorb new technologies and planning capacity of the new technology, which may arise in the next few years.

The ability of design and development new product (C6): Mainly used to investigate the suppliers' ability to develop new products, whether can research according to customers' requirements, whether can put forward proper suggestion in the development process of the customer's product and the success rate of develop new product, the cost and cycle of develop new product.

The rate of on-time provide products (C7): The ability that the suppliers can provide products on time in a certain period of time, if it is low, indicating that the production capacity can't meet the requirements, or the organization and management of the production process; cannot keep up the supply chain run.

Flexible production (C8): The changement of market environment requires suppliers to have better product flexibility. Improve response capabilities, can be produced on demand, including quantity flexibility and time flexibility, quantity flexibility is the satisfied scope to the changement of customer' demand number, time flexible to customer needs speed of response.

Cost advantages (C9): Including the price quotations, freight, duties, customs fees, storage charges and other expenses, it is a comprehensive cost index, the lower the cost, and the more competitive advantage.

The asset-liability ratio (C10): Reflects the long-term solvency of suppliers, how much debt that the suppliers have, check whether the financial position is the stable, the higher the debt ratio, the higher the financial risk, and are generally lower than 45% is more appropriate.

Sales profit margins (C11): Measure whether the supplier with sustained profitability. Only in the case of profits, the suppliers have the funds to develop technology, improve quality and expand production and training of personnel.

The ability and attitude of coordinate with customer (C12): For example take measures to facilitate customer orders, a variety of service, adopt measures for customers save cost and other reasonable security measures, etc.

After-sales service (C13): Such as maintenance service, installation service, upgrade service, training service, etc.

INTUITIONISTIC FUZZY SETS GROUP DECISION MAKING METHOD

Zadeh (1965) proposed fuzzy set theory, then fuzzy theory has been widely used to study fuzzy decision problem. Atanassov (1986, 1989) expanded the fuzzy sets, put forward the concept of intuitionistic fuzzy sets, compared with the fuzzy set, it gives the degree of membership and non-membership about the element x relative to the set A, had a strong ability to express uncertain information. In this study, combined iintuitionistic fuzzy sets with TOPSIS multi-attribute decision making to resolve the problem of supplier selection.

Intuitionistic fuzzy set A in a finite set X can be written as: A = {<x, $\mu_A(x)$, $\upsilon_A(x)$ >| x ∈ X} where, $\mu_A(x)$, $\upsilon_A(x)$: X → [0, 1] are membership function and non-membership function, $0 \le \mu_A(x) + \upsilon_A(x) \le 1$.

Define $\pi_A = 1 - \mu_A(x) - \upsilon_A(x)$ as hesitation degree:

$$\alpha + \beta = (\mu_A(x) + \mu_B(x) - \mu_A(x)\mu_B(x), v_A(x)v_B(x)\} \quad (1)$$

$$\alpha \otimes \beta = \left\{\mu_\alpha(x)\mu_\beta(x), v_\alpha(x) + v_\beta(x) - v_\alpha(x)v_\beta(x) \mid x \in X\right\} \quad (2)$$

$$\lambda\alpha = (1 - (1 - \mu_A(x))^\lambda, v_A(x)^\lambda) \quad (3)$$

Model and calculation steps: Set A = {A_1, A_2, …, A_n} is a series of being evaluated object, $X = \{X_1, X_2, \dots, X_n\}$ is a series of evaluate indexes for being evaluated object.

Step 1: Determine the weights of decision makers: Let $D_k = \{\mu_k, v_k, \pi_k\}$ be an intuitionistic fuzzy number for rating of k[th] decision maker. Then the weight of k[th] decision maker can be obtained as:

$$\lambda_k = \frac{(\mu_k + \pi_k(\frac{\mu_k}{\mu_k + v_k}))}{\sum_{k=1}^{l} \pi_k(\frac{\mu_k}{\mu_k + v_k})} \quad (4)$$

Step 2: Construct Level indicators' aggregated intuitionistic fuzzy decision matrix:

- Build two indicators' aggregate intuitionistic fuzzy decision vector according to the views of decision makers.
- Set $C^{(k)} = (c_{ij}^{(k)})_{mxn}$ is each decision maker's intuitionistic fuzzy decision matrix, λ = λ_1, λ_2, … λ_l is each decision maker's weight

$$c_{ij} = [1 - \prod_{k=1}^{l}(1-\mu_{ij}^{(k)})^{\lambda_k}, \prod_{k=1}^{l}(v_{ij}^{(k)})^{\lambda_k}, \prod_{k=1}^{l}(1-\mu_{ij}^{(k)})^{\lambda_k} - \prod_{k=1}^{l}(v_{ij}^{(k)})^{\lambda_k}] \quad (5)$$

$$C = \left[(\mu(x_1), v(x_1), \pi(x_1)) \quad (\mu(x_2), v(x_2), \pi(x_2)) \quad \dots \quad (\mu(x_n), v(x_n), \pi(x_n))\right] = \left[c_1 \quad c_2 \quad \dots \quad c_n\right]$$

- Determine the weight of two indicators. Set $q_j^{(k)} = \left[\mu_j^{(k)}, v_j^{(k)}, \pi_j^{(k)}\right]$ is the k[th] decision maker's intuitionistic fuzzy number about index and then the weights of the criteria are calculated by:

$$\begin{aligned} q_j &= IFWA_\lambda(q_j^{(1)}, q_j^{(2)}, \dots, q_j^{(l)}) \\ &= \lambda_1 q_j^{(1)} \oplus \lambda_2 q_j^{(2)} \oplus \lambda_3 q_j^{(3)} \oplus \dots \oplus \lambda_l q_j^{(l)} \\ &= \left[1 - \prod_{k=1}^{l}(1-\mu_j^{(k)})^{\lambda_k}, \prod_{k=1}^{l}(v_j^{(k)})^{\lambda_k}, \prod_{k=1}^{l}(1-\mu_j^{(k)})^{\lambda_k} - \prod_{k=1}^{l}(v_j^{(k)})^{\lambda_k}\right] \end{aligned} \quad (6)$$

$$Q = [q_1, q_2, q_3, \dots, q_j]$$

- Construction of weighted summary intuitionistic fuzzy decision matrix

$$C \otimes Q = \{(x, \mu(x) \cdot \mu_q(x), v(x) + v_q(x) - v(x) \cdot v_q(x)) \mid x \in X\}$$

$$\pi_q(x) = 1 - v(x) - v_q(x) - \mu(x) \cdot \mu_q(x) + v(x) \cdot v_q(x)$$

C' [($\mu_q(x_1)$, v_q(x_1,($\pi_q(x_1)$)) ($\mu_q(x_2)$, v_q(x_2,($\pi_q(x_2)$)) … ($\mu_q(x_n)$, vq(x_n,($\pi_q(x_n)$ = $[C_1', C_2', C_3']$ (7)

$$where \quad c_j' = (\mu_j', v_j', \pi_j') = (\mu_q(x_j), v_q(x_j), \pi_q(x_j))$$

- The comparison with intuitionistic fuzzy decision vector and the index level of similarity
  Let $A = \{x_i, \mu_a(x_i), v_a(x_i)\}$ is the intuitionistic fuzzy set of index grade

$$S_w^p(A, C') = 1 - \frac{1}{\sqrt[p]{n}} \sqrt[p]{\sum_{1}^{n}(\frac{1}{3}\varphi_1(i) + \frac{1}{3}\varphi_1(i) + \frac{1}{3}\varphi_1(i))^p} \quad (8)$$

where,

$$m_a(i) = \frac{1}{2}(\mu_a(x_i) + 1 - v_a(x_i))$$

$$m_q(i) = \frac{1}{2}(\mu_q(x_i) + 1 - v_q(x_i)) \quad (9)$$

$$\phi_1(i) = \left|\mu_q(x_i) - \mu_a(x_i)\right|$$

$$\phi_2(i) = \left|m_q(x_i) - m_a(x_i)\right|$$

$$\phi_3(i) = \left|(1\text{-}v_a(x_i)) - (1\text{-}v_q(x_i))\right|$$

Then get level index' evaluation level. Further get level index' aggregated intuitionistic fuzzy decision matrix.

Step 3: Determine the weights of level index: Let $w_j^{(k)} = \{\mu_j^{(k)}, v_j^{(k)}, \pi_j^{(k)}\}$ be an intuitionistic fuzzy number assigned to criterion X_j by the

k^{th} decision maker. Then the weights of the criteria are calculated by:

$$w_j = [1-\prod_{k=1}^{l}(1-\mu_j^{(k)})^{\lambda_k}, \prod_{k=1}^{l}(v_j^{(k)})^{\lambda_k}, \prod_{k=1}^{l}(1-\mu_j^{(k)})^{\lambda_k} - \prod_{k=1}^{l}(v_j^{(k)})^{\lambda_k}] \quad (10)$$

Step 4: Construct aggregated weighted intuitionistic fuzzy decision matrix:

$$r_{ij}^{'} = \{(\mu_{A_i}(x)\cdot\mu_w(x), v_{A_i}(x)+v_w(x)-v_{A_i}(x)\cdot v_w(x), 1-\mu_{A_i}(x)\cdot\mu_w(x)-v_{A_i}(x)-v_w(x)+v_{A_i}(x)\cdot v_w(x)) \mid x\in X\} \quad (11)$$

$r_{ij}^{'}$ is an element of the aggregated weightedintuitionistic fuzzy decision matrix R'.

Step 5: Obtain intuitionistic fuzzy positive-ideal solution and intuitionistic fuzzy negative-ideal solution. Then A^+ and A^- which are intuitionistic fuzzy positive-ideal solution and intuitionistic fuzzy negative-ideal solution are obtained as:

$$A^* = (\mu_{A^*w}(x_j), v_{A^*w}(x_j) \qquad A^- = (\mu_{A^-w}(x_j), v_{A^-w}(x_j)$$

$$\mu_{A^*w}(x_j) = \max_i \mu_{A_iw}(x_j) \qquad \mu_{A^-w}(x_j) = \min_i \mu_{A_iw}(x_j)$$

$$v_{A^*w}(x_j) = \min_i v_{A_iw}(x_j) \qquad v_{A^-w}(x_j) = \max_i v_{A_iw}(x_j) \quad (12)$$

Step 6: Calculate the separation measures. The separation measures S_{i+} and S_{i-} is calculated as:

$$S_{2+} = \sqrt{\frac{1}{2n}\sum_{i=1}^{n}[(\mu A_i w(x_j) - \mu_{A^*}w(x_j))^2 + (vA_iw(x_j) - v_{A^*w(x_j)})^2 + (> \pi A_iw(x_j) - v_{A^*w(x_j)})^2]} \quad (13)$$

$$S_i = \sqrt{\frac{1}{2}[(\mu_{A_{iw}}(x_j) - \mu_{A^-w}(x_j))^2 + (v_{A_{iw}}(x_j) - v_{A^-w}(x_j))^2 + (\pi_{A_{iw}}(x_j) - v_{A^-w}(x_j))^2} \quad (14)$$

Step 7: Calculate the relative closeness coefficient:

$$K_i = \frac{S_{i-}}{S_{i+}+S_{i-}} \quad (15)$$

After the relative closeness coefficient of each alternative is determined, alternatives are ranked according to descending order K_i.

Table 1: Classification of decision-makers' importance

	DM1	DM2	DM3
Linguistic terms	Very important	Medium	Important
Weights	0.398	0.232	0.370

Table 2: Linguistic terms description of decision-makers and indicators

Linguistic terms	Intuitionistic fuzzy set
Very important	(0.90, 0.10)
Important	(0.80, 0.15)
Medium important	(0.50, 0.45)
Unimportant	(0.35, 0.60)
Very unimportant	(0.10, 0.90)

Table 3: Linguistic terms description of divide index level

Linguistic terms	Intuitionistic fuzzy set
Very Good (VG)	(0.90, 0.10)
Good (G)	(0.75, 0.15)
Medium good (M)	(0.50, 0.40)
Bad (B)	(0.25, 0.65)
Very Bad (VB)	(0.10, 0.90)

THE SUPPLIER SELECTION RESEARCH

Suppose there are 3 suppliers to be choosed: A1, A2 and A3, 3 decision makers DM1, DM2 and DM3. The calculation steps are as follows:

Step 1: Determine the weights of decision makers. The importance language describes and weights of 3 experts according to the Eq. (4) are shown in Table 1 and 2.
According to the Eq. (4) calculate the weight of decision-makers as follows:

$$\lambda_{DM1} = \frac{0.9}{0.9+(0.80+0.05\frac{0.80}{0.95})+(0.50+0.05\frac{0.50}{0.95})} = 0.398$$

$$\lambda_{DM2} = \frac{(0.50+0.05\frac{0.50}{0.95})}{0.9+(0.80+0.05\frac{0.80}{0.95})+(0.5+0.05\frac{0.5}{0.95})} = 0.232$$

$$\lambda_{DM3} = \frac{(0.8+0.05\frac{0.80}{0.95})}{0.9+(0.50+0.05\frac{0.50}{0.95})+(0.80+0.05\frac{0.80}{0.95})} = 0.370$$

Step 2: Construct Level indicators' aggregated intuitionistic fuzzy decision matrix:

- Build two indicators' aggregate intuitionistic fuzzy decision vector according to the views of decision makers. The linguistic terms description of devide index level are given in Table 3. The 2 indicators' are evaluated by the experts and the ratings are given in Table 4.
- Calculating the aggregated intuitionistic fuzzy decision matrix according to the Eq. (5), the results are shown in Table 5.
- Determine the weight of two indicators.

Table 4: The ratings given by the experts

Supplier	A1			A2			A3		
C	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3
C1	VG	G	G	G	VG	G	G	G	M
C2	G	VG	G	VG	VG	VG	G	G	G
C3	G	G	G	G	G	G	G	VG	G
C4	G	G	VG	G	M	G	VG	G	G
C5	G	G	VG	VG	G	G	VG	G	G
C6	VG	VG	G	G	G	VG	M	G	VG
C7	G	G	VG	G	G	G	VG	G	G
C8	G	VG	G	M	VG	G	G	G	G
C9	G	G	VG	G	G	VG	G	M	G
C10	VG	G	G	G	VG	G	G	G	G
C11	G	G	VG	VG	G	G	G	VG	G
C12	G	G	G	G	M	G	VG	G	G
C13	G	G	G	VG	G	VG	G	VG	G

Table 5: Aggregated intuitionistic fuzzy decision matrix

C	A1	A2	A3
C1	(0.826, 0.128, 0.046)	(0.798, 0.137, 0.066)	(0.677, 0.216, 0.107)
C2	(0.798, 0.137, 0.066)	(0.900, 0.100, 0.000)	(0.750, 0.150, 0.100)
C3	(0.750, 0.150, 0.100)	(0.750, 0.150, 0.100)	(0.798, 0.137, 0.066)
C4	(0.822, 0.129, 0.049)	(0.706, 0.188, 0.105)	(0.826, 0.128, 0.046)
C5	(0.822, 0.129, 0.049)	(0.826, 0.128, 0.046)	(0.826, 0.128, 0.046)
C6	(0.860, 0.116, 0.024)	(0.822, 0.129, 0.049)	(0.765, 0.191, 0.044)
C7	(0.822, 0.129, 0.049)	(0.750, 0.150, 0.100)	(0.826, 0.128, 0.046)
C8	(0.798, 0.137, 0.066)	(0.734, 0.202, 0.065)	(0.750, 0.150, 0.100)
C9	(0.822, 0.129, 0.049)	(0.822, 0.129, 0.049)	(0.706, 0.188, 0.105)
C10	(0.826, 0.128, 0.046)	(0.798, 0.137, 0.066)	(0.750, 0.150, 0.100)
C11	(0.822, 0.129, 0.049)	(0.826, 0.128, 0.046)	(0.798, 0.137, 0.066)
C12	(0.750, 0.150, 0.100)	(0.706, 0.188, 0.105)	(0.826, 0.128, 0.046)
C13	(0.750, 0.150, 0.100)	(0.876, 0.110, 0.014)	(0.798, 0.137, 0.066)

The criteria's importance is evaluated by experts. The results are shown in Table 6. According to the Eq. (6) calculate the weight of criteria:

$$Q = \begin{pmatrix} (0.871, 0.116, 0.013) \\ (0.800, 0.150, 0.050) \\ (0.753, 0.194, 0.054) \\ (0.830, 0.137, 0.034) \\ (0.800, 0.150, 0.050) \\ (0.883, 0.110, 0.008) \\ (0.868, 0.118, 0.014) \\ (0.871, 0.116, 0.013) \\ (0.800, 0.150, 0.050) \\ (0.830, 0.137, 0.034) \\ (0.719, 0.225, 0.055) \\ (0.883, 0.110, 0.008) \\ (0.719, 0.225, 0.055) \end{pmatrix}^T$$

- Construction of weighted summary intuitionistic fuzzy decision matrix according to Eq. (7), the results are shown in Table 7.
- The comparison with intuitionistic fuzzy decision vector and the index level of similarity. Calculating the index level of similarity according to Eq. (8), the results are shown in Table 8. We can get level indicators' evaluation level based on Table 8, the results are shown in Table 9. Then according to the Eq. (5) calculate Level indicators' weights, the results are shown in Table 10.

Table 6: The evaluation of criteria's importance

	Decision maker		
Criteria	DM1	DM2	DM3
C1	VI	VI	I
C2	I	I	I
C3	I	M	I
C4	I	VI	I
C5	I	I	I
C6	VI	I	VI
C7	I	VI	VI
C8	VI	VI	I
C9	I	I	I
C10	I	VI	I
C11	I	I	M
C12	VI	I	VI
C13	I	I	M

Step 3: Determine the weights of level index:

The level index's importance is evaluated by experts. The results are shown in Table 11. According to the Eq. (10) calculate the weight of criteria:

Table 7: Summary intuitionistic fuzzy decision matrix

C	A1	A2	A3
C1	(0.719, 0.229, 0.051)	(0.695, 0.237, 0.068)	(0.590, 0.307, 0.103)
C2	(0.638, 0.266, 0.095)	(0.720, 0.235, 0.045)	(0.600, 0.278, 0.123)
C3	(0.564, 0.315, 0.121)	(0.564, 0.315, 0.121)	(0.601, 0.304, 0.095)
C4	(0.682, 0.248, 0.070)	(0.586, 0.299, 0.115)	(0.685, 0.247, 0.068)
C5	(0.658, 0.260, 0.083)	(0.661, 0.259, 0.080)	(0.661, 0.259, 0.080)
C6	(0.759, 0.213, 0.028)	(0.725, 0.225, 0.050)	(0.675, 0.280, 0.045)
C7	(0.714, 0.231, 0.055)	(0.651, 0.250, 0.099)	(0.717, 0.230, 0.052)
C8	(0.695, 0.237, 0.068)	(0.639, 0.295, 0.066)	(0.653, 0.249, 0.098)
C9	(0.658, 0.260, 0.083)	(0.658, 0.260, 0.083)	(0.565, 0.310, 0.125)
C10	(0.685, 0.247, 0.068)	(0.662, 0.255, 0.083)	(0.622, 0.266, 0.112)
C11	(0.591, 0.325, 0.084)	(0.594, 0.324, 0.081)	(0.574, 0.331, 0.095)
C12	(0.662, 0.234, 0.095)	(0.623, 0.277, 0.100)	(0.729, 0.224, 0.047)
C13	(0.539, 0.341, 0.119)	(0.630, 0.310, 0.059)	(0.574, 0.331, 0.095)

Table 8: The index level of similarity

Criteria	Supplier	VG	G	M	B	VB
B1	A1	0.785	0.885	0.865	0.615	0.415
	A2	0.799	0.899	0.851	0.601	0.401
	A3	0.750	0.850	0.900	0.650	0.450
B2	A1	0.830	0.928	0.820	0.570	0.370
	A2	0.798	0.898	0.852	0.602	0.402
	A3	0.806	0.906	0.844	0.594	0.394
B3	A1	0.835	0.935	0.815	0.565	0.365
	A2	0.786	0.886	0.864	0.614	0.414
	A3	0.823	0.923	0.827	0.577	0.377
B4	A1	0.784	0.884	0.866	0.616	0.416
	A2	0.779	0.871	0.879	0.621	0.421
	A3	0.742	0.842	0.908	0.658	0.458
B5	A1	0.754	0.854	0.896	0.646	0.446
	A2	0.767	0.867	0.884	0.634	0.434
	A3	0.787	0.887	0.863	0.613	0.413

Table 9: Level indicators' evaluation level

Criteria supplier	B1	B2	B3	B4	B5
A1	G	G	G	G	M
A2	G	G	G	M	M
A3	M	G	G	M	G

Table 10: Level indicators' aggregated intuitionistic fuzzy decision matrix

Criteria	A1	A2	A3
B1	(0.750, 0.150, 0.100)	(0.750, 0.150, 0.100)	(0.500, 0.400, 0.100)
B2	(0.750, 0.150, 0.100)	(0.750, 0.150, 0.100)	(0.750, 0.150, 0.100)
B3	(0.750, 0.150, 0.100)	(0.750, 0.150, 0.100)	(0.750, 0.150, 0.100)
B4	(0.750, 0.150, 0.100)	(0.500, 0.400, 0.100)	(0.500, 0.400, 0.100)
B5	(0.500, 0.400, 0.100)	(0.500, 0.400, 0.100)	(0.750, 0.150, 0.100)

Table 11: The evaluation of criteria's importance

	DM1	DM2	DM3
B1	VI	VI	I
B2	I	I	I
B3	I	VI	I
B4	VI	M	I
B5	M	I	I

$$w = \begin{pmatrix} (0.871, 0.116, 0.013) \\ (0.800, 0.150, 0.050) \\ (0.830, 0.137, 0.034) \\ (0.812, 0.165, 0.023) \\ (0.712, 0.232, 0.056) \end{pmatrix}^{T}$$

Step 4: Construct aggregated weighted intuitionistic fuzzy decision matrix ccording to Eq. (11), the results are shown in Table 12.

Step 5: Obtain intuitionistic fuzzy positive-ideal solution and intuitionistic fuzzy negative-ideal solution.
According to the Eq. (12) calculate the positive-ideal solution and negative-ideal solution. The results are shown in Table 13.

Step 6: Calculate the separation measures:
According to the Eq. (13) and (14) calculate the separation measures and the results are shown in Table 14.

Step 7: Calculate the relative closeness coefficient according to Eq. (15) and the results are shown in Table 15.

Three partner are ranked according to the Table 15, the alternatives are ranked as A2>A3>A1, so A2 is the best.

Table 12: Aggregated weighted intuitionistic fuzzy decision matrix

B	A1	A2	A3
B1	(0.653, 0.249, 0 098)	(0.653, 0.249, 0.098)	(0.435, 0.470, 0.095)
B2	(0.600, 0.278, 0.123)	(0.600, 0.278, 0.123)	(0.600, 0.278, 0.123)
B3	(0.622, 0.266, 0.112)	(0.622, 0.266, 0.112)	(0.622, 0.266, 0.112)
B4	(0.609, 0.290, 0.101)	(0.406, 0.499, 0.095)	(0.406, 0.499, 0.95)
B5	(0.356, 0.539, 0.105)	(0.356, 0.539, 0.105)	(0.534, 0.347, 0.119)

Table 13: Intuitionistic fuzzy positive-ideal solution and negative ideal solution

	B1	B2	B3	B4	B5
A^*	(0.653, 0.249, 0.098)	(0.600, 0.278, 0.123)	(0.622, 0.266, 0.112)	(0.406, 0.499, 0.095)	(0.534, 0.347, 0.119)
A^-	(0.435, 0.470, 0.095)	(0.600, 0.278, 0.123)	(0.622, 0.266, 0.112)	(0.609, 0.290, 0.101)	(0.356, 0.539, 0.105)

Table 14: The separation measures

Supplier	S^*	S^-
A1	0.124	0.098
A2	0.083	0.135
A3	0.098	0.124

Table 15: The relative closeness coefficient

Supplier	K_i
A1	0.442
A2	0.619
A3	0.558

CONCLUSION

In this study, we review supplier selection criteria and supplier selection methods and models, propose an new method called intuitionistic fuzzy set TOPSIS method for multi-attribute decision making. We can select the best supplier by calculating the relative closeness coefficient of alternatives. At last an example is used to identify the correct of this method.

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