Models for Selecting an ERP System with Intuitionistic Trapezoidal Fuzzy Information

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***Abstract*—To solve multiple attribute decision making problems with intuitionistic trapezoidal fuzzy information, two optimization models based on the maximizing deviation method, by which the attribute weights can be determined, is established. We utilize the intuitionistic trapezoidal fuzzy weighted geometric mean (ITFWGM) operator to aggregate the intuitionistic trapezoidal fuzzy information corresponding to each alternative and get the overall value of the alternatives, then rank the alternatives and select the most desirable one(s) according to the distance between the overall value of the alternatives and ideal solution. Finally, an illustrative example about selecting an ERP system is given.**

***Index Terms*—Multiple Attribute Decision Making; Intuitionistic Trapezoidal Fuzzy Numbers; Operational Laws; Intuitionistic Trapezoidal Fuzzy Weighted Geometric Mean (ITFWGM) Operator; Attribute Weight**

I. INTRODUCTION

In today's dynamic and unpredictable business environment, companies face the tremendous challenge of expanding markets and rising customer expectations. This compels them to lower total costs in the entire supply chain, shorten throughput times, reduce inventories, expand product choice, provide more reliable delivery dates and better customer service, improve quality, and efficiently coordinate globe demand, supply and production [1,2]. In order to accomplish these objectives, more and more companies are turning to the enterprise resource planning systems (ERP). An ERP is a packaged enterprise-wide information system that integrates all necessary business functions, such as product planning, purchasing, inventory control, sales, financial and human resources, into a single system with a shared database [3, 4]. An enterprise resource planning (ERP) is an enterprise-wide application software package that integrates all necessary business functions into a single system with a common database. In order to implement an ERP project successfully in an organization, it is necessary to select a suitable ERP system. This paper presents a new model, which is based on the intuitionistic trapezoidal fuzzy information processing, for dealing with the problem of ERP system selection. The remainder of this paper is set out as follows. In the next section, we introduce some basic concepts related to intuitionistic trapezoidal fuzzy sets. In Section 3 we introduce the MADM problem deal with selecting an ERP system with intuitionistic trapezoidal fuzzy information, in which the information about attribute weights is completely known, and the attribute values take the form of intuitionistic trapezoidal fuzzy numbers. We utilize intuitionistic trapezoidal fuzzy weighted geometric mean (ITFWGM) operator to aggregate the intuitionistic trapezoidal fuzzy information corresponding to each alternative, and then rank the alternatives and select the most desirable one(s). In Section 4, an illustrative example is pointed out. In Section 5 we conclude the paper and give some remarks.

II. PRELIMINARIES

In the following, we shall introduce some basic concepts related to intuitionistic trapezoidal fuzzy numbers.

Definition 1. Let $\tilde{a}$ is an intuitionistic trapezoidal fuzzy number, its membership function is[14-16]:

$$\mu_{\tilde{a}}(x)=\begin{cases}\dfrac{x-a}{b-a}\mu_{\tilde{a}}, & a\le x<b;\\ \mu_{\tilde{a}}, & b\le x\le c;\\ \dfrac{d-x}{d-c}\mu_{\tilde{a}}, & c<x\le d;\\ 0, & others.\end{cases} \tag{1}$$

its non-membership function is:

$$\nu_{\tilde{a}}(x)=\begin{cases}\dfrac{b-x+\nu_{\tilde{a}}(x-a_1)}{b-a_1}, & a_1\le x<b;\\ \nu_{\tilde{a}}, & b\le x\le c;\\ \dfrac{x-c+\nu_{\tilde{a}}(d_1-x)}{d_1-c}, & c<x\le d_1;\\ 0, & \text{others}.\end{cases} \tag{2}$$

where $0\le\mu_{\tilde{a}}\le 1; 0\le\nu_{\tilde{a}}\le 1$ and $\mu_{\tilde{a}}+\nu_{\tilde{a}}\le 1; a,b,c,d\in R$. Then $\tilde{a}=\left\langle\left(\left[a,b,c,d\right];\mu_{\tilde{a}}\right),\left(\left[a_1,b,c,d_1\right];\nu_{\tilde{a}}\right)\right\rangle$ is called an intuitionistic trapezoidal fuzzy number.

For convenience, let $\tilde{a}=\left(\left[a,b,c,d\right];\mu_{\tilde{a}},\nu_{\tilde{a}}\right)$.

Definition 2. Let $\tilde{a}_1=\left(\left[a_1,b_1,c_1,d_1\right];\mu_{\tilde{a}_1},\nu_{\tilde{a}_1}\right)$ and $\tilde{a}_2=\left(\left[a_2,b_2,c_2,d_2\right];\mu_{\tilde{a}_2},\nu_{\tilde{a}_2}\right)$ be two intuitionistic trapezoidal fuzzy number, and $\lambda\ge 0$, then[16]

(1) $\tilde{a}_1+\tilde{a}_2=\left(\left[a_1+a_2,b_1+b_2,c_1+c_2,d_1+d_2\right];\right.$
$\left.\mu_{\tilde{a}_1}+\mu_{\tilde{a}_2}-\mu_{\tilde{a}_1}\cdot\mu_{\tilde{a}_2},\nu_{\tilde{a}_1}\cdot\nu_{\tilde{a}_2}\right)$;

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(2) $\tilde{a}_1 \cdot \tilde{a}_2 = \left(\left[a_1 \cdot a_2, b_1 \cdot b_2, c_1 \cdot c_2, d_1 \cdot d_2\right];\right.$ $\left.\mu_{\tilde{a}_1} \cdot \mu_{\tilde{a}_2}, \nu_{\tilde{a}_1} + \nu_{\tilde{a}_2} - \nu_{\tilde{a}_1} \cdot \nu_{\tilde{a}_2}\right)$;

(3) $\lambda\tilde{a}_1 = \left(\left[\lambda a_1, \lambda b_1, \lambda c_1, \lambda d_1\right]; 1-\left(1-\mu_{\tilde{a}_1}\right)^{\lambda}, \nu_{\tilde{a}_1}^{\lambda}\right)$;

(4) $\tilde{a}_1^{\lambda} = \left(\left[a_1^{\lambda}, b_1^{\lambda}, c_1^{\lambda}, d_1^{\lambda}\right]; \mu_{\tilde{a}_1}^{\lambda}, 1-\left(1-\nu_{\tilde{a}_1}\right)^{\lambda}\right)$

Definition 3. Let $\tilde{a}_1 = \left(\left[a_1, b_1, c_1, d_1\right]; \mu_{\tilde{a}_1}, \nu_{\tilde{a}_1}\right)$ and $\tilde{a}_2 = \left(\left[a_2, b_2, c_2, d_2\right]; \mu_{\tilde{a}_2}, \nu_{\tilde{a}_2}\right)$ be two intuitionistic trapezoidal fuzzy number, then the normalized Hamming distance between $\tilde{a}_1$ and $\tilde{a}_2$ is defined as follows[16]:

$$\begin{aligned} d\left(\tilde{a}_1, \tilde{a}_2\right) = & \\ \frac{1}{8}\Big(&\left|\left(1+\mu_{\tilde{a}_1}-\nu_{\tilde{a}_1}\right)a_1 - \left(1+\mu_{\tilde{a}_2}-\nu_{\tilde{a}_2}\right)a_2\right| \\ &+\left|\left(1+\mu_{\tilde{a}_1}-\nu_{\tilde{a}_1}\right)b_1 - \left(1+\mu_{\tilde{a}_2}-\nu_{\tilde{a}_2}\right)b_2\right| \\ &+\left|\left(1+\mu_{\tilde{a}_1}-\nu_{\tilde{a}_1}\right)c_1 - \left(1+\mu_{\tilde{a}_2}-\nu_{\tilde{a}_2}\right)c_2\right| \\ &+\left|\left(1+\mu_{\tilde{a}_1}-\nu_{\tilde{a}_1}\right)d_1 - \left(1+\mu_{\tilde{a}_2}-\nu_{\tilde{a}_2}\right)d_2\right|\Big) \end{aligned} \tag{3}$$

Definition 4. For a normalized intuitionistic trapezoidal fuzzy decision making matrix $\tilde{R} = \left(\tilde{r}_{ij}\right)_{m\times n} = \left(\left[a_{ij}, b_{ij}, c_{ij}, d_{ij}\right]; \mu_{ij}, \nu_{ij}\right)_{m\times n}$, where $0 \le a_{ij} \le b_{ij} \le c_{ij} \le d_{ij} \le 1$, $0 \le \mu_{ij}, \nu_{ij} \le 1$, $0 \le \mu_{ij} + \nu_{ij} \le 1$, the intuitionistic trapezoidal fuzzy positive ideal solution and intuitionistic trapezoidal fuzzy negative ideal solution are defined as follows:

$$\tilde{r}^{+} = \left(\left[a^{+}, b^{+}, c^{+}, d^{+}\right]; \mu^{+}, \nu^{+}\right) = \left(\left[1,1,1,1\right]; 1,0\right)$$

$$\tilde{r}^{-} = \left(\left[a^{-}, b^{-}, c^{-}, d^{-}\right]; \mu^{-}, \nu^{-}\right) = \left(\left[0,0,0,0\right]; 0,1\right).$$

Definition 5. Let $\tilde{a}_1 = \left(\left[a_1, b_1, c_1, d_1\right]; \mu_{\tilde{a}_1}, \nu_{\tilde{a}_1}\right)$ and $\tilde{a}_2 = \left(\left[a_2, b_2, c_2, d_2\right]; \mu_{\tilde{a}_2}, \nu_{\tilde{a}_2}\right)$ be two intuitionistic trapezoidal fuzzy number, then the distance between $\tilde{a}_1 = \left(\left[a_1, b_1, c_1, d_1\right]; \mu_{\tilde{a}_1}, \nu_{\tilde{a}_1}\right)$, $\tilde{a}_2 = \left(\left[a_2, b_2, c_2, d_2\right]; \mu_{\tilde{a}_2}, \nu_{\tilde{a}_2}\right)$ and intuitionistic trapezoidal fuzzy positive ideal solution are denoted as $d\left(\tilde{a}_1, \tilde{r}^{+}\right)$ and $d\left(\tilde{a}_2, \tilde{r}^{+}\right)$, if $d\left(\tilde{a}_1, \tilde{r}^{+}\right) < d\left(\tilde{a}_2, \tilde{r}^{+}\right)$, then $\tilde{a}_1 > \tilde{a}_2$.

In the following, we shall develop a new operator called intuitionistic trapezoidal fuzzy weighted geometric mean (ITFWGM) operator.

Definition 6. Let $\tilde{a}_j = \left(\left[a_j, b_j, c_j, d_j\right]; \mu_{\tilde{a}_j}, \nu_{\tilde{a}_j}\right)$ $\left(j = 1, 2, \cdots, n\right)$ be a collection of intuitionistic trapezoidal fuzzy numbers, and let ITFWGM: $Q^n \to Q$, if

$$\text{ITFWGM}_{\omega}\left(\tilde{a}_1, \tilde{a}_2, \cdots, \tilde{a}_n\right) = \prod_{j=1}^{n}\left(\tilde{a}_j\right)^{\omega_j} \tag{4}$$

where $\omega = \left(\omega_1, \omega_2, \cdots, \omega_n\right)^T$ be the weight vector of $\tilde{a}_j$ $\left(j = 1, 2, \cdots, n\right)$, and $\omega_j > 0$, $\sum_{j=1}^{n}\omega_j = 1$, then ITFWGM is called the intuitionistic trapezoidal fuzzy weighted geometric mean (ITFWGM) operator.

We can derive the Theorem 1 from Definition 2.

Theorem 1. Let $\tilde{a}_j = \left(\left[a_j, b_j, c_j, d_j\right]; \mu_{\tilde{a}_j}, \nu_{\tilde{a}_j}\right)$ $\left(j = 1, 2, \cdots, n\right)$ be a collection of intuitionistic trapezoidal fuzzy numbers, then their aggregated value by using the ITFWGM operator is also an intuitionistic trapezoidal fuzzy numbers, and

$$\begin{aligned} &\text{ITFWGM}_{\omega}\left(\tilde{a}_1, \tilde{a}_2, \cdots, \tilde{a}_n\right) \\ &= \left(\left[\prod_{j=1}^{n} a_j^{\omega_j}, \prod_{j=1}^{n} b_j^{\omega_j}, \prod_{j=1}^{n} c_j^{\omega_j}, \prod_{j=1}^{n} d_j^{\omega_j}\right];\right. \\ &\left.\prod_{j=1}^{n}\left(\mu_{\tilde{a}_j}\right)^{\omega_j}, 1-\prod_{j=1}^{n}\left(1-\nu_{\tilde{a}_j}\right)^{\omega_j}\right) \end{aligned} \tag{5}$$

where $\omega = \left(\omega_1, \omega_2, \cdots, \omega_n\right)^T$ be the weight vector of $\tilde{a}_j$ $\left(j = 1, 2, \cdots, n\right)$, and $\omega_j > 0$, $\sum_{j=1}^{n}\omega_j = 1$.

III. MODELS FOR SELECTING ERP SYSTEMS WITH INTERVAL-VALUED INTUITIONISTIC FUZZY INFORMATION

The following assumptions or notations are used to represent the intuitionistic trapezoidal fuzzy MADM problems with incomplete weight information:

(1) The alternatives are known. Let $A = \left\{A_1, A_2, \cdots, A_m\right\}$ be a discrete set of alternatives; (2) The attributes are known. Let $G = \left\{G_1, G_2, \cdots, G_n\right\}$ be a set of attributes; (3) The information about attribute weights is incompletely known. Let $w = \left(w_1, w_2, \cdots, w_n\right) \in H$ be the weight vector of attributes, where $w_j \ge 0$, $j = 1, 2, \cdots, n$, $\sum_{j=1}^{n} w_j = 1$, H is a set of the known weight information, which can be constructed by the following forms [17-20], for $i \ne j$: **Form 1.** A weak ranking: $w_i \ge w_j$; **Form 2.** A strict ranking: $w_i - w_j \ge \alpha_i$, $\alpha_i > 0$; **Form 3.** A ranking of differences: $w_i - w_j \ge w_k - w_l$, for $j \ne k \ne l$; **Form 4.**

A ranking with multiples: $w_i \geq \beta_i w_j$, $0 \leq \beta_i \leq 1$;

Form 5. An interval form: $\alpha_i \leq w_i \leq \alpha_i + \varepsilon_i$, $0 \leq \alpha_i < \alpha_i + \varepsilon_i \leq 1$.

Suppose that $\tilde{R} = (\tilde{r}_{ij})_{m\times n} = ([a_{ij}, b_{ij}, c_{ij}, d_{ij}]; \mu_{ij}, \nu_{ij})_{m\times n}$ is the intuitionistic trapezoidal fuzzy decision matrix, where $\mu_{ij} \subset [0,1]$, $\nu_{ij} \subset [0,1]$, $\mu_{ij} + \nu_{ij} \leq 1$, $i = 1, 2, \cdots, m$, $j = 1, 2, \cdots, n$.

The maximizing deviation method [21] is selected here to compute the differences of the performance values of each alternative. For the attribute $G_j \in G$, the deviation of alternative A_i to all the other alternatives can be defined as follows:

$$D_{ij}(w) = \sum_{k=1}^{m} d(\tilde{r}_{ij}, \tilde{r}_{kj}) w_j, i = 1, 2, \cdots, m, j = 1, 2, \cdots, n.$$

Let

$$D_j(w) = \sum_{i=1}^{m} D_{ij}(w) = \sum_{i=1}^{m}\sum_{k=1}^{m} d(\tilde{r}_{ij}, \tilde{r}_{kj}) w_j, j = 1, 2, \cdots, n.$$

$$\begin{aligned} &d(\tilde{r}_{ij}, \tilde{r}_{kj}) = \\ &\frac{1}{8}\Big(\left|(1+\mu_{ij}-\nu_{ij})a_{ij} - (1+\mu_{kj}-\nu_{kj})a_{kj}\right| + \\ &\left|(1+\mu_{ij}-\nu_{ij})b_{ij} - (1+\mu_{kj}-\nu_{kj})b_{kj}\right| + \\ &\left|(1+\mu_{ij}-\nu_{ij})c_{ij} - (1+\mu_{kj}-\nu_{kj})c_{kj}\right| + \\ &\left|(1+\mu_{ij}-\nu_{ij})d_{ij} - (1+\mu_{kj}-\nu_{kj})d_{kj}\right|\Big) \end{aligned}$$

Then $D_j(w)$ represent the deviation value of all alternatives to other alternatives for the attribute $G_j \in G$.

Based on the above analysis, we have to choose the weight vector w to maximize all deviation values for all the attributes. To do so, we can construct a non-linear programming model as follows (M-1):

$$\begin{cases} \max D(w) = \sum_{j=1}^{n}\sum_{i=1}^{m} D_{ij}(w) = \sum_{j=1}^{n}\sum_{i=1}^{m}\sum_{k=1}^{m} d(\tilde{r}_{ij}, \tilde{r}_{kj}) w_j \\ \text{Subject to} \quad w \in H, \sum_{j=1}^{n} w_j = 1, w_j \geq 0, j = 1, 2, \cdots, n \end{cases}$$

By solving the model (M-1), we get the optimal solution $w = (w_1, w_2, \cdots, w_n)$, which can be used as the weight vector of attributes.

If the information about attribute weights is completely unknown, we can establish another programming model (M-2):

$$\begin{cases} \max D(w) = \sum_{i=1}^{m} D_i(w) = \sum_{j=1}^{n}\sum_{i=1}^{m}\sum_{k=1}^{m} d(\tilde{r}_{ij}, \tilde{r}_{kj}) w_j \\ s.t. \ \sum_{j=1}^{n} w_j^2 = 1, w_j \geq 0, j = 1, 2, \cdots, n \end{cases}$$

By solving (M-2), we get a simple and exact formula for determining the attribute weights as follows:

$$w_j = \sum_{i=1}^{m}\sum_{k=1}^{m} d(\tilde{r}_{ij}, \tilde{r}_{kj}) \Big/ \sum_{j=1}^{n}\sum_{i=1}^{m}\sum_{k=1}^{m} d(\tilde{r}_{ij}, \tilde{r}_{kj}) \quad (6)$$

Based on the above models, we develop a model for selecting an ERP system based on ITFWG operator under intuitionistic trapezoidal fuzzy environment. The method involves the following steps:

Step 1. If the information about the attribute weights is partly known, then we solve the model (M-1) to obtain the attribute weights. If the attribute weight is completely unknown, then we can obtain the attribute weights by using Eq. (6).

Step 2. Utilize the weight vector w and ITFWG operator, we obtain the overall values $\tilde{r}_i$ of the alternative A_i $(i = 1, 2, \cdots, m)$.

$$\begin{aligned} \tilde{r}_i &= ([a_i, b_i, c_i, d_i]; \mu_i, \nu_i) \\ &= \text{ITFWGM}_w(\tilde{r}_{i1}, \tilde{r}_{i2}, \cdots, \tilde{r}_{in}), i = 1, 2, \cdots, m. \end{aligned} \quad (7)$$

Step 3. Calculate the distances between overall values $\tilde{r}_i$ and intuitionistic trapezoidal fuzzy positive ideal solution $\tilde{r}^+$.

$$\begin{aligned} &d(\tilde{r}_i, \tilde{r}^+) = \\ &\frac{1}{8}\Big(\left|(1+\mu_i-\nu_i)a_i - (1+\mu^+-\nu^+)a^+\right| + \\ &\left|(1+\mu_i-\nu_i)b_i - (1+\mu^+-\nu^+)b^+\right| + \\ &\left|(1+\mu_i-\nu_i)d_i - (1+\mu^+-\nu^+)d^+\right| + \\ &\left|(1+\mu_i-\nu_i)d_i - (1+\mu^+-\nu^+)d^+\right|\Big) \end{aligned} \quad (8)$$

Step 4. Rank all the alternatives A_i $(i = 1, 2, \cdots, m)$ and select the best one(s) in accordance with $d(\tilde{r}_i, \tilde{r}^+)$. The smaller $d(\tilde{r}_i, \tilde{r}^+)$, the better the alternatives A_i.

Step 5. End.

IV. ILLUSTRATIVE EXAMPLE

This section presents a numerical example to illustrate the method proposed in this paper. Suppose an organization plans to implement ERP systems. There is a panel with five possible ERP systems to select. The company employs some professional organizations (or experts) to aid this decision-making. The Project team selects four attribute to evaluate the alternatives: ①G_1 is the function and technology; ②G_2 is strategic fitness;③G_3 is the vendor's ability;④G_4 is the vendor's reputation. The five possible alternatives $A_i (i = 1, 2, \cdots, 5)$ are to be evaluated using the intuitionistic trapezoidal fuzzy information by the decision maker under the above four attributes, as listed in the following matrix.

$$\tilde{R}=\begin{bmatrix} ([0.5,0.6,0.7,0.8];0.5,0.4) & ([0.1,0.2,0.3,0.4];0.6,0.3) & ([0.5,0.6,0.8,0.9];0.3,0.6) & ([0.4,0.5,0.6,0.7];0.2,0.7) \\ ([0.6,0.7,0.8,0.9];0.7,0.3) & ([0.5,0.6,0.7,0.8];0.7,0.2) & ([0.4,0.5,0.7,0.8];0.7,0.2) & ([0.5,0.6,0.7,0.9];0.4,0.5) \\ ([0.1,0.2,0.4,0.5];0.6,0.4) & ([0.2,0.3,0.5,0.6];0.5,0.4) & ([0.5,0.6,0.7,0.8];0.5,0.3) & ([0.3,0.5,0.7,0.9];0.2,0.3) \\ ([0.3,0.4,0.5,0.6];0.8,0.1) & ([0.1,0.3,0.4,0.5];0.6,0.3) & ([0.1,0.3,0.5,0.7];0.3,0.4) & ([0.6,0.7,0.8,0.9];0.2,0.6) \\ ([0.2,0.3,0.4,0.5];0.6,0.2) & ([0.3,0.4,0.5,0.6];0.4,0.3) & ([0.2,0.3,0.4,0.5];0.7,0.1) & ([0.5,0.6,0.7,0.8];0.1,0.3) \end{bmatrix}$$

Then, we utilize the approach developed to get the most desirable ERP system (s).

Then, we utilize the approach developed to get the most desirable alternative(s).

Case 1: If the information about the attribute weights is partly known and the known weight information is given as follows:

$$H=\{0.25\le w_1\le 0.28, 0.20\le w_2\le 0.25,\\ 0.22\le w_3\le 0.25, 0.25\le w_4\le 0.30,\\ w_j\ge 0,\ j=1,2,3,4, \textstyle\sum_{j=1}^{4} w_j=1\}$$

Then, we utilize the approach developed to get the most desirable alternative(s).

Step 1. Utilize the model (M-1) to establish the following single-objective programming model:

$$\begin{cases}\max D(w)=5.020w_1+4.104w_2+4.300w_3+4.615w_4\\ s.t.\ \ w\in H\end{cases}$$

Solving this model, we get the weight vector of attributes: $w=(0.28\ \ 0.20\ \ 0.22\ \ 0.30)^T$

Step 2. Utilize the weight vector w and by Eq. (7), we obtain the overall values $\tilde{r}_i$ of the alternative $A_i\ (i=1,2,3,4,5)$.

$$\tilde{r}_1=([0.3389,0.4560,0.5810,0.6867];0.3521,0.5403)$$
$$\tilde{r}_2=([0.5010,0.6018,0.7267,0.8566];0.5918,0.3307)$$
$$\tilde{r}_3=([0.2276,0.3636,0.5595,0.6860];0.3997,0.3499)$$
$$\tilde{r}_4=([0.2328,0.4193,0.5506,0.6759];0.4016,0.3862)$$
$$\tilde{r}_5=([0.2855,0.3912,0.4947,0.5971];0.3344,0.2320)$$

Step 3. Calculate the distances between overall values $\tilde{r}_i=([a_i,b_i,c_i,d_i];\mu_i,\nu_i)$ and intuitionistic trapezoidal fuzzy positive ideal solution

$$\tilde{r}^+=([a^+,b^+,c^+,d^+];\mu^+,\nu^+)=([1,1,1,1];1,0).$$

$$d(\tilde{r}_1,\tilde{r}^+)=0.7907, d(\tilde{r}_2,\tilde{r}^+)=0.5766$$
$$d(\tilde{r}_3,\tilde{r}^+)=0.7590, d(\tilde{r}_4,\tilde{r}^+)=0.7616$$
$$d(\tilde{r}_5,\tilde{r}^+)=0.7563$$

Step 4. Rank all the alternatives $A_i\ (i=1,2,3,4,5)$ in accordance with the distances $d(\tilde{r}_i,\tilde{r}^+)$ between overall values $\tilde{r}_i=([a_i,b_i,c_i,d_i];\mu_i,\nu_i)$ and intuitionistic trapezoidal fuzzy positive ideal solution: $A_2\succ A_5\succ A_3\succ A_4\succ A_1$, and thus the most desirable alternative is A_2.

Case 2: If the information about the attribute weights is completely unknown, we utilize another approach developed to get the most desirable alternative(s).

Step 1. Utilize the Eq. (6) to get the weight vector of attributes: $w=(0.2783\ \ 0.2275\ \ 0.2384\ \ 0.2558\ )^T$.

Step 2 Utilize the decision information given in matrix $\tilde{R}$, and the ITFWGM operator, we obtain the overall preference values $\tilde{r}_i$ of the ERP system $A_i\ (i=1,2,\cdots,5)$.

$$\tilde{r}_1=([0.3275,0.4460,0.5729,0.6792];0.3650,0.5275)$$
$$\tilde{r}_2=([0.4998,0.5997,0.7265,0.8519];0.6066,0.3165)$$
$$\tilde{r}_3=([0.2276,0.3603,0.5549,0.6776];0.4161,0.3525)$$
$$\tilde{r}_4=([0.2147,0.4037,0.5360,0.6624];0.4160,0.3729)$$
$$\tilde{r}_5=([0.2773,0.3824,0.4856,0.5878];0.3589,0.2286)$$

Step 3. Calculate the distances between overall values $\tilde{r}_i=([a_i,b_i,c_i,d_i];\mu_i,\nu_i)$ and intuitionistic trapezoidal fuzzy positive ideal solution $\tilde{r}^+=([a^+,b^+,c^+,d^+];\mu^+,\nu^+)=([1,1,1,1];1,0)$.

$$d(\tilde{r}_1,\tilde{r}^+)=0.7907, d(\tilde{r}_2,\tilde{r}^+)=0.5766$$
$$d(\tilde{r}_3,\tilde{r}^+)=0.7590, d(\tilde{r}_4,\tilde{r}^+)=0.7616$$
$$d(\tilde{r}_5,\tilde{r}^+)=0.7563$$

Step 4. Rank all the alternatives $A_i\ (i=1,2,3,4,5)$ in accordance with the distances $d(\tilde{r}_i,\tilde{r}^+)$ between overall values $\tilde{r}_i = \left(\left[a_i, b_i, c_i, d_i\right]; \mu_i, \nu_i\right)$ and intuitionistic trapezoidal fuzzy positive ideal solution: $A_2 \succ A_5 \succ A_3 \succ A_4 \succ A_1$, and thus the most desirable ERP system is A_2.

Step 5. Rank all the ERP systems $A_i \left(i = 1, 2, 3, 4, 5\right)$ in accordance with the scores $S\left(\tilde{r}_i\right)$ $\left(i=1,2,\cdots,5\right)$ of the overall preference values $\tilde{r}_i \left(i=1,2,\cdots,5\right)$: $A_2 \succ A_5 \succ A_3 \succ A_4 \succ A_1$, and thus the most desirable ERP system is A_2.

V. Conclusion

In this paper, we have investigated the problem of MADM with completely known information on attribute weights to which the attribute values are given in terms of intuitionistic trapezoidal fuzzy numbers. Two optimization models based on the maximizing deviation method are established to derive the attribute weights. Then, we utilize the intuitionistic trapezoidal fuzzy weighted geometric mean (ITFWGM) operator to aggregate the intuitionistic trapezoidal fuzzy information corresponding to each alternative, and then rank the alternatives and select the most desirable one(s). Finally, an illustrative example about selecting an ERP system is given.

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