Intuitionistic Fuzzy QUALIFLEX Method for Optimistic and Pessimistic Decision Making

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Abstract

Intuitionistic fuzzy sets are suitable for capturing imprecise or uncertain decision information in multiple criteria decision analysis. In addition, optimism and pessimism generally affect the manner in which subjective judgments are construed. This paper proposes an outranking model, a QUALIFLEX method, for relating optimism and pessimism within the intuitionistic fuzzy decision environment. This paper treats the influences of optimism and pessimism differently by using the unipolar bivariate model. In addition, the proposed method investigates all possible permutations of alternatives with respect to the consequences of all criteria. A ranking procedure is employed to compare intuitionistic fuzzy values by using the inclusion comparison probability.

Keywords: Intuitionistic Fuzzy Sets, Multiple Criteria Decision Analysis, QUALIFLEX Method, Optimism, Pessimism

1. Introduction

Intuitionistic fuzzy sets (IFSs), characterized by three functions expressing degrees of membership, non-membership, and hesitation (or indeterminacy), were introduced by Atanassov [1, 2]. IFSs have received more and more attention since their appearance. Nikolova et al. [3] presented advanced developments of IFS theory, including intuitionistic fuzzy geometry, intuitionistic fuzzy topology, intuitionistic fuzzy logic, an intuitionistic fuzzy approach to artificial intelligence, and intuitionistic fuzzy generalized nets. Because they are useful in modeling imprecision or uncertainty, valuable applications of IFSs have been developed in many different fields, including pattern recognition [4, 5], medical diagnosis [6], drug selection [7], microelectronic fault analysis [8, 9], machine learning [10], weight assessment [11, 12], decision-making problems [13-15], and others. A considerable number of studies have been made on intuitionistic fuzzy multiple criteria decision making; however, the IFS outranking models have been less developed. QUALIFLEX [16-18], which is a generalization of Jacquet-Lagreze’s permutation method, is a useful outranking method, owing to its flexibility with regard to cardinal and ordinal information. This paper leverages Paelinck’s QUALIFLEX [18] to develop an intuitionistic fuzzy QUALIFLEX method.

On the other hand, some researches [19-22] have been investigated to the issue of optimism and pessimism in the intuitionistic fuzzy environment. Optimism and pessimism, pioneered by Scheier and Carver [23] and Scheier et al. [24], are fundamental constructs in a variety of theories and research dealing with generalized expectations for good and bad outcomes, respectively, in life events. Although theories differ in their specifics, a common idea is that optimists and pessimists diverge in their explanations and predictions of future events. Optimists interpret their lives positively and anticipate desirable outcomes, whereas pessimists construe their lives negatively and expect unfavorable outcomes [25]. In view of multiple criteria decision making problems, optimism and pessimism can reflect individual differences of different decision makers. Therefore, the identification of their influence on the decision making process is highly valuable and useful in multiple criteria decision analysis. Chen [19-21] presented several scoring methods of relating optimism and pessimism to multiple criteria decision making within IFS decision environments. Chen [20] related optimism and pessimism to multiple criteria decision analysis in the context of IFSs based on the unipolar bivariate model. Chen [19] investigated several multiple attributes evaluation cases in consumer decision
making reality and demonstrated the feasibility and applicability of the intuitionistic fuzzy multiple criteria decision-making method with consideration of optimism/pessimism. Chen [21] developed optimistic and pessimistic estimations with several fuzzy point operators to draw the influences of optimism and pessimism on multiple criteria decision making for the sake of a better fit than the unidimensional model. Chen [22] presented a new method to reduce cognitive dissonance and to relate optimism and pessimism in multiple criteria decision analysis based on interval-valued fuzzy sets. Some new score functions were developed to quantify optimism and pessimism based on optimistic and pessimistic point operators [19-22]. Considering that optimism and pessimism are measured by using optimistic and pessimistic point operators, respectively, this paper incorporated optimistic and pessimistic estimations into intuitionistic fuzzy QUALIFLEX method for the multi-criteria decision analysis.

2. Decision Environment Based on IFSs

The concept of IFSs is an extension of the concept of ordinary fuzzy sets. We first review some basic concepts related to IFSs [1, 2].

An IFS $A$ on a universe $X$ is defined as an object of the following form:

$$ A = \left\{ (x, \mu_A(x), \nu_A(x)) \mid x \in X \right\}, $$

(1)

Where $\mu_A : [0, 1] \to X$ and $\nu_A : [0, 1] \to X$ such that $0 \leq \mu_A(x) + \nu_A(x) \leq 1$ for all $x \in X$. The values of $\mu_A(x)$ and $\nu_A(x)$ represent the degrees of membership and non-membership of $x \in X$ in $A$, respectively.

For every $A \in IFS(X)$ (the class of IFSs on the universe $X$), the value of

$$ \pi_A(x) = 1 - \mu_A(x) - \nu_A(x) $$

(2)

represents the degree of hesitancy (or uncertainty) associated with the membership of element $x \in X$ in IFS $A$, where $0 \leq \pi_A(x) \leq 1$. Furthermore, for every two $A, B \in IFS(X)$, the inclusion relation is as follows: $A \subseteq B$ iff $\mu_A(x) \leq \mu_B(x)$ and $\nu_A(x) \geq \nu_B(x)$ for every $x \in X$.

In this paper, the vagueness and incomplete preference information problems in multiple criteria decision analysis will be dealt with IFS theory. A multiple criteria decision-making problem can be concisely expressed in a decision matrix $D$. Suppose that there exist $m$ non-dominated alternatives and the alternative set is $A = \{A_1, A_2, \ldots, A_m\}$. Each alternative is assessed on the basis of $n$ criteria denoted by $X = \{x_1, x_2, \ldots, x_n\}$. Let $w_j$ be the weight of criterion $x_j \in X$, which satisfies the normalization conditions: $w_j \in [0, 1]$ ( $j = 1, 2, \ldots, n$) and $\sum_{j=1}^{n} w_j = 1$. Let $\mu_y$ indicate the degree to which the alternative $A \in A$ satisfies the criterion $x_j \in X$ given by the decision maker. Denote by $\nu_y$ the degree to which the alternative $A$ does not satisfy the criterion $x_j$. Notice that $0 \leq \mu_y \leq 1$, $0 \leq \nu_y \leq 1$, and $\mu_y + \nu_y \leq 1$. Moreover, the degree of hesitancy is given by $\pi_y = 1 - \mu_y - \nu_y$. The decision matrix $D$ is given in the following form:

$$ D = \begin{pmatrix}
  x_1 & x_2 & \cdots & x_n \\
  A_1 & (\mu_{11}, \nu_{11}) & (\mu_{12}, \nu_{12}) & \cdots & (\mu_{1n}, \nu_{1n}) \\
  \vdots & \vdots & \ddots & \vdots & \vdots \\
  A_m & (\mu_{m1}, \nu_{m1}) & (\mu_{m2}, \nu_{m2}) & \cdots & (\mu_{mn}, \nu_{mn})
\end{pmatrix}. $$

(3)

Let $A_j = (\mu_y, \nu_y)$. The characteristics of the alternative $A_j$ can be represented by the IFS as follows:

$$ A_j = \left\{ (x_1, \mu_{j1}, \nu_{j1}), (x_2, \mu_{j2}, \nu_{j2}), \ldots, (x_n, \mu_{jn}, \nu_{jn}) \right\} $$$$ = \left\{ (x, \mu_y, \nu_y) \mid x_j \in X \right\}. $$

(4)
3. Optimistic/Pessimistic Point Operators

For a given IFS $A_i$ and given numerical parameters $\alpha_y, \beta_y \in [0,1]$, we follow Chen’s research [19-22] to define optimistic and pessimistic point operators $J_{\alpha_y,\beta_y}$ and $H_{\alpha_y,\beta_y}$, respectively, as follows:

\[ J_{\alpha_y,\beta_y}(A_i) = \left\{ x_j, \mu_i \cdot \alpha_y + \beta_y \cdot \pi_y \mid x_j \in X \right\}, \]
\[ H_{\alpha_y,\beta_y}(A_i) = \left\{ x_j, \mu_i \cdot \pi_y \cdot \beta_y \mid x_j \in X \right\}. \]

Consider $X_y = \{ x_j, \mu_i, \nu_j \}$, where $i=1,2,\ldots,m$ and $j=1,2,\ldots,n$. Let $\eta$ be a positive integer. Denote $J_{\alpha_y,\beta_y}^\eta(X_y) = J_{\alpha_y,\beta_y}(J_{\alpha_y,\beta_y}^{\eta-1}(X_y))$, where $J_{\alpha_y,\beta_y}^0(X_y) = X_y$. Let $\mu_y^{\pi\eta}$ and $\pi_y^{\pi\eta}$ denote $\mu_{x_j,x_i}(\alpha_{ij}(x_j))$ and $\pi_{x_j,x_i}(\alpha_{ij}(x_j))$, respectively.

\[ \mu_y^{\pi\eta} = \mu_j + (1-\mu_j) \cdot [1-(1-\alpha_y)^\eta] \cdot \alpha_y \cdot \nu_j \cdot \pi_j \sum_{k=0}^{\eta-1} (1-\alpha_y)^k \cdot \beta_y^{\eta-k}, \]
\[ \pi_y^{\pi\eta} = (1-\mu_j - \beta_y^{\eta} \cdot \nu_j) - (1-\mu_j) \cdot [1-(1-\alpha_y)^\eta] + \alpha_j \cdot \nu_j \cdot \pi_j \sum_{k=0}^{\eta-1} (1-\alpha_y)^k \cdot \beta_y^{\eta-k}. \]

Denote $H_{\alpha_y,\beta_y}^\eta(X_y) = H_{\alpha_y,\beta_y}(H_{\alpha_y,\beta_y}^{\eta-1}(X_y))$, in which $H_{\alpha_y,\beta_y}^0(X_y) = X_y$. For convenience, let $\mu_y^{H\eta}$ and $\pi_y^{H\eta}$ denote $\mu_{x_j,x_i}(\alpha_{ij}(x_j))$ and $\pi_{x_j,x_i}(\alpha_{ij}(x_j))$, respectively.

\[ \mu_y^{H\eta} = \nu_j + (1-\nu_j) \cdot [1-(1-\beta_y)^\eta] - \beta_y \cdot \mu_j \cdot \pi_j \sum_{k=0}^{\eta-1} (1-\beta_y)^k \cdot \alpha_y^{\eta-k}, \]
\[ \pi_y^{H\eta} = (1-\nu_j - \alpha_y^{\eta} \cdot \mu_j) - (1-\nu_j) \cdot [1-(1-\beta_y)^\eta] + \beta_y \cdot \nu_j \cdot \pi_j \sum_{k=0}^{\eta-1} (1-\beta_y)^k \cdot \alpha_y^{\eta-k}. \]

The values of $J_{\alpha_y,\beta_y}$ reflect that the optimistic decision makers construe the decision matrix positively and anticipate favorable outcomes. The point operator $J_{\alpha_y,\beta_y}$ assigns to every point $x_j \in X$ a point $J_{\alpha_y,\beta_y}(X_y)$ of the rectangle with vertices $(\mu_{ij}, \nu_j)$, $(\mu_{ij}, 0)$, $(\mu_{ij} + \pi_{ij}, 0)$, and $(\mu_{ij} + \pi_{ij}, \nu_j)$, depending on the values of $\alpha_y$ and $\beta_y$. Use of $J_{\alpha_y,\beta_y}$ on $X_y$ enhances the evaluation of alternative $A_i$ with respect to criterion $x_j$ on the fuzzy concept “fulfillment of the decision maker’s requirements.” This point operator deforms optimistic estimations by simultaneously increasing their membership degree and decreasing their non-membership degree. Thus, it allows optimists to alter their decision situation to reflect more positive and less negative outcome expectations. Furthermore, the membership degree of $J_{\alpha_y,\beta_y}(X_y)$ is the sum of the membership degree of $X_y$ and part of the hesitancy degree. The repeated use of $J_{\alpha_y,\beta_y}$ will lead to the highest possible membership degree of one (ultra-optimistic) if the time to redistribute the hesitancy degree is sufficiently large.

The operator $H_{\alpha_y,\beta_y}$ assigns to every point $x_j \in X$ a point $H_{\alpha_y,\beta_y}(X_y)$ of the rectangle with vertices $(\mu_{ij}, \nu_j)$, $(0, \nu_j)$, $(0, \nu_j + \pi_{ij})$, and $(\mu_{ij}, \nu_j + \pi_{ij})$, depending on the values of $\alpha_y$ and $\beta_y$. Application of $H_{\alpha_y,\beta_y}$ magnifies the intensity of the fuzzy concept “failure to satisfy the decision maker’s requirements” due to the increasing degree of non-membership, thus satisfying the condition that pessimistic decision-makers construe the decision situation negatively and validate unfavorable outcomes. The membership degree of $H_{\alpha_y,\beta_y}(X_y)$ is equal to the part of the membership degree of $X_y$. Thus, we will obtain the lowest possible membership degree of zero.
by applying the $H_{\alpha, \beta}$ operator sufficiently many times; meanwhile, the non-membership degree reaches its maximal value of one (ultra-pessimistic).

4. QUALIFLEX Method

Li [26] defined the likelihood of an alternative not being inferior to another alternative. Then, he constructed a likelihood matrix and determined the optimal degrees of membership for ranking the alternatives. Later, Li [14] extended the likelihood measure to define an inclusion comparison probability to make comparisons between alternatives. More specifically, he compared two alternatives via the probability of the inclusion comparison event of the closeness IFSs. Considering the advantages of the inclusion comparison probability and possibility-degree formulas, we employed the concept of an inclusion comparison probability between IFSs to develop a new QUALIFLEX method for handling multiple criteria decision-making problems in the IFS context. In the following, we developed an inclusion-based approach to identify the concordance/discordance index.

Given the alternative set $A$ with $m$ alternatives, $m!$ permutations of the ranking of the alternatives exist. Let $P_l$ denote the $l$-th permutation. $P_l = (\ldots, A_{\rho}, \ldots, A_{\rho})$ for $l=1,2,\ldots,m!$, where the alternative $A_{\rho}$ is ranked higher than or equal to $A_{\rho'}$.

For every two IFS values $A_{\rho}$ and $A_{\rho'}$, the inclusion comparison probability [14], denoted by $p(A_{\rho} \supseteq A_{\rho'})$, of the event “$A_{\rho} \supseteq A_{\rho'}$” is given by

$$p(A_{\rho} \supseteq A_{\rho'}) = \max \left\{ 1 - \frac{1 - \mu^L_{\rho} - \mu^U_{\rho'}}{\mu^L_{\rho} + \mu^U_{\rho'}}, 0 \right\}. \quad (11)$$

The inclusion comparison probability has some useful properties [14], including:

1. $0 \leq p(A_{\rho} \supseteq A_{\rho'}) \leq 1$;
2. if $\mu^L_{\rho} + \mu^U_{\rho'} \leq \mu^L_{\rho'}$, then $p(A_{\rho} \supseteq A_{\rho'}) = 0$;
3. if $\mu^L_{\rho} \geq \mu^L_{\rho'} + \mu^U_{\rho'}$, then $p(A_{\rho} \supseteq A_{\rho'}) = 0$;
4. $p(A_{\rho} \supseteq A_{\rho'}) + p(A_{\rho} \subseteq A_{\rho'}) = 1$;
5. if $p(A_{\rho} \supseteq A_{\rho'}) = p(A_{\rho} \subseteq A_{\rho'})$, then $p(A_{\rho} \supseteq A_{\rho'}) = p(A_{\rho} \subseteq A_{\rho'}) = 0.5$;
6. if $p(A_{\rho} \supseteq A_{\rho'}) \geq 0.5$ and $p(A_{\rho'} \supseteq A_{\rho}) \geq 0.5$, then $p(A_{\rho} \supseteq A_{\rho'}) \geq 0.5$.

The concordance/discordance index, $I^j(A_{\rho}, A_{\rho'})$, for each pair of alternatives, $(A_{\rho}, A_{\rho'})$, $A_{\rho}, A_{\rho'} \in A$, at the level of preorder, according to the criterion $x_j \in X$ and the ranking corresponding to the $l$-th permutation, is:

$$I^j(A_{\rho}, A_{\rho'}) = \begin{cases} p(A_{\rho} \supseteq A_{\rho'}) & \text{if } p(A_{\rho} \supseteq A_{\rho'}) > 0.5, \\ 0 & \text{if } p(A_{\rho} \supseteq A_{\rho'}) = 0.5, \\ -p(A_{\rho} \supseteq A_{\rho'}) & \text{if } p(A_{\rho} \supseteq A_{\rho'}) < 0.5. \end{cases} \quad (12)$$

Furthermore, the concordance/discordance index $I^j$, between the pre-order according to the criterion $x_j$ and the ranking corresponding to the permutation $P_l$, is:

$$I^j = \sum_{A_{\rho}, A_{\rho'} \neq \lambda} I^j(A_{\rho}, A_{\rho'}). \quad (13)$$

The weighted concordance/discordance index $I^j(A_{\rho}, A_{\rho'})$ for each pair of alternatives $(A_{\rho}, A_{\rho'})$ at the level of preorder with respect to the $n$ criteria in $X$ and the ranking corresponding to the permutation $P_l$ is:

$$I^j(A_{\rho}, A_{\rho'}) = \sum_{j=1}^{n} I^j(A_{\rho}, A_{\rho'}) \cdot w_j. \quad (14)$$

Combining $I^j$ and $I^j(A_{\rho}, A_{\rho'})$, the comprehensive concordance/discordance index $I^j$ for the permutation $P_l$ is:
The evaluation criterion of the chosen hypothesis for ranking of the alternatives is the arithmetic sum of all weighted inclusion comparison probabilities corresponding to the element by element consistency.

5. Illustrative Example

The following practical example involves a medical decision-making problem concerning acute inflammatory demyelinating disease. The example demonstrates the effective use of the intuitionistic fuzzy QUALIFLEX method with optimism and pessimism.

The patient, Mrs. Hwang, was a 48-year-old widowed female with a history of diabetes mellitus. Her physician made a diagnosis of acute inflammatory demyelinating disease. The attending physician assessed Mrs. Hwang’s medical history and her current physical conditions, providing the following treatment options: (1) steroid therapy \( A_1 \), (2) plasmapheresis \( A_2 \), and (3) albumin immune therapy \( A_3 \). Each treatment had advantages and disadvantages. The set of all alternatives is denoted by \( A = \{A_1, A_2, A_3\} \). The physician described three treatment methods using the following criteria: (1) probability of a cure \( x_1 \), (2) severity of the complications \( x_2 \), (3) expense \( x_3 \), and (4) probability of a recurrence \( x_4 \). The set of evaluative criteria is denoted by \( X = \{x_1, x_2, x_3, x_4\} \). In addition, the weight vector is \( (w_1, w_2, w_3, w_4) = (0.27, 0.15, 0.33, 0.25) \).

Using the linguistic rating system in Zhang and Liu [27], the three treatment methods were evaluated on the basis of the four criteria. According to [27], the linguistic evaluations were converted into intuitionistic fuzzy values. These results are presented in Table 1.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Treatment options</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( A_1 )</td>
</tr>
<tr>
<td>Probability of a cure ( x_1 )</td>
<td>MP</td>
</tr>
<tr>
<td>(0.35, 0.55)</td>
<td>(0.85, 0.10)</td>
</tr>
<tr>
<td>Severity of the complications ( x_2 )</td>
<td>P</td>
</tr>
<tr>
<td>(0.25, 0.65)</td>
<td>(0.65, 0.25)</td>
</tr>
<tr>
<td>Expense ( x_3 )</td>
<td>G</td>
</tr>
<tr>
<td>(0.75, 0.15)</td>
<td>(0.35, 0.55)</td>
</tr>
<tr>
<td>Probability of a recurrence ( x_4 )</td>
<td>EP</td>
</tr>
<tr>
<td>(0.05, 0.95)</td>
<td>(0.75, 0.15)</td>
</tr>
</tbody>
</table>

Let \( \eta = 1 \) for simplicity. Moreover, it is reasonable to assume that \( \alpha_\mu = \mu_\eta \) and \( \alpha_\nu = \nu_\eta \) in the point operators of \( J_{\alpha_\mu, \beta_\nu} \) and \( H_{\alpha_\mu, \beta_\nu} \) for each \( A \in A \) and \( x_j \in X \). If Mrs. Hwang is an optimist, then the adjusted decision matrix is given by the \( J_{\mu_\eta, \nu_\eta} \) point operator:

\[
D' = A_1 \begin{bmatrix}
0.385, 0.303 \\
0.893, 0.010 \\
0.825, 0.023
\end{bmatrix}.
\] (16)

If Mrs. Hwang is a pessimist, then the adjusted decision matrix is given by the \( H_{\mu_\eta, \nu_\eta} \) point operator:

\[
D'' = A_1 \begin{bmatrix}
0.123, 0.605 \\
0.723, 0.105 \\
0.563, 0.165
\end{bmatrix}.
\] (17)
There are 6 (=3!) permutations of the ranking for each of the alternatives that have to be tested; they are: $P_1 = (A_1, A_2, A_3)$, $P_2 = (A_1, A_3, A_2)$, $P_3 = (A_2, A_1, A_3)$, $P_4 = (A_2, A_3, A_1)$, $P_5 = (A_3, A_1, A_2)$, and $P_6 = (A_3, A_2, A_1)$.

For the two IFS values $A_{p,j}$ and $A_{p',j}$ of each pair of alternatives $(A_p, A_{p'})$, the inclusion comparison probability $p(A_{p,j} \supseteq A_{p',j})$ is presented in Table 2, including the results of optimistic and pessimistic point operators.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Alternative pairs</th>
<th>(based on optimistic point operator)</th>
<th>Alternative pairs</th>
<th>(based on pessimistic point operator)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$(A_1, A_2)$</td>
<td>$(A_1, A_2)$</td>
<td>$(A_2, A_1)$</td>
<td>$(A_2, A_1)$</td>
</tr>
<tr>
<td>$x_1$</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.66</td>
</tr>
<tr>
<td>$x_2$</td>
<td>0</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$x_3$</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>$x_4$</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criteria</th>
<th>$(A_1, A_2)$</th>
<th>$(A_1, A_2)$</th>
<th>$(A_2, A_1)$</th>
<th>$(A_2, A_1)$</th>
<th>$(A_3, A_2)$</th>
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<tr>
<td></td>
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<td>$(A_1, A_2)$</td>
<td>$(A_1, A_2)$</td>
<td>$(A_1, A_2)$</td>
<td>$(A_2, A_3)$</td>
</tr>
<tr>
<td>$x_1$</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.74719</td>
<td>1</td>
</tr>
<tr>
<td>$x_2$</td>
<td>0</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>$x_3$</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$x_4$</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
</tr>
</tbody>
</table>

Next, we computed the concordance/discordance index $I'_j(A_{p,j}, A_{p',j})$. Take $(A_1, A_2)$ for example. Because $p(A_{1,j} \supseteq A_{2,j}) = 0.34 \times 0.5$, $I'_1(A_1, A_2) = -0.34$. The weighted concordance/discordance index $I'(A_{p,j}, A_{p',j})$ was determined for each pair of $(A_p, A_{p'})$ in $P_i$. By using $J_{a_j, b_j}$, the results of the comprehensive concordance/discordance index $I'$ for each permutation $P_i$ are as follows: $I'_1=1.3182$, $I'_2=0.5682$, $I'_3=1.6582$, $I'_4=1.8482$, $I'_5=0.7582$, and $I'_6=1.0982$. By using $H_{a_j, b_j}$, the results of $I'$ for each permutation $P_i$ are as follows: $I'_1=1.3417$, $I'_2=0.5917$, $I'_3=1.6817$, $I'_4=1.8717$, $I'_5=0.7817$, and $I'_6=1.1217$. Because $I'$ gives the maximal value, the best order of the candidate treatment options is $P_2 = (A_1, A_3, A_2)$. The best choice for Mrs. Hwang is plasmapheresis ($A_2$).

6. Conclusions

This paper developed a new outranking method for handling multiple criteria optimistic and pessimistic decision-making problems within an IFS framework. First, we used optimistic and pessimistic estimations with the useful point operators in IFSs to handle the influences of optimism and pessimism on decision making. Afterwards, using a criterion-wise preference of alternatives via inclusion comparison probabilities between IFSs, we proposed a QUALIFLEX-based model to measure the level of concordance of the complete preference order for managing multiple criteria decisions. In addition, the real-world efficacy of the methodology was illustrated by applying the intuitionistic fuzzy QUALIFLEX method with optimism and pessimism to a practical medical decision-making problem.

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