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Intuitionistic Fuzzy Multicriteria Group Decision for Evaluating and Selecting Information Systems Projects

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Abstract: Evaluating and selecting information systems projects for development in an organization are a multicriteria group decision-making problem in which multiple, often conflicting criteria have to be considered by several decision makers whose preferences in the decision making process are often inter-dependent. To effectively solve this problem, this study presents an intuitionistic fuzzy approach with the use of intuitionistic fuzzy values for adequately modeling the subjectiveness and imprecision of the decision making process. The inter-dependence of the preferences of the decision makers are properly represented by the use of fuzzy measure. An intuitionistic fuzzy group decision making method with Choquet integral-based TOPSIS is utilized for determining the overall performance of alternative information systems projects across all the criteria, leading to effective decisions being made in evaluating and selecting information systems projects. An example is presented for demonstrating the applicability of the proposed approach for solving the information systems project evaluation and selection problem in the real world setting.

Key words: Information systems project selection, intuitionistic fuzzy sets, linguistic variables, group decision making, TOPSIS

INTRODUCTION

The rapid advance in information and communication technologies has effectively facilitated the development of information systems projects in modern organizations for reorganizing their business processes and streamlining the provision of their products and services (Deng, 2005). Such a development helps organizations create and maintain their competitive advantages through fast business transactions, increasingly automated business processes, improved customer service and provision of effective decision support. As a result, evaluating and selecting the most suitable information systems project from competing projects for development becomes a critical issue in modern organizations (Lee and Kim, 2001).

The evaluation and selection of information systems projects in an organization is a multicriteria group decision making problem (Lee and Kim, 2001). In evaluating and selecting specific information systems projects to develop in an organization, multiple, often conflicting evaluation and selection criteria have to be simultaneously considered (Deng, 2005) and multiple decision makers are usually involved in assessing the overall performance of alternative information systems projects across all the evaluation and selection criteria on which the selection decision can be made (Lee and Kim, 2001).

Inter-dependency between criteria and the preferences of decision makers in evaluating and selecting information systems projects is often existent (Chen and Cheng, 2009). Furthermore, subjectiveness and imprecision are always present in the information systems project evaluation and selection process. This is due to the presence of incomplete information, abundant information, conflicting evidence, ambiguous information, and subjective information (Deng, and Yeh, 2006; Zimmermann, 1986). Fuzzy sets theory (Zadeh, 1965), has been widely used due to its capability in effectively modeling the subjective and imprecise human decision behavior (Deng and Yeh, 2006; Zimmermann, 1986; Sylwester, 2010).

Intuitionistic fuzzy sets (Atanassov, 1999) are an extension of the fuzzy sets for better modeling imprecise and subjective human decision behaviors. Tremendous efforts have been spent and significant advances have been made in the development of the intuitionistic fuzzy sets theory and its applications for solving various

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decision making problems (Atanassov, 1999; Bustince *et al.*, 2007). The popularity of the intuitionistic fuzzy sets for solving multicriteria group decision making problem is due to its capacity for adequately modeling the subjective and imprecise assessment of decision makers.

This study presents an intuitionistic fuzzy multicriteria group decision making approach for effectively evaluating and selecting information systems projects. The subjectiveness and imprecision of the decision making process are modeled through the use of intuitionistic fuzzy values. And the fuzzy measure is used for adequately representing the inter-dependence between the criteria or the preferences of individual decision makers. To effectively aggregate the assessments of multiple decision makers in evaluating the performance of alternative information systems project and the importance of selection criteria, an extended TOPSIS is utilized. To adequately determine the overall performance of alternative information systems projects across all the criteria, the concept of ideal solution is adopted.

The rest of this study is organized as follows. Here, we introduce the basic definitions and notations about intuitionistic fuzzy sets, fuzzy measure and intuitionistic fuzzy Choquet integral. Here, we present an intuitionistic fuzzy multicriteria group decision making approach for solving the information systems project evaluation and selection problem. Here, we give a numerical example for demonstrating the applicability of the proposed approach in solving the information systems project evaluation and selection problem. Finally conclusions are summarized.

PRELIMINARY CONCEPTS AND NOTATIONS

Definition 1: Let $X = \{x_1, ..., x_n\}$ be a universe of discourse, P(X) be the power set of X. A fuzzy measure on P(X) is a set function m: $P(X) \rightarrow [0, 1]$, satisfying the following conditions:

- $m(\varnothing) = 0$, $m(X) = 1$
- If $A, B \in P(X)$ and $A \subseteq B$ then $m(A) \leq m(B)$

When inter-dependent or interactive phenomena among criteria as well as among the decision makers in multicriteria group decision making situations are present, the overall importance of a criterion $i \in N$ is not solely determined by itself i, but also by all other criteria T, $i \in T$. Suppose that w(i) denotes the importance degree of i. w(i) = 0 suggests that element is unimportant. The fuzzy measure defined as above is capable of representing a weight on not only each criterion but also each combination of criteria in which the total of all the w_i (i = 1, ...n) does not necessarily equal to one.

To reduce the computational complexity, the λ-fuzzy measure g that acts as a special kind of fuzzy measure is proposed as follows (Sugeno, 1974):

$$g(A \cup B) = g(A) + g(B) + \lambda g(A)\, g(B) \quad (1)$$

where $-1 < \lambda < \infty$ for all $A, B \in P(X)$ and $A \cap B = \varnothing$.

If X is a finite set, then $\cup_{i=1}^{n} x_i = X$. The λ-fuzzy measure g satisfies following condition:

$$g(X) = g\left(\bigcup_{i=1}^{n} x_i\right) = \begin{cases} \frac{1}{\lambda}\left(\prod_{i=1}^{n}[1+\lambda g(x_i)] - 1\right) & \text{if } \lambda \neq 0, \\ \sum_{i=1}^{n} g(x_i) & \text{if } \lambda = 0, \end{cases} \quad (2)$$

where, $x_i \cap x_j = \varnothing$ for all i, j= 1, 2, ..., n and $I \neq j$. It can be noted that $g(x_i)$ for a subset with a single element x_i is called a fuzzy density, and can be denoted as $g_i = g(x_i)$.

Especially for every subset $A \in P(X)$, we have:

$$g(A) = \begin{cases} \frac{1}{\lambda}\left(\prod_{i \in A}[1+\lambda g(i)] - 1\right) & \text{if } \lambda \neq 0 \\ \sum_{i \in A} g(i) & \text{if } \lambda = 0 \end{cases} \quad (3)$$

Based on Eq. 2, the value λ of can be uniquely determined from g(X) = 1, which is equivalent to solving the equation as follows:

$$\lambda + 1 = \prod_{i=1}^{n}(1 + \lambda g_i) \quad (4)$$

Let X be an ordinary finite non-empty set. An intuitioni- stic fuzzy set in X is an expression A given by $A = \{<x, t_A(x), f_A(x)> \mid x \in X\}$, where, $X\, t_A: \rightarrow [0,1]$, $f_A: X \rightarrow [0,1]$ with the condition: $0 \leq t_A(x) + f_A(x) \leq 1$, for all x in X. The numbers $t_A(x)$ and $f_A(x)$ denote, respectively, the degree of membership and the degree of non-membership of the element x in the set A. $\pi_A(x)$ as defined in $\pi_A(x) = 1 - t_A(x) - f_A(x)$ is referred to as an intuitionistic fuzzy index or the hesitation margin of x in the set A. It expresses a hesitation degree of whether x belongs to A or not. It is obvious that $0 \leq \pi_A(x) \leq 1$, for each $x \in X$. Obviously, when $t_A(x) = 1 - f_A(x)$ for every x in X, i.e., if $t_A(x) + f_A(x) = 1$, the set A is a fuzzy set. For the computational convenience, $(t_A(x), f_A(x))$ is referred to as an intuitionistic fuzzy value.

Giving two intuitionistic fuzzy values A and B, the following order relations are valid:

- A = B iff $t_A(x) = t_B(x)$ and $f_A(x) = f_B(x)$ for all $x \in X$
- $A \leq B$ iff $t_A(x) \leq t_B(x)$ and $f_A(x) \geq f_B(x)$ for all $x \in X$

(b) is not always satisfied in some situations. When (b) cannot be used to compare intuitionistic fuzzy values, we can use a score function and an accuracy function of intuitionistic fuzzy values for the comparison between two intuitionistic fuzzy values discussed in the following (Tan and Chen, 2010).

Definition 2: Let $\tilde{a} = (t_{\tilde{a}}, f_{\tilde{a}})$ and $\tilde{b} = (t_{\tilde{b}}, f_{\tilde{b}})$ be two intuitionistic fuzzy values, $S(\tilde{a}) = t_{\tilde{a}}-f_{\tilde{a}}$ and $S(\tilde{b}) = t_{\tilde{b}}-f_{\tilde{b}}$ be the score functions of $\tilde{a}$ and $\tilde{b}$, respectively and let $H(\tilde{a}) = t_{\tilde{a}}+f_{\tilde{a}}$ and $H(\tilde{b}) = t_{\tilde{b}}+f_{\tilde{b}}$ be the accuracy functions of $\tilde{a}$ and $\tilde{b}$, respectively, then If $S(\tilde{a})<S(\tilde{b})$, then $\tilde{a}$ is smaller than $\tilde{b}$, denoted by $\tilde{a}<\tilde{b}$;If $S(\tilde{a}) = S(\tilde{b})$, then:

- If $H(\tilde{a})<H(\tilde{b})$, then $\tilde{a}$ is smaller than $\tilde{b}$, denoted by $\tilde{a}<\tilde{b}$; (b) If $H(\tilde{a}) = H(\tilde{b})$, then $\tilde{a}$ and $\tilde{b}$ represent the same information, denoted by $\tilde{a} = \tilde{b}$

A distance measure between intuitionistic fuzzy values can be defined as follows (Atanassov, 1999):

Definition 3: Let $X = \{x_1, ..., x_n\}$ be a universe of discourse, $\tilde{a}= (t_{\tilde{a}}(x_i), f_{\tilde{a}}(x_i))$ and $\tilde{b} = (t_{\tilde{b}}(x_i), f_{\tilde{b}}(x_i))$ (i = 1, ..., n) be two intuitionistic fuzzy values on X, if:

$$d(\tilde{a},\tilde{b}) = \frac{1}{2}\sum_{i=1}^{n} w_i(|t_{\tilde{a}}(x_i) - t_{\tilde{b}}(x_i)| + |f_{\tilde{a}}(x_i) - f_{\tilde{b}}(x_i)| + |\pi_{\tilde{a}}(x_i) - \pi_{\tilde{b}}(x_i)|)$$

where, $w = (w_1, w_2, ..., w_n)$ is the weight vector of x_j such that $w_i \in[0, 1]$ and $\Sigma^n_{i=1} w_i = 1$, then $d(\tilde{a}, \tilde{b})$ is called the weighted Hamming distance between $\tilde{a}$ and $\tilde{b}$.

Obviously, the interactive characteristic among X in the weighted Hamming distance between intuitionistic fuzzy values is not taken into account in Definition 3. In order to overcome this limitation, a new distance measure between intuitionistic fuzzy values, called the Choquet integral-based Hamming distance, is defined as follows.

Definition 4: Let $X = \{x_1, ..., x_n\}$ be a universe of discourse, $\tilde{a}= (t_{\tilde{a}}(x_i), f_{\tilde{a}}(x_i))$ and $\tilde{b} = (t_{\tilde{b}}(x_i), f_{\tilde{b}}(x_i))$ (i = 1, 2, ..., n) be two intuitionistic fuzzy values on X and m be a fuzzy measure on P(X). $d(\tilde{a}, \tilde{b})$ is called Choquet integral-based Hamming distance, if defined as:

$$d(\tilde{a},\tilde{b}) = \frac{1}{2}\sum_{i=1}^{n} d_{(i)}(\tilde{a},\tilde{b})(m(A_{(i)}) - m(A_{(i+1)})) \quad (5)$$

Where:

$$d_i(\tilde{a},\tilde{b}) = |t_{\tilde{a}}(x_i) - t_{\tilde{b}}(x_i)| + |f_{\tilde{a}}(x_i) - f_{\tilde{b}}(x_i)| + |\pi_{\tilde{a}}(x_i) - \pi_{\tilde{b}}(x_i)|$$

and (·) indicates a permutation such that $d_{(1)}(\tilde{a}, \tilde{b}) \le ... \le d_{(n)}(\tilde{a}, \tilde{b})$, $A_{(i)} = \{x_{(i)}, ..., x_{(n)}\}$, $A_{(n+1)} = \varnothing$.

Obviously, if m is an additive measure on P(X) such that $m(A) = \Sigma_{i\in A} w_i$ $(A \subseteq X)$, the Choquet integral-based Hamming distance is reduced to a weighted Hamming distance.

Definition 5: Let $\tilde{a}_i = (t_{\tilde{a}_i}, f_{\tilde{a}_i})$ (i = 1, 2, ..., n) be a collection of intuitionistic fuzzy values on X, and m be a fuzzy measure on P(X). The intuitionistic fuzzy Choquet integral operator of $\tilde{a}_i$ with respective to m is defined by:

$$\begin{aligned} IFC_m(\tilde{a}_1, \cdots, \tilde{a}_n) &= \tilde{a}_{(1)}(m(A_{(1)}) - m(A_{(2)})) \oplus \tilde{a}_{(2)}(m(A_{(2)}) - m(A_{(3)})) \oplus \cdots \oplus \tilde{a}_{(n)}(m(A_{(n)}) - m(A_{(n+1)})) \\ &= \sum_{i=1}^{n}{}^{\oplus} \tilde{a}_{(i)}(m(A_{(i)}) - m(A_{(i+1)})) \end{aligned}$$

where, (·) indicates a permutation on X such that $\tilde{a}_{(1)} \le ... \le \tilde{a}_{(n)}$. And $A_{(i)} = ((i), ..., (n))$, $A_{(n+1)} = \varnothing$. Furthermore, their aggregated value is also an intuitionistic fuzzy value, and:

$$IFC_m(\tilde{a}_1, \cdots, \tilde{a}_n) = \left(1 - \prod_{i=1}^{n}(1 - t_{\tilde{a}_{(i)}})^{m(A_{(i)}) - m(A_{(i+1)})}, \prod_{i=1}^{n}(f_{\tilde{a}_{(i)}})^{m(A_{(i)}) - m(A_{(i+1)})}\right)$$

INTUITIONISTIC FUZZY MULTICRITERIA GROUP DECISION MAKING APPROACH

Evaluating and selecting information systems projects in an organization is complex and challenging. The complexity of the selection process is due to the multidimensional nature of the decision process, the conflicting nature of the multiple selection criteria and the presence of subjectiveness and imprecision in the human decision making process (Santhanam and Kyparisis, 1996). As a result, the information systems project evaluation and selection problem is a multicriteria group decision making problem.

The main concerns with the existing approaches lie with (a) The inappropriateness of handling the subjectiveness and imprecision, (b) Cognitive demanding on the decision maker in making subjective assessments, and (c) The use of additive aggregation operators that ignore the inter-dependence among criteria or decision makers in the multicriteria group decision making process. To effectively overcome these concerns, this section presents an intuitionistic fuzzy multicriteria group decision making approach based on TOPSIS (Hwang and Yoon, 1981) method for solving the information systems project evaluation and selection problem.

Evaluating and selecting information systems projects usually involves in (a) discovering all the alternative information systems projects denoted as a_i, $A = (a_1, a_2, ..., a_m)$ is the set of the considered alternatives, (b) Identifying the selection criteria, c_j, $C = (c_1, c_2, ..., c_n)$ is the set of the criteria used for evaluating the alternatives, (c) Inviting a group of expert e_k, $E = (e_1, e_2, ..., e_r\}$ is the set of the experts involved, (d) Assessing the performance ratings of the alternative projects x_{ij} with respect to each criterion and the relative importance of the selection criteria, (e) Aggregating the ratings for producing an overall performance index for each project across all criteria and (f) Selecting the best information systems project (Lee and Kim, 2001).

To effectively model the existing subjectiveness, imprecision and vagueness, linguistic variables approximated by intuitionistic fuzzy values are shown as in Table 1 by multiple decision makers and are applied in the information systems project evaluation and selection process due to their capability in describing complex phenomena which are hard to defined precisely (Deng and Yeh, 2006).

For every alternative information systems project $a_i(i = 1,..., m)$, expert $e_k(k = 1,..., r)$ is invited to express his/her individual subjective preference with respect to criterion $c_j(j = 1, ..., n)$ using the linguistic variables expressed in intuitionistic fuzzy values. As a result, a decision matrix of the multicriteria group decision making problem by expert $e_k(k = 1, ..., r)$ can be obtained as follows:

$$R^k = \begin{pmatrix} \tilde{a}_{11}^k, \tilde{a}_{12}^k, & \cdots, & \tilde{a}_{1n}^k \\ \tilde{a}_{21}^k, \tilde{a}_{22}^k, & \cdots, & \tilde{a}_{2n}^k \\ \cdots & \cdots & \cdots \\ \tilde{a}_{m1}^k, \tilde{a}_{m2}^k, & \cdots, & \tilde{a}_{mn}^k \end{pmatrix} \tag{6}$$

Generally, invited experts may come from similar fields so that they possess similarly professional knowledge and preference. That is to say, there are interactive phenomena among experts. It is more suitable to use fuzzy measure to represent the importance of experts. The λ-fuzzy measure g can be used for determining the importance of each expert e_k ($k = 1, 2, ..., r$). According to (4), the parameter λ of expert e_k can be calculated. Then the importance of each combination of experts can be obtained by Eq. 3.

Having considered the inter-dependence of the preferences of experts, intuitionistic fuzzy Choquet integral operator can be used to aggregate all experts' individual subjective assessments for the alternative information systems projects into a group opinion. In order to do this, $\tilde{a}_{ij}^k$ in Eq. 6 is reordered such that

Table 1: Linguistic variables approximated by intuitionistic fuzzy values

Linguistic variable	Intuitionistic fuzzy value
Extremely good (EG)/extremely high EH)	(1.00, 0.00)
Very good (VG)/very high (VH)	(0.80, 0.10)
Good (G)/high (H)	(0.70, 0.20)
Medium good (MG)/medium high (MH)	(0.60, 0.30)
Fair (G)/medium (M)	(0.50, 0.40)
Medium bad (MB)/medium low (ML)	(0.40, 0.50)
Bad (B)/low (L)	(0.30, 0.60)
Very bad (VB)/very low (VL)	(0.20, 0.70)
Extremely bad (EB)/Extremely low (EL)	(0.00, 1.00)

$\tilde{a}_{ij}^{(k)} \le \tilde{a}_{ij}^{(k+1)}$ by Definition 2. The aggregated collective intuitionistic fuzzy decision matrix for the information systems project evaluation and selection problem can then be obtained as follows:

$$R = \begin{pmatrix} \tilde{a}_{11}, \tilde{a}_{12}, & \cdots, & \tilde{a}_{1n} \\ \tilde{a}_{21}, \tilde{a}_{22}, & \cdots, & \tilde{a}_{2n} \\ \cdots & \cdots & \cdots \\ \tilde{a}_{m1}, \tilde{a}_{m2}, & \cdots, & \tilde{a}_{mn} \end{pmatrix} \tag{7}$$

Where:

$$\tilde{a}_{ij} = IFC_g(\tilde{a}_{ij}^1, \cdots, \tilde{a}_{ij}^r) = (1 - \prod_{k=1}^{r}(1 - t_{\tilde{a}_{ij}^{(k)}})^{g(A_{(k)}) - g(A_{(k+1)})}, \prod_{k=1}^{r}(f_{\tilde{a}_{ij}^{(k)}})^{g(A_{(k)}) - \mu(A_{(k+1)})}) \tag{8}$$

$A_{(k)} = \{e_{(k)}, ..., e_{(r)}\}$, $A_{(r+1)} = \varnothing$ and $g(A_{(k)})$ can be calculated.

In line with the TOPSIS method, the positive intuitionistic fuzzy positive-ideal solution and the intuitionistic fuzzy negative-ideal solution can be determined. Assume J_1 be a collection of benefit criteria and J_2 be a collection of cost criteria. The intuitionistic fuzzy positive-ideal solution, denoted as $\tilde{a}^+ = (\tilde{a}^+_1, ..., \tilde{a}^+_n)$ and the intuitionistic fuzzy negative-ideal solution, denoted as $\tilde{a}^- = (\tilde{a}^-_1, ..., \tilde{a}^-_n)$, are defined as follows, respectively:

$$\begin{aligned} \tilde{\alpha}^+ &= \{\langle c_j, ((\max_i t_{\tilde{a}_{ij}} | j \in J_1, \min_i t_{\tilde{a}_{ij}} | j \in J_2), \\ &(\min_i f_{\tilde{a}_{ij}} | j \in J_1, \max_i f_{\tilde{a}_{ij}} | j \in J_2)])\rangle | i = 1, 2, \ldots, m\} \\ &= (\tilde{\alpha}_1^+, \tilde{\alpha}_2^+, \ldots, \tilde{\alpha}_n^+) \text{ where, } \tilde{\alpha}_j^+ = (t_{\alpha_j^+}, f_{\alpha_j^+})(j = 1, ..., n) \end{aligned}$$

$$\begin{aligned} \tilde{\alpha}^- &= \{\langle c_j, ((\min_i t_{\tilde{a}_{ij}} | j \in J_1, \max_i t_{\tilde{a}_{ij}} | j \in J_2), \\ &(\max_i f_{\tilde{a}_{ij}} | j \in J_1, \min_i f_{\tilde{a}_{ij}} | j \in J_2)])\rangle | i = 1, 2, \ldots, m\} \\ &= (\tilde{\alpha}_1^-, \tilde{\alpha}_2^-, \ldots, \tilde{\alpha}_n^-) \text{ where, } \tilde{\alpha}_j^- = (t_{\alpha_j^-}, f_{\alpha_j^-})(j = 1, ..., n) \end{aligned}$$

According to the Choquet integral-based Hamming distance, the separation measures, $d_i(a_i, \tilde{\alpha}^+)$ and $d_i(a_i, \tilde{\alpha}^-)$, of each alternative from intuitionistic fuzzy positive-ideal and negative-ideal solutions, $\tilde{\alpha}^+$ and $\tilde{\alpha}^-$, are calculated, respectively:

$$d_i(a_i,\tilde{\alpha}^+)=\frac{1}{2}\sum_{j=1}^{n} d_{i(j)}(\tilde{a}_{ij},\tilde{\alpha}_j^+)(g(A_{(j)})-g(A_{(j+1)})) \tag{9}$$

Where:

$$d_{ij}(\tilde{a}_{ij},\tilde{\alpha}_j^+)=|t_{\tilde{\alpha}_j^+}-t_{\tilde{a}_{ij}}|+|f_{\tilde{\alpha}_j^+}-f_{\tilde{a}_{ij}}|+|\pi_{\tilde{\alpha}_j^+}-\pi_{\tilde{a}_{ij}}|$$

and $(\cdot)$ indicates a permutation such that $d_{i(1)}(\tilde{a}_{ij}, \tilde{\alpha}^+_j)\le \ldots \le d_{i(n)}(\tilde{a}_{ij}, \tilde{\alpha}^+_j)$, $A_{(j)} = \{c_{(j)}, \ldots, c_{(n)}\}$, $A_{(n+1)} = \varnothing$. $g(A_{(j)})$ is the importance of each combination of criteria, which can be obtained by Eq. 3:

$$d_i(a_i,\tilde{\alpha}^-)=\frac{1}{2}\sum_{j=1}^{n} d_{ij}(\tilde{a}_{ij},\tilde{\alpha}_j^-)(g(A_{(j)})-g(A_{(j+1)})) \tag{10}$$

Where:

$$d_{ij}(\tilde{a}_{ij},\tilde{\alpha}_j^-)=|t_{\tilde{\alpha}_j^-}-t_{\tilde{a}_{ij}}|+|f_{\tilde{\alpha}_j^-}-f_{\tilde{a}_{ij}}|+|\pi_{\tilde{\alpha}_j^-}-\pi_{\tilde{a}_{ij}}|$$

and $(\cdot)$ indicates a permutation such that $d_{i(1)}(\tilde{a}_{ij},\tilde{\alpha}_j^-)\le\cdots\le d_{i(n)}(\tilde{a}_{ij},\tilde{\alpha}_j^-)$ $A_{(j)} = \{c_{(j)}, \ldots, c_{(n)}\}$, $A_{(n+1)} = \varnothing$.

An alternative is preferred if it has the shortest distance from the positive ideal solution and, at the same time, the farthest distance from the negative ideal solution. With this in mind, the overall performance of alternative a_i with respect to all the selection can be calculated as follows:

$$r(a_i)=\frac{d_i(x_i,\tilde{\alpha}^-)}{d_i(x_i,\tilde{\alpha}^+)+d_i(x_i,\tilde{\alpha}^-)},\ i=1,2,\ldots,m \tag{11}$$

where, $0\le r(a_i)\le 1$. The larger the index value, the better the performance of the alternative.

For solving the real information systems project evaluation and selection problem, the multicriteria group decision making approach discussed above can be summarized in the form of an algorithm as follows:

Step 1: Construct an intuitionistic fuzzy decision matrix based on the subjective assessments of individual decision makers

Step 2: Determine the importance of each expert e_k (k = 1,..., r). Then the importance of each combination of experts can be obtained by Eq. 3

Step 3: Construct a collective intuitionistic fuzzy decision matrix

Step 4: Obtain the intuitionistic fuzzy positive-ideal solut-ion and the intuitionistic fuzzy negative-ideal solution

Step 5: Confirm the importance of each criterion c_j (j = 1, 2, ..., n), that is, the fuzzy density $g_k = g(e_k)$ of each criterion c_j. According to (4), the parameter λ of criterion c_j can be calculated. Then the importance of each combination of criteria c_j can be obtained by Eq. 3

Step 6: Calculate the separation measures from the intuitionistic fuzzy positive-ideal solution and negative-ideal solution, $\tilde{\alpha}^+$ and $\tilde{\alpha}^-$, respectively

Step 7: Calculate the closeness coefficient to the intuiti-onistic fuzzy ideal solution

Step 8: Rank all the alternatives

A NUMERICAL EXAMPLE

This section presents an example in evaluating and selecting information systems projects in an organization. A high-technology manufacturing company has to select a suitable information system project to develop a new product. After preliminary screening, four alternative information systems projects, a_1, a_2, a_3 and a_4, remain for further evaluation. A committee of three decision makers, e_1, e_2 and e_3, has been formed for evaluating and selecting the most suitable project. Four selection criteria are identified including (a) the Strategic Alignment Capability (c_1), (b) the Finance Attractiveness (c_2), (c) the Potential Risk (c_3) and (d) the Technical Capability (c_4) (Lederer and Sethi, 1988; Moore and Baker, 1969). The four information systems projects are to be evaluated with respect to these four selection criteria, leading to one information systems project being selected for development in the organization.

The Strategic Alignment Capability of an information systems project reflects the perception of the decision maker on how individual information systems projects serve the organizational strategy and objectives in the long term (Ghasemzadeh and Archer, 2000). The Financial Attractiveness of an information systems project concerns with the economical feasibility of an information systems project (Santhanam and Kyparisis, 1995). It is measured by the project cost, the contribution to profitability, and the project's growth rate. The Potential Risk of an information systems project involves the subjective assessment of the decision maker regarding the potential of failure of an information systems project (Lee and Kim, 2001). This is often assessed from the technical risk, the risk of cost overruns and the size risk of individual project involved for selection. The Technical

Capability of an information systems project reflects the expectation of the management of an organization towards the technical specification of an information systems project with respect to the information systems function and architecture (Deng, 2005).

Following the procedure of the proposed approach as above, the information systems project evaluation and selection problem can be solved as follows:

Step 1: Construct the three intuitionistic fuzzy decision matrices based on the subjective assessments of individual decision makers using the linguistic variables defined as in Table 1:

$$R^1 = \begin{pmatrix} G, & MG, & VL, & G \\ MG, & F, & L, & MG \\ VG, & VG, & VL, & VG \\ MG, & F, & VL, & G \end{pmatrix} = \begin{pmatrix} (0.70,0.20), & (0.60,0.30), & (0.20,0.70), & (0.70,0.20) \\ (0.60,0.30), & (0.50,0.40), & (0.30,0.60), & (0.60,0.30) \\ (0.80,0.10), & (0.80,0.10), & (0.20,0.70), & (0.80,0.10) \\ (0.60,0.30), & (0.50,0.40), & (0.20,0.70), & (0.70,0.20) \end{pmatrix}$$

$$R^2 = \begin{pmatrix} VG, & G, & L, & G \\ G, & MG, & ML, & F \\ VG, & G, & VL, & VG \\ G, & F, & L, & MG \end{pmatrix} = \begin{pmatrix} (0.80,0.10), & (0.70,0.20), & (0.30,0.60), & (0.70,0.20) \\ (0.70,0.20), & (0.60,0.30), & (0.40,0.50), & (0.50,0.40) \\ (0.80,0.10), & (0.70,0.20), & (0.20,0.70), & (0.80,0.10) \\ (0.70,0.20), & (0.50,0.40), & (0.30,0.60), & (0.60,0.30) \end{pmatrix}$$

$$R^3 = \begin{pmatrix} G, & MG, & VL, & G \\ F, & G, & ML, & MG \\ VG, & VG, & L, & G \\ G, & MG, & L, & MG \end{pmatrix} = \begin{pmatrix} (0.70,0.20), & (0.60,0.30), & (0.20,0.70), & (0.70,0.20) \\ (0.50,0.40), & (0.70,0.20), & (0.40,0.50), & (0.60,0.30) \\ (0.80,0.10), & (0.80,0.10), & (0.30,0.60), & (0.70,0.20) \\ (0.70,0.20), & (0.60,0.30), & (0.30,0.60), & (0.60,0.30) \end{pmatrix}$$

Step 2: Determine the importance of each expert, that is, the fuzzy density $g_k = g(e_k)$ of each expert e_k (k= 1, 2, 3)

Suppose that $g(e_1) = 0.40$, $g(e_2) = 0.40$, $g(e_3) = 0.40$. According to (4), then λ of expert can be determined $\lambda_2 = -0.44$. Then the importance of each combination of experts can be obtained by (3), we have $g(e_1, e_2) = g(e_1, e_3) = g(e_2, e_3) = 0.73$, $g(e_1, e_2, e_3) = 1$.

- **Step 3:** Construct the collective intuitionistic fuzzy decision matrix

By Definition 2, $\tilde{\alpha}^k_{ij}$ is reordered such that $\tilde{\alpha}^{(k)}_{ij} \le \tilde{\alpha}_{ij}^{k+1}$, utilize the intuitionistic fuzzy Choquet integral operator:

$$\tilde{a}_{ij} = IFC_g(\tilde{a}^1_{ij}, \tilde{a}^2_{ij}, \tilde{a}^3_{ij}) = (1 - \prod_{k=1}^{3}(1 - t_{\tilde{a}^{(k)}_{ij}})^{g(A_{(k)}) - g(A_{(k+1)})}, \prod_{k=1}^{3}(f_{\tilde{a}^{(k)}_{ij}})^{g(A_{(k)}) - g(A_{(k+1)})}])$$

to aggregate all intuitionistic fuzzy decision matrices $R^k = (\tilde{\alpha}^k_{ij})_{4\times4}$ (k = 1, 2, 3) into a collective intuitionistic fuzzy decision matrix $R = (\tilde{\alpha}_{ij})_{4\times4}$ as follows:

$$R = \begin{pmatrix} (0.75,0.15), & (0.64,0.26), & (0.24,0.66), & (0.70,0.20) \\ (0.62,0.28), & (0.62,0.28), & (0.37,0.53), & (0.58,0.32) \\ (0.80,0.10), & (0.78,0.12), & (0.24,0.66), & (0.78,0.12) \\ (0.68,0.22), & (0.54,0.36), & (0.27,0.63), & (0.64,0.26) \end{pmatrix}$$

- **Step 4:** Obtain the intuitionistic fuzzy positive-ideal solution and the intuitionistic fuzzy negative-ideal solution

Strategic Alignment Capability, Finance Attractiveness and Technical Capability are benefit criteria $J_1 = \{c_1, c_2, c_4\}$. Potential Risk is cost criteria $J_2 = \{c_3\}$. Then the intuitionistic fuzzy positive-ideal solution and the intuitionistic fuzzy negative-ideal solution are obtained as follows:

$$\tilde{\alpha}^+ = ((0.80,0.10),(0.78,0.12),(0.24,0.66),(0.78,0.12))$$
$$\tilde{\alpha}^- = ((0.62,0.28),(0.54,0.36),(0.37,0.53),(0.58,0.32))$$

- **Step 5:** Confirm the importance of each criterion c_j (j = 1, 2, 3, 4), that is, the fuzzy density $g_k = g(e_k)$ of each criterion c_j

According to decision makers opinions, we have $g(c_1) = 0.40$, $g(c_2) = 0.25$, $g(c_3) = 0.37$, $g(c_4) = 0.20$. According to (4), the λ of criteria can be determined $\lambda_2 = -0.44$. By (3), we have $g(c_1, c_2) = 0.60$, $g(c_1, c_3) = 0.70$, $g(c_1, c_4) = 0.56$, $g(c_2, c_3) = 0.68$, $g(c_2, c_4) = 0.43$, $g(c_3, c_4) = 0.54$, $g(c_1, c_2, c_3) = 0.88$, $g(c_1, c_2, c_4) = 0.75$, $g(c_2, c_3, c_4) = 0.73$, $g(c_1, c_3, c_4) = 0.84$, $g(c_1, c_2, c_3, c_4) = 1.0$.

Step 6: Calculate the separation measures

According to (9) and (10), respectively, we have:

$d_1(a_1, \tilde{\alpha}^+) = 0.0654$, $d_1(a_1, \tilde{\alpha}^-) = 0.1238$, $d_2(a_2, \tilde{\alpha}^+) = 0.1677$, $d_2(a_2, \tilde{\alpha}^-) = 0.02$, $d_3(a_3, \tilde{\alpha}^+) = 0.0$, $d_3(a_3, \tilde{\alpha}^-) = 0.1861$, $d_4(a_4, \tilde{\alpha}^+) = 0.1311$, $d_4(a_4, \tilde{\alpha}^-) = 0.0652$.

Step 7: Calculate the closeness coefficients

According to Eq. 11, the closeness coefficient of each alternative is calculated as follows:

$r(a_1) = 0.6543$, $r(a_2) = 0.1066$, $r(a_3) = 1$, $r(a_4) = 0.3321$

Step 8: Rank the alternatives

Rank all the alternatives a_i (i = 1, 2, 3, 4) according to the closeness coefficients $r(a_i)$:

Thus a_3 is selected as appropriate IS projects among the alternatives.

CONCLUSION

Information systems project evaluation and selection has become increasingly important for organizations in today's competitive environment. The evaluation and selection process, however, is complex and challenging due to the multi-dimensional nature of the process, the presence of subjectiveness and imprecision inherent in the human decision making process, and the existence of interdependence between the criteria and the preferences of decision makers. This study presents an intuitionistic fuzzy multicriteria group decision making approach for effectively solving the information systems project evaluation and selection problem. Linguistic variables approximated by intuitionistic fuzzy values are used for adequately modeling the subjectiveness and imprecision of the decision making process. A fuzzy Choquet integral operator is utilized for effectively aggregating the fuzzy assessments of the decision makers into a collective opinion. With the use of the ideal solution concept, the overall performance of each information systems project across all the selection criteria is calculated. An example is presented which shows that the proposed approach is effective for solving the information systems project evaluation and selection problem.

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REFERENCES

Atanassov, K., 1999. Intuitionistic Fuzzy Sets: Theory and Applications, 35, Studies in Fuzziness and Soft Computing. Springer Verlag, Heidelberg.

Bustince, H., F. Herrera and J. Montero, 2007. Fuzzy Sets and Their Extensions: Representation, Aggregation and Models. Physica-Verlag, Heidelberg.

Chen, C.T. and H.L. Cheng, 2009. A comprehensive model for selecting information system project under fuzzy environment. Int. J. Proj. Manage., 27: 389-399.

Deng, H. and C.H. Yeh, 2006. Simulation-based evaluation of defuzzification-based approaches to fuzzy multiattribute decision making. IEEE Trans. Syst. Man Cybernetics, Part A: Syst. Humans, 36: 968-977.

Deng, H., 2005. A fuzzy approach to selecting information systems projects. Int. J. Comput. Inf. Sci., 6: 13-21.

Ghasemzadeh, F. and N.P. Archer, 2000. Project portfolio selection through decision support. Decis. Support Syst., 29: 73-88.

Hwang, C.L. and K. Yoon, 1981. Multiple Attributes Decision Making Methods and Applications. Springer, Berlin, Pages: 259.

Lederer, A.L. and V. Sethi, 1988. The implementation of strategic information systems planning methodologies. MIS Quart., 12: 445-461.

Lee, J.W. and S.H. Kim, 2001. An integrated approach for interdependent information system project selection. Int. J. Proj. Manage., 19: 111-118.

Moore, J.R. and N.R. Baker, 1969. An analytical approach to scoring model design application to research and development project selection. IEEE Trans. Eng. Manage., 16: 90-98.

Santhanam, R. and J. Kyparisis, 1995. A multiple criteria decision model for information system project selection. Comput. Oper. Res., 22: 807-818.

Santhanam, R. and G.J. Kyparisis, 1996. A decision model for interdependent information system project selection. Eur. J. Operat. Res., 89: 380-399.

Sugeno, M., 1974. Theory of fuzzy integrals and its applications. Ph.D. Thesis, Institute of Technology, Tokyo.

Sylwester, F., 2010. Method of management support for electric power distribution systems. Prez. Elektrotechniczn., 86: 330-335.

Tan, C. and X. Chen, 2010. Intuitionistic fuzzy Choquet integral operator for multi-criteria decision making. Expert Syst. Appl., 37: 149-157.

Zadeh, L.A., 1965. Fuzzy sets. Inform. Control, 8: 338-353.

Zimmermann, H.J., 1986. Fuzzy Sets, Decision Making and Expert System. Kluwer Academic Publisher, Boston, ISBN: 0-898-38149-5.