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Optimizing partners' choice in IS/IT outsourcing projects: The strategic decision of fuzzy VIKOR

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The decision of strategic information system/information technology (IS/IT) outsourcing requires close attention to the evaluation of supplier/vendor selection process because the selection decision involves conflicting multiple criteria and is replete with complex decision-making problems. Selecting the most appropriate suppliers/vendors is considered an important strategic decision that may impact the performance of outsourcing engagements. The purpose of this study is to provide a more efficient delivery approach for evaluating and assessing possible suppliers/vendors. Using the fuzzy VIKOR method, this study provides a rational and systematic process for developing the best alternative and compromise solution under each of the selection criteria. The study's finding offers an important reference for resolving fuzzy multi-criteria decision-making problems.

1. Introduction

In recent years, advances in technology have forced firms to develop their core competencies through the outsourcing of strategic information system/information technology (IS/IT). Dhar and Balakrishnan (2006) indicated that IS/IT outsourcing is a way to transfer some or all of IS/IT-related decision-making rights, business processes, internal activities, and services to external providers, which can more effectively manage time and costs as well as improve productivity, quality, and customer satisfaction. Consequently, many organizations seek to improve their competitiveness, reduce costs, focus more of their internal resources on core activities, and sustain their competitive advantage by engaging in IS/IT outsourcing (Parry et al., 2006).

IS/IT outsourcing, and facilities management in particular, is growing dramatically and continues to be a tempting strategy by which organizations can leverage their specialized technologies and core competencies. In conceptual and empirical studies, the concept of transaction cost economics (TCE) and resource-based view (RBV) have emerged as theoretical approaches explaining the choice of a strategy in the IS/IT outsourcing decision-making process (Cao and Wang, 2007; Williamson, 1985). TCE is concerned with discovering the most efficient arrangement for an economic transaction in regard to which a firm must basically choose between carrying out the transaction itself, engaging in an externalized transaction, or collaborating with a third party (Gemser et al., 2004). In general, TCE has provided firms with the greatest efficiency in terms of cost minimization and has identified organizational capabilities for improving competence and sustained performance (Santos and Eisenhardt, 2005). From the RBV standpoint IS/IT outsourcing provides an alternative strategy that gives firms the ability to effectively leverage knowledge transfer capabilities in which knowledge is a potential source of competitive advantage (Bourlakis and Bourlakis, 2005). Thus, firms have the competitive advantage when they possess capabilities, processes, and/or knowledge that help them

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differentiate the value that they provide their customers from that provided by their competitors (Collins and Hitt, 2006).

Firms seek to capitalize on and increase their capabilities and endowments, and interfirm cooperation allows firms to share resources and, thereby, overcome resource-based constraint to growth (Halawi et al., 2006). Recent studies have focused on the capability of partnerships to create significant competitive advantages in a complex environment. Having a long-term relationship with a well-chosen supplier can reduce the cost of material and improve corporate competitiveness. Many research results have indicated that the decision involved in selecting suppliers becomes the most important activity of an outsourcing process (Aissaoui et al., 2007). In the management of IS/IT outsourcing activities, supplier/vendor selection decisions are an important component of the IS/IT outsourcing process, where the firm has to choose between a number of distinct IS/IT suppliers/vendors (Araz and Ozkarahan, 2007; Xia and Wu, 2007). In general, selecting the right supplier/vendor is always a difficult task for decision-makers; in particular, the trend of IS/IT outsourcing activities requires close attention to the outsourcing contract selection process because the process of selection decisions is replete with complex decision problems (Almeida, 2007), especially in uncertain situations involving multiple and possibly conflicting criteria or objectives and including a variety of preferences among decision makers. Therefore, the decision to outsource IS/IT projects should be weighed carefully, as an effective decision is critical to the company's future success.

In the supplier/vendor evaluation process, the strategic decision often incorporated critical product- and service-related decision criteria, such as price, delivery performance, and quality (Opricovic, 1998; Amid et al., 2006). Dickson (1966) identified 23 supplier/vendor selection criteria that provided a framework for the evaluation of the supplier/vendor selection process. Weber et al. (1991) proposed that supplier/vendor selection is a multi-criteria decision-making process since supplier/vendor selection is a multi-criteria problem that includes both tangible and intangible criteria (Demirtas and Üstün, 2008). Ellram (1990) presented three dimensions of selection criteria, which emphasized the financial stability of the supplier/vendor, the organizational culture and strategic fit of supplier/vendor, as well as the technological capabilities of the supplier/vendor. In other studies, Grupe (1997) and Akomode et al. (1998) determined several criteria to which firms must pay close attention during the outsourcing process because the selection of an available supplier/vendor is critical to the success of an outsourcing relationship.

Decision making, however, is the procedure of seeking the best solution among a set of feasible alternatives in the presence of multiple criteria. Firms are faced with complex and multi-criteria decision-making problems in selecting IS/IT suppliers/vendors, and the inherently subjective nature of human judgments may not always be realistic or feasible in dealing with the complexity and uncertainty involved in real-world decision-making problems (Yu, 1973; Opricovic, 1998; Wadhwa and Ravi Ravindran, 2007). An effective tool is needed to help firms prequalify their suppliers/vendors based on their overall performances in order to adequately exploit and evaluate the outsourcing decision (Talluri and Narasimhan, 2004; Bottani and Rizzi, 2008). In choosing an analytical method, such as mathematical, statistical, or theoretical models for dealing with imprecise, uncertain, and complex decision-making problems, researchers have proposed several effective tools connected with fuzzy set applications and different multi-criteria decision-making (MCDM) approaches, such as the technique for order preference by similarity to ideal solution (TOPSIS). Further studies have extended MCDM in a fuzzy environment by using a fuzzy multi-criteria decision-making (FMCDM) method or other advanced techniques, such as the VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method, to solve the problem for the supplier/vendor selection.

Fuzzy logic, or fuzzy set theory, was proposed by Zadeh (1965) in 1965 as a mathematical concept to deal with decision-making problems in which the phenomena are imprecise, and uncertain, with conflict of preferences involved in the selection process. Zadeh's fuzzy set theory offers a mathematical system form and helps to reduce the complexity of modeling nonlinear problems by using linguistic variable or fuzzy numbers to identify the conditions in the system and reduce them to a rule base that gives varying responses to varying multiple inputs (Opricovic and Tzeng, 2007; Bellman and Zadeh, 1970). MCDM is a complex, dynamic process in which the ratings and the weights of criteria are measured in crisp numbers. The classical MCDM method, TOPSIS, was first developed by Yoon and Hwang (1985) as a multiple-criteria decision-making method that viewed a multi-attribute decision-making (MADM) or a MCDM problem with m alternatives as a geometric formula with m points in k-dimensional space (Chen, 2000). The basic principle of this method is that the chosen alternative should have the shortest possible distance from the positive ideal solution (PIS) and the farthest possible distance from the negative ideal (NIS). With this characteristic, the process is employed to obtain crisp performance values for determining the rank order of all alternatives and identifying solutions from a finite set of alternatives by two reference points based on the shortest distance from the PIS and the farthest from the NIS or nadir using these two reference points (Dweiri and Kablan, 2006; Chen et al., 2006). Thus, MCDM establishes preferences for evaluating, ranking problems, and selecting available alternatives from a set of alternatives in the presence of multiple (usually conflicting) criteria (Gomes et al., 2008). Specifically, MCDM methods generally required the definition of quantitative weights for the criteria among the feasible alternatives and established criteria.

Moreover, Bellman and Zadeh (1970) manipulated the fuzzy set concept and the MCDM method to consider the fuzziness in the decision data and group decision-making process. They proposed a FMCDM process based on the incorporated efficient fuzzy model and concepts of positive and negative ideal points for solving multi-criteria decision-making problems with multi-judges and multiple criteria in a fuzzy environment (Zeleny, 1974). In addition, the VIKOR method was developed by Opricovic (1998) in 1998 to solve MCDM problems with conflicting and non-commensurable criteria (Opricovic and Tzeng, 2004). It is used to determine a ranked list from a set of alternatives, the compromise solution for a problem with conflicting criteria, and to determine the weight stability intervals for preference stability of the compromise solution obtained with the given weights (Opricovic and Tzeng, 2007). The VIKOR method of compromise-ranking determines a compromise solution that provides the maximum group utility for the majority and a minimum of individual regret for the opponent. Within the VIKOR method, the compromise ranking could be performed by comparing the measure of closeness to the ideal alternative through the process of ranking and selecting a set of alternatives in the presence of conflicting criteria.

Based on empirical evidence, multiple and contradictory evaluation standards exist in most decision-making processes. The VIKOR method is an effective tool in multi-criteria decision making, particularly in situations where the decision-maker is unable to indicate preferences among decisions that may result in diverse outcomes. However, in the decision-making process, crisp data may not always be adequate to present the real situation, since human perception, judgment, intuition, and preference remain vague and difficult to measure. Fuzzy logic, or fuzzy set theory, is a way of addressing vague concepts and provides a means for representing uncertainty in order to handle the vagueness involved in real-world situations. Therefore, the purpose of this study is to provide a more efficient delivery approach for selecting the supplier/vendor that fits best. Particularly, the study proposes an integrated VIKOR framework under the fuzzy environment condition by using realistic examples to determine the compromise solution for a problem with conflicting criteria and to determine the preferable compromise ranked list from a set of alternatives for making an IS/IT outsourcing decision. The fuzzy VIKOR, as proposed, was also described by Wang and Chang (2005). It made an effective sourcing decision to find a preferable compromise with a best solution.

In this study, the proposed fuzzy VIKOR method is presented in Section 2. Sample and data for this study are discussed in Section 3. The illustrative example of the proposed method for the supplier/vendor selection is presented in Section 4. Section 5 draws a conclusion, including managerial implications, limitations, and future research.

2. Proposed fuzzy VIKOR method

Based on the concept of fuzzy logic and the VIKOR method, the proposed fuzzy VIKOR method has been developed to provide a rational, systematic process by which to discover a best solution and a compromise solution that can be used to resolve a fuzzy multi-criteria decision-making problem. The proposed fuzzy VIKOR allows decision-makers to specify the preferred solutions for a given decision problem in real organizational settings. The procedure of fuzzy VIKOR consists of the following steps:

Step 1: Generate feasible alternatives, determine the evaluation criteria, and form a group of decision makers. Assume that there are m alternatives, k evaluation criteria, and n decision makers.

Step 2: Define linguistic variables and their corresponding triangular fuzzy numbers. Linguistic variables were used to evaluate the importance of the criteria and the ratings of alternatives with respect to various criteria. A triangular fuzzy number can be defined as a triplet $\tilde{A} = (a_1, a_2, a_3)$ of crisp numbers with $a_1 < a_2 < a_3$ and membership function $f_{\tilde{A}}(x)$ of the fuzzy number $\tilde{A}$ is given by (see Fig. 1)

$$f_{\tilde{A}}(x) = \begin{cases} 0, & x < a_1 \\ (x - a_1)/(a_2 - a_1), & a_1 \leqslant x \leqslant a_2 \\ (a_3 - x)/(a_3 - a_2), & a_2 \leqslant x \leqslant a_3 \\ 0, & x > a_3 \end{cases} \quad (1)$$

Suppose that $\tilde{A}$ and $\tilde{B}$ are two triangular fuzzy numbers (TFN) parameterized by the triplet (a_1, a_2, a_3) and (b_1, b_2, b_3), respectively, the operational laws of these two triangular fuzzy numbers are as follows: $\tilde{A}(+)\tilde{B} = (a_1, a_2, a_3)(+)(b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$ $\tilde{A}(-)\tilde{B} = (a_1, a_2, a_3)(-)(b_1, b_2, b_3) = (a_1 - b_3, a_2 - b_2, a_3 - b_1)$ $\tilde{A}(\times)\tilde{B} = (a_1, a_2, a_3)(\times)(b_1, b_2, b_3) = (a_1 b_1, a_2 b_2, a_3 b_3)$ $\tilde{A}(\div)\tilde{B} = (a_1, a_2, a_3)(\div)(b_1, b_2, b_3) = ((a_1/b_3), (a_2/b_2), (a_3/b_1))$ $k\tilde{A} = (ka_1, ka_2, ka_3)$ and $(\tilde{A})^{-1} = ((1/a_3)(1/a_2)(1/a_1))$

Based on these operational laws, Fig. 2 shows an example of three fuzzy numbers $\tilde{A} = (1.2, 3.5, 5.2)$, $\tilde{B} = (2, 4.8, 7.3)$, and $\tilde{C} = (5.3, 8.2, 9.8)$.

In the following, a five-scale linguistic variable fuzzy number was used and it used the study of Chen and Huang (1992) to access the importance of evaluation criteria with a fuzzy set. The linguistic scales and corresponding triangular fuzzy numbers for the weight of criteria and the rating of alternatives, respectively, are as follows:

Linguistic scales for the important weight of criteria: ⌈Very Low (VL)⌋ (0.00,0.00,0.25), Low (L)⌋ (0.00,0.25,0.50),

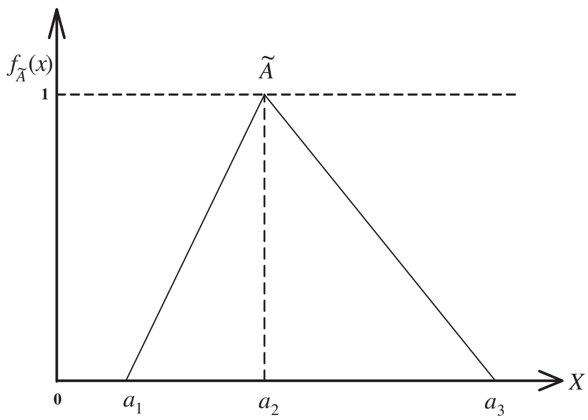

Fig. 1. Membership function of triangular fuzzy number.

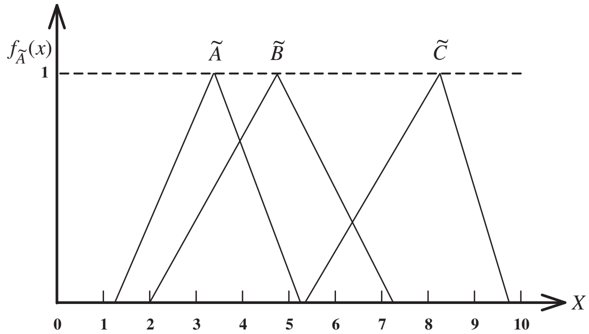

Fig. 2. Three triangular fuzzy numbers.

⌈Medium (M)⌋ (0.25,0.50,0.75), ⌈High (H)⌋ (0.50,0.75, 1.00), Very High (VH)⌋ (0.75,1.00,1.00). Linguistic scales for the rating of alternative: ⌈Worst (W)⌋ (0.0,0.0,2.5), ⌈Poor (P)⌋ (0.0,2.5,5.0), Fair (F)⌋ (2.5,5.0,7.5), ⌈Good (G)⌋ (5.0,7.5, 10), Best (B)⌋ (7.5, 10, 10).

Step 3: Integrate decision-makers' preferences and opinions. The decision is derived by aggregating the fuzzy weight of criteria and fuzzy rating of alternatives from n decision-makers calculated

$$\tilde{w}_j = \frac{1}{n}\left[\sum_{e=1}^{n} \tilde{w}_j^e\right], \quad j = 1,2,\ldots,k \tag{2}$$

In addition, the preferences and opinions of n decision-makers with respect to j criterion for the important weight of each criterion and the rating of each alternative in the ith alternative can be calculated by

$$\tilde{x}_{ij} = \frac{1}{n}\left[\sum_{e=1}^{n} \tilde{x}_{ij}^e\right]], \quad i = 1,2,\ldots,m \tag{3}$$

Step 4: Calculate fuzzy weighted average and construct the (normalized) fuzzy decision matrix

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_k \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mk} \end{bmatrix} \end{array}$$

$$i = 1,2,\ldots,m; j = 1,2,\ldots,k \tag{4}$$

$$\tilde{W} = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_k], \quad j = 1,2,\ldots,k \tag{5}$$

where $\tilde{x}_{ij}$ is the rating of alternative A_i with respect to criterion C_j, and $\tilde{w}_j$ is the important weight of the jth criterion. This study, therefore, denoted linguistic variables $\tilde{x}_{ij}$ and $\tilde{w}_j$ as triangular fuzzy numbers.

Step 5: Determine the fuzzy best value (FBV) and fuzzy worst value (FWV):

$$\tilde{f}_j^* = \max_i \tilde{x}_{ij}, \quad \tilde{f}_j^- = \min_i \tilde{x}_{ij} \tag{6}$$

Step 6: Calculate the values $\tilde{w}_j(\tilde{f}_j^* - \tilde{x}_{ij})/(\tilde{f}_j^* - \tilde{f}_j^-), \tilde{S}_i, \tilde{R}_i$

$$\tilde{S}_i = \sum_{j=1}^{k} \tilde{w}_j(\tilde{f}_j^* - \tilde{x}_{ij})/(\tilde{f}_j^* - \tilde{f}_j^-) \tag{7}$$

$$\tilde{R}_i = \max_j [\tilde{w}_j(\tilde{f}_j^* - \tilde{x}_{ij})/(\tilde{f}_j^* - \tilde{f}_j^-)] \tag{8}$$

where $\tilde{S}_i$ is A_i with respect to all criteria calculated by the sum of the distance for the FBV, and $\tilde{R}_i$ is A_i with respect to the jth criterion, calculated by the maximum distance of FBV

Step 7: Calculate the values $\tilde{S}^*$, $\tilde{S}^-$, $\tilde{R}^*$, $\tilde{R}^-$, $\tilde{Q}_i$:

$$\tilde{S}^* = \min_i \tilde{S}_i, \quad \tilde{S}^- = \max_i \tilde{S}_i$$
$$\tilde{R}^* = \min_i \tilde{R}_i, \quad \tilde{R}^- = \max_i \tilde{R}_i \tag{9}$$

$$\tilde{Q}_i = v(\tilde{S}_i - \tilde{S}^*)/(\tilde{S}^- - \tilde{S}^*) + (1 - v)(\tilde{R}_i - \tilde{R}^*)/(\tilde{R}^- - \tilde{R}^*) \tag{10}$$

Here, $\tilde{S}^*$ is the minimum value of $\tilde{S}_i$, which is the maximum majority rule or maximum group utility, and $\tilde{R}^*$ is the minimum value of $\tilde{R}_i$, which is the minimum individual regret of the opponent. Thus, the index $\tilde{Q}_i$ is obtained and is based on the consideration of both the group utility and individual regret of the opponent. In addition, v here means the weight of the strategy of the maximum group utility. When $v > 0.5$, the decision tends toward the maximum majority rule; and if $v = 0.5$, the decision tends toward the individual regret of the opponent.

Step 8: Defuzzify triangular fuzzy number $\tilde{Q}_i$ and rank the alternatives, sorting by the value Q_i. There are many defuzzification strategies for converting a fuzzy number into a crisp value. This study utilized the method of maximizing set and minimizing set to defuzzify triangular fuzzy number $\tilde{Q}_i$. This method can be defined as follows:

The maximizing set is defined by $R = \{(x, f_R(x)) | x \in R\}$ and

$$f_R(x) = \begin{cases} (x - x_1)/(x_2 - x_1), & x_1 \leqslant x \leqslant x_2 \\ 0 & \text{otherwise} \end{cases} \tag{11}$$

The minimizing set is defined by $L = \{(x, f_L(x)) | x \in R\}$ and

$$f_L(x) = \begin{cases} (x - x_2)/(x_1 - x_2), & x_1 \leqslant x \leqslant x_2 \\ 0 & \text{otherwise} \end{cases} \tag{12}$$

The right utility $U_R(\tilde{Q}_i)$ is defined by

$$U_R(\tilde{Q}_i) = \sup_x (f_{\tilde{Q}_i}(x) \wedge f_R(x)) \tag{13}$$

The left utility $U_L(\tilde{Q}_i)$ is defined by

$$U_L(\tilde{Q}_i) = \sup_x (f_{\tilde{Q}_i}(x) \wedge f_L(x)) \tag{14}$$

The total utility $U_T(\tilde{Q}_i)$ is defined by

$$U_T(\tilde{Q}_i) = [U_R(\tilde{Q}_i) + 1 - U_L(\tilde{Q}_i)]/2 \tag{15}$$

Here, the index Q_i (in which $U_T(\tilde{Q}_i)$ is precise in value) can be obtained after defuzzifying $\tilde{Q}_i$, and Q_i can then be used to rank alternatives. Consequently, the smaller the value Q_i, the better the alternative.

Step 9: Determine a compromise solution. Assume that the two conditions given below are acceptable. Then, by using the index Q_i, determine a compromise solution (a') as a single optimal solution.

[C1] Acceptable advantage:

$$Q(a'') - Q(a') \geqslant DQ$$

$$DQ = \frac{1}{m-1}(DQ = 0.25 \text{ if } m \leqslant 4) \quad (16)$$

[C2] Acceptable stability in decision making: under this condition, $Q(a')$ must be $S(a')$ or/and $R(a')$.

If **[C1]** is not accepted and $Q(a^{(m)}) - Q(a') < DQ$, then $a^{(m)}$ and a' are the same compromise solution. However, a' does not have a comparative advantage, so the compromise solutions $a', a'', \ldots, a^{(m)}$ are the same. If **[C2]** is not accepted, the stability in decision-making is deficient, although a' has a comparative advantage. Hence, compromise solutions of a' and a'' are the same.

Step 10: Select the best alternative. Choose $Q(a')$ as the best solution with the minimum of Q_i.

3. Sample and data

This study integrated fuzzy logic and the VIKOR method to propose the fuzzy VIKOR as systematic solution process for solving fuzzy multi-criteria decision-making problems with the best decision and compromise solution from a number of potential alternatives for a supplier/vendor selection in IS/IT outsourcing project. For the purpose of analysis, decision criteria referred to the study of Dickson (1966), Weber et al. (1991), Ellram (1990), Grupe (1997), and Akomode et al. (1998). As suggested by their studies, 15 strategic decision criteria were adapted. To ensure that these potential assessment criteria were valid measures of IS/IT outsourcing, this study further conducted random interviews with five Taiwan-based computer information manufacturers regarding their prime considerations for supplier/vendor selection. They were asked to estimate the relative importance of the decision-making criteria, using a seven-point Likert scale from 1 (unimportant) to 7 (very important).

Upon completion of the interviews, five decision criteria (i.e., location, management and operation, ethical standard, operating controls, and transportation costs) were excluded because they were considered to be relatively unimportant to outsourcing with mean scores 1.8, 2.2, 3.4, 3.2, and 2.6, respectively. The remaining ten key criteria were constructed, as shown in Table 1, as very important to the success of strategic outsourcing, with a mean value that exceeded 6.0 for each criterion—quality, delivery time, price, reputation, experience, market share, financial performance, performance history, technical capability, and flexibility of supplier/vendor.

Table 1
Mean score of key decision criteria for selection of suppliers/vendors

Criteria	Mean score
C_1: Technical capability	7.0
C_2: Financial performance	6.8
C_3: Performance history	6.6
C_4: Quality	7.0
C_5: Price	6.8
C_6: Flexibility	6.2
C_7: Reputation	6.8
C_8: Delivery time	6.2
C_9: Experience	6.4
C_{10}: Market share	6.2

For the evaluation of the potential supplier/vendor, this study used five IS/IT outsourcing suppliers/vendors and five decision-making experts, who were provided by one of the computer information manufacturers to establish these ten decision criteria as examples for the purpose of this study. The characteristics of the five decision-making experts are shown in Table 2. All of the managers have a minimum of 10 years experience in supplier project management and a sufficient educational background related to their technical management abilities. Additionally, all of the managers have their Project Management Professional (PMP) certification from the Project Management Institute (PMI). Table 3 shows the characteristics of the five suppliers/vendors.

4. The illustrative example

This study assumes that a Taiwan-based computer information manufacturer is engaged in the decision about an IS/IT outsourcing project and intends to select its service supplier/vendor. Suppose that this manufacturer can accept one of five potential suppliers/vendors for this project. Based on the study's purpose, five IS/IT outsourcing suppliers/vendors $(A_1, A_2, \ldots, A_5)$ are then proposed as feasible alternatives to be evaluated by five decision-making experts $(D_1, D_2, \ldots, D_5)$ according to ten decision criteria, such as technological ability (C_1), experience (C_9), and market share (C_{10}), to select most suitable supplier/vendor for the effectiveness of the outsourcing project. The data used for assessment in this study are given, and the evaluation procedure of the proposed fuzzy VIKOR is expressed and summarized as follows:

First, this study generates feasible alternatives (m) and determines ten evaluation criteria (k) and five decision makers (n).

The second step is to define linguistic variables and their corresponding triangular fuzzy numbers.

Then, we integrate the decision makers' preferences and opinions by aggregating the important fuzzy weight of the criteria and the ratings of alternatives, as shown in Tables 4 and 5.

According to Eqs. (2)–(5), the fuzzy weighted average can be obtained, and the results of the aggregate fuzzy weight of criteria are shown in Table 6. Therefore, we construct the weighted normalized fuzzy decision matrix, shown in Table 7.

In addition, the determinants of FBV and FWV are shown in Table 8, based on Eq. (6).

By using Eqs. (7)–(9), the values $\tilde{S}_i$, $\tilde{R}_i$, $\tilde{S}^*$, $\tilde{S}^-$, $\tilde{R}^*$, and $\tilde{R}^-$ can be calculated, shown in Tables 9 and 10.

With Eqs. (10)–(15), the value $\tilde{Q}_i$ can be calculated and defuzzified as shown in Table 11.

Finally, we determine a compromise solution as follows: [C1] acceptable advantage—by using Eq. (16), we can obtain $Q(a'') - Q(a') = 0.3343 \geqslant 0.25$ (C1 Accept) and [C2] acceptable stability in decision making. The results

Table 2
The characteristics of the five decision-making experts

	Gender	Age	Educational level	Experience (years)	Job title	Job responsibility
Decision-making expert 1 (D_1)	Male	51	Bachelor's in mechanical engineering	>20	Technical program manager (PMP)	Leading teams and working on new products and solutions. Supplier management to meet schedules and deliver quality products and related services.
Decision-making expert 2 (D_2)	Male	45	Bachelor's in information engineering	>15	Software program manager (PMP)	Managing ODM supplier activities and the supply chain. Developing and improving products, processes, and components.
Decision-making expert 3 (D_3)	Female	48	Master's in computer science	>15	R&D project manager (PMP)	Leading project team and R&D supplier management. Directing the design and development of new products. Managing internal partners and external vendors.
Decision-making expert 4 (D_4)	Male	46	Bachelor's in computer science	>10	Technical program manager (PMP)	Evaluation and selection of new communications products and suppliers. Developing and managing solutions for product issues.
Decision-making expert 5 (D_5)	Female	50	Master's in electrical engineering	>15	Engineering project manager (PMP)	Managing the engineering team and improving product processes and components. ODM suppliers and contract management.

Table 3
The characteristics of the five suppliers/vendors

	Supplier 1 (A_1)	Supplier 2 (A_2)	Supplier 3 (A_3)	Supplier 4 (A_4)	Supplier 5 (A_5)
Year established	1998	1987	1980	1990	1994
Capital	NT $1.3 million	NT $1.8 million	NT $5.3 million	NT $2 million	NT $2.3 million
Annual sales	NT $4 million	NT $5.2 million	NT $6.4 million	NT $5.5 million	NT $5.8 million
Number of employees	320	400	500	160	280
Solutions and services	Enterprise Resource Planning (ERP), Supply Chain Management (SCM), System Integration (SI), Electronic Commerce (EC), Software Development, Application Service Provider (ASP)	Software Development, System Architecture, Business Process Consultation, System Integration (SI) and Training, Enterprise Resource Planning (ERP), Knowledge Management (KM)	System Integration and Development, E-business Consulting service, Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM)	E-business Services, Enterprise Resource Planning (ERP), Customer Relationship Management (CRM), Mailing and Data Management, System Integration (SI) Services	Customer Relationship Management (CRM), Supply Chain Management (SCM), Business Intelligence, Enterprise Resource Planning (ERP), System Integration (SI) Services
Outsourcing location	Taiwan, China	Taiwan, China	Taiwan, Hong Kong, China	Taiwan, China	Taiwan, China
Earnings per share (2006)	1.07	1.65	1.04	2.18	1.42

are shown in Table 12 (C2 Accept). Both C1 and C2 are acceptable. Therefore, we use Q_i to identify the most acceptable alternative A_2 as a single optimal solution. From the result, the best solution is $Q(a')$, which is the alternative A_2. Therefore, the result suggests that A_2 would be the best supplier/vendor for the IS/IT outsourcing project when the firm seeks to facilitate the desirable outsourcing operation.

5. Conclusion

Despite increasingly competitive markets and challenging operating conditions, outsourcing has become a strategic business solution. IS/IT outsourcing, as a legitimate management strategy, encompasses a variety of approaches to contracting for IT services (Chen and Huang, 1992). However, TCE explains the existence of alternative forms of organization on the basis of their relative efficiencies in response to the combined effects of environmental uncertainty, opportunism, and bounded rationality (Bellman and Zadeh, 1970; Yoon and Hwang, 1985). In an outsourcing decision context, the concept of TCE provides a useful framework for understanding the IS/IT outsourcing decision and the conditions under which outsourcing is likely to benefit organizations (Chen, 2000). Because the primary motivation of outsourcing is to minimize costs and leverage resources, TCE posits that firms can better reduce the costs involved and avoid opportunism among exchange partners by bringing all transactions under a common cooperative structure. In addition, the advantage of outsourcing is to provide organizations with a way to leverage the supplier/vendor's superior technical know-now, superior management practices, economics of scale, and increasingly, access to strategic and business advice (Gomes et al., 2008; Zeleny, 1974). RBV suggests that firms have a competitive advantage when they possess one or more resources that are "idiosyncratically fit, valuable, leveraged, unique, and costly to copy or substitute" (Kalling, 2003). Thus, the process of supplier/vendor selection is crucial to success of outsourcing activity and achieves a competitive advantage. However, it is necessary to develop the decision criteria for evaluation and selection of potential suppliers/vendors because the supplier/vendor selection decision is complicated and involves decision-making problems. The process of making a selection decision involves distinguishing the best option from all feasible alternatives in order to understand the issues associated with the problem of selecting a supplier/vendor for IS/IT outsourcing. Fuzzy logic provides an appropriate decision-making method which has been employed to explain and predict trends or future phenomena by providing an analysis of various decision-making techniques. Further, this study proposed an integrated VIKOR approach in a fuzzy environment to solve fuzzy multi-criteria decision-making problems and thereby distinguish the best option from all of the feasible alternatives. By illustrating the results of the analysis, the proposed fuzzy VIKOR method was able to achieve substantial advantages through the spatially explicit evaluation of complex and voluminous data sets, which are difficult to state in conventional quantitative expressions.

Unlike traditional logic, crisp mathematical models are inadequate to solve real-life problems, since human judgments, perceptions, and preferences are inherently imprecise and are often full of fuzziness and uncertainty. The proposed fuzzy VIKOR is a mathematical strength-enabling system that captures the uncertainties associated with human cognitive processes in order to deliver

Table 4
The importance weight of each criterion

	D_1	D_2	D_3	D_4	D_5
C_1	H	H	VH	M	VH
C_2	H	H	H	VH	VH
C_3	M	L	L	L	VL
C_4	VH	VH	H	VH	H
C_5	H	VH	M	H	H
C_6	VH	VH	VH	H	H
C_7	H	VH	H	H	VH
C_8	H	H	H	M	M
C_9	M	M	M	VL	VL
C_{10}	VH	VH	M	H	M

Table 6
The aggregate fuzzy weight of criteria

	Fuzzy weight		
C_1	0.55	0.80	0.95
C_2	0.60	0.85	1.00
C_3	0.05	0.25	0.50
C_4	0.65	0.90	1.00
C_5	0.50	0.75	0.95
C_6	0.65	0.90	1.00
C_7	0.60	0.85	1.00
C_8	0.40	0.65	0.90
C_9	0.15	0.30	0.55
C_{10}	0.50	0.75	0.90

Table 7
The weighted normalized fuzzy decision matrix

	A_1			A_2			A_3			A_4			A_5		
C_1	3.0	5.5	8.0	4.0	6.5	8.5	6.5	9.0	10.0	4.0	6.5	8.5	5.5	8.0	9.5
C_2	1.5	3.0	5.0	4.0	6.5	8.5	1.0	3.5	6.0	5.5	8.0	9.0	5.5	8.0	9.5
C_3	2.5	5.0	7.0	4.0	6.5	8.0	0.5	3.0	5.5	4.5	7.0	8.5	7.0	9.5	10.0
C_4	3.5	6.0	8.5	2.5	5.0	7.5	1.0	3.0	5.5	3.0	5.5	7.5	6.0	8.5	9.5
C_5	5.5	8.0	9.0	1.5	4.0	6.5	3.0	5.0	7.5	1.5	4.0	6.0	0.0	2.0	4.5
C_6	5.5	8.0	9.5	4.5	7.0	9.0	2.0	4.5	7.0	4.5	7.0	8.5	5.0	7.0	8.5
C_7	5.5	8.0	9.5	7.0	9.5	10.0	6.0	8.5	10.0	6.5	9.0	10.0	5.5	8.0	9.5
C_8	7.0	9.5	10.0	6.5	9.0	10.0	4.5	7.0	9.0	7.0	9.5	10.0	6.0	8.5	9.5
C_9	1.0	3.5	6.0	4.0	6.0	8.0	5.0	7.5	9.0	5.0	7.5	9.5	5.0	7.5	9.0
C_{10}	4.5	7.0	9.0	3.5	6.0	8.0	5.5	8.0	9.0	0.0	2.0	4.5	0.5	3.0	5.5

Table 5
The rating of each alternative under each criterion

	A_1					A_2					A_3					A_4					A_5				
	D_1	D_2	D_3	D_4	D_5	D_1	D_2	D_3	D_4	D_5	D_1	D_2	D_3	D_4	D_5	D_1	D_2	D_3	D_4	D_5	D_1	D_2	D_3	D_4	D_5
C_1	F	F	G	F	F	P	F	G	G	B	B	G	G	B	B	B	G	F	G	P	B	G	G	B	F
C_2	W	P	W	P	B	F	B	G	P	G	F	F	P	P	P	P	G	B	B	B	B	G	B	G	F
C_3	F	P	F	P	B	P	G	B	P	B	P	F	P	P	P	P	B	B	F	G	B	B	B	B	G
C_4	F	F	F	G	G	G	P	P	G	F	P	P	F	W	F	F	P	G	B	P	G	B	B	F	B
C_5	B	B	G	B	P	G	P	P	F	P	G	F	F	G	W	B	P	P	P	P	P	W	P	P	P
C_6	G	F	G	B	B	B	F	F	G	G	G	P	G	P	P	B	F	B	F	F	B	G	G	B	W
C_7	B	F	B	G	G	B	B	G	B	B	B	G	B	G	G	G	G	B	B	B	G	B	B	G	F
C_8	B	B	B	G	B	G	B	B	G	B	P	B	G	G	G	B	B	B	B	G	F	B	B	B	G
C_9	P	P	F	P	F	F	W	G	B	G	G	B	B	F	F	G	G	F	G	B	G	B	B	G	P
C_{10}	G	G	B	G	P	B	G	P	G	P	B	B	F	B	F	P	P	P	P	W	P	P	P	P	F

Table 8
Fuzzy best value and fuzzy worst value

	$\tilde{f}_i^*$			$\tilde{f}_i^-$		
C_1	6.5	9.0	10.0	3.0	5.5	8.0
C_2	5.5	8.0	9.5	1.0	3.0	5.0
C_3	7.0	9.5	10.0	0.5	3.0	5.5
C_4	6.0	8.5	9.5	1.0	3.0	5.5
C_5	5.5	8.0	9.0	0.0	2.0	4.5
C_6	5.5	8.0	9.5	2.0	4.5	7.0
C_7	7.0	9.5	10.0	5.5	8.0	9.5
C_8	7.0	9.5	10.0	4.5	7.0	9.0
C_9	5.0	7.5	9.5	1.0	3.5	6.0
C_{10}	5.5	8.0	9.0	0.0	2.0	4.5

Table 9
$\tilde{S}_i$ and $\tilde{R}_i$

m	$\tilde{S}_i$			$\tilde{R}_i$		
A_1	2.2839	3.5072	4.0833	0.6000	0.8500	1.0000
A_2	1.9196	2.7642	2.8204	0.4550	0.5727	0.7125
A_3	2.9773	4.4067	4.5730	0.6500	0.9000	1.0000
A_4	2.0514	2.9490	3.4236	0.5000	0.7500	0.9000
A_5	1.9645	2.9707	3.8161	0.6000	0.8500	1.0000

Table 10
$\tilde{S}^*$, $\tilde{S}^-$, $\tilde{R}^*$, $\tilde{R}^-$

$\tilde{S}^*$	1.9196	2.7642	2.8204
$\tilde{S}^-$	2.9773	4.4067	4.5730
$\tilde{R}^*$	0.4550	0.5727	0.7125
$\tilde{R}^-$	0.6500	0.9000	1.0000

Table 11
The rating of Q_i and rank of each alternative

m	$\tilde{Q}_i$			Q_i	Rank
A_1	0.5440	0.6498	0.8603	0.6847	4
A_2	0.0000	0.0000	0.0000	0.0000	1
A_3	1.0000	1.0000	1.0000	1.0000	5
A_4	0.1777	0.3271	0.4982	0.3343	2
A_5	0.3930	0.4865	0.7840	0.5545	3

Table 12
Acceptable stability in decision making

Q_i	$A_2>A_4>A_5>A_1>A_3$
S_i	$A_2>A_4>A_5>A_1>A_3$
R_i	$A_2>A_4>A_1=A_5>A_3$

more efficient solutions in group decision making. Consequently, the concept of fuzzy VIKOR seeks to identify an acceptable, feasible solution which is determined by the maximum group utility of the majority and the minimum individual regret of the opponent. Thus, this method provides a compromise solution for a problem with conflicting criteria to help a group to reach an agreement and reduce weight variability amongst decision makers.

5.1. Managerial implications

The findings of this study have contributed towards providing meaningful and advanced knowledge by demonstrating various criteria and a simple, efficient method with which buyers or decision makers can enhance their ability to predict an appropriate supplier/vendor in their efforts to develop the firms' outsourcing strategies. According to the results of this study, decision makers encounter critical factors that were found to influence a firm's decisions about selecting a particular partner. The presence of evaluation criteria as suggested by five manufacturers in this study provide the future seller an understanding of the buyer's needs and help them decide whether they should enhance their organizational capabilities to meet customers' requirements. Specifically, this study provides important insights with which decision makers can recognize the identified variables that determine their ultimate decision in the context of outsourcing. This implies that the powers of decision makers could have a crucial effect on the selection of supplier/vendor strategies related to the outsourcing activities since their decisions and recommendations contribute greatly to the success of outsourcing operations. As such, an important contribution of this study is to increase firms' awareness of the potential impact of decision makers and provide a normative direction for the future presence of a qualified decision-making group.

Although the expertise and judgment of the decision makers play critical roles in the IS/IT outsourcing project, decision makers make decisions on the basis of their knowledge of the facts and personal experience. Their judgments and preferences are often vague, which makes it difficult to estimate their preference with an exact numerical value since crisp data are inadequate to model real-life situations. Another significant contribution to this study is the proposed fuzzy VIKOR, a mathematical model for taking into consideration the presence of vagueness, uncertainty, and imprecision of information in the supplier/vendor selection problem. Specifically, fuzzy VIKOR is a thoughtful, flexible, and efficient method that is easily understood by practitioners and researchers. In a real situation, decision makers have difficulty in accurately assess the potential supplier/vendor in an uncertainty environment. With the help of the fuzzy VIKOR method, decision makers can simply apply to reduce the lead time for the supplier/vendor selection and evaluation process, whereas other methods are actually even more complicated and time consuming to execute properly. In this study, the empirical evidence demonstrated the validity of the fuzzy VIKOR method and provides an example which decision makers can follow and employ to make proper decisions or allocate organizational resources efficiently in the fuzzy dynamic environment with numerous criteria that they are facing. In addition, the analytic method suggested here is a significant theoretical contribution to the literature, and will help to establish groundwork for future research.

In general, the study contributes by providing a decision-making framework that incorporates decision criteria into the strategic selection of suppliers/vendors. The application of the framework in an illustrative example appears to constitute an adequate approach, which demonstrates the implementable solutions to IS/IT supplier/vendor selection problems for outsourcing a project. Specifically the results of this study enable firms and even decision-makers to enhance their ability is managing by paying close attention to interrelated factors and hence they may successfully identify a potentially effective partner for managing their outsourcing activities.

5.2. Limitations and future research

Fuzzy VIKOR is utilized in the present study as an analytical model as an exemplar in a case analysis to aid in conflict management situations. Further research can apply this method flexibly to other situations. While the fuzzy VIKOR may be a viable method to address the supplier/vendor selection problem, the fuzzy VIKOR decision algorithm proposed here is capable of not only in helping to resolve the uncertainty and vagueness inherent in the group decision-making process, but also in assessing the suitability of best-alternative and compromise solutions under each of the strategic criteria.

While this study used previous research to generate an alternative analytical method, the modification developed for this application is required to provide an advanced solution in IS/IT-related projects. Thus, future research may need to enhance the efficiency of the models by obtaining a comprehensive and effective explanation and providing practical guidance for decision makers. Future research may also need to apply other analytical methods to determine the supplier/vendor choice and performance in order to reinforce the findings of this study.

The study results show that decision criteria significantly influence the choice of supplier/vendor. However, they do not provide adequate evidence to explain the decision criteria and performance implications of selecting a particular supplier/vendor by the proposed method. Therefore, future research should further examine the related criteria and performance of selecting a supplier/vendor and the efficiency of firms' operations. Furthermore, this study examines the criteria of the supplier/vendor choice by focusing on some particular factors. Future research could improve the predictive power of the theoretical framework by utilizing the TCE or RBV model to identify additional intervening factors that were not considered in the current study. Alternatively, future research on outsourcing arrangement could focus on decision makers' characteristics, since decision makers have great powers to influence decision making in the selection of the supplier/vendor decision process.

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