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IT PORTFOLIO INVESTMENT EVALUATION ON E-COMMERCE SOLUTION ALTERNATIVES

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Abstract

Our study examines the group decision-making process and proposes a multi-criteria framework for e-commerce solution investment in information technology (IT) portfolios. First, the evaluation criteria that fit in the IT evaluation context are constructed. Second, the Fuzzy Analytic Hierarchy Process (FAHP) is employed to determine the weights of decision criteria and the benefit score to the company. Third, the Fuzzy Multiple Criteria Decision-Making (FMCDM) approach is used to synthesize the team decision. Finally, an empirical case of five proposed portal solutions in a car manufacturing company is used to exemplify the approach.

Keywords: IT portfolio, IT investment evaluation, fuzzy decision-making, e-commerce investment.

1. INTRODUCTION

In today's rapid information processing era, business depends much on information technologies (IT) to improve organizational efficiency and effectiveness, and companies use them to provide competitive advantage (Irani 2002; Powell 1992). Many of the large organizations even spend more than half of their annual capital expenditure (Premkumar & Ramamurthy 1995; Willcocks & Lester 1997) on IT investment. With such great amount of investment cost and unavoidable nature (Escobar-Perez 1998) of IT investment, no matter it is outsourced or in-sourced, enterprise tends to employ ways to evaluate or justify their potential investments. The investment decision-making is based on a variety of considerations such as comparison with existing investments in IT portfolio, long term benefits to the companies, etc. in order to increase decision quality. This study attempts to exam the group decision-making process and proposes a multi-criteria framework for IT solution alternative selection in IT department.

In the context of IT investment outsourcing, Dickson (1966) identifies 23 criteria, such as price, quality delivery, etc to evaluate and select vendors. A research conducted by (Weber, et al. 1991) reveal that it is often that more than one criterion (i.e., multi-criteria) is used for vendor selection. A considerable number of decision models have been developed based on the multiple criteria decision-making (MCDM) theory. Such examples are analytical hierarchy process (AHP) (Ghousypour & O'Brien 1998), discrete choice analysis (Verma & Pullman 1998) and data envelopment analysis (Weber & Current 2000; Narasimhan et al 2001)

When evaluating an appropriate vendor for e-commerce solution in existing portfolio, the benefit of investment sometime can not be quantified in financial terms for decision-makers (Irani 2002; Lefley & Sarkis 1997). It is usually vague or imprecise during the MCDM process. In order to handle the vagueness in information and the fuzziness of human judgment or preference, Zadeh propose fuzzy set theory (Zadeh 1965) in 1965 and a decision-making method in a fuzzy environment is developed in (Bellman & Zadeh 1970). A number of subsequent studies used fuzzy set theory to deal with uncertainty in the vendor selection problem (Holt 1998; Boer et al. 2001). Fuzzy set theory is useful when the investment situation is full of uncertainty and imprecision due to the subjectivity of human judgment. In this paper, we suggest fuzzy set theory as a way to improve the vendor selection problem.

Fuzzy Analytic Hierarchy Process (FAHP) or Fuzzy Multiple Criteria Decision-Making (FMCDM) analysis has been widely used to deal with decision-making problems that involve multiple criteria evaluation and multiple selections of alternatives. In literature, several researches (Altrock & Krause 1994; Baas & Kwakernaak 1997) have demonstrated the advantages of using fuzzy logic to handle qualitative or unquantifiable criteria and show reliable results. Therefore, this study attempts to apply the fuzzy set theory to establish a FAHP and FMCDM incorporated framework in solving managerial decision-making problem on selection of alternatives. Specifically, the framework can help a company to select e-commerce solution alternatives with the consideration of their existing IT investment portfolio.

Two teams are involved in this study, the weighting team and scoring team. Function of weighting team is to determine the weights of each criterion. The evaluation criteria of e-commerce solution investment come from diverse perspectives, so there is no reason to treat all these criteria as if they were of the same importance. This study first uses the FAHP to determine the criteria weights from subjective judgments of weighting team. On the other hand, function of scoring team is to determine each criterion's level of benefits to existing IT portfolio and the company under different alternatives. Finally, this study uses the FMCDM to evaluate synthetic value of IT alternatives based on each criterion.

The remainder of this paper is organized as follows. Section 2 presents the proposed approach that includes the construction of evaluation criteria, the FAHP based evaluation weights and the FMCDM based decision-making process. The proposed method is further illustrated with a case study in Section 3. Section 4 discusses case implication and Section 5 concludes.

2. IT INVESTMENT PORTFOLIO ALTERNATIVES EVALUATION MODEL

The purpose of this section is to establish a FMCDM framework to handle the evaluation problem of potential e-commerce investment in IT portfolio. The investment involves IT solution selection and the consulting team selection. The contents include three subsections: building hierarchical structure of evaluation criteria, determining the evaluation criteria weights and scoring and ranking the investment alternatives based on each criterion.

2.1. Building hierarchical structure of evaluation criteria

The decision-making process for vendor and IT solution selection is usually complex and involves vague information. Oftentimes, organizations need to involve “several decision-makers” to face “several vendors and solutions” based on “numerous criteria”. And sometimes “several experts” from outside the organization are needed for the purpose of objective evaluation and professional suggestion. In such a context, MCDM can be used as an analytic method to evaluate the advantages and disadvantages of alternatives based on multiple criteria (Chou et al. 2006).

In solving IT portfolio investment evaluation problem, we evaluate investment alternatives based on several dimensions, of which involves several criteria. Through brainstorming sessions among management, comprehensive consultation with several experts, and extensive literature review (Ryan & Harrison 2000; Mirani & Lederer 1998; Jones & Beatty 1998; Irani 2002; Escobar-Perez 1998), key dimensions of the criteria and criteria for evaluation were derived. The hierarchical structure of criteria to deal with the problems of IT solution selection of the portfolio in this study is shown in Table 1. Five dimensions are included in this study and 24 evaluation criteria for the hierarchical structure were used in this study.

2.2. Determining the evaluation criteria weights

Due to the ability to combine quantitative and qualitative decision-making criteria (Berghout & Renkema 2001), multi-criteria methods are used in many decision-making situations. With different dimensions of criteria for e-commerce solution in an IT portfolio, each criterion weight may not be equally the same for decision-making since different importance is imposed on criteria. Due to several criteria dimensions, evaluation of e-Commerce solution alternatives as mentioned above is complicated. It needs more flexible method to solve the problem. The AHP method proposed by Saaty (1980) has been used to evaluate alternative IT investment (Lai et al. 2002; Ossadnik & Lange 2002). However, it allows evaluating relative importance weights, but not the importance level (Hsieh et al. 2004) of criteria. In addition, the crisp values that AHP uses to score alternatives are subjective (Prabhu & Vizayakumar 2001). It sometimes can not reflect what the true thinking of decision-makers. The judgment of criteria based on crisp value is unrealistic (Mirani & Lederer 1998) since the information the evaluator give may be imprecise and fuzzy during the evaluation process.

Owing to the reason that it is sometimes not easy for an evaluator to assess his/her opinion by a precise value, it would be better to use linguistic variables such as high, medium, or low instead. A range value to represent linguistic variables can express opinions and feelings more accurately. Therefore, a fuzzy concept is introduced to represent the weights of each criterion in our model by using a range or a relative degree. We use linguistic variables and range values in the proposed multi-criteria decision model to overcome shortcomings of AHP as mentioned above. We call this fuzzy AHP (FAHP) approach. In addition, when considering weights for each criterion in potential IT alternative evaluation, existing IT portfolio is also taken into consideration. It is very important to know relative relationship between the potential investment and existing investments in IT portfolio to avoid the redundancy of investments. Furthermore, the integration of new IT solution to existing IT portfolio in order to achieve the best benefit of the company is also important.

D1: Company's Internal Consideration Competitive advantage improvement Ease of Operation Information Quality improvement Meet user requirements Compatibility or integration ability with existing IT /IS portfolio Cost (hardware, and maintenance)
D2: Company's External Consideration Adherence to government regulations Compatibility or integration ability with partners IS Ability to react competitions promptly
D3: Risk Consideration Adequacy of manpower Skill of IT staffs
D4: Software Consideration Image and stability of the software company Software functionalities Technical platform for Software development Subsequent service provision Total cost of ownership System flexibility Testimonials from other customers
D5: Consulting Company's Consideration Consulting quality and obtainability Understanding level of consulting company to the organization Understanding level of consulting company to the industry of the org Performance of previous similar projects Whether or not having good relationship with customers Cost (implementation cost)

Table 1. Hierarchical structure of criteria of IT solution investment in IT portfolio

2.2.1. Use triangular fuzzy number and linguistic variables to compare two evaluation criteria

We first use fuzzy numbers with triangular membership functions to solve the MCDM problems. The determination of the membership functions is using simple operations such as addition, multiplication in the parameters (Laarhoven & Pedrycz 1983). We then make use of linguistic variable, which are composed of words or sentences that can represent meaning in natural language, to get the relative importance of the criteria. Examples of linguistic terms used in this e-commerce selection evaluation are “equally important” (Eq), “weakly important” (Wk), “Very important” (Ve), ”Strongly important”(St) and “absolutely important” (Ab). The “equally important” means that two criteria are perceived as “equally important” to the evaluator while the “absolutely important” means one of the criteria is perceived as extremely out-weighting the other criteria. The technique used for computation in this study is based on the fuzzy number scale defined by (Mon et al. 1994). Each scale of fuzzy number represents a linguistic scale and is defined by three symmetric triangular fuzzy numbers. As shown in Table 2, the membership function of linguistic scale used in IT portfolio investment is synthesis of fuzzy number scales (Mon et al. 1994) and linguistic scales (Chiou & Tzeng 1993).

Fuzzy number scale	Linguistic scale	Triangular fuzzy number
$\tilde{1}$	Equally important (Eq)	(1, 1, 3)
$\tilde{3}$	Weakly important (Wk)	(1, 3, 5)
$\tilde{5}$	Very important (Ve)	(3, 5, 7)
$\tilde{7}$	Strongly important (St)	(5, 7, 9)
$\tilde{9}$	Equally important (Eq)	(7, 9, 9)

Table 2. Fuzzy number scale and linguistic scale mapping

2.2.2. Fuzzy analytic hierarchy process (FAHP)

We summarize two steps to determine the evaluation criteria weights by FAHP as follows:

(1) Construct pair-wise comparison matrices among all the criteria in the dimensions of the hierarchy system. Members in the weighting team evaluate which is more important between every two criteria. That is, weighting team needs to assign linguistic terms to the pair-wise comparisons among criteria. The following is an $n \times n$ matrix that defines the pair-wise comparison among criteria. For example, the first row of the matrix denotes the comparison between criteria one and the other $n-1$ criteria.

$$\tilde{M} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} \quad (1)$$

where

$$\tilde{a}_{ij} = \begin{cases} \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}, & \text{criterion } i \text{ is relatively important} \\ & \text{to criterion } j. \\ 1, & i = j, \\ \tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1} & \text{criterion } i \text{ is relatively} \\ & \text{less important to criterion } j. \end{cases}$$

(2) Use geometric mean technique to define the fuzzy geometric mean and fuzzy weights of each criterion as follows (Buckley 1985):

$$\tilde{r}_i = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \cdots \otimes \tilde{a}_{in})^{\frac{1}{n}}, \quad (2)$$

$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \cdots \oplus \tilde{r}_n)^{-1}, \quad (3)$$

where \tilde{a}_{in} is fuzzy comparison value of criterion i to criterion n , thus, \tilde{r}_i is geometric mean of fuzzy comparison value of criterion i to each criterion, \tilde{w}_i is the normalized fuzzy weight of the i th criterion. It can be indicated by a triangular fuzzy number, $\tilde{w}_i = (Lwi, Mwi, Uwi)$. Lwi , Mwi and Uwi stand for the lower, middle and upper values of the fuzzy weight of the i th criterion.

2.3. Use Fuzzy multiple criteria decision-making (FMCDM) theory to synthesize decision

Past literatures show the advantages of using FMCDM theory in handling qualitative criteria (Chen 2002; Tang et al. 1999). This study uses this approach to evaluate score of potential e-commerce solution in IT portfolio and rank the priority for them accordingly. The following is the method and procedures of the FMCDM theory.

(1) Scoring each criteria of investment alternatives using linguistic variables

The scoring is to evaluate each criterion's level of benefits to existing IT portfolio and the company under different alternatives. Linguistic variables are used as a way to measure each criterion's level of benefits to existing IT portfolio and the company under different alternatives. For each criterion, linguistic variables such as "very high", "high", "medium", "low" and "very low" are used. For example, a linguistic variable of "high" means that a particular criterion can bring "high" benefits to existing IT portfolio and the company considering a particular alternative. Each linguistic variable can

be represented by a triangular fuzzy number within the scale range of zero to one hundred. Table 3 shows the linguistic scale and its triangular fuzzy number conversion.

Linguistic scale	Triangular fuzzy number
Very high	(85, 100, 100)
High	(60, 75, 90)
Medium	(30, 50, 70)
Low	(10, 25, 40)
Very Low	(0, 0, 20)

Table 3. Linguistic scale and its triangular fuzzy number conversion

After the scoring team members use linguistic variable to measure each criterion's benefits to existing IT portfolio and the company under different alternatives, \tilde{A}_{ij}^k is used to indicate the fuzzy scoring value of member k to criterion j under alternative i. All of the evaluation criteria will be represented as $\tilde{A}_{ij}^k = (LA_{ij}^k, MA_{ij}^k, UA_{ij}^k)$ per scoring member. Owing to different experience and knowledge for each scoring member, the perception of each member varies and the definitions of the linguistic variables vary as well. This study uses average value to integrate the fuzzy judgment values of m scoring team members, that is,

$$\tilde{A}_{ij} = \left(\frac{1}{m}\right) \odot (\tilde{A}_{ij}^1 \oplus \tilde{A}_{ij}^2 \oplus \dots \oplus \tilde{A}_{ij}^m) \quad (4)$$

The sign \odot denotes fuzzy multiplication, the sign \oplus denotes fuzzy addition, shows the average scoring of the judgment from the decision-makers, which can be displayed by a triangular fuzzy number as $\tilde{A}_{ij} = (LA_{ij}, MA_{ij}, UA_{ij})$. The end-point values of LA_{ij} , MA_{ij} and UA_{ij} can be solved by the method from (Buckley 1985) as,

$$LA_{ij} = \frac{\sum_{k=1}^m LA_{ij}^k}{m} ; \quad MA_{ij} = \frac{\sum_{k=1}^m MA_{ij}^k}{m} ; \quad UA_{ij} = \frac{\sum_{k=1}^m UA_{ij}^k}{m} \quad (5)$$

(2) Fuzzy synthetic decision

Fuzzy number calculation technique is used to calculate synthetic value of weights of the each e-commerce solution criterion and the fuzzy scoring values. The result shows the fuzzy overall value of the integral evaluation. According to the each criterion weight \tilde{w}_j derived by FAHP, the criteria weight vector $\tilde{W} = (\tilde{W}_1, \dots, \tilde{W}_j, \dots, \tilde{W}_n)^t$ can be obtained, whereas the fuzzy performance matrix \tilde{A} of each of the alternatives can also be obtained from the fuzzy performance value of each alternative under n criteria, that is, $\tilde{A} = (\tilde{A}_{ij})$. From the criteria weight vector \tilde{w} and fuzzy performance matrix \tilde{E} , the final fuzzy synthetic decision can be conducted, and the derived result will be the fuzzy synthetic decision matrix \tilde{R} , that is, $\tilde{R} = \tilde{A} \odot \tilde{w}$.

The sign “ \odot ” indicates the calculation of the fuzzy numbers. This includes fuzzy addition and fuzzy multiplication. Since the calculation of fuzzy multiplication is rather complex, it is usually denoted by the approximate multiplied result of the fuzzy multiplication. And the approximate fuzzy number \tilde{R}_i of the fuzzy synthetic decision of each alternative can be shown as $\tilde{R}_i = (LR_i, MR_i, UR_i)$, where LR_i , MR_i and UR_i are the lower, middle and upper synthetic performance values of the alternative i. That is:

$$\begin{aligned} LR_i &= \sum_{j=1}^n LA_{ij} \times Lw_j, \quad MR_i = \sum_{j=1}^n MA_{ij} \times Mw_j \\ UR_i &= \sum_{j=1}^n UA_{ij} \times Uw_j \end{aligned} \quad (6)$$

(3) Ranking the alternatives:

The result of the fuzzy synthetic decision for each alternative is a fuzzy number. Therefore, a defuzzification procedure to nonfuzzy the fuzzy numbers is needed to locate the Best Nonfuzzy Performance value (BNP). Methods such as mean of maximal (MOM), center of area (COA), and a-cut are applied to the defuzzified fuzzy ranking. The use of COA method to find out the BNP is a

simple and practical method, so it is used in this study. The BNP value of the fuzzy number \tilde{R}_i can be obtained by (Prabhu & Vizayakumar 2001):

$$BNP_i = [(UR_i - LR_i) + (MR_i - LR_i)]/3 + LR \quad \forall i \quad (7)$$

According to the value of the derived BNP for each of the alternatives, the ranking of the e-commerce solution of each of the alternatives can then be obtained.

3. CASE OF SELECTING AN E-COMMERCE SOLUTION

3.1 Background of the e-Commerce initiative at ACB

To demonstrate how the model is used, we conducted a case study of a vehicle company (ACB) in Taiwan. The IT department in ACB endeavors to the computerization of the company. Not only focus on streamlining the manufacturing process, the IT department also takes care of numerous systems in the company, including ERP, SCM, KM, DMS, CRM, etc. This enhanced flexibility and communication quality between ACB and its employees, customers, dealers, suppliers. Recently, ACB has planned an e-commerce initiative, which seeks to launch a e-commerce solution on the Internet. Users of this initiative would be mainly the Business department and the CEO office. The IT department was in charge of the planning, design, and construction of the e-commerce portal. The project manager from the IT department was assigned as the project leader. He proposed several choices for selection: (1) develop a new portal by IT department themselves, (2) buy a new portal solution package, or (3) leave the existing website as it is without any change. In seeking to buy a new portal solution package, five vendors submitted the proposals to ACB for evaluation. A variety of solution proposals such as IBM WebSphere solution, Oracle Portal solution or Microsoft SharePoint solution was proposed by the vendors. Two of proposals were rejected because of either wrong system platform specification or inappropriate system functions. As a result, five alternatives left for the company to consider, and those are (1) Leave as it is, (2) In-house development, (3) Vendor A (4) Vendor B, and (5) Vendor C.

3.2 Fuzzy MCDM for e-Commerce portal evaluation

ACB requires that the selection of solution and vendors need to follow formal procedures. This study used the case to demonstrate the process of solution and vendor selection. By following the FMCDM approach, ACB need to select the evaluation criteria, weight the criteria, estimate the scoring matrix, and ranking the alternatives. ACB teamed up two groups to do the evaluation of e-commerce solution alternatives. One is criteria selection and weighting team and the other is scoring team. The former team is comprised of different stakeholders, including an executive manager, the IT manager, two IT staffs from e-commerce division, and the manger and one staff from purchasing department. The scoring team, on the other hand, is to evaluate e-commerce alternative performance impact to the existing IT portfolio based on the criteria selected. The team comprises of an executive manager, IT experts, accounting experts, and a consultant outside of ACB. The reason for having different experts in the team serves as different purpose (Chou et al. 2006). For example, the executive manager is to ensure that the new e-commerce investment is aligned with strategic business objectives, while the IT experts is to ensure that the e-commerce initiatives is feasible in terms of architecture, methodology, design and technology.

3.3 Selection of evaluation criteria

The criteria selection and weighting team was responsible for selecting the criteria used in ACB. The team held several brainstorming sessions to review the evaluation criteria described in Section 2.2. Finally, the team members all agreed to use the criteria as they are in Section 2.2.

3.4 The weights calculation of the evaluation criteria

The criteria selection and weighting team was also responsible for deciding the weights of evaluation criteria. We use the FAHP method to obtain the weights, and average weights were derived by geometric mean method suggested by Buckley (1985). The computational procedure of the weights of dimensions is demonstrated as follows:

(1) Every member of the weighting team gave her/his opinions on the importance of evaluation dimensions. They gave the pair-wise comparison with regards to the opinions on the relative importance of evaluation dimensions by using linguistic variables as mentioned in Section 2.2. The pair-wise comparison matrix of dimensions among five weighting team members is obtained.

(2) The linguistic variables were then converted to fuzzy numbers as defined in Table 2 to get every member's fuzzy matrix.

(3) The triangular fuzzy number defined in Table 2 is then used to compute the synthetic relative importance of dimensions among weighting team members. The geometric mean technique suggested by (Buckley 1985) is used. For example, we compute the synthetic relative importance of dimensions 1 to 2 among weighting team members. From matrixes in (2), we obtain the fuzzy number of $\tilde{1}$, $\tilde{1}$, $\tilde{7}$, $\tilde{5}$, $\tilde{1}$, $\tilde{1}$ among these five team members on the pair-wise comparison of dimension 1 to 2. By applying the triangular fuzzy number on these obtained fuzzy numbers, we can calculate the geometric mean of the relative importance.

$$\begin{aligned}\tilde{a}_{12} &= [(1,1,3) \otimes (1,1,3) \otimes (5,7,9) \otimes (3,5,7) \otimes (1,1,3) \otimes (1,1,3)]_6^{\frac{1}{6}} \\ &= [(1 \times 1 \times 5 \times 3 \times 1 \times 1), (1 \times 1 \times 7 \times 5 \times 1 \times 1), (3 \times 3 \times 9 \times 7 \times 3 \times 3)]_6^{\frac{1}{6}} \\ &= (15, 35, 5103)_6^{\frac{1}{6}} = (1.572, 1.811, 4.161)\end{aligned}$$

The same computation procedure is applied to compute the geometric mean of relative importance of dimensions among weighting team members. Finally, the synthetic pair-wise comparison matrices among six team members are as follows.

	D1	D2	D3	D4	D5
D1	1	(1.572, 1.811, 4.161)	(1.201, 2.269, 3.01)	(1.201, 2.725, 4.474)	(1.734, 3.883, 5.937)
D2		1	(1.572, 1.811, 4.161)	(1.572, 1.811, 3.288)	(1.572, 1.811, 4.161)
D3			1	(1.734, 4.474, 5.937)	(1.572, 2.725, 3.223)
D4				1	(1.201, 3.883, 5.937)
D5					1

(4) The geometric mean of fuzzy comparison value of dimension i to each dimension can be obtained by following the equation (7) in Section 2.2.2.

$$\begin{aligned}\tilde{r}_1 &= (\tilde{a}_{11} \otimes \tilde{a}_{12} \otimes \tilde{a}_{13} \otimes \tilde{a}_{14} \otimes \tilde{a}_{15})_5^{\frac{1}{5}} = \left(\frac{(1 \times 1.572 \times \dots \times 1.734)^{\frac{1}{5}}, (1 \times 1.811 \times \dots \times 3.883)^{\frac{1}{5}}}{(1 \times 4.161 \times \dots \times 5.937)^{\frac{1}{5}}} \right) \\ &= (1.315, 2.126, 3.195)\end{aligned}$$

Similarly, the remaining \tilde{r}_i can also be obtained as:

$$\tilde{r}_2 = (1.315, 2.126, 3.123), \tilde{r}_3 = (2.315, 2.223, 4.213)$$

$$\tilde{r}_4 = (2.315, 3.142, 3.125), \tilde{r}_5 = (3.315, 3.427, 4.234)$$

(5) The normalized fuzzy weight of the ith dimension/criteria can be obtained by following the equation (8) in Section 2.2.2.

$$\begin{aligned}\tilde{w}_1 &= \tilde{r}_1 \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \tilde{r}_3 \oplus \tilde{r}_4 \oplus \tilde{r}_5)^{-1} \\ &= (1.315, 2.126, 3.195) \otimes [(3.195 + \dots + 4.234)^{-1}, (2.126 + \dots + 3.427)^{-1}, (1.315 + \dots + 3.31)^{-1}] \\ &= (1.315, 2.126, 3.195) \otimes (0.056, 0.912, 0.095) = (0.074, 1.939, 0.304)\end{aligned}$$

Similarly, the remaining \tilde{w}_i can also be obtained as:

$$\tilde{w}_2 = (0.024, 0.823, 0.312), \tilde{w}_3 = (0.012, 0.201, 0.087)$$

$$\tilde{w}_4 = (0.042, 1.023, 0.256), \tilde{w}_5 = (0.036, 1.246, 0.334)$$

The geometric mean value and importance weights of the dimensions are summarized as Table 4.

(6) The best non-fuzzy value (BNP) of the fuzzy weights on each dimension can be computed by applying the COA method as mentioned in Section 2.3. For example, to calculate the BNP of the fuzzy weights on dimension of “Internal consideration”, BNP can be obtained as:

$$\begin{aligned} \text{BNP}_{w1} &= \frac{[(U_{w1}-L_{w1})+(M_{w1}-L_{w1})]}{3} + L_{w1} \\ &= \frac{[(0.304-0.074)+(1.939-0.074)]}{3} + 0.074 = 0.772 \end{aligned}$$

Dimension	Geometric mean value	Importance weights
Internal Consideration	(1.315, 2.126, 3.195)	(0.074, 1.939, 0.304)
External Consideration	(1.315, 2.126, 3.123)	(0.024, 0.823, 0.312)
Risk Consideration	(2.315, 2.223, 4.213)	(0.012, 0.201, 0.087)
Software Consideration	(2.315, 3.142, 3.125)	(0.042, 1.023, 0.256)
Consulting Consideration	(3.315, 3.427, 4.234)	(0.036, 1.246, 0.334)

Table 4. Geometric mean value and the weights of dimensions evaluated by the weighting team

Likewise, the weights for the criteria among members of the weighting team can be calculated. In terms of dimension, we can find that the internal consideration is of great importance among dimensions because it has the highest BNP value. (i.e. 0.772) Followed by consulting companies’ consideration (0.539), software consideration (0.44) and external consideration (0.386), risk consideration (0.1) becomes least importance among dimensions.

3.5 Estimating the scoring matrix

For each alternative (i.e. No investment, In-house development, Vendor A, B and C) in ACB, members in the scoring team gave a score to each criterion in which they had expertise. Again linguistic variables are used for scoring team to score each alternative. As mentioned in Section 2.3, linguistic variables such as “very low”, “low”, “medium”, “high” and “very high” can be used. In this case, the linguistic variables represent level of benefits to the company under each dimension/criteria based on each alternative. Each linguistic variable is indicated by a triangular fuzzy number within the scale range between 0 and 100. The conversion of linguistic scale and its triangular fuzzy number are shown in Table 5.

Linguistic scale	Triangular fuzzy number
Very high	(85, 100, 100)
High	(60, 75, 90)
Medium	(30, 50, 70)
Low	(10, 25, 40)
Very Low	(0, 0, 20)

Table 5. Linguistic scale and its triangular fuzzy number conversion

Similar to the computation procedure in the weighting team, we can translate all scoring members’ linguistic variables into a score. The score of all members on each criterion for each alternative can then be averaged.

By multiplying each criterion with its corresponding global weight and summed up all values, we can get a final fuzzy score of each alternative. Because of limited space of this paper, we will show the results of the final fuzzy score of each criterion for all alternatives in the conference.

3.6 Ranking the alternatives

The final fuzzy synthetic decision (\tilde{R}_1) can be processed after the weights from the weighting team and the score of each criterion for each alternative are obtained. Results of the final fuzzy synthetic values of all alternatives are shown in Table 6.

	As it is	In-house Dev.	Vendor A	Vendor B	Vendor C
Synthetic Value	(15.23, 22.32, 66.24)	(15.23, 43.28, 76.15)	(43.23, 52.63, 81.23)	(43.23, 32.12, 36.57)	(63.47, 104.33, 97.34)

Table 6. Final fuzzy sum scores of all alternatives

Finally, we use Equation (7) to get the crisp score value of all alternatives by calculating the best non-fuzzy value (BNP) of the fuzzy synthetic values. This allows us to prioritize the rankings among alternatives. Take the first alternative “As it is” as an example, the BNP value is:

$$BNP_1 = [(51.2 - 12.3) + (31.2 - 12.3)]/3 + 12.3 = 31.57$$

The final crisp scores of all alternatives are shown in Table 7. Vendor C is the recommended choice in this case study.

Crisp score of synthetic value	As it is	In-house Dev.	Vendor A	Vendor B	Vendor C
	31.57	42	68.37	53.23	84.22

Table 7. Final crisp scores of all alternatives

4. DISCUSSIONS

Taking a closer look at the evaluation results, in terms of weighting team, we found that the internal consideration is of great importance among dimensions, followed by consulting companies’ consideration, software consideration and external consideration. Risk consideration is least importance among dimensions.

In the dimension of internal consideration, the criteria of “Ease of Operation” (0.572) and “Meet user requirements” (0.563) pose greater importance. The reason for this result is probably the weighting team is composed of member from purchasing department. They act as the users in the evaluation of IT solution alternatives. In the dimension of external consideration, the criterion of “Compatibility or integration ability with partners IS” is of the greatest importance among criteria in this dimension. The BNP value of 0.572 is even the same as the criteria of “Ease of Operation” in internal consideration dimension. In the dimension of risk consideration, criteria are relatively low in importance. In the dimension of software consideration, criteria of “System flexibility” (0.663), “Testimonials from other customers” (0.572) and “Software functionalities” (0.428) are the most important criteria in this category. This shows that the weighting team focuses much on the system flexibility when investing a new IT solution. Testimonials from other customers yet play another important role in deciding the software for the IT solution. We found that ACB tends to adopt IT solutions from a well-know software companies, such as IBM, Oracle and Microsoft. In the dimension of Consulting Companies’ Consideration, criteria of “Consulting quality and obtainability” (0 .523), “Understanding level of consulting company to the organization” (0 .512) and cost of implementation (0 .517) are the most important criteria in this category.

Similar to the emphasis on manufacturing quality, ACB requires that the consulting quality. In addition, ACB is a car manufacturing company, it would be better if the consulting company have the automotive industry experience.

5. CONCLUSION

IT investment in today's environment is inevitable and it usually involves huge amount of capital budget and several stakeholders. Our purpose of this study was to develop a scientific framework for the evaluation of IT solution alternatives. It serves as a useful approach to evaluate alternatives fairly and objectively by the stakeholders. Also, the effective evaluation procedure is helpful for promoting the decision quality. This study examines this group decision-making process and proposes a multi-criteria framework for IT solution evaluation. This study first lists out the evaluation criteria that are fit in the context of IT solution evaluation. In order to deal with the subjective judgment among each evaluator, this study employs Fuzzy Analytic Hierarchy Process (FAHP) to determine the weights of decision criteria for weighting team and benefit score to the company for scoring team. Then the Fuzzy Multiple Criteria Decision-Making (FMCDM) approach is used to synthesize the team decision. This approach allows decision-makers to formalize and effectively solve the complicated, multi-criteria and fuzzy/vague IT investment problem. An empirical case study of five proposed portal solutions for IT investment alternatives for ACB is used to exemplify the approach. The overall evaluation results suggest that Vendor C have the highest score, so as to be recommended for decision-making. The underlying concepts applied in this approach were intelligible to the decision-makers. Also, computation hours required to carry out the evaluation is short considering the complicated decision-making process. The approach and framework provided in this study assists companies in making critical decisions during the investment of IT solutions.

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