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Presenting an organizational planning Selection Model for ERP Systems Based on Intuitionistic Fuzzy Sets

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ABSTRACT

The ERP system, as an information system, meets the needs of an organization in a form of one integrated system, and because its implementation requires a lot of time and money, therefore the correct choice of it, is critical for organizations. This research has provided a model based on multi-criteria decision making techniques and fuzzy intuitionistic logic. . Intuitionistic Fuzzy Sets is the appropriate tools for encountering with uncertain situation of problems that the membership arena in it, isn't disport to just the forms of membership and nonmember ship, and therewith, there is an area that isn't any information about it. The information of decision Matrix & Criteria Evaluation Matrix which were gathered by distributing 2 questionnaires to decision making experts, was collected in the form of Intuitionistic Fuzzy Triangular Numbers. Then based on this logic, the vikor method was modeled.
The criteria's of this essay has been selected from the literature review. Afterward 4 options of most popular ERP systems are selected for evaluation and the proposed idea were applied on them. In conclusion, the analysis of the data shows that the proposed method, is a practical and suitable method for though managerial decisions to avoid failure.
KEYWORDS: Enterprise resource planning (ERP) system, Intuitionistic Fuzzy Sets (IFS), Multi-criteria decision-making (MCDM), Evaluation and Selection

1. INTRODUCTION

Unprecedented growth in information and communication technology has affected the whole computational and practical procedures in all parts of the organization. Therefore, competitive business environment, the need for creating integration in the supply chain inside and outside the organization, and revolution in the field of information systems technology had been the main factors for implementing enterprise resource planning (ERP) systems. These systems increase operational efficiency and effectiveness of organizations and prepare them to participate in the competitive market through creating management and operational integration inside and outside the organization, and facilitating and accelerating business processes. Indeed, ERP systems are the culmination of evolution in information systems at the present time. This system is a commercial software package which is responsible for the integration of information flow across the organization including the financial, accounting, human resources, supply chain and customer information sectors. The capabilities of this technology has also made public and private organizations, alongside the business sectors, to use them and provide customer service improvement. Studies show that about 60% of present companies on the Fortune 500 list (the top 500 companies) implement and use ERP systems (Opricovic, 1998). Although the implementation of ERP systems encounters many problems including economic sanctions in our country, the idea of ERP systems for the purpose of organizational integration is important in many aspects. In this section, it has been attempted to explain ERP systems, the importance of choosing the right ERP systems, and the problems arising from its implementation.

The primary objective of this study is to learn about the criteria for selecting an appropriate ERP system and finding them in previous studies. Other objectives include: the application of intuitional and vague information of decision makers in charge of selecting these systems, and selecting the best system in accordance with the needs of the organization to achieve growth and progress, and finally investigating whether a model can be presented by this method or not. If the answer is "yes", how?

Is it possible to present a practical model for the selection of an ERP system?

How is it possible to select an appropriate ERP regarding the use of intuitional information and Intuitionistic Fuzzy Sets intuitive?

1.1 Enterprise Resource Planning (ERP) Systems

When it comes to the definition of Enterprise Resource Planning (ERP) systems, most authors use the functionality feature of these systems as a definition of enterprise resource planning systems. This is due to the fact that there is no widely accepted definition for these systems. Countless examples of these definitions will be observed in the literature review. Some of them are the following:

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ERP systems are comprehensive software solutions which are offered in software packages. They are seeking for the integration of the full range of business processes and functions in order to create a holistic view of business in a single information and technology information architecture (Klaus & Gable, 2000).

ERP systems are a set of integrated applications which support the central activities of the organization such as manufacturing and support of supplies, finance and accounting, sales and marketing, and human resources sectors (Aladwani, 2001).

American Production and Inventory Control Society defines ERP systems as a method for effective planning and control of all resources required for receiving, producing, sending and responding to customers' needs in production, distribution, and service companies (APICS, 1998).

According to Davenport, ERP systems are a commercial software package which aim to integrate the flow of information among all parts of the organization including finance, accounting, human resources, supply chain, and customers management. (Wei, 2004)

1.2 Problems arising from the implementation of enterprise resource planning system

ERP implementation also brings some problems in the organization which can lead to the failure or inefficiency of the establishment if not considered and controlled. In Table 2-3, the raised problems and importance weight coefficients are given. (Bozorgmehri, 2007)

Table 1: The problems of implementing enterprise resource planning system and weight coefficients (Bozorgmehri, 2007)

Number	Title	weight	In charge
1	Lack of support and commitment of senior management	5	Employer
2	Absence of proper infrastructure	2	Employer
3	Lack of recognition of organization processes	4	Supplier, Counselor
4	Failure to select a qualified counselor and supervisor	3	Employer
5	Lack of appropriate and optimal solutions	5	Employer, Counselor
6	Failure to use the proper team for deployment	4	Supplier
7	Abundant changes and localization	5	Employer, Counselor
8	Lack of attention to culture and education in order to reduce peripheral resistance	4	All
9	Lack of attention to business processes reengineering (BRP)	3	All
10	Lack of commitment and persistence on the strategic decision to deploy ERP	4	Employer, Counselor
11	Change in Management, structure, or goals and mission of the organization during the establishment	4	Employer
12	Lack of knowledge management and the risks of loss of key personnel	3	All
13	Lack of proper planning for the implementation of ERP	3	All
14	Absence of IT master plan (ITMP)	3	Employer, Counselor
15	Lack of attention to providing and allocating adequate funding	1	Employer
16	Absence of explanations and a comprehensive monitoring plan	4	Employer, Counselor
17	Lack of proper, comprehensive, accurate and efficient supervision	4	Supervisor

1.3. Importance of proper selection of enterprise resource planning system

From the early 1990s, ERP systems market, with an annual average growth rate of 30 to 40 percent, was one of the sectors with the highest growth rate in the IT industry. (Verville & Haligten, 2003). At costs of several thousands, hundreds of thousands, or even millions of dollars, purchasing ERP software is among heavy costs for organizations which spent a large part of their capital funds. Although a significant portion of ongoing capital expenditures is allocated to information technology costs in organizations which is continuously increasing, unfortunately few individuals have enough information about how to spend the money or what organizations must bear the costs, or when it is needed to purchase IT-based systems such as ERP. Unfortunately, companies which demand ERP, encounter the issue of selecting ERP systems in a very ignorant and ill-considered way regardless of socio-technical challenges in the way. Even companies' national culture can play an important role in discouraging members on investment during the selection process.

Most companies avoid involving in the process of proper selection. The reason is that the ERP market is occupied by very few large companies claiming that their products are suitable systems for all dimensions and views in different organizations. Thus, despite the very high and considerable risk in the purchase and implementation of ERP, these vendors implicitly discourage companies from getting involved in the process of proper selection. While this argument is not correct in any way.

Overall, there is no generic ERP solution that can adapt to all organizations. In other words, the existing commercial ERP packages are not able to provide a generic model for all business models in all industries. And therefore, there is no specific ERP software package to be the solution to all the functions of an organization or to meet all the needs of a business. (Hong & Kim, 2002) (Sarkis & Sundarraj, 2000)

It should be noted that even if a company management is fully aware of the ERP system selection process, this process is still a high ambiguity and semi-structured problem. Because only part of the problem can be solved by defining and adopting procedures such as the standard calculation of investment. But on the other hand, decision makers need to evaluate all the effective and intangible aspects which are important and relevant to the business. (Kenarolu, 2004)

2. LITERATURE REVIEW

Optimization models have been of interest to mathematicians and industry stakeholders since the industrial movement in the world, and especially since World War II. The main emphasis is on classical optimization models, i.e. having a measurement criterion (or an objective function). So that these models can be totally linear, nonlinear or mixed. But in recent years, the focus of research shifted to multiple-criteria models for complex decision-makings. In these decision making, rather than using just one criterion, multiple criteria are used for the optimization measurement. These decision making models can be divided into two categories: the multi-objective and multi-criteria models. Multi-objective models are used to design, while the multi-criteria models are used to select the top option.

The use of quantitative decision making methods is among the common tools in the process of selecting organizational software including ERP systems. According to the needs of each project, various methods have been used.

In general, the three main steps in the process of software selection of these decision-making methods have been compared and summarized as follows:

1) Determining the evaluation criteria
2) prioritizing the evaluation criteria
3) evaluating candidate software products and choosing the final purchase (ŞEN& BARAÇLI, 2006)

On the other hand, the theory of fuzzy sets was first proposed by Professor Lotfi Zadeh in 1965 and since then, it has had very effective usages. Fuzzy set theory has had many usages in the fields of Engineering and Management. That's why the most known qualitative and quantitative models in these fields have been developed using the fuzzy structures. Real-world problems which also include multi-criteria decision making problems usually have a complex structure due to the uncertainty and ambiguity in defining and understanding them. The use of fuzzy sets is an approach to overcome these complexities. So researchers are now focusing on the theory of fuzzy logic methods and multi-criteria approaches on fuzzy sets. Studies in this area (both fuzzy and non-fuzzy approaches) are as follows:

Many methods have been proposed for choosing the proper ERP systems or management information systems project. They are ranked according to their popularity. Although it is a very simple method, it does not seem reliable.

Teltumbde (Teltumbde, 2000) has proposed ten criteria for the evaluation of ERP system projects and created a framework based on the Nominal Group Technique (NGT) and Analytic Hierarchy Process (AHP) for the ultimate choice.

Santhanam and Kyparisis (Santhanam, & Kyparisis, 1995) have suggested a nonlinear method to optimize the allocation of resources and interaction with factors.

Lee and Kim (Lee & Kim, 2001) have used a combinational method consisting of Analytic Network Process (ANP) and ideal planning for the selection of information systems. But these methods of mathematical programming cannot include all the features in details and do not easily turn into quantitative methods because the features are limited by some financial factors. Professional organizations such as research institutes and consulting firms employ many experts to analyze the data in relation to ERP systems. This information can include market share, vendor's share, system performance and other data. In fact, choosing the right ERP system project involves multiple factors. For example, the project risk, compatibility, vendor's ability and other factors may not be properly defined.

Fuzzy multi-criteria decision making is very useful in the overall evaluation of linguistic variables and assessment weights of ERP system options. (Liang & Lien, 2007) (Sarkis & Sundarraj, 2000)

Selçuk Perçin (Selçuk Perçin, 2008), in an article entitled "Use of ANP method for selecting and testing ERP systems", proposed a model in which an appropriate mechanism has been introduced for the better understanding of various criteria effecting the selection of ERP systems. In this paper, 12 criteria were examined to evaluate selected options.

Prajoot and Mahanti (Kaur Mahanti, 2008), presented an article entitled "A fuzzy ANP-based approach for selecting ERP vendors", in which it is stated that this method is a useful quantitative method with non-quantitative characteristics. It has also been noted that this method will be very useful for solving the problem of the risk due to poor decision making. The use of fuzzy logic will help considerably to selecting a better methodology. Because despite the related ambiguities, it leads the preferences of decision makers to the best possible way. It this project, it has also been concluded that ANP method is a realistic, easy, flexible and inexpensive method.

Karsak and Ozgul (Karsak & Ozgul, 2009), in another study, entitled "Comprehensive decision-making procedure for selecting ERP system", referred to the application of Quality Function Deployment (QFD) method and fuzzy linear regression. They combined the framework of obtained features from ERP vendors in the market, customer's needs as features of the company, and strategic selection criteria.

Vincent et al (Vincent & Waiman, 2001), in another study entitled “group multi-criteria decision making: a case study of software selection ", used the AHP method to prioritize software systems. This study used the Delphi method in addition to the above mentioned methods. Moreover, it is flexible enough and can change decision-makers indexes.

Wei and Wang (Wei & Wang, 2004), in another article entitled "A comprehensive framework for ERP system selection", used theory of fuzzy sets in this discussion. In this study, concepts such as process reengineering were mentioned. A comprehensive 10-step approach for selecting the most appropriate ERP system has been developed which includes formation of a minimum for process reengineering, data collection and removal of options without qualities, creating hierarchies and assigning weights to the attributes, final ranking of appropriate ERP system, and so on. Having presented a real case study, they concluded that the proposed method would be very useful for selecting the most appropriate system. Some benefits including four cases are enumerated in this study. Liang and Lien (Liang & Lien, 2007), in a study entitled "Selecting optimal ERP software system by combining the fuzzy AHP-based method and ISO 9126 standard", addressed this issue with two case studies. In this article, a 5-step procedure has been proposed for group decision-makers on selecting an ERP software. This procedure introduces ISO 9126 standard approach for the interpretation of quality features of the above mentioned software. According to the two case study conducted in this paper, which were implemented in two different industries with different features, this method was practically very simple and flexible and adopted 32 criteria from two general titles: software quality feature and management feature. On the basis of comparing the two companies, A and B in this study, they have concluded that various industries assign different weights priorities for the criteria. But time has been detected as the most important criterion in this project.

3. RESEARCH METHODOLOGY

Implementation strategy of this paper is based on the following steps due to its combined approach:

First step: Studying library resources

At this stage of researcher’s studies, results were achieved which led to finding the keywords used in the study. Then the research was started using these keywords. Previous researches regarding any word were found and classified.

Step Two: Identifying the criteria

According to the literature review, important and key criteria which were most used in the references must be obtained in this section.

Step Three: Determining the significance of criteria

At this stage, the data obtained in the two previous steps regarding identifying basic and significant variables for the selection of ERP system are summarized, and finally, the 32 criteria which are of more importance for the selection of Enterprise Resources Management (ERM) software, particularly in higher education studies, were used to prepare the questionnaire. Then, the experts in this area have been identified. They were then invited to participate in meetings in order to fill out these questionnaires and comment on them. Based on their comments, the weight and importance of each criterion was evaluated.

Step Four: Presenting VIKOR model with intuitionistic fuzzy information

At this stage, The VIKOR model is presented with intuitionistic fuzzy information. First appropriate linguistic variables for expressing views and preferences of the experts are identified and then main modelling of the research is stated.

To describe the characteristics of software quality in our proposed procedure, the application of ISO 9126 software quality model is chosen as follows:

1. Operational criteria (functional): suitability, accuracy, interoperability with other parts, utility, security
2. Reliability criteria: maturity, fault tolerance, data recoverability
3. Usability: such as understandability, learnability, operability
4. Efficiency: time behavior, resource behavior
5. Maintainability: analyzability, changeability, testability, stability
6. Portability: adaptability, installability, conformance, replaceability

These 21 main criteria are the quality indicators.

Studies have indicated that the 11 sub-criteria of the 3 main criteria were also identified. The 11 criteria which are classified them as management criteria, are as follows:

1. Sub-criteria of vender: market share and reputation, industrial credentials, service and support, training solution,
2. Sub-criteria of cost: software cost, hardware cost, annual maintenance cost, and staff training cost.
3. Sub-criteria of time factors: time for planning and preparation, time for BRP and system tuning, time for testing and go-alive.

3.1 VIKOR Model

VIKOR method was introduced as one of the operational and valuable MCDM methods. This method focuses on the ranking and selection from a set of options in the presence of conflicting criteria. Practical problems are often characterized by inconsistent and incomparable criteria and it's possible that there is no solution to satisfy all the criteria simultaneously. It's a compromise solution to the problem with a number of conflicting criteria that can help decision makers to reach a final decision. Compromise solution which its basics were created by Yu Zeleny, is a feasible solution that eventually leads to the ideal. Here compromise means an agreement made by the parties consent. VIKOR method determines compromise ranking and compromise solution by the introduction of a multi-criteria ranking index based on the closest to the ideal solution criteria. The method uses LP-metric for compromise ranking as an aggregation function in the compromise programming method.

If there are n criteria and m options in a multi-criteria decision problem, to choose the best option using this method, the procedures are as follows:

1-1-3 Formation of decision matrix

According to the number of criteria, number of options and assessment of all options for different criteria, decision matrix is formed as follows:

$$X=\begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

Where x_ij is the performance of i, (i = 1,2, ..., m) option in relation to criterion j (j = 1,2, ..., n).

3-1-2 Removing the scales

At this stage, the criteria with different scales are converted to the criteria without scales, and the matrix F then is converted as follows:

$$F=\begin{bmatrix} f_{11} & \cdots & f_{1n} \\ \vdots & \ddots & \vdots \\ f_{m1} & \cdots & f_{mn} \end{bmatrix} \quad (2)$$

In this matrix:

$$f_{ij}=\frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^2{}_{ij}}} \quad (3)$$

3-1-3 Determining the weight vector of criteria

At this stage, according to weight coefficients of different criteria in the decision-taking, a vector is defined as follows:

$$W=[w_1,w_2,\ldots,w_n] \quad (4)$$

3-1-4 Determining the ideal and anti-ideal solution for each criterion

The ideal solutions for positive and negative criteria are respectively calculated using the following equations:

$$f_j^* = max_i F_{ij} \quad (5)$$

$$f_j^* = min_i F_{ij} \quad (6)$$

The anti-ideal solutions for positive and negative criteria are respectively calculated using the following equations:

$$f_j^- = min_i F_{ij} \quad (7)$$

$$f_j^- = max_i F_{ij} \quad (8)$$

In these equations, f_j^* is the ideal solution for the criterion j among all the options, and f_j^- is the anti-ideal solution for the criterion j among all options.

3-1-5 Calculating (S) value and (R) value
S and R values are calculated according to the following equations:

$$S_i = \sum_{j=1}^{n} w_j \frac{F_j^* - F_{ij}}{F_j^* - F_j^-}, \qquad i=1,2,\ldots, \qquad (9)$$

$$R_i = \left\{ w_j \frac{F_j^* - F_{ij}}{F_j^* - F_j^-} \right\}, \qquad i=1,2,\ldots,m \qquad (10)$$

Where w_jj is the appropriate value to the weight of the criterion j.

3-1-6 Calculating VIKOR Index (Q value)
Q value is calculated according to the following formula:

$$Q_i = v\left[\frac{S_i - S^-}{S^* - S^-}\right] + (1-v)\left[\frac{R_i - R^-}{R^* - R^-}\right], \qquad (11)$$

$$S^- = \text{Max } S_i S^* = \text{min } S_i R^- = \text{Max } R_i R^* = \text{Min } R_i \qquad (12)$$

In this equation:
$\frac{S^* - S^-}{S_i - S^-}$ represents the distance rate from the ideal solution and $\frac{R^* - R^-}{R_i - R^-}$ represents the distance rate from the anti-ideal solution and V parameter is selected according to the consensus of group decisionmakers. The value represents a decision by opinion of most people when v>0.5, it represents decision by consensus of decision maker when v=0.5, and it represents decision by refuse when v<0.5. Q value is a function of S_i and R_i.

3-1-7 Ranking the options based on R, S and Q values
At this stage, given the values of R and S and Q of options in three groups, they are ranked from the smaller to larger ones. Finally, the ideal solution is selected if only it is the ideal solution in all three groups. It should be noted that in Q group, the ideal solution must satisfy the following two conditions:
Condition 1: If $A_1$and A_2 are respectively the first and second ideal option in the group, and n is the number of options, the following equation is satisfied:

$$Q(A_2) - Q(A_1) \geq \frac{1}{n-1} \qquad (13)$$

Condition 2: A_1option must be the ideal solution at least in one of R and S groups.
When the first condition is not established, a set of options are selected as the ideal solutions as follows:
Ideal solutionsA_1 =A_2 and,…,and A_m
The highest value of m is calculated according to the following formula:

$$Q(A_m) - Q(A_1) < \frac{1}{n-1} \qquad (14)$$

If the second condition is not satisfied, the two options A_1 and A_2 are selected as the best options.

Intuitive Fuzzy Sets
Definition: In an intuitive fuzzy set or briefly IFS, every fuzzy set A on a nonempty set X is defined as follows:

$$(A = \{(x, \mu_A(x), v(X)) | x \in X\} \qquad (15)$$

Where $\mu_A(x)$ is the membership degree and $v_A(x)$ is the non-membership degree of in the A set, such that:

$$\mu_A : X \to [0,1], x \in X \to \mu_A(x) \in [0,1] \qquad (16)$$

$$v_A : X \to [0,1], x \in X \to v_A(x) \in [0,1] \qquad (17)$$

There is the following equation between the membership degree and non-membership degree:

$$\mu_A(x) + v_A(x) \leq 1, \forall x \in X \qquad (18)$$

For every intuitive set A, X will be:

$$\pi_A(x) = 1 - \mu_A(x) - v_A(x) \qquad (19)$$

Where $\pi_A(x)$ is called the intuitionistic index in the set A and it shows the hesitation degree of X in A. In fact, it is the membership space that we have no idea of it. When $\pi_A(x) = 0$, the fuzzy intuitive set A becomes a general fuzzy set A. So, every fuzzy set is a special form of intuitive fuzzy sets:

$$A = \{(x, \mu_A(x), 1 - \mu_A(x)) | x \in X\} \qquad ((20)$$

3.2.1 Triangular fuzzy numbers

Triangular fuzzy numbers A, B, assuming: $v_A(x) \neq v_B(x), \mu_A(x) \neq \mu_B(x)$, are defined as follows:

$$A = ([a'_1, b_1, c'_1); \mu_A], [(a_1, b_1, c_1); v_A] \qquad ((21)$$

$$B = ([a'_2, b_2, c'_2); \mu_B], [(a_2, b_2, c_2); v_B] \qquad ((22)$$

Triangular fuzzy numbers are displayed graphically in Figure 2-11:

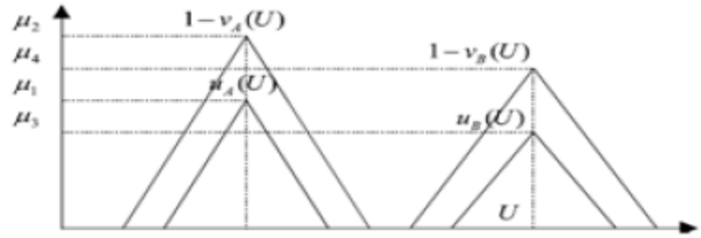

Figure 1. Triangular fuzzy numbers

The four main arithmetic operations on triangular fuzzy numbers are defined as follows:

$$A+B = ([(a'_1+a'_2, b_1+b_2, c'_1+c'_2); \min\{\mu_A, \mu_B\}], [(a_1+c_2, b_1-b_2, c_1-c_2); \max\{v_A, v_B\}]) \qquad ((23)$$

$$A-B = ([(a'_1-a'_2, b_1-b_2, c'_1-c'_2); \min\{\mu_A, \mu_B\}], [(a_1-c_2, b_1-b_2, c_1-a_2); \max\{v_A, v_B\}]) \qquad ((24)$$

Also for $A > 0$ and $B > 0$, we have:

$$(A \times B = ([a'_1 a'_2, b_1 b_2, c'_1 c'_2); \min\{\mu_A, \mu_B\}], [a_1 a_2, b_1 b_2, c_1 c_2); \max\{V_A, V_B\}]) \qquad (25)$$

$$A/B = ([a'_1/a'_2, b_1/b_2, c'_1/c'_2); \min\{\mu_A, \mu_B\}], [a_1/c_2, b_1/b_2, c_1/a_2); \max\{V_A, V_B\}]) \qquad (26)$$

$$max(A, B) = \langle [(max(x_1, y_1), max(x_2, y_2), max(x_3 . y_3)); min(\mu_A, \mu_B)], [(max(x'_1, y'_1), max(x'_2, y'_2), max(x'_3 . y'_3)); max(v_A, v_B)] \rangle \qquad (27)$$

$$max(A, B) = \langle [(max(x_1, y_1), max(x_2, y_2), max(x_3 . y_3)); min(\mu_A, \mu_B)], [(max(x'_1, y'_1), max(x'_2, y'_2), max(x'_3 . y'_3)); max(v_A, v_B)] \rangle \qquad (28)$$

3-2-2 VIKOR method in intuitive fuzzy environment

In VIKOR method, the importance value associated with each option and performance of each option in relation to other options is very important. It is very hard to determine the accurate data, especially on personal judgment which is usually very vague. The reason is that personal judgments are made under different conditions and situations. Fuzzy sets and other non-fuzzy sets are very good in the identification of present uncertainties during obtaining the data. Therefore, the extension of VIKOR method for the non-standard fuzzy environment is quite natural. In the non-standard fuzzy environment, intuitive fuzzy handles this uncertainty very well. In many situations, there is not enough information to define accurately the membership degree for the specified elements and there might be doubts in the membership and non-membership degrees. Thus, in many real-world problems due to lack of sufficient and available information, intuitive fuzzy will be capable to overcome this problem.

We assume that $D = [x_{ij}]_{m \times n}$, is an intuitive fuzzy decision matrix for a multi-criteria decision-making problem with *m* $A_1, A_2, \ldots, A_m$ options, in which the decision maker wants to select the appropriate option among them and there are n $C_1, C_2, \ldots, C_n$ criteria which measure the performance of options. Therefore, x_{ij} is the A_i option price with respect to criterion C_j and W_1 is the criteria weight in an intuitive fuzzy way.

The first step: At this stage, the positive and negative ideal solutions are determined for each criterion.

We have:

$$x_j^{+} = \max_i x_{ij} \quad , \qquad x_j^{-} = \min_i x_{ij} \tag{29}$$
$$A^{+} = \{x_1^{+}, x_2^{+}, \dots, x_n^{+}\}$$
$$A^{-} = \{x_1^{-}, x_2^{-}, \dots, x_n^{-}\}$$

Second step: In this stage, the R_i and S_i values for each option i = 1,2, ..., m is calculated:

$$S_i = \sum_{j=1}^{n} W_j \times \left(\frac{x_j^{+} - x_{ij}}{x_j^{+} - x_j^{-}}\right) =$$

$$\sum_{j=1}^{n} \langle \left[\left(w_{1j}, w_{2j}, w_{3j}\right); \mu_{w_j}\right], \left[\left(w'_{1j}, w'_{2j}, w'_{3j}\right); v_{w_j}\right] \rangle \times \left[\frac{\left\langle \left[\left(x_{1j}^{+}-x_{3ij}, x_{2j}^{+}-x_{2ij}, x_{3j}^{+}-x_{1ij}\right);\min(\mu_{x_j^{+}},\mu_{x_{ij}})\right], \left[\left({x'_{1j}}^{+}-x'_{3ij}, {x'_{2j}}^{+}-x'_{2ij}, {x'_{3j}}^{+}-x'_{1ij}\right);;\max(v_{x_j^{+}},v_{x_{ij}})\right]\right\rangle}{\left\langle \left[\left(x_{1j}^{+}-x_{3j}^{-}, x_{2j}^{+}-x_{2j}^{-}, x_{3j}^{+}-x_{1j}^{-}\right);\min(\mu_{x_j^{+}},\mu_{x_j^{-}})\right], \left[\left({x'_{1j}}^{+}-{x'_{3j}}^{-}, {x'_{2j}}^{+}-{x'_{2j}}^{-}, {x'_{3j}}^{+}-{x'_{1j}}^{-}\right);;\max(v_{x_j^{+}},v_{x_j^{-}})\right]\right\rangle}\right],$$

$$S_i == \langle [(S_{1i}, S_{2i}, S_{2i}); \mu_{S_i}], [(S'_{1i}, S'_{2i}, S'_{3i}); v_{S_i}] \rangle$$

And

$$R_i = \max_j W_j \times \left(\frac{x_j^{+} - x_{ij}}{x_j^{+} - x_j^{-}}\right) =$$

$$\max_j \left(\langle \left[\left(w_{1j}, w_{2j}, w_{3j}\right); \mu_{w_j}\right], \left[\left(w'_{1j}, w'_{2j}, w'_{3j}\right); v_{w_j}\right] \rangle \times \left[\frac{\left\langle \left[\left(x_{1j}^{+}-x_{3ij}, x_{2j}^{+}-x_{2ij}, x_{3j}^{+}-x_{1ij}\right);\min(\mu_{x_j^{+}},\mu_{x_{ij}})\right], \left[\left({x'_{1j}}^{+}-x'_{3ij}, {x'_{2j}}^{+}-x'_{2ij}, {x'_{3j}}^{+}-x'_{1ij}\right);;\max(v_{x_j^{+}},v_{x_{ij}})\right]\right\rangle}{\left\langle \left[\left(x_{1j}^{+}-x_{3j}^{-}, x_{2j}^{+}-x_{2j}^{-}, x_{3j}^{+}-x_{1j}^{-}\right);\min(\mu_{x_j^{+}},\mu_{x_j^{-}})\right], \left[\left({x'_{1j}}^{+}-{x'_{3j}}^{-}, {x'_{2j}}^{+}-{x'_{2j}}^{-}, {x'_{3j}}^{+}-{x'_{1j}}^{-}\right);;\max(v_{x_j^{+}},v_{x_j^{-}})\right]\right\rangle}\right] \right),$$

$$R_i = \langle [(R_{1i}, R_{2i}, R_{2i}); \mu_{R_i}], [(R'_{1i}, R'_{2i}, R'_{3i}); v_{R_i}] \rangle$$

Third step: Calculating VIKOR index $Q_i \ \ i = 1, \dots, m$ according to the following equations:

$$S^{+} = \min_i S_i \quad , \qquad S^{-} = \max_i S_i$$
$$R^{+} = \min_i R_i \quad , \qquad R^{-} = \max_i R_i$$

$$Q_i = \vartheta \times \left[\frac{\left\langle [(S_{1i} - S_3^{+}, S_{2i} - S_2^{+}, S_{3i} - S_1^{+}); \min(\mu_{S_i}, \mu_{S^{+}})], [(S'_{1i} - {S'_3}^{+}, S'_{2i} - {S'_2}^{+}, S'_{3i} - {S'_1}^{+});; \max(v_{S_i}, v_{S^{+}})] \right\rangle}{\left\langle [(S_1^{-} - S_3^{+}, S_2^{-} - S_2^{+}, S_3^{-} - S_1^{+}); \min(\mu_{S^{-}}, \mu_{S^{+}})], [({S'_1}^{-} - {S'_3}^{+}, {S'_2}^{-} - {S'_2}^{+}, {S'_3}^{-} - {S'_1}^{+});; \max(v_{S^{-}}, v_{S^{+}})] \right\rangle}\right] +$$

$$(1 - \vartheta) \times \left[\frac{\left\langle [(R_{1i} - R_3^{+}, R_{2i} - R_2^{+}, R_{3i} - R_1^{+}); \min(\mu_{R_i}, \mu_{R^{+}})], [(R'_{1i} - {R'_3}^{+}, R'_{2i} - {R'_2}^{+}, R'_{3i} - {R'_1}^{+});; \max(v_{R_i}, v_{R^{+}})] \right\rangle}{\left\langle [(R_1^{-} - R_3^{+}, R_2^{-} - R_2^{+}, R_3^{-} - R_1^{+}); \min(\mu_{R^{-}}, \mu_{R^{+}})], [({R'_1}^{-} - {R'_3}^{+}, {R'_2}^{-} - {R'_2}^{+}, {R'_3}^{-} - {R'_1}^{+});; \max(v_{R^{-}}, v_{R^{+}})] \right\rangle}\right]$$

The fourth step: According to VIKOR method, the option that has the minimum Q value is a suitable option and will be introduced as the proposed option. But here, $Q_i \ \ , i = 1, \dots, m$ values are all intuitive fuzzy. To select the minimum triangular fuzzy number, it needs to be compared with other options. To do this, a specific number is required for the fuzzy number. The specific intuitive fuzzy value of each option is called Q_i^{*} and it is calculated according to the following formula:

$$Q_i^{*} = \frac{(Q_{1i} + Q_{2i} + Q_{3i})\mu_{Q_i} + \ (Q'_{1i} + Q_{2i} + Q'_{3i})v_{Q'_i}}{6}$$

The ideal solution (with the minimum Q_i) is obtained when the two following conditions are maintained:
1. The first condition (reception characteristics):

$$Q(A^{[2]}) - Q(A^{[1]}) \geq DQ$$
$$DQ = \frac{1}{m-1}$$

So that:
$A^{[1]}$، $A^{[2]}$: They are located in the first and second place according to ascending ranking based on Q criterion.
M: Number of options
2. The second condition (stability of decision making reception)
Option $A^{[1]}$ should also have the best rank in the S or (and) R .
If one of the above conditions is not maintained, then a series of compromise solutions will be proposed as follows:
1) If the second condition in not maintained, then options $A^{[1]}$ and $A^{[2]}$
2) If the second condition in not maintained, then options $A^{[1]}$ and $A^{[2]}$، ...، $A^{[m]}$.
$A^{[m]}$: It's an option in ^{M} position that the equation $Q(A^{[m]}) - Q(A^{[1]}) \geq D$ is true about it.(Wei, C. C., Wang, M. J. , 2004)

4. Implementation

Various criteria which are in conflict with each other influence the selection and effective implementation of ERP systems software. As a result, the prioritization and selection of appropriate software for the implementation of ERP is a multi-criteria decision making. Accordingly, a method is proposed for this problem. According to the proposed method, the first step should be to determine the criteria for the assessment of options.

Library studies have been conducted to determine effective criteria for the selection of ERP software for the implementation, and an expert team were invited for the consultation. Finally, 32 criteria have been specified as critical factors affecting the issue. It should be noted that many factors affect the issue. But the 32 criteria are considered as the critical and basic criteria and other criteria are disregarded.

The questionnaire was used as the data collection method. Questionnaires are the most widely used means in quantitative survey research. Since the subject of the research is new and innovative and there were no standardized questionnaires in this area, two questionnaires were designed using data obtained from brainstorming sessions and content analysis of available documents. The first questionnaire consisted of 32 questions and the second questionnaire included four main parts which totally contained 32 questions.

For this purpose a questionnaire was prepared in two stages. In the first questionnaire, the importance of 32 significant criteria were evaluated which were obtained through the analysis of the qualitative section of the research. In the second questionnaire, the importance of each criterion for each of the proposed options was questioned and evaluated.

4.1 Determining the criteria weight and completing the evaluation matrix

In the next step, questionnaires distribution is used to determine the weight of the criteria used in the assessment. At this stage, the experts will assist in determining the weight of evaluation criteria by entering information based on the scales and linguistic variables described in the previous chapter. After completing the questionnaires, expert's opinions are integrated using geometric mean and finally, the ultimate weight of the criteria is extracted. Geometric mean method for the aggregation of expert opinion is a well-known method in multi-criteria decision making methods.

$$w_j = \frac{1}{k}\left[w_j^1 + w_j^2 + \cdots + w_j^k\right]$$

To aggregate the expert opinion, the geometric mean of the seven matrix is obtained and converted into a table that is seen in Table 2.

Table 2. Weight of criteria for selecting ERP software

	Criteria	Fuzzy weight
1	Suitability	⟨[(0.51,0.73,0.81); 0.5], [(0.61,0.73,0.91); 0.45]⟩
2	Accuracy	⟨[(0.51,0.73,0.82); 0.5], [(0.61,0.73,0.91); 0.45]⟩
3	Interoperability with other parts	⟨[(0.48,0.71,0.82); 0.5], [(0.58,0.72,0.93); 0.45]⟩
4	Utility	⟨[(0.48,0.71,0.81); 0.5], [(0.89,0.71,0.93); 0.45]⟩
5	Maturity	⟨[(0.39,63,0.74); 0.4], [(0.5,0.63,0.84); 0.55]⟩
6	Security	⟨[(0.62,0.83,0.86); 0.6], [(0.72,0.83,0.97); 0.3]⟩
7	Fault tolerance	⟨[(0.44,63,0.72); 0.1], [(0.52,0.63,0.79); 0.45]⟩
8	Data recoverability	⟨[(0.39,0.64,0.76); 0.5], [(0.49,0.64,0.89); 0.45]⟩
9	Understandability	⟨[(0.41,0.66,0.76); 0.4], [(0.52,0.66,0.87); 0.55]⟩
10	Learnability	⟨[(0.24,0.5,0.64); 0.4], [(0.35,0.5,0.75); 0.55]⟩
11	Operability	⟨[(0.24,0.46,0.59); 0.1], [(0.32,0.46,0.69); 0.90]⟩
12	Time behavior	⟨[(0.42,0.67,0.78); 0.5], [(0.52,0.67,0.92); 0.45]⟩
13	Resource behavior	⟨[(0.3,0.56,0.69); 0.4], [(0.41,0.56,0.81); 0.55]⟩
14	Analyzability	⟨[(0.45,0.69,0.79); 0.5], [(0.55,0.69,0.9); 0.45]⟩
15	Changeability	⟨[(0.39,0.63,0.74); 0.4], [(0.49,0.63,0.84); 0.55]⟩
16	Stability	⟨[(0.51,0.74,0.83); 0.6], [(0.61,0.74,0.96); 0.3]⟩
17	Testability	⟨[(0.44,0.67,0.75); 0.4], [(0.55,0.67,0.85); 0.55]⟩

18	Adaptability	⟨[(0.16,0.44,0.58); 0.4], [(0.29,0.44,0.69); 0.55]⟩
19	Installability	⟨[(0.24,0.5,0.64); 0.4], [(0.35,0.5,0.75); 0.55]⟩
20	System conformance	⟨[(0.29,0.56,0.68); 0.4], [(0.41,0.56,0.81); 0.55]⟩
21	Replaceability	⟨[(0.26,0.51,0.64); 0.4], [(0.37,0.51,0.73); 0.55]⟩
22	Market share and popularity	⟨[(0.27,0.53,0.66); 0.4], [(0.38,0.53,0.78); 0.55]⟩
23	Industrial licensing	⟨[(0.36,0.61,0.74); 0.5], [(0.46,0.61,0.86); 0.45]⟩
24	Selling support services	⟨[(0.51,0.73,0.81); 0.5], [(0.6,0.73,0.91); 0.45]⟩
25	Vector training solution (training quality)	⟨[(0.45,0.69,0.79); 0.5], [(0.55,0.69,0.9); 0.45]⟩
26	System software cost	⟨[(0.35,0.6,0.71); 0.4], [(0.46,0.6,0.81); 0.55]⟩
27	System hardware cost	⟨[(0.32,57,0.69); 0.4], [(0.44,0.57,0.79); 0.55]⟩
28	Annual cost of system maintenance	⟨[(0.36,0.6,0.72); 0.5], [(0.46,0.6,0.81); 0.45]⟩
29	Cost of staff training	⟨[(0.36,0.61,0.74); 0.5], [(0.46,0.61,0.81); 0.45]⟩
30	Required time for programming and preparation	⟨[(0.39,0.62,0.74); 0.5], [(0.49,0.63,0.84); 0.45]⟩
31	Required time for BRP and settings	⟨[(0.3,0.56,0.69); 0.4], [(0.41,0.56,0.81); 0.55]⟩
32	Required time for testing and delivering	⟨[(0.48,0.7,0.79); 0.5], [(0.58,0.7,0.88); 0.45]⟩

4.2 Case study and data collection

Regarding the selection of the appropriate ERP software for the implementation, there were currently four related software on the agenda of the company under study. This process is carried out in this thesis. The four potential situations are as follows:

1. SAP Software
2. PeopleSoft software
3. Oracle software
4 Sage Group Software

4-3 Formation of evaluation matrix

After the introduction of options, the evaluation matrix is formed. Seven experts completed the matrix for the formation of the evaluation matrix and their comments were aggregated using the geometric mean. These comments are presented in Appendix 7.

4.4 VIKOR Method Calculations

After determining the positive and negative ideal solution for each criterion, the distance between the positive and negative ideal solution is calculated (Table 3). All the values of the distance from the negative ideal are equal to one. The value of VIKOR coefficient for options, for three different coefficient values of the maximum group utility is calculated v = 0,0.5,1. These values are presented in Table 4.

Table 3 - the ideal coefficients of positive and negative studied options

Indexes / Options	S	R
A	⟨[(−3.49,10.68, −142.3); 0.1], [(−4.16,10.68, −181.5); 0.9]⟩	⟨[(0.003,0.76, −1.22); 0.1], [(0.01,0.7624, −1.78); 0.9]⟩
B	⟨[(−3.48,13.04, −108.4); 0.1], [(−4.83,13.04, −94.14); 0.9]⟩	⟨[(0.009,0.79, −1.44); 0.1], [(0.02,0.79, −1.12); 0.9]⟩
C	⟨[(−5.62,7.3, −51.62); 0.1], [(−8.58,7.3, −51.92); 0.9]⟩	⟨[(−0.14,1.21, −0.52); 0.1], [(−0.005,1.21, −0.48); 0.9]⟩
D	⟨[(−5.37,12.42, −55.8); 0.1], [(−7.19,12.42, −65.6); 0.9]⟩	⟨[(−0.03,0.99, −0.74); 0.1], [(−0.03,0.99, −0.77); 0.9]⟩

Table 4. The VIKOR coefficient of studied options

Indexes / Options	Q			S	R
	$v = 0$	$v = 0.5$	$v = 1$		
A	-0.8076	-0.7680	-0.7284	-28.4995	-0.0577
B	-0.0892	-0.5341	-0.9347	-14.5385	-0.1589
C	-0.0387	-0.4600	-0.8872	-8.8131	0.1212
D	4.4599	4.5735	4.7047	-9.8690	0.0326

4-5- Final ranking

After this step, Q values should be sorted based on an ascending order. Also the coefficient value of $DQ = \frac{1}{(4-1)}$ is equal to 333/0.

When v = 0 :

First option: Q_1 = -0.8076 value

The second option: Q_2 = -0.0892 value

The first condition: Q_2-Q_1≥DQ → (-0.0892 - (- 0.8076)) ≥0.333

Second condition: the first option must be in the first rank at least in one of the S or R index. And as it is clear from 3-4, the first option is in the first rank in the S index.

Considering that the first option satisfies both conditions, thus it's selected as the best software by itself.

When v = 0.5:

The first option: Q_1 = -0.7680 value

The second option: Q_2 = -0.5341 value

The first condition: Q_2-Q_1≥DQ → (-0.7680 - (- 0.5341)) ≱0.333

The first option satisfies the second, but does not satisfy the first condition. Therefore, only one option can be selected as the best option for software implementation. And this is how several software should be introduced as ideal for the implementation. Accordingly and based on the definitions, since the first condition has not been satisfied, the last option for which the first condition is not satisfied, is among the selected options. The fourth priority, i.e. the fourth software with Q_4 = 4.5735 value, satisfies the first condition. The third option also does not satisfy the first condition:

$$Q_4 - Q_1 \geq DQ \quad \rightarrow (4.5735 - (-0.5341)) \geq 0.33$$

So, these three software C, B, A are selected as the best options.

When v = 1:

The second option: Q_2 = -0.9347 value

The third option: Q_3 = -0.8872 value

The first condition: Q_3-Q_2≥DQ → (-0.8872 - (- 0.9347)) ≱0.333

Regarding that the second option satisfies the second condition, but does not satisfy the first condition, thus only one option cannot be selected as the best option for software implementation and this is how several software should be introduced as ideal for the implementation. Accordingly and with respect to the definitions, since the first condition has not been satisfied, the last option for which the first condition is not satisfied, is one of the selected options. The fourth priority, i.e. the fourth software with $Q_4 = 4.5735$ value, satisfies the first condition. The third option also does not satisfy the first condition. Namely:

$$Q_4 - Q_2 \geq DQ \quad \rightarrow (4.5735 - (-0.5341)) \geq 0.33$$

So, these three software B, C, A are selected as the best options.

5. Conclusion

With regard to the fact that the selection and prioritization of ERP software are influenced by various criteria and these criteria are in conflict with each other, and also evaluation criteria are generally qualitative and vague, thus this issue cannot be decided simply and by mental arithmetic. Therefore, the present thesis aims to provide a decision-making approach based on intuitive fuzzy for the selection of ERP software. This approach uses multi-criteria decision making method. Also, VIKOR method was used for the final ranking. Finally, triangular fuzzy numbers were used for data expression and evaluation.

In this study, the proposed approach was used to rank the options. SAP software in the first case, SAP, People Soft and Oracle software in the second case, and People Soft, Oracle and SAP software in the third case were selected as the best options. In Table 5 below, the best options in different v cases are displayed:

Table 5. Result of selected options in different v cases

Q in different v cases / options	$v = 0$	$v = 0.5$	$v = 1$
A		✓	✓
B		✓	✓

C		✓	✓
D			

As a result, SAP software is selected as the best option since it has been ranked as the top choice in most cases.

5 -1- Suggestions on Further Studies

- ✓ The proposed approach has been only used for the selection of ERP software and it has provided useful results. Therefore, this approach can be used for other decision-making situations in the field of ERP in organizations.
- ✓ Providing a decision support system (DSS) using the proposed approach can make possible the sufficiency and easily use of this approach for organizations.
- ✓ It is assumed that the criteria are independent of each other. However, the criteria are usually affected by each other. For this purpose, the ANP method can be used to determine the weight of criteria.
- ✓ On this topic, fuzzy Likert scale has been used for quantifying the qualitative criteria. But other methods such as distributing questionnaires and brainstorming can also be used.
- ✓ Some of the used criteria were formed by several sub-criteria. Therefore, each of these criteria can be calculated based on the related sub-criteria.

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