

Selecting Enterprise Resource Planning System Using Fuzzy Analytic Hierarchy Process Method

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Abstract

To select an enterprise resource planning (ERP) system is time consuming due to the resource constraints, the software complexity, and the different of alternatives. A comprehensively systematic selection policy for ERP system is very important to the success of ERP project. In this paper, we propose a fuzzy analytic hierarchy process (FAHP) method to evaluate the alternatives of ERP system. The selection criteria of ERP system are numerous and fuzzy, so how to select an adequate ERP system is crucial in the early phase of an ERP project. The framework decomposes ERP system selection into three main factors. The goal of this paper is to select the best alternative that meets the requirements with respect to product factors, system factors and management factors. The sub-attributes (sub-factors) related to ERP selection have been classified into twelve main categories of Functionality, Reliability, Usability, Efficiency, Maintainability, Cost, Implementation time, User friendliness, Flexibility, Vendor Reputation, Consultancy Services, and R&D Capability and arranged in a hierarchy structure. These criteria and factors are weighted and prioritized and finally a framework is provided for ERP selection with the fuzzy AHP method. Also, a real case study from Iran is also presented to demonstrate efficiency of this method in practice.

Keywords: ERP System Selection; Analytic Hierarchy Process (AHP); Fuzzy Logic; Decision Analysis; ERP Vendor.

1. Introduction

An Enterprise Resource Planning (ERP) system represents an information management system which is supposed to manage the data flow among the working modules of a company. An ERP system generally includes a shared data base and different modules and applications which are used in order to facilitate planning, production, sales, marketing, distribution, human resources, project management, inventory, data processing and information storage. ERP systems allow the company's processes to be automated thus increasing the operational efficiency [1]. The use and the importance of computing information systems and their applications to improve effectiveness and efficiency of business functions have increased significantly. Furthermore, because of the exponential increase in the competition in the globalized economy, coupled with ever so changing customer needs and wants, the complexity of the business processes has also risen. These all have led to ERP systems becoming an essential part of any modern day solution to the increasingly complex business environment [2]. ERP is increasingly important in modern business because of its ability to integrate the flow of material, finance, and information and to support organizational strategies [3-4]. A successful ERP project involves managing business process change, selecting an ERP software system and a co-operative vendor, implementing this system, and examining the practicality of the new system [5].

There are three phases that constitute ERP system life cycle. These phases are selection, implementation and use. Problem identification, requirements specification, evaluation of options and selection of system can be regarded as the activities within the ERP selection process. ERP selection is the first phase and is regarded as the most critical success factor for ERP implementation [6]. Determining the best ERP software that fits with the organizational necessity and criteria, is the first step of tedious implementation process. Hence, selecting a suitable ERP system is an extremely difficult and critical decision for managers. An unsuitable selection can significantly affect not only the success of the implementation but also performance of the company. However, many companies install their ERP systems hurriedly without fully understanding the implications for their business or the need for compatibility with overall organizational goals and strategies [7-8]. The result of this hasty approach is failed projects or weak systems whose logic conflicts with organizational goals.

ERP selection issue can be viewed as a multiple criteria decision making (MCDM) problem in the presence of many quantitative and qualitative criteria that should be considered in the selection procedure including a set of possible vendor alternatives. A decision maker is required to choose among quantifiable or non-quantifiable and multiple criteria. The decision maker's evaluations on qualitative criteria are always subjective and thus imprecise. The objectives are usually conflicting and therefore the solution is highly dependent on the

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preferences of the decision maker. Besides, it is very difficult to develop a selection criterion that can precisely describe the preference of one alternative over another. The evaluation data of ERP alternatives suitability for various subjective criteria, and the weights of the criteria are usually expressed in linguistic terms. This makes fuzzy logic a more natural approach to this kind of problems. In this paper, we used its fuzzy analytic hierarchy process (FAHP) extension to obtain more decisive judgments by prioritizing criteria and assigning weights to the alternatives.

This paper presents a comprehensive framework for selecting a suitable ERP system based on an AHP-based decision analysis process. The proposed procedure allows a company to identify the elements of ERP system selection and formulate the fundamental-objective hierarchy and means objective network. The pertinent attributes for evaluating a variety of ERP systems and vendors can be derived according to the structure of objectives.

Cebeci and Ruan investigated some quality consultants using fuzzy AHP [5]. Wei, Chien, and Wang proposed a comprehensive framework for selecting a suitable ERP system based on an AHP-based decision analysis process [7]. The AHP is one of the extensively used multi-criteria decision-making methods. One of the main advantages of this method is the relative ease with which it handles multiple criteria. In addition to this, AHP is easier to understand and it can effectively handle both qualitative and quantitative data. The literature cited herein is just an exemplary sample of what has been studied in the area of ERP system selection. The quantity and quality of the published articles in this field are a testament to both importance and the complexity of the ERP system selection problem. What differentiates our approach from the ones conducted previously is the following: first, it ensures that the structure of objectives is consistent with corporate goals and strategies. The project team can understand the relationships among different objectives and assess their influence by modeling them to the hierarchical and network structures. Second, the project team can decompose the complex ERP selection problem into simpler and more logical judgments of the attributes. Particularly, knowledge of structure of objectives can help the project team to identify the company requirements and develop appropriate system specifications. These objectives also indicate how outcomes should be measured and what key points should be considered in the decision process. Third, the approach is flexible enough to incorporate extra attributes or decision makers in the evaluation. Notably, the proposed framework can accelerate the reaching of consensus among multiple decision makers. Finally, the approach systematically assesses corporate attributes and guidance based on the company goals and strategic development. It can not only reduce costs during the selection phase, but also mitigate the resistance and invisible costs in the implementation stage.

The remaining part of the paper is organized as follows: Section 2 describes the related work. The fuzzy analytic hierarchy process algorithm is introduced in Section 3. The ERP system selection framework is presented in Section 4. The Application of FAHP in ERP System Selection using a real case study and the obtained results are discussed in section 5. Finally, Section 6 gives the conclusion of the study.

2. Related Work

Selection process is a critical success factor. The process of selecting an Enterprise Resource Planning (ERP) system is a complex problem which involves multiple actors and variables, since it is a decision-making process which is characterized as unstructured type [4,5]. The number of studies have explored various selection methods of ERP system either qualitative or quantitative.

Owing to the essence of IT system, selection problem is a Multi-criteria decision-making (MCDM) process. Several papers adopted analytic hierarchy process (AHP) to be the analytical tool [6,7]. Lin [8] and Luo and Strong [9] studied the ERP evaluation models for universities. Selection criteria of ERP system is also a crucial issue in ERP project. When implementing an ERP project, price and time are both the most important factors. Besides, the vender's support is also a crucial issue [10]. Except the investment cost of ERP project, the annual maintenance cost and human resource cost are also the potential expense for organizations [11-13]. There was an ERP selection model containing three categories of selection attributes including project factors, software system factors and vender factors [3].

In the Wei and Wang [3] several methods have been proposed for selecting a suitable ERP system [14-18]. The scoring method is one of the most popular. Although it is intuitively simple, it does not ensure resource feasibility. Teltumbde [14] suggested 10 criteria for evaluating ERP projects and constructed a framework based on the Nominal Group Technique (NGT) and the analytic hierarchy process (AHP) to make the final choice.

Lee and Kim [17] combined the analytic network process (ANP) and a 0-1 goal programming model to select an information system. However, these mathematical programming methods can not contain sufficient detailed attributes, above all, which are not easy to quantify, so that the attributes were restricted to some financial factors, such as costs and benefits. Furthermore, many of them involved only the consideration of internal managers, but do not offer a comprehensive process for combining evaluations of different data sources to select an ERP project objectively.

Wei and Wang [3] stated clearly that; a successful ERP project involves selecting an ERP software system and vendor, implementing this system, managing business processes, and examining the practicality of the system. However, a wrong ERP project selection would either fail

the project or weaken the system to an adverse impact on company performance [19-20]. It is obvious that one firm organization needs some metrics in order to choose the right ERP and its implementers. Thus decision needs some tools. Wei, Chien and Wang [7] introduced AHP based approach to ERP system selection.

Ayag and Ozdemir, [47], used fuzzy ANP as the methodology for the selection of ERP software and presented a case study in a firm in electronics sector and Percin, [48], also proposed ANP as a viable decision making tool for ERP selection problem. The criteria used in the study are divided into two groups: system factors (i.e., functionality, strategic fitness, flexibility, user friendliness, implementation time, total costs, and reliability) and vendor factors (i.e., market share, financial capability, implementation ability, R&D capability, and service support). With this study, they showed the utility and versatility of ANP for this complex selection problem. Similarly, Unal and Guner, [49], and Cebeci, [50], proposed a methodology based on AHP and fuzzy AHP respectively for ERP supplier selection for an organization in the textile industry. A similar application of fuzzy AHP was also performed in an automotive company for the selection of ERP outsourcing firm [51]. With another study, Sen, Baracl, Sen, and Basligil [52], showed the viability of a combined decision making methodology for the ERP selection problem. Within the proposed methodology, the fuzzy set theory and random experiment based methods are combined and successfully applied to both quantitative and qualitative factors. The hybrid methodology was proposed by Kilic, Zaim, and Delen, [53], they used fuzzy AHP and TOPSIS for the selection of ERP software for an airline company.

3. Fuzzy Analytic Hierarchy Process Algorithm

Analytic Hierarchy Process: AHP was proposed by Saaty [21] to model subjective decision-making processes based on multiple attributes in a hierarchical system. Saaty introduced AHP as a powerful and flexible decision making technique that helps decision makers to set priorities and choose the best alternative [21]. From that moment on, it has been widely used in corporate planning, portfolio selection, and benefit/cost analysis by government agencies for resource allocation purposes. It should be highlighted that all decision problems are considered as a hierarchical structure in the AHP. The first level indicates the goal for the specific decision problem. In the second level, the goal is decomposed of several criteria and the lower levels can follow this principal to divide into other sub-criteria. Therefore, the general form of the AHP can be depicted as shown in Fig.1.

The four main steps of the AHP can be summarized as follows [22]:

Step 1: Set up the hierarchical system by decomposing the problem into a hierarchy of interrelated elements;

Step 2: Compare the comparative weight between the attributes of the decision elements to form the reciprocal matrix;

Step 3: Synthesize the individual subjective judgment and estimate the relative weight;

Step 4: Aggregate the relative weights of the elements to determine the best alternatives/strategies.

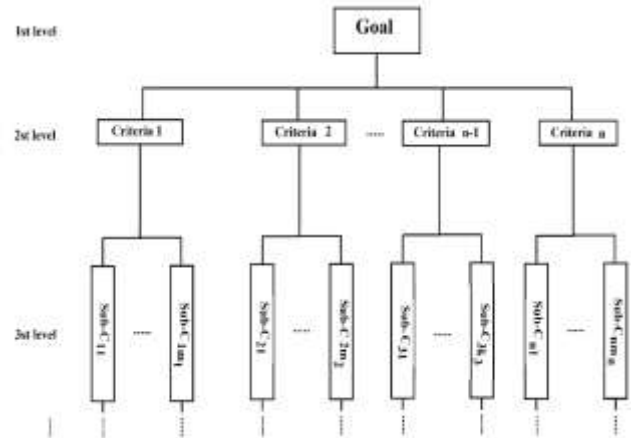


Fig. 1. The hierarchical structure of the AHP.

Fuzzy Analytic Hierarchy Process: The fuzzy AHP technique can be viewed as an advanced analytical method developed from the traditional AHP. Despite the convenience of AHP in handling both quantitative and qualitative criteria of multi-criteria decision making problems based on decision makers' judgments, fuzziness and vagueness existing in many decision-making problems may contribute to the imprecise judgments of decision makers in conventional AHP approaches [23]. So, many researchers [24-32] who have studied the fuzzy AHP which is the extension of Saaty's theory, have provided evidence that fuzzy AHP shows relatively more sufficient description of these kind of decision making processes compared to the traditional AHP methods. Yu [33] employed the property of goal programming to solve group decision making fuzzy AHP problem. Weck et al. [34] evaluated alternative production cycles using fuzzy AHP. Sheu [35] presented fuzzy-based approach to identify global logistics strategies. Kulak and Kahraman [36] used fuzzy AHP for multi-criteria selection among transportation companies. Kuo et al. [37] integrated fuzzy AHP and artificial neural network for selecting convenience store location. Cheng [27, 38] proposed a new algorithm for evaluating naval tactical missile systems by the fuzzy AHP based on grade value of membership function. Zhu et al. [39] made a discussion on the extent analysis method and applications of fuzzy AHP.

In complex systems, the experiences and judgments of humans are represented by linguistic and vague patterns. Therefore, a much better representation of these linguistics can be developed as quantitative data, this type of data set is then refined by the evaluation methods of fuzzy set theory. On the other hand, the AHP method is mainly used in nearly crisp (non-fuzzy) decision applications and creates and deals with a very unbalanced scale of judgment. Therefore, the AHP method does not take into account the uncertainty associated with the mapping [40]. The AHP's subjective judgment, selection and preference of decision-makers have great influence on the success of

the method. The conventional AHP still cannot reflect the human thinking style. Avoiding these risks on performance, the fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems.

In this study, Chang's [41] extent analysis on fuzzy AHP is formulated for a selection problem. Chang's extent analysis on fuzzy AHP depends on the degree of possibilities of each criterion. According to the responses on the question form, the corresponding triangular fuzzy values for the linguistic variables are placed and for a particular level on the hierarchy the pairwise comparison matrix is constructed.

The fuzzy AHP algorithm is constructed in six steps using Chang's extent analysis method [27, 41], a popular fuzzy AHP approach. The method is relatively easier than other proposed approaches and has been used in several cases [42-43]. Let $X = \{x_1, x_2, \dots, x_n\}$ be an object set and $G = \{g_1, g_2, \dots, g_n\}$ be a set of goals. According to the method of Chang's extent analysis, each object is taken and extent analysis for each goal is performed, respectively. Therefore, m extent analysis values for each object can be obtained with the following signs: $M^1_{g_i}, M^2_{g_i}, \dots, M^m_{g_i}$, $i = 1, 2, \dots, n$, where all $M^j_{g_i} (j = 1, 2, \dots, m)$ are triangular fuzzy numbers. Among various membership functions, the triangular fuzzy number is the most popular in the engineering applications. The triangular fuzzy number \tilde{M} is denoted simply by (l, m, u) and shown in Fig. 2. The parameters l and u , respectively, represent the smallest and the largest possible values and m stands for the most promising value that describe a fuzzy event. Each triangular fuzzy number has linear representations on its left and right side such that its membership function can be defined as the following:

$$\mu(x) = \begin{cases} 0 & x < l \\ (x-l)/(m-l) & l \leq x \leq m \\ (u-x)/(u-m) & m \leq x \leq u \\ 0 & x > u \end{cases} \quad (1)$$

In this study, only addition and multiplication are used. Defining two triangular fuzzy numbers M_1 and M_2 by the triplets as $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ the addition and multiplication operations of M_1 and M_2 can be expressed as follows:

Addition: if \oplus denotes addition.

$$M_1 \oplus M_2: (l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (2)$$

Multiplication: if \otimes denotes multiplication.

$$M_1 \otimes M_2: (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2), \quad l_1, l_2 \geq 0 \quad (3)$$

The steps of Chang's analysis can be given as in the following:

Step 1: The AHP framework is composed of a goal, a set of factors and related sub-factors. The components of the framework are related to each other by different types

of conjunctive arrows (unidirectional and bilateral) based on relationship types.

Step 2: The local weights of the factors and sub-factors are determined by pair-wise comparisons. In this step, the factors are compared with each other assuming that there is no dependency among them. The fuzzy synthetic extent value (S_i) with respect to the i^{th} criterion is defined as:

$$S_i = \sum_{j=1}^m M^j_{g_i} \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M^j_{g_j} \right]^{-1}, \quad i = 1, 2, \dots, n \quad (4)$$

$$\sum_{j=1}^m M^j_{g_i} = \sum_{j=1}^m (l_j^i, m_j^i, u_j^i) = \left(\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j \right) \quad (5)$$

$$\sum_{i=1}^n \sum_{j=1}^m M^j_{g_i} = \sum_{i=1}^n \left(\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j \right) = \left(\sum_{i=1}^n \sum_{j=1}^m l_j, \sum_{i=1}^n \sum_{j=1}^m m_j, \sum_{i=1}^n \sum_{j=1}^m u_j \right) \quad (6)$$

$$\left[\sum_{i=1}^n \sum_{j=1}^m M^j_{g_i} \right]^{-1} = \left(1 / \sum_{i=1}^n \sum_{j=1}^m u_j, 1 / \sum_{i=1}^n \sum_{j=1}^m m_j, 1 / \sum_{i=1}^n \sum_{j=1}^m l_j \right). \quad (7)$$

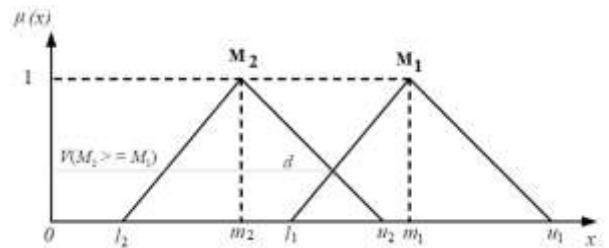


Fig. 2. Membership functions of linguistic variables

As $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ defined as (see Fig.2):

$$V(M_2 \geq M_1) = \sup_{y \geq x} [\min(\mu_{M_1}(x), \mu_{M_2}(y))] = hgt(M_2 \cap M_1) = \mu_{M_2}(d) = \begin{cases} 1 & m_2 \geq m_1 \\ 0 & l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases} \quad (8)$$

were x and y are the values on the axis of membership function of each criterion and d is the highest intersection point μ_{M_1} and μ_{M_2} .

To compare M_1 and M_2 ; we need both the values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$.

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i (i = 1, 2, \dots, k)$ can be defined by:

$$V(M \geq M_1, M_2, \dots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2 \text{ and } \dots \text{ and } (M \geq M_k))] = \min V(M \geq M_i) \quad (9)$$

Assume that $d'(A_i) = \min V(S_i \geq S_k)$, for $k=1, 2, 3, 4, 5, \dots, n; k \neq i$, then the weight vector is given by:

$$W' = [d'(A_1), d'(A_2), \dots, d'(A_n)]^T \quad (10)$$

Where $A_i (i = 1, 2, 3, 4, 5, 6, \dots, n)$ are n elements.

Step 4: Via normalization, the normalized weight vectors are:

$$W = [d(A_1), d(A_2), \dots, d(A_n)]^T \quad (11)$$

Where W is non-fuzzy numbers. Also, the non-fuzzy weight factor would be as $W = (\min V(S_1 \geq S_j), \min V(S_2 \geq S_j), \min V(S_n \geq S_j))$.

The weight factor is normalized and used in the third step.

Step 5: The weights of the factors and sub-factors are determined.

Step 6: The selection for the different of alternatives is determined.

4. ERP System Selection Framework

4.1 Procedure of Selection

This research, a framework is developed using fuzzy analytic hierarchy process (FAHP) to selection of an ERP system. The methodology comprises of many steps. Every ERP project is considered as a multi-stage process. Hence, a framework proposed to better explain different dimensions of the select most suitable ERP system.

Figs. 3 illustrate the conceptual framework of the proposed methodology for the ERP selection process. The complete procedure of our proposed ERP selection model is shown in Fig. 3. The model involves four principle essentials. In this paper an ERP selection methodology is proposed. The evaluation procedure of this study consists of seven steps as follows Fig. 3:

I. Organize the committee of decision makers:

First of all, managers formed a project team which was included personnel chosen from different departments and was supported by top management to select an ERP system.

II. Identify the ERP system criteria:

The project team created a vision to define the corporate mission, objectives, and strategy.

III. Construct the structure of objectives of ERP selection project:

The project team conducted the business process reengineering with a function list which was created to define what the requirements were.

IV. Extract the attributes for selecting ERP systems:

Selecting a suitable ERP project involves various factors. Project team made a preliminary analysis of the strengths and weaknesses of each criteria. Team members expressed their opinions on the importance and the strengths of the relationships between selection criteria pair wise in the form of linguistic variables such as very strong, strong, medium, weak, and none to build the structure of comparison frame.

V. Identify ERP system alternatives:

After collecting all possible information about the current system and establishing the evaluation criteria, the project team evaluated all software vendors' characteristics in the market. Finally, they filtered out unqualified vendors and selected three software vendors.

VI. Evaluate the ERP systems by the fuzzy AHP method:

To help the project team make a decision, we offer to use fuzzy AHP decision making methodology to decide on the best vendor to select. The fuzzy AHP approaches allow team members to use their experience, values and knowledge to decompose a problem into smaller sets by solving them with their own procedures in making a decision.

VII. Make the final decision ERP system alternatives:

Discuss the results and make the final decision. The project team compared the sub-attributes with respect to main attributes in the hierarchical approach by utilizing fuzzy triangular numbers in fuzzy AHP procedure. A detailed questionnaire related with the data regarding the qualitative criteria for ERP selection model was prepared for the paired comparisons to tackle the ambiguities involved in the process of the linguistic assessment of the data. Finally, with the weights of importance we attempted to find best ERP vendor among all alternatives.

4.2 The AHP Model

The AHP hierarchy is composed of four levels, as illustrated in Fig. 4. Level 1 reveals the goal for selection the most suitable ERP system. Level 2 consists of three main objectives, namely choosing the product factors, system factors and management factors. Level 3 contains the associated attributes that are used to measure various products, systems and management, respectively. The four level consists of the alternative ERP systems.

The ERP selection critical success factors have been vastly addressed and analyzed in ERP literature by many researchers [44-46].

From this model, main critical of the selection are determined. Then, critical success factors for ERP selection are evaluated and the assessment factors are determined. The factors are grouped and the assessment framework is constructed. The fuzzy analytic hierarchy process is then used for this framework (Fig.4).

Criteria of product: Selecting a suitable ERP project involves various factors. The product criteria is derived from the international norm ISO/IEC 9126 [54]. The ISO 9126 software quality model is chosen to describe the

ERP product characteristic and we categorize it as product aspect in the model. This quality model identifies five external attributes of interest, namely functionality, reliability, efficiency, usability and maintainability.

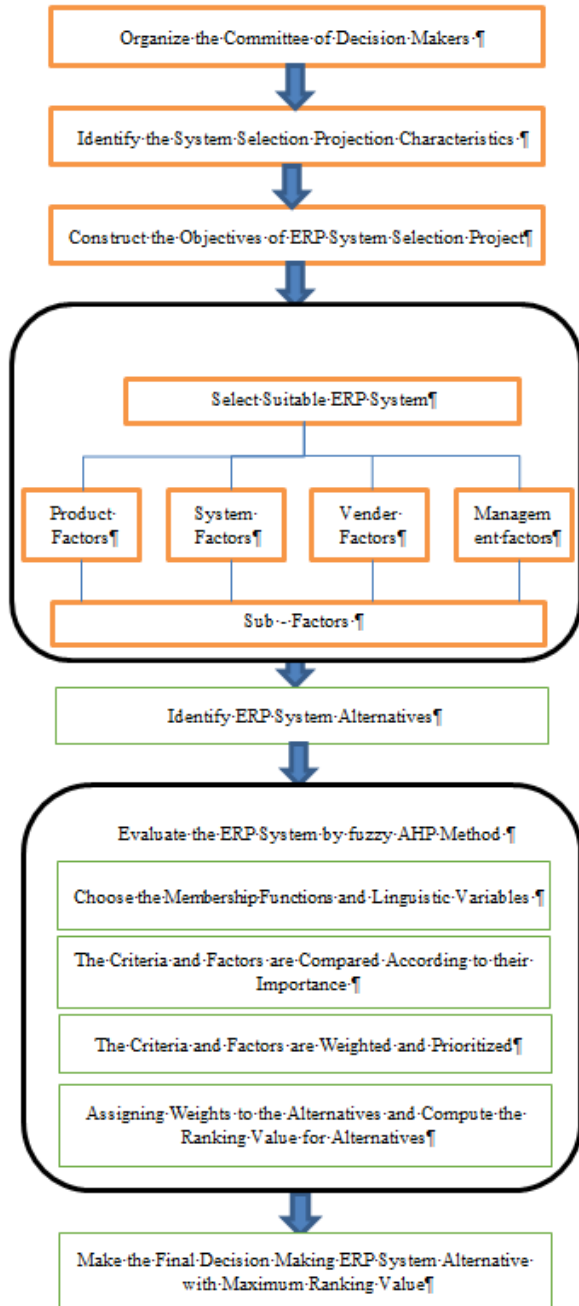


Fig. 3. The proposed methodology for the selection of ERP system.

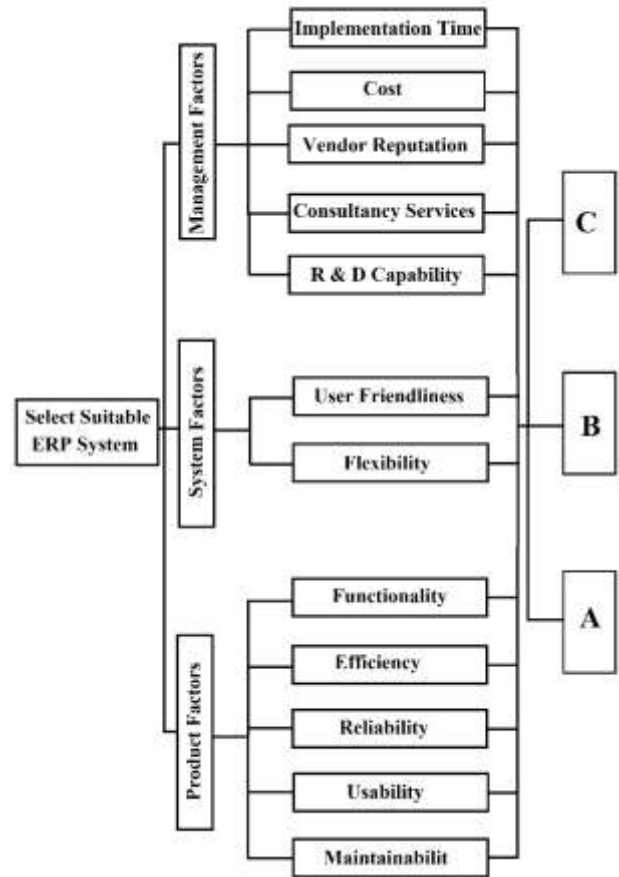


Fig. 4. AHP framework for ERP selection

The detailed characterization is presented as follows [55]:

(1) **Functionality** :This attribute is defined as the degree to which the software functions satisfies stated or implied needs and can be broken down into five sub-characteristics as follows: suitability, accuracy, interoperability, compliance and security.

(2) **Reliability** :This attribute is defined as the capability of software that could maintain its level of performance under stated conditions for a stated period of time. It can be decomposed into three sub-characteristics as follows: maturity, fault tolerance and recoverability.

(3) **Usability** :This attribute is defined as the degree to which the software is available for use and can be broken down into three sub-characteristics as follows: understandability, learnability and operability.

(4) **Efficiency** :This attribute is defined as the degree to which the software makes optimal use of system resources. It can be decomposed into two sub-characteristics as follows: efficiency of time behavior and efficiency of resource behavior.

(5) **Maintainability** :This attribute is defined as the ease with which repair may be made to the software and can be broken down into four sub-characteristics as follows: analyzability, changeability, stability and testability.

Criteria of management: the management criteria of ERP system contains five major criteria: vander factors,

cost factors and time factors. The detailed characterization of three factors is presented as follows:

(1) Sub criteria of vender factors: market share and reputation, industrial credential, service and support, training solution. We gathered these factors based on vendor’s reputation. By vendor’s ability criteria, we implied vendor’s technology level, implementation and service ability, consulting service, training support. As far as vendor’s condition we considered vendor’s financial condition, certifications and credentials.

(2) Sub criteria of cost factors: software cost, hardware cost, annual maintenance cost, and staff training cost. This price contains licensing arrangement cost, product and technology cost and consulting cost, which involves adapting and integrating cost, supporting cost, training cost, maintenance (upgrades) cost.

(3) Sub criteria of time factors: time for planning and preparation, time for BPR and system tuning, time for testing and go-live.

In addition to management and product criteria we considered system criteria such as user friendliness and flexibility.

As shown in Fig. 4 our model includes four hierarchy levels. Finally, with the weights of importance we attempted to find best ERP vendor among all alternatives.

5. The Application of FAHP in ERP System Selection

The AHP model provides priority weights for the ERP packages, based on the ERP project team’s preferences on multiple characteristics. The alternative with the highest priority weight is then selected for the company (Fig. 4). A case study in Iran belong to different industries are conducted to prove the practicality of our proposed model in this section.

The proposed model is composed of four hierarchical stages: goal, sub-goals (factors), sub-factors and alternative ERP systems which are related to each other by means of conjunctive arrows. This model has been applied to measure the firm’s readiness to selection an ERP system. Firstly, the general manager of company organizes the project team including eight senior managers in different sections. Unfavorable alternatives are eliminated by thorough examination of system specifications and requirements derived from the main goals. After the preliminary elimination which is subjected to budget, time and system functions, three feasible ERP system alternatives are came out. The sub-factors are determined according to the vision and the strategies of the company. After assigning the weights to each sub-factor, the evaluation team compared all ERP alternatives. Assume that twelve sub-factors are evaluated under a fuzzy environment. For selecting best ERP, main factors the product factors, system factors and management factors are used in application, are explained in fuzzy sets and fuzzy numbers. Fig.4 shows the all main factors and sub-factors. The project team compared the sub-factors with respect to main factors in the hierarchical

approach by utilizing fuzzy triangular numbers in fuzzy AHP procedure. To create pair wise comparison matrix, linguistic scale is used which is given in Table 1.

The matrix of paired comparisons for alternatives (A, B and C) is given in Tables 2-6. Tables 3-6 show the judgment matrix (Pairwise comparisons) and weight vector of each matrix.

Table 1. Linguistic scale for relative importance

Linguistic scale	Triangular fuzzy scale	Inverse Triangular fuzzy scale
Just Equal	(1,1,1)	(1,1,1)
Equal importance	(1/2,1,3/2)	(2/3,1,2)
Moderate importance	(1,3/2,2)	(1/2,2/3,1)
Strong importance	(3/2,2,5/2)	(2/5,1/2,2/3)
Very Strong importance	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely importance	(5/2,3,7/2)	(2/7,1/3,2/5)

According to decision maker’s preferences for main factors, pair wise comparison values are transformed into triangular fuzzy number’s as in Table 2.

After forming fuzzy pairwise comparison matrix, weights of all main factors are determined by the help of FAHP. According to the FAHP method, firstly synthesis values must be calculated.

Table 2. The Fuzzy pairwise comparison matrix regarding main factors

Main Factors	Product	System	Management
Product	(1,1,1)	(2,5/2,3)	(1/2,1,3/2)
System	(1/3,2/5,1/2)	(1,1,1)	(1/2,2/3,1)
Management	(2/3,1,2)	(1,3/2,2)	(1,1,1)

Tables 3, 4 and 5 indicate the product, system, and management sub-factors’ Pairwise comparisons.

Table 3. Judgment matrix (Pairwise comparisons) of product sub-factors

Product	Functionality	Reliability	Usability	Efficiency	Maintainability
Functionality	(1,1,1)	(5/2,3,7/2)	(2/7,1/3,2/5)	(1,3/2,2)	(3/2,2,5/2)
Reliability	(2/7,1/3,2/5)	(1,1,1)	(3/2,2,5/2)	(1,3/2,2)	(1/2,1,3/2)
Usability	(5/2,3,7/2)	(2/5,1/2,2/3)	(1,1,1)	(2/5,1/2,2/3)	(1,3/2,2)
Efficiency	(1/2,2/3,1)	(1/2,2/3,1)	(3/2,2,5/2)	(1,1,1)	(1/2,1,3/2)
Maintainability	(2/5,1/2,2/3)	(2/3,1,2)	(1/2,2/3,1)	(2/3,1,2)	(1,1,1)

Table 4. Pairwise comparisons of system sub-factors

System	User friendliness	Flexibility
User friendliness	(1,1,1)	(0.25,0.5,0.75)
Flexibility	(1.33,2,4)	(1,1,1)

Table 5. Pairwise comparisons of management sub-factors

Management	Cost	Implementation Time	Vendor Reputation	Consultancy Services	R&D Capability
Cost	(1,1,1)	(3/2,2,5/2)	(1/3,2/5,1/2)	(1/2,1,3/2)	(1,3/2,2)
Implementation Time	(2/5,1/2,2/3)	(1,1,1)	(3/2,2,5/2)	(1/2,1,3/2)	(2,5/2,3)
Vendor Reputation	(2,5/2,3)	(3,2,1/2,2/3)	(1,1,1)	(2/7,1/3,2/5)	(1/2,1,3/2)
Consultancy Services	(2/3,1,2)	(2/3,1,2)	(5/2,3,7/2)	(1,1,1)	(3/2,2,5/2)
R&D Capability	(1/2,2/3,1)	(1/3,2/5,1/2)	(2/3,1,2)	(2/5,1/2,2/3)	(1,1,1)

Table 6 indicate the pairwise comparisons of alternatives, the ERP vendors, (A, B and C) regarding various sub-factor of product, system, management and vendor factor.

Table 6. Pairwise comparisons of alternatives with twelve categories (sub-factors)

Functionality	A	B	C
A	(1,1,1)	(1/2,2/3,1)	(2/3,1,2)
B	(1,3/2,2)	(1,1,1)	(1/2,1,3/2)
C	(1/2,1,3/2)	(2/3,1,2)	(1,1,1)
Reliability	A	B	C
A	(1,1,1)	(1,1,1)	(1/2,2/3,1)
B	(1,1,1)	(1,1,1)	(2/3,1,2)
C	(1,3/2,2)	(1/2,1,3/2)	(1,1,1)
Usability	A	B	C
A	(1,1,1)	(2/3,1,2)	(1,1,1)
B	(1/2,1,3/2)	(1,1,1)	(1/2,1,3/2)
C	(1,1,1)	(2/3,1,2)	(1,1,1)
Efficiency	A	B	C
A	(1,1,1)	(1,3/2,2)	(2/3,1,2)
B	(1/2,2/3,1)	(1,1,1)	(2/3,1,2)
C	(2/3,1,2)	(1/2,1,3/2)	(1,1,1)
Maintainability	A	B	C
A	(1,1,1)	(1,1,1)	(1,3/2,2)
B	(1,1,1)	(1,1,1)	(1/2,1,3/2)
C	(1/2,2/3,1)	(2/3,1,2)	(1,1,1)
Cost	A	B	C
A	(1,1,1)	(1/2,1,3/2)	(1/2,1,3/2)
B	(2/3,1,2)	(1,1,1)	(1/2,1,3/2)
C	(2/3,1,2)	(2/3,1,2)	(1,1,1)
Implementation time	A	B	C
A	(1,1,1)	(2/3,1,2)	(2/3,1,2)
B	(1/2,1,3/2)	(1,1,1)	(1,1,1)
C	(1/2,1,3/2)	(1,1,1)	(1,1,1)
User Friendliness	A	B	C
A	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)
B	(2/3,1,2)	(1,1,1)	(1/2,1,3/2)
C	(1/2,2/3,1)	(2/3,1,2)	(1,1,1)
Flexibility	A	B	C
A	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)
B	(2/3,1,2)	(1,1,1)	(1/2,1,3/2)
C	(1/2,2/3,1)	(2/3,1,2)	(1,1,1)
Vendor Reputation	A	B	C
A	(1,1,1)	(1/2,2/3,1)	(2/3,1,2)
B	(1,3/2,2)	(1,1,1)	(1/2,1,3/2)
C	(1/2,1,3/2)	(2/3,1,2)	(1,1,1)
Consultancy Services	A	B	C
A	(1,1,1)	(1/2,2/3,1)	(2/3,1,2)
B	(1,3/2,2)	(1,1,1)	(1/2,1,3/2)
C	(1/2,1,3/2)	(2/3,1,2)	(1,1,1)
R&D Capability	A	B	C
A	(1,1,1)	(1,1,1)	(2/3,1,2)
B	(1,1,1)	(1,1,1)	(2/3,1,2)
C	(1/2,1,3/2)	(1/2,1,3/2)	(1,1,1)

5.1 Data Analysis

The final fuzzy weights of 12 sub-factors are calculated as shown in Table 7. Table 8 shows the final scores for the ERP vendors. As shown in Table 8, the ERP system B is the dominant solution in the final rank.

The alternative with maximum weight value is the best choice in the decision-making problem.

Table 7. Final fuzzy weights of sub-factors

Factors	Fuzzy sub-factors weights
Functionality	(0.51,0.76,0.95)
Reliability	(0.49,0.77,0.92)
Usability	(0.54,0.81,0.96)
Efficiency	(0.37,0.66,0.84)
Maintainability	(0.36,0.56,0.79)
Cost	(0.51,0.76,0.96)
Implementation time	(0.56,0.79,0.99)
User Friendliness	(0.62,0.89,0.99)
Flexibility	(0.39,0.62,0.92)
Vendor Reputation	(0.51,0.71,0.84)
Consultancy Services	(0.47,0.72,0.99)
R&D Capability	(0.59,0.84,0.99)

According to Table 7, the decision makers are fairly consistent in ranking the attributes. For valuation, the consistency index of each decision maker’s paired comparison matrix should be less than the threshold value 0.1 to ensure that the decision maker was consistent in assigning paired comparisons, otherwise the decision maker may need to reconsider his evaluation [21].

From Table 8, the weight of ERP vendor alternative B is 0.6572, and the weights for ERP vendor alternatives A and C are 0.2278 and 0.0898 respectively. According to fuzzy AHP method, the best ERP vendor alternative is B. Thus, the project team agrees that system B is the most suitable decision for Company.

Table 8. The ranking values of the fuzzy appropriateness indices for alternatives

Alternatives	Fuzzy Weight	Non- Fuzzy Weight	Final Ranking
A	(0.1622,0.2204,0.3007)	0.2278	2
B	(0.5080,0.6483,0.8152)	0.6572	1
C	(0.0573,0.0856,0.1264)	0.0898	3

It is obvious that the most appropriate ERP system is B. Thus, the committee can be comfortable in recommending alternative B as the most suitable ERP system for the selection project for this company.

The reason for choosing the combination of AHP and fuzzy is based on these decision modeling techniques’ strengths and suitability to the current decision situation. The specific reason of combining of AHP and fuzzy in our study can be described as follows: First of all, it is an out ranking method suitable for ranking the alternatives among conflicting criteria. The second is that fuzzy is a rather simple ranking method with respect to conception and application when compared with the other MCDM methods. Third one is the popularity of it.

5.2 Comparisons

5.2.1 Comparison with Kilic Approach

In Kilic, (2014), an ERP system selection problem at a large airline company in Turkey is considered. First, based on the requirements and the demands of the

company executives, the ERP selection criteria are determined. Then, the alternative ERP firms and their offerings are investigated and determined. After determining the criteria and solution alternatives, the proposed hybrid methodology, consisting of fuzzy AHP which incorporates the vagueness of the decision making process and TOPSIS, is applied and validated. Specifically, the importance/weights of the selection criteria are obtained via fuzzy AHP based on the triangular fuzzy preference scales. Then these weights are used in the TOPSIS methodology to reach the ranking of alternative ERP system suppliers.

The use of a hybrid selection/evaluation methodology proved to produce results that are both technically sound and organizationally acceptable. Knowing that the vagueness and complexity of the decision situation are handled using the strengths of two popular decision support methods makes the decision makers confident in their final selection. They feel that by breaking the complex problem space into smaller pieces, dealing with them at that granular level, and then aggregating them at the higher decision level have a much better chance of producing optimal (or near optimal) decisions.

Weakness: It should be acknowledged that the paper of [53] is subject to some limitations. Perhaps the most serious limitation of this study is its narrow focus on a single case study in aviation industry. To generalize on the findings and the viability/validity/value of the methodology, more real-world cases need to be performed. Another limitation of the individual methods is the independent structure of the selection criteria. Since the comparisons are made in a piece-meal/pairwise fashion, reaching the true optimal may not be possible. Also, for manageability purposes, various low-level criteria are grouped in clusters, by doing so, some detailed specifications may have been lost. Finally, the methodology proposed in this study, as systematic as it may sound, is a heuristic one. That is, it does not guarantee finding the optimal solution. The "optimality" of the results is often subject to the richness (in terms of quantity and quality) of the participants; positively influenced by their knowledge, experience and dedication.

5.2.2 Comparison with Cebeci Approach

In Cebeci, (2009), presents an approach to select a suitable ERP system for textile industry. The proposed ERP selection methodology was applied successfully for a textile manufacturing company for young people as a real case study. The methodology also gives some suggestions about successful ERP implementation. The proposed methodology can be used for other sectors with some changes. Decisions are made today in increasingly complex environments. In more and more cases the use of experts in various fields is necessary, different value systems are to be taken into account, etc. In many of such decision-making settings the theory of fuzzy decision making can be of use. Fuzzy group decision-making can overcome this difficulty. In general, many concepts, tool and techniques of artificial intelligence, in particular in the field of knowledge

representation and reasoning, can be used to improve human consistency and implement ability of numerous models and tools in broadly perceived decision-making and operations research. The proposed decision support system integrated with strategic management by using BSC may be an alternative to some methods for ERP selection. In this paper, ERP packages and vendors for textile companies were compared using fuzzy AHP.

The presented methodology is flexible and can be used for other sectors with some sector specific characteristics changes. Humans are often uncertain in assigning the evaluation scores in crisp AHP. Fuzzy AHP can capture this difficulty.

Weakness: In this paper, [50], Fuzzy AHP cannot support all phases of ERP selection and implementation. Hence, an intelligent decision support system or expert system can be added when gathering data for selection process.

6. Conclusions

In this paper, we present an approach to select a suitable ERP system. In order to deal with this problem appropriately, the analytic hierarchy process (AHP) method is extended into a fuzzy domain. A framework is developed to select most suitable ERP system using this fuzzy AHP. The factors and sub-factors are determined, classified, weighted and prioritized and then a framework is provided for ERP selection with the fuzzy analytic hierarchy process (FAHP) method. Then, we used fuzzy AHP to obtain pairwise comparison judgments by prioritizing criteria and assigning weights to the factors and alternatives. The framework decomposes ERP system selection into four main factors. The goal of this paper is to select the best alternative that meets the requirements with respect to "product factors", "system factors" and "management factors". The sub-attributes (sub-factors) related to ERP selection have been classified into twelve main categories of "Functionality", "Reliability", "Usability", "Efficiency", "Maintainability", "Cost", "Implementation time", "User friendliness", "Flexibility", "vendor Reputation", "Consultancy Services", and "R&D Capability" and arranged in a hierarchy structure.

In this paper intends to show how effective is fuzzy AHP as a decision-making tool in system selection problem. Even with the complete accurate information, different decision making methods may lead to totally different results. Thus, the proposed methodology demonstrates the selection of the best ERP vendor under the cost and product quality restrictions in the presence of vagueness. It is seen that fuzzy AHP is a useful decision-making methodology to make more precise selection-decisions that may help the company to achieve a competitive edge in a complexity environment. Fuzzy AHP approach incorporates quantitative data of the criteria, which have to be evaluated by qualitative measures. The proposed selection methodology is flexible to incorporate new or extra criteria or decision making for the evaluation process.

A real case study from Iran is also presented to demonstrate efficiency of this method in practice. In the future we offer to apply other decision-making methods using fuzzy concept to capture the uncertainty in complex approaches. Also, in this topic it is possible to make the decision by using fuzzy analytic network process (ANP)

model and compare with fuzzy AHP model and the expert system can be used before the ERP system selected.

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