Fuzzy Multi-criteria Method for Revaluation of ERP System Choices Using Real Options

A.Cagri Tolga

Abstract— **Many corporate had implemented ERP systems since mid 1990s. Some of them began late mid 2000s. ERP systems are newly well understood and confusion about these systems is becoming clear. In this study a corporate based on construction has many companies and much of them are using different ERP systems. Top management decided to unify and revaluate the system and unravel the entanglement about this topic.**

Evaluation process of ERP systems needs to take many criteria into account. An efficient method called AHP is suitable for this revaluation process because of its understandability. Professionals in the evaluation process are asked to part of the system and AHP method's comprehensibility allows this integration.

ERP systems has many risks in implementing phase, these risks have to be handled by more complex evaluation method. Financial options based real options fits like a glove for this revaluation process. Real options give top management much flexibility about their decision. They might use option to wait in revaluating the ERP system or they might exercise the option immediately. Vagueness and in the process, lack of data or disallowance of getting out the data from the company drives the problem solvers to use fuzzy logic. This study integrates fuzzy real options with fuzzy AHP to revaluate the ERP systems of the corporate that is construction based.

Index Terms— **binomial lattice, ERP selection, fuzzy, multi-criteria, real options.**

I. Introduction

ENTREPRISE resource planning (ERP) systems help to integrate management, staff, and equipment, combining all aspects of the business into one system in order to facilitate every element of the manufacturing process. ERP groups traditional company and management functions (such as accounting, human resources [HR], manufacturing management, and customer relationship management [CRM]) into a coherent whole. Manufacturing management also includes inventory, purchasing, and quality and sales management. ERP systems ensure that information entered in one information system can be shared with other systems used elsewhere in the corporation. When information is shared by systems throughout the organization, the enterprise becomes more efficient [1]. Therefore, in today's world implementing ERP system is inevitable for any mid size or large scale corporate. Evaluating the ERP system is generally made by management and information system (MIS) department of the company. However, valuation of an ERP system is more complex through its nature. Not only one department most of the top management should be the part of the decision process. ERP system selection has many dimensions concerning cost, scalability, adaptability, and etc. Evaluation of business strategy explains the form of doing business. Because when an ERP system is implemented many business forms will change and the workers might attempt to offer resistance.

Due to many dimensions said above a multi-criteria method should be charged to evaluation process of an ERP system. A solution method called analytical hierarchy process (AHP) is used for multi-criteria process and the efficiency of the method is proved because of its solution offer to more complex problems. On the contrary of its complexity, the method has comprehensible steps and the logic of the model could be understood on average. Beneath these advantages the AHP method takes monetary and non-monetary criteria into consideration.

The conventional investment analysis methods such as present worth (PW), equal annual worth (EAW), rate of return analysis, B/C ratio, etc. analyses were used for economic evaluation of ERP systems. The dynamic side of the ERP system evaluation necessitates more sophisticated method for economic investment analysis. One of the attributes will concern this analysis and will be integrated to AHP method using real options. A real option valuation (ROV) model's principles are based on financial options. However, the nature of real options involves permanent, fixed or immovable assets. Valuation of real options necessitates real option analysis. The key advantage and value of real option analysis is to integrate managerial flexibility into the valuation process and thereby assist in making the best decisions [2]. Real options give a right but not an obligation to make or not to make an investment for a certain period.

Real circumstances in daily life are very often uncertain and vague in several ways. And when there is a lack of information, a system might not be known completely. Zadeh [3] suggested a strict mathematical outline named fuzzy set theory that overcomes these inadequacies. Many companies do not share to get the financial data out the corporation because of their secrecy. Due to these said reasons fuzzy logic will be used in real option analysis and also in AHP method in this study.

Reference [4] presents a comprehensive framework for selecting a suitable ERP system using AHP method. Other study about AHP is made by [5] for manufacturing companies. Selecting the most appropriate software between two elected candidates after some analysis for the final

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decision by using a technique with analytic hierarchy process (AHP) support in a factory which is planning to use ERP software that fits its functions study is made by [6].

An approach to select a suitable ERP system for textile industry using fuzzy AHP is made by [7]. The author uses balanced scorecard to show how the overall strategic objectives are translated into the performance drivers that the company has identified as critical success factors. AHP method under fuzziness allowing decision makers to express their evaluations in linguistic expressions, crisp or fuzzy numbers is applied by [8] in an automotive firm for selecting the best alternative among three ERP outsourcing firms.

Researchers worked on another fuzzy multi-criteria method called analytical network process (ANP) for selecting ERP systems. An easy ERP software selection procedure by setting up ANP and artificial neural network (ANN) models is offered by [9]. Calculation of geometric mean of answers that obtained from many experts is unnecessary in that procedure. An intelligent approach to ERP software selection through a fuzzy ANP is proposed by taking into consideration quantitative and qualitative elements to evaluate ERP software alternatives by [10]. A general level conceptual framework to sequence ERP module implementations and expanded model to a more detailed level in a case study is presented by [11]. The priorities for the implementation sequence of the ERP modules are determined in the said study.

An active ERP implementation management perspective to manage ERP risks based on the Real Options (RO) theory, addressing uncertainties over time, resolving uncertainties in changing environments that cannot be predefined is offered by [12]. Reference [13] suggests a method that could help information technology (IT) managers to produce a well-structured valuation process in IT investment decision-making, and to understand the interactions between IT risks and options value in a clear way. The study also illustrates how the proposed procedure is applied to an ERP project in a construction company. Reference [14] tackles the problem using a real-option analysis framework, and applies multistage stochastic integer programming in formulating an analytical model whose solution will yield optimum or near-optimum investment decisions for ERP projects. Another study introducing a real options-based methodology which overcomes the limitations of traditional valuation methods and enabling decision-makers to value an ERP system investment incorporating multiple options is offered by [15].

The organization of this paper is as follows. In section 2 revaluation criteria for ERP systems and hierarchy of these criteria is given. The third section consists of knowledge of fuzzy AHP method. In section 4, fuzzy real options solution method using binomial lattice solution method is given. The steps and the backbone of the proposed method are presented in Section 5. Finally in section 6 the conclusions of this study are discussed.

II. The Revaluation and Reselection Criteria for ERP System

The criteria set of this study those necessitated by fuzzy AHP are determined by collaborations of professionals. Five main criteria are set including culture and structures, adaptation and development, solution partner, productivity, and fuzzy real options value (FROV). Also sixteen sub-criteria and seven sub-sub criteria are offered with connection to the main criteria. Criteria numbers are determined with diligence because of not to diminish the efficiency of the method. Definitions of all these main, sub and sub-sub criteria are given in Table I. The hierarchy that AHP method needs is illustrated in Fig. 1.

This work is designed by the help of a construction based company (XYZ hereafter) in Turkey. The XYZ enterprise has twelve companies in four different sectors those include construction, energy, cement production, and foundry. These companies were using different systems including ERP systems and different mid-size local software.

The top management decided to unify them. They also decided to revaluate and reselect a unique system for their needs. A team whose members are from enterprise (HR director, MIS director), from university and from consultant company is composed for this revaluation and reselection process. A literature search is made as given in the

TABLE I
CRITERIA FOR ERP SYSTEM REVALUATION AND RESELECTION

ERP Main Criteria	Sub Criteria	Sub-sub Criteria	Definition
Culture and Structures (CS)	Business strategy (CB)		Changing type of business, explanation of it and ability to design the processes at the employer side
	Socio-Economic factors (CE)		Competencies of physical and environmental conditions
	Human Resources (CH)		Competency of enterprise human resources
	Top management support (CT)		Stability and support of corporate top management
Adaptation and Development (AD)	Flexibility (AF)	Table Customization (AFT)	Existence of table customization
		Module Customization (AFM)	Existence of module customization
		Code Customization (AFC)	Existence of code customization
	Process Adaptability (AP)		Adaptation of system to the process
	Implementation time (AI)		Application time offered by the solution partner
	Efficient and fast reporting (AE)		Competency of fast en efficient reporting
	Production structure (AS)	Production (ASP)	Appropriateness of production processes
		Commercial (ASC)	Appropriateness of commercial processes
	Auditability (AA)	Internal (AAI)	Appropriateness of system to internal audit
		External (AAE)	Appropriateness of system to external (Treasury, SPK, etc.) audit
Solution Partner-Vendor (SP)	Conceptual design (SC)		Tailoring concepts between employer and the solution partner
	Service and support (SS)		Service after sale and human, financial and physical resources transferred by the solution partner
	References and reputation (SR)		Works done by the solution partner in the sector and awareness
Productivity (P)	Functionality (PF)		Functionality of the system, easily manageability and user friendliness of interface
	Scalability (PS)		Expandability or reducibility of the system
	Integration (PI)		Harmony with the environ systems (Office, Explorer, Mozilla etc.)
FROV	-		Fuzzy Real Option Value of ERP system alternatives

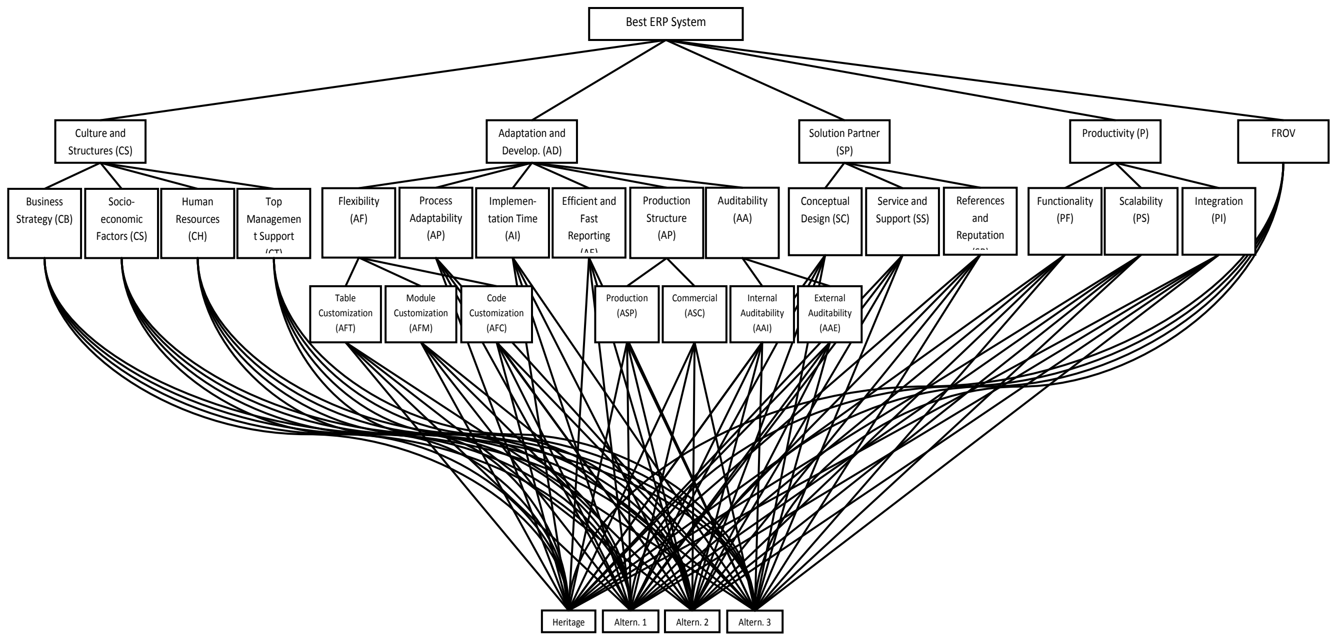

Fig. 1. Hierarchy for ERP system revaluation and reselection process.

introduction section for criteria determination. Then many meetings are organized for this process. Delphi method is applied with the help of team members and the criteria set shown below are decided to use in the revaluation and reselection process. One of the ERP system alternatives mostly used by 4 companies of the XYZ enterprise called heritage. In addition three more alternatives are added to the data set with judgments of team members.

III. Fuzzy Analytic Hierarchy Process (FAHP)

The AHP method developed by Saaty [16] considers and compares both qualitative and quantitative data simultaneously. Its data requirement is minimal and capable of handling multiple objectives for ERP system selection projects and decomposing the problem into multilevel structure or hierarchy. In fuzzy AHP, fuzzy numbers represent the measurement of experts' view toward the preference of assessment by forming the pair-wise comparison matrices. In this study, though we use trapezoidal fuzzy numbers, Buckley's fuzzy AHP method will be employed [17].

AHP can accelerate the development of a consensus amongst multiple decision makers in ERP system selection process.

IV. Fuzzy Real Options Method

Making a decision of investing or reinvesting in an ERP project is similar to purchasing of an option on a future investment however it is a real investment. The nature of the investment in ERP system selection decisions is discrete and you have to decide whether to carry on the option or exercise it every year. Since there is a lack of data or vagueness fuzzy real option analysis is needed. In real option analysis lattice models for evaluating the alternatives are fit like a glove for this type of investment. In financial options dividend paying stocks' options are computed differing from non-dividend paying stocks. Dividend payment reduces the price of option and calculation has to be made according to this clause. An analogy might be made between financial and real options about this topic. In real options for example competitor entrance diminishes the future cash flows (CF) or high inflation might cause a decline in CF, though in this case dividend paying stock options computing has to be applied. In this study since there is no statement affecting the CF, non-dividend paying real options analysis is utilized.

Binomial tree method was developed by Cox et al. [18] for pricing the options in a discrete form. The method puts on the future expected rewards transparently. Though the binomial method has more flexibility the input variables of the model could be changed anytime during the life of the options. The volatility of the prices can be fixed without complex change in the model. The results and the model can be explained to the decision maker easily. In real options the decision are made at anytime and it could be made in discrete point in any period, though the binomial lattice solution method is convenient for real options.

The binomial tree is easier to work with because of its regular grid and its flexibility, allowing relatively easy extension to time-varying drift and volatility parameters.

In this chapter, we present general fuzzy form of the binomial tree model for the case of incomplete data or vagueness. The binomial tree approach is illustrated in Fig. 2. Suppose that p_u, and p_d are the probabilities of up, and down movements at each node and Δt is the length of the time step. For a non-dividend paying stock, parameter values that match the mean and standard deviation of price changes when terms of order higher than Δt are ignored:

$$a = e^{r\Delta t} \tag{1}$$

$$\Delta x = \sigma\sqrt{\Delta t} \tag{2}$$

$$u = e^{\Delta x} \tag{3}$$

$$d = 1 \div u \tag{4}$$

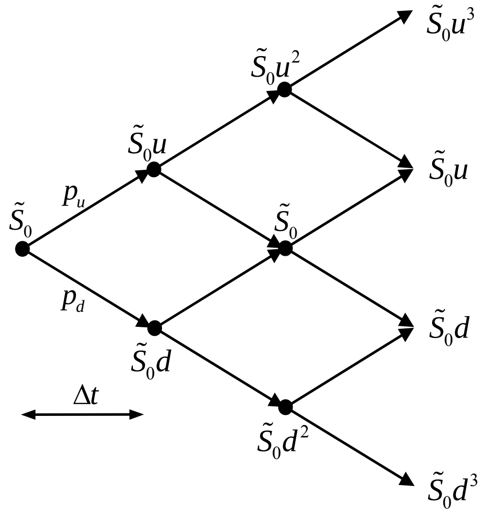

Fig. 2. Binomial lattice.

Here, σ points out the uncertainty of expected cash flows, r quantifies the annualized continuously compounded rate on a safe asset.

$$p_u = \frac{a-d}{u-d} \tag{5}$$

$$p_d = \frac{u-a}{u-d} \tag{6}$$

As mentioned above if there is lack of data or vagueness is occurred fuzzy notations have to be used. $\tilde{S}_0$ denotes the possible values of the present value of expected cash flows, in a similar manner $\tilde{X}$ quantifies the possible values of investment cost.

At time zero, the present value of expected cash flows, $\tilde{S}_0$ is known. At time Δt, there are two possible $\tilde{S}_0$ values, $\tilde{S}_0u$, and $\tilde{S}_0d$; at time $2\Delta t$, there are three possible $\tilde{S}_0$ values, $\tilde{S}_0u^2$, $\tilde{S}_0$, and $\tilde{S}_0d^2$; and so on. In general, at time $i\Delta t$, $2i+1$ $\tilde{S}_0$ values are considered. These are:

$$\tilde{S}_{i,j} = \tilde{S}_0 u^j d^{i-j},\ j = 0,1,\ldots,i \tag{7}$$

Notice that the $u = 1 \div d$ relationship is used in computing the $\tilde{S}_0$ value at each node of the tree in Fig. 2. For example, $\tilde{S}_0u^{-2} = \tilde{S}_0d^2$. Real options by lattice methods are evaluated by starting at the end of the tree (time *T*) and working backward. The value of the real option is known at time T. Let us express the approach algebraically. Because the value of the real option at its expiration date is $\max(0, \tilde{S}_0 - X)$, we know that

$$\tilde{c}_{T,j} = \max(0, \tilde{S}_{T,j} - X),\ j = 0,1,\ldots,T \tag{8}$$

After computing the $\tilde{c}_{T,j}$ values, (no early exercise) $\tilde{c}_{i,j}$ values at each node could be calculated by the formula below:

$$\tilde{c}_{i,j} = e^{-r\Delta t}[p_u\tilde{c}_{i+1,j+1} + p_d\tilde{c}_{i+1,j}] \tag{9}$$

for $0 \le i \le T-1$ and $0 \le j \le i$. When early exercise is considered, this value for $\tilde{c}_{i,j}$ must be compared with the option's intrinsic value, and we obtain:

$$\tilde{c}_{i,j} = \max\left\{e^{-r\Delta t}[p_u\tilde{c}_{i+1,j+1} + p_d\tilde{c}_{i+1,j}], \tilde{S}_{i,j} - \tilde{X}\right\} \tag{10}$$

While attaining to these data, experts defined them in a fuzzy manner. Beneath these, because the nature of fuzzy terms, we need to compare whether the second term of the result in (8) is greater or smaller than zero. An efficient and fast alternative fuzzy number ranking is offered by [19]. In comparing fuzzy numbers with zero and in ranking fuzzy numbers this offered method is used in this study. In the following section full steps of the new offered method's formulae are presented.

V. Steps of The Model

This study offers a fuzzy real option with non-dividend paying binomial lattice method integrated fuzzy AHP for revaluation of ERP systems. The steps are as follows:

Step 1: Construct the pair-wise comparison matrix containing fuzzy numbers obtained from questionnaires.

Step 2: Find geometric mean of each row by (11):

$$\tilde{z}_i = \left[\prod_{j=1}^{n} \tilde{t}_{ij}\right]^{1/n}, \text{for each } i \text{ value} \tag{11}$$

Step 3: Calculate the fuzzy weights, $\tilde{w}_i$, by (12):

$$w_i = \tilde{z}_i \otimes \left[\sum_{j=1}^{n} \tilde{z}_j\right]^{-1} \tag{12}$$

Repeat Step 3 for every performance grades.

Step 4: For fuzzy real options value, calculate all $\tilde{S}_{i,j}$ values by (7).

Step 5: Calculate $\tilde{c}_{T,j}$ values by (8) do not forget to compare fuzzy values with zero by (13).

$$P_{KT}(\tilde{N},\tilde{U}) = \begin{cases} \tilde{N} \succ \tilde{U} & \text{if } I(w) \in (0.5,1] \\ \tilde{N} = \tilde{U} & \text{if } I(w) = 0.5 \\ \tilde{U} \succ \tilde{N} & \text{if } I(w) \in [0,0.5) \end{cases} \tag{13}$$

Let $\tilde{N} = (n_1, n_2, n_3, n_4)$ and $\tilde{U} = (u_1, u_2, u_3, u_4)$ be two different fuzzy numbers. Calculation of index $I(\omega)$ is the key factor in said method and that method can be applied to both triangular and trapezoidal fuzzy numbers. Using (14) in triangular fuzzy numbers is as easy as winking.

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$$I(\omega)=\begin{cases} 0 & , \quad u_1 \geq n_4 \\ \dfrac{\dfrac{(n_4-u_1)^2}{(u_2-u_1-n_3+n_4)}}{(n_4+n_3-n_2-n_1)+(u_4+u_3-u_2-u_1)} & , \quad u_2 \geq n_3, u_1 < n_4 \\ \dfrac{n_4+n_3-u_2-u_1}{(n_4+n_3-n_2-n_1)+(u_4+u_3-u_2-u_1)} & , \quad u_3 \geq n_2, u_2 < n_3 \\ \dfrac{(n_4+n_3-u_2-u_1)-\dfrac{(n_2-u_3)^2}{(u_4-u_3+n_2-n_1)}}{(n_4+n_3-n_2-n_1)+(u_4+u_3-u_2-u_1)} & , \quad u_3 < n_2, u_4 > n_1 \\ 1 & , \quad u_4 \leq n_1 \end{cases} \tag{14}$$

Step 6: Compute all $\tilde{c}_{i,j}$ values by (9), till finding $\tilde{c}_{0,0}$ value. This value is fuzzy real option value of one alternative.

Step 7: Repeat Steps 4-7 for each alternative and find all alternatives' FROVs.

Step 8: Normalize these values for integrating fuzzy AHP.

Step 9: Combine fuzzy weights and fuzzy performance grades those are obtained from calculations by Steps 1-8. Then, calculate the fuzzy utilities $\tilde{U}_i, \forall i$ by (15):

$$\tilde{U}_i = \sum_{j=1}^{n} \tilde{w}_j \tilde{r}_{ij}, \ \forall i \tag{15}$$

Step 10: Rank the alternatives in descending order according to Kahraman and Tolga's [19] fuzzy number ordering method.

VI. Conclusion

ERP systems have become vital for challenging corporate in recent years. Utilizing the right system offers cost advantage and efficiency according to the system gets you in front of your competitors. However if a corporate has different ERP systems each are implemented different times to different companies, this means there is a confusion about ERP implementation. A revaluation process is needed to select unique suitable and right ERP system to be implemented to whole enterprise.

Risky and dynamic side of the selection process is evaluated by real options. Real options give the management flexibility about making an investment about ERP systems. Fuzzy AHP is a multi-criteria evaluation method for choosing procedure and it is more comprehensible than the other methods. This property saves time, workload and money because of the application time of the problem. Beneath its saving resources the method produces the right decision to the problem.

In case of lack of information and vague data situations fuzzy logic is offered. In this study fuzzy form is used because of the company does not want to take out the other part of the data crisply. Fuzzy logic overcomes these difficulties. Though these deficiencies, the main contribution of this work is to make revaluation among the ERP system choices using fuzzy real options integrated fuzzy AHP method.

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