AN INTEGRATED FUZZY APPROACH FOR ERP DEPLOYMENT STRATEGY SELECTION UNDER CONFLICTING CRITERIA

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Abstract: Manufacturing and service organizations are in the need of using Enterprise Resource Planning (ERP) systems to integrate many functions from purchasing to storage and production planning to calculation of costs. Using ERP systems by the integration in the level of information provides companies remarkable advantages in terms of profitability, productivity and efficiency in processes. The level of uncertainty in the selection of ERP deployment strategies is relatively high and needs to be carefully analyzed. While the correct strategy may provide various advantages to the firms, incomplete strategy may cause money loss. In this paper, modified fuzzy DEMATEL and evaluation based on distance from average solution (EDAs) methods are used for choosing the best ERP deployment strategy. For the presented integrated model, an illustrative example is conducted through an ERP consultant company working with various furniture companies. In rating of ERP deployment strategies four main criteria and eleven sub criteria are considered to rank Single-system, Cloud-based, Operational, Peer, Hybrid and multi-level deployment strategies
Keywords: ERP, Fuzzy DEMATEL, EDAs, ERP Deployment Strategy

ÇELİŞEN KRİTERLER ALTINDA BULANIKLAŞTIRILMIŞ ERP YAYILIM STRATEJİSİ SEÇİMİ YAKLAŞIMI

Öz: *İmalat ve hizmet sektöründeki organizasyonlar satınalmadan depolamaya, üretim planlamasından maliyet hesaplamasına kadar birçok fonksiyonun entegrasyonu için Kurumsal Kaynak Planlamasına (ERP) ihtiyaç duymaktadırlar. Şirketlerin, ERP sistemlerini bilgi seviyeleri ile birleştirmeleri onlara yürüttükleri süreçlerde karlılık, verimlilik ve etkinlik gibi hissedilir avantajlar sağlamaktadır. ERP yayılım stratejisinin seçimindeki belirsizlik seviyesi nispeten yüksek olup dikkatli analiz yapılmasını gerektirmektedir. Doğru strateji şirketlere çeşitli avantajlar getireceği gibi, kusurlu strateji seçimi para kaybı ile sonuçlanabilir. Bu makalede, modifiye edilmiş bulanık DEMATEL ve ortalama çözüme olan uzaklığın değerlendirilmesinin temel alındığı (EDAs) metotları en iyi ERP yayılım stratejisini seçmek için kullanılmıştır. Kullanılan model için açıklayıcı bir örnek olması açısından çeşitli mobilya şirketlerinin ERP danışmanlığını yapan şirket verilerinden faydalanılmıştır. ERP yayılım stratejilerini derecelendirmek için dört ana kriter ve onbir alt kriter ortaya konulmuş olup tekil-sistem, bulut-tabanlı, operasyonel, parçalı, hibrit ve çok-seviyeli yayılım stratejileri değerlendirilmiştir.*
Anahtar Kelimeler: *ERP, Bulanık DEMATEL, EDAs, ERP Yayılım Stratejisi*

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I. Introductıon

Firms must take care of all processes of business due to the rapid growth of industries and increased global competition. In order to enrich competitive advantages in market, firms are considering on different strategies. In the past few decades, business and manufacturing departments have developed strategies that enable them to control large amount of sources such as money, labors, material and machines by using sophisticated enterprise resource planning (ERP) (Hsu et al.,2015:925-942). ERP systems can largely improve business productivity and better serve customers by creating values through integrating business processes and sharing current information (Jayawickrama et al.,2016:205:223). Moreover, implementing ERP deployment strategies on companies has various benefits such as using centralized system to gather local and global data in one system, effective cost-management in sophisticated supply chains, elimination of language, payment, customized obstacles and developing adaptability (Ehie and Madsen, 2005:545-557; O'Leary, 2002:99-110). The implementation of ERP needs to infrastructure analysis since many ERP deployment strategies were concluded with failures or were not obtained expected benefits. It is evident that implementation of ERP requires significant amount of financial, human and technical resource to succeed in business. ERP implementation is classified as one of the most expensive information technologies in the corporate world (Jones et al., 2006:411-434; Kumar and Hillegersberg, 2000:22-26). As a result, plentiful researches have been done in order to explore potential factors and strategies. In this study, diverse and useful ERP deployment strategies are analyzed which can greatly be helpful in choosing appropriate strategy for different companies. Although many investments have been conducted until now, it is difficult to guarantee the benefits of ERP systems implementation (Kandananond, 2014:377-382). Therefore, one of the most important steps in implementation of ERP strategies is recognition and exploration of both organization and ERP deployment strategies. In other words, the success and failure of implementation depend largely on strategies' example.

In one study, critical factors for successful implementation of ERP strategies are proposed (Nah et al., 2001:285-296). The paper also discusses about difficulties of ERP implementation. ERP is described as a packaged business software system that helps the company to control the efficiency and effectiveness in using the resources by providing a total and integrated solution for the organizations that information processing is needed (Samani et al., 2014). It supports a process-oriented view of the business as well as business processes standardized across enterprise. The companies usually need a system which help them in the following needs (Nah et al., 2001:285-296):

- Automate and combine an organization's business procedures;
- Share common date and practices across the entire enterprise; and
- Produce and access information in a real-time environment.

There is no unique answer for "what is the best enterprise system?" There are many important criteria which determine the suitable system for a company. Indeed, the priority of ERP strategies is changeable from one company to another. The purpose of this study is to compare diverse ERP deployment strategies for a furniture company according to relational criteria. Therefore, real data is obtained from an ERP consultant company and the relation of criteria is determined by academician, managers and experts. In this paper, fuzzy DEMATEL and Evaluation based on Distance from Average Solution (EDAs) methods are used for choosing the best ERP deployment strategy. Four main criteria and eleven sub criteria were determined by decision making groups. Determined sub criteria include Agility, Easy to Learn, Adaptability, Security, Innovative Technology (IT), Expandability, Module Framework, Preliminary Buying Cost, Maintenance and Updating Cost, Service Quality and History of Company. Criteria and related sub criteria are seen in Figures (3-6). The weights of criteria and sub criteria are obtained by modified fuzzy DEMATEL method (Baykasoğlu et al.,2013:899-907), and alternatives are ranked by EDAs.

This study contains six parts. To begin with, importance of this research and implementing of ERP deployment strategies are explained in introduction section. Secondly, related literature review is done in section two. Basic concept of ERP is clarified in third section. After that, integrated fuzzy DEMATEL and EDAS methods are proposed for solving ERP deployment strategies selection problem. In the fifth section, illustrative example of a consultant company and results are presented. Finally, conclusion of this work and possible further studies are introduced in sixth section.

II. Literature Review

ERP is a software solution that integrates the operational processes of the business functions of an enterprise. However, implementing ERP systems is a complex process. ERP is the process of optimizing the performance of enterprise business processes through the utilization of integrated IT-based solutions (Sohrabi and Vanani, 2013:130-140). ERP is defined as business software for at least three of the following sections of business: accounting, manufacturing, material management or distribution and human resource (HR) management (Jakupovic et al., 2012:19-39). In one study, possible CSFs for the life cycle of an ERP system are investigated. The effects of CSFs from the perspective of Information Technology Governance (ITG) are also analyzed. As a result, it is essential for an ERP system to have a performance measurement index in order to deliver value within organizations (Li et al., 2017:269-279). Moreover, applicability of ERP systems to Make-To-Order (MTO) companies is explored by assessing the fit or alignment between ERP functionality and MTO production strategy (Aslan et al., 2012:692-705). In another research, researchers discussed ERP implementation in manufacturing and service sector organizations. They concentrated on empirical evidence of an innovative knowledge management

(KM) approach for improving knowledge competence in ERP success (Jayawickrama et al., 2016:205-223). Many studies conducted in ERP area are related to success factors in implementation of ERP (Somers and Nelson, 2001:10; Hong and Kim, 2002:25-40). ERP software selection is inspired by Strengths, Weaknesses, Opportunities and Threats (SWOT) which is a method for strategic analysis (Lee et al., 2004:1709-1713). Technological factors affecting cloud Enterprise Resource Planning Systems adoption are defined by (Kinuthia and Chung, 2017:1-22). ERP critical success factors are analyzed through fuzzy cognitive maps by two phase structural model (Baykasoğlu and Gölcük, 2017:256-274). Claybaughet et al., (2017) presented the differences in the propensity of firms to initiate and commit to the assimilation of an enterprise technology upgrade. A diverse approach is proposed by (Jagoda et al., 2017:91-109), they offered a framework aims to enhance the overall ERP implementation outcomes, ensuring critical success factors and eliminating common causes of failures.

The long term impacts of the good quality decisions on the overall organizational performance have increased awareness to virtues of using Multiple Attribute Decision Making (MADM) methods (Baykasoğlu et al., 2015:1-38). In the literature, a vast variety of MADM methods are proposed, such as Multi-Attribute Utility Theory (MAUT) (Fishburn, 1970; Keeney, 1988:149-157), Analytic Hierarchy Process (AHP) (Saaty, 1980), Analytic Network Process (ANP) (Saaty, 1996), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Hwang and Yoon, 1981), Elimination et Choice Translating Reality (ELECTRE) (Roy, 1990:49-73), VlseKriterijumska Optimizacija I Kompromisno Resenje technique (VIKOR) (Opricovic and Tzeng, 2004:445-453) and Decision-Making Trial and Evaluation Laboratory (DEMATEL) (Fontela, 1976). DEMATEL method, developed in the Geneva Research Centre of the Battelle Memorial Institute, is one of the methods that can be used to model causal dependencies among criteria. DEMATEL method is able to visualize the complex cause and effect relationships in an understandable manner (Baykasoğlu and Gölcük, 2017:256-274). DEMATEL can be applied to develop a structural model for analyzing complex interrelation ships among criteria (Büyüközkan and Çifçi, 2012:3000-3011). In one study, DEMATEL method is used to estimate weights of criteria for a supplier selection problem (Dalalah et al.,2011:8384-8391). In another research, DEMATEL modified ANP technique is applied for evaluating performance of internal hospital supply chain (Supeekit at al., 2016:318-330). A combined MCDM model based on DEMATEL and ANP is used for the selection of airline service quality improvement criteria (Chen, 2016:7-18). Combined fuzzy DEMATEL and fuzzy AHP is implemented to analyze the human resource evaluation criteria (Chou et al., 2012:64-71).

EDAS method is compared with VIKOR, TOPSIS, SAW (Simple Additive Weighting) and COPRAS (Complex Proportional Assessment) methods in order to show that EDAS method is stable in different weights and well consistent with other methods (Ghorabaee et al., 2015:435-451).

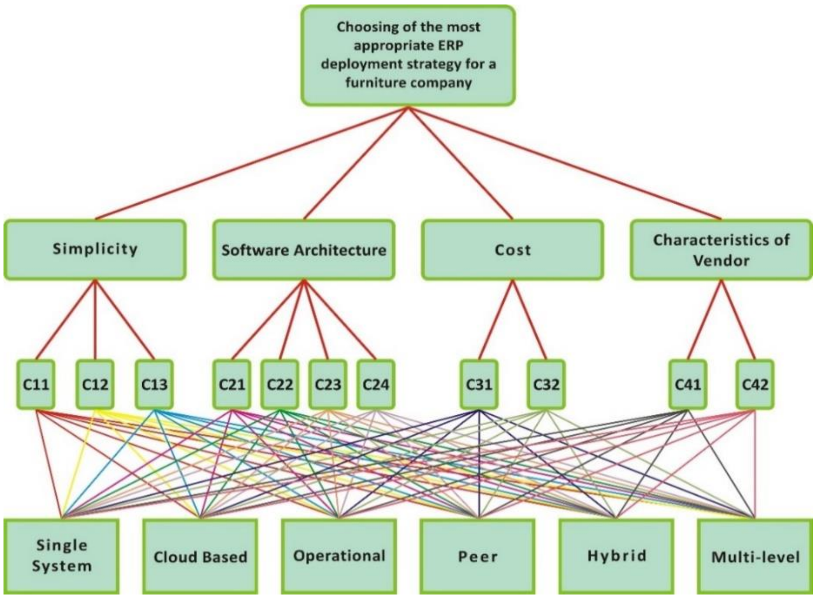

Figure 1. The hierarchy structure to determine the best ERP deployment strategy for a furniture company

III. Basic Concept of Enterprise Resource Planning (ERP)

ERP systems include integrated modules that every module is focused on allocated area of business operations. For instance, inventory control, project control and etc. ERP systems have attracted increasing attention within the last few decades as companies try to seek ways to reach strategic and competitive advantage by these technologies. ERP systems are complex software packages that combine information and business processes within and across functional areas of business (Davenport, 2000:163-180; Kalling, 2003:46). ERP is a system that helps the company to facilitate manufacturing, inventory control, logistics and accounting. Competitive situations made companies to implement enterprise-wide information systems. For this reason, companies can diminish their costs through improving strategies and decision-making with implementation of ERP. Organizations try to achieve important benefits by investment in ERP systems. Benefits may come in the form of improved business productivity such as shortened lead time, lower cost and efficiency communication among functional boundaries (Nwankpa, 2015:335-344;Watson and Schneider, 1999:3). Five types of ERP benefits are introduced as operational, managerial, strategic, IT infrastructure and organizational; besides, ERP benefits are determined as continuous procedures with benefits that identify at diverse rate and in different core procedures (Shang and Seddon, 2002:271-299). The companies have changed their view about ERP deployment strategies because of rapid changes in global business. Today's need for high security, agility, low cost and intelligibility has intensified the demand for diverse deployment strategies. ERP systems were once deployed as integrated systems running in local data centers. Early monolithic ERP systems had some restrictions such as low security, expensive to implement and high maintenance cost. But now firms require a packaged-software to control their sources efficiently and at low cost. Nowadays companies have more choices in selection of ERP deployment strategies. Operational success, profitability and holding on to the market may be influenced by the chosen deployment strategy. There are many types of strategies supposed by the firms and literature. This study considers a consultant firm’s deployment strategies implemented before. Single-system, cloud-based, operational, peer, hybrid and multi-level approaches (ERP, 2014).

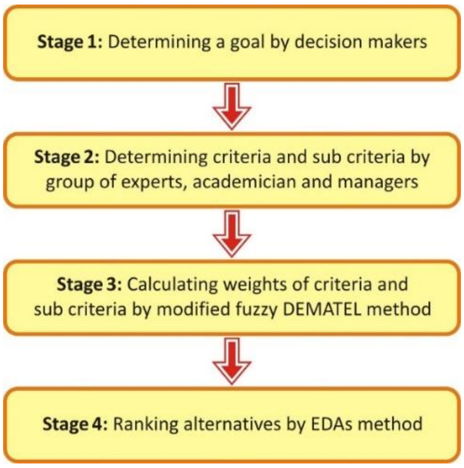

Figure 2. Flowchart of proposed integrated model

IV. Method

A. Fuzzy DEMATEL

The relationship of criteria is determined by modified fuzzy DEMATEL. Geneva research center of the Battelle memorial Institute proposed DEMATEL for determining relationship of complex structures (Büyüközkan and Çifçi, 2012a:3000-3011; Büyüközkan and Çifçi, 2012b:2341-2354). According to the modified fuzzy DEMATEL method, the relationship of criteria are represented with direct relation matrix (Dalalah et al.,2011:8384-8391). Steps of this method are as follows:

i. The direct relation matrix shows relationship between criteria by linguistic terms where $\tilde{Z}_{ij} = (Z_{ij,l}, Z_{ij,m}, Z_{ij,u})$ expresses effect of criterion C_i on criterion C_j.

ii.

$$\tilde{Z} = \begin{bmatrix} 0 & \cdots & \tilde{Z}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{Z}_{n1} & \cdots & 0 \end{bmatrix} \tag{1}$$

iii. The normalized direct relation fuzzy matrix is calculated as follows:

$$\widetilde{\mathrm{X}} = \begin{bmatrix} \widetilde{\mathrm{X}}_{11} & \cdots & \widetilde{\mathrm{X}}_{1\mathrm{n}} \\ \vdots & \ddots & \vdots \\ \widetilde{\mathrm{X}}_{\mathrm{n}1} & \cdots & \widetilde{\mathrm{X}}_{\mathrm{nn}} \end{bmatrix} \tag{2}$$

Where

$$\tilde{X}_{ij} = \frac{\tilde{Z}_{ij}}{R} \qquad and \qquad R = (r_l, r_m, r_u) \tag{3}$$

$$r_s = \max_{1 \le i \le n} \left(\textstyle\sum_{j=1}^{n} Z_{ij,s}\right) \quad \forall s = l, m, u \tag{4}$$

iv. Primary normalized direct relation fuzzy matrix can be considered as sub-matrices (X_l, X_m, X_u). It was approved that $\lim_{w\to\infty}(X_s)^w = O$ and $\lim_{k\to\infty}(I + X_s + \cdots + X_s^2 + \cdots + X_s^k) = (I - X_s)^{-1}, \forall s = l, m, u$ where O is the null matrix and I is the identity matrix (Goodman, 1988). As a result, total relation fuzzy matrix $\tilde{T}$ can be acquired as follows (Dalalah et al.,2011:8384-8391):

$$\tilde{T} = \lim_{w\to\infty}\left(\tilde{X} + \tilde{X}^2 + \cdots + \tilde{X}^w\right) = \tilde{X}(I - X)^{-1} \tag{5}$$

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \cdots & \tilde{t}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \cdots & \tilde{t}_{nn} \end{bmatrix} \qquad \tilde{t}_{ij} = \left(t_{ij,l}, t_{ij,m}, t_{ij,u}\right) \tag{6}$$

The sum of row and sum of columns for sub matrices T_l, T_m, T_u denoted by the fuzzy numbers $\widetilde{D}$ and $\tilde{R}$ (Dalalah et al.,2011: 8384-8391).

$$\widetilde{D}_i = \textstyle\sum_{j=1}^{n} \tilde{t}_{ij} \quad (i = 1,2, \dots, n) \tag{7}$$

$$\tilde{R}_i = \textstyle\sum_{i=1}^{n} \tilde{t}_{ij} \;\; (j = 1,2, \dots, n) \tag{8}$$

v. Defuzzification is used to obtain the weights of criteria. In this method, signed distance method of (Yao and Wu, 2000:275-288) is applied for defuzzification. Yao and Wu, (2000) introduced signed distance to define ranking of fuzzy numbers. The signed distance used for fuzzy numbers has some similar features with signed distance in real numbers (Baykasoğlu et al., 2011:165-179). For ranking of fuzzy numbers, this method can be expressed as follows:

Let F be the family of the fuzzy numbers on R. The sign distance is defined as $d^* = (a.0) = a \; on \; R$

Then for $a, b \in R, d^*(a,b) = a - b. For\ \widetilde{D}, \tilde{E} \in F, with\ \alpha - cut(0 \leq \alpha \leq 1)$, there is a closed interval $D(\alpha) = [D_L(\alpha), D_R(\alpha)]$. Then, the signed distance of $\widetilde{D}, \tilde{E}$ is defined as follows (Yao and Wu, 2000:275-288).

$$d(\widetilde{D}, \tilde{E}) = \frac{1}{2}\int_0^1 [D_L(\alpha) + D_R(\alpha) - E_L(\alpha) - E_R(\alpha)]d\alpha \qquad (9)$$

It can be proved that d is an extension of d^*. And,

$$d(\widetilde{D}, \tilde{E}) > 0 \text{ if } f \;\; d(\widetilde{D}, 0) > d(\tilde{E}, 0) \text{ if } \; f \;\; \tilde{E} < \widetilde{D}$$
$$d(\widetilde{D}, \tilde{E}) < 0 \text{ if } f \;\; d(\widetilde{D}, 0) < d(\tilde{E}, 0) \text{ if } \; f \;\; \widetilde{D} < \tilde{E}$$
$$d(\widetilde{D}, \tilde{E}) = 0 \text{ if } f \;\; d(\widetilde{D}, 0) = d(\tilde{E}, 0) \text{ if } \; f \;\; \widetilde{D} \approx \tilde{E}$$

According to these definitions, the signed distance of a triangular fuzzy number $A = (\underline{a}, a, \overline{a})$ is defined as (Baykasoğlu et al., 2011:165-179):

$$d(\tilde{A}, 0) = \frac{1}{2}\int_0^1 \left[\overline{a} + (a - \underline{a})\alpha + \overline{a} - (\overline{a} - a)\alpha\right]d\alpha = \frac{1}{4}(\underline{a} + 2a + \overline{a}) \qquad (10)$$

The distance of each fuzzy number is used as its defuzzified value. Following equation is used for defuzzification of $\widetilde{D}_i$ and $\tilde{R}_i$:

$$S(\tilde{X}_{ij}, 0) = \frac{1}{4}(X_{ij,l}, X_{ij,m}, X_{ij,u}) \qquad (11)$$

Using of recent equation for defuzzifying $\widetilde{D}_i$ and $\tilde{R}_i$ results in $\widetilde{D}_i^{def}$ and $\tilde{R}_i^{def}$ respectively. The casual diagram can be obtained by mapping the ordered pairs of $(\widetilde{D}_i^{def} + R_i^{def})$ and $(\widetilde{D}_i^{def} - R_i^{def})$ where the horizontal axis $(\widetilde{D}_i^{def} + R_i^{def})$ is called prominence and the vertical axis $(\widetilde{D}_i^{def} - R_i^{def})$ is called relation (Baykasoğlu et al.,2013:899-907).

The importance of criteria is calculated as follows:

$$w_i = \left((\widetilde{D}_i^{def} + R_i^{def})^2 + (\widetilde{D}_i^{def} - \tilde{R}_i^{def})^2\right)^{\frac{1}{2}} \qquad (12)$$

The importance of every criterion is calculated as follows:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (13)$$

Where w_i expresses the ith criterion weights which is used in decision making process (Dalalah et al.,2011:8384-8391). The weights of sub criteria are calculated as well as main criteria by using modified fuzzy DEMATEL method. Then, additive weighted aggregation (AWA) is used for calculation of overall weights (Xu, 2009:1369-1374).

$$W = w_m * w_s \tag{14}$$

Where w_m= weight of main criteria, w_s =weight of sub criterion

B. The Evaluation Based on Distance from Average Solution (EDAs) method

EDAs method was developed in (Ghorabaee et al., 2015:435-451). In this method, the best alternative is selected according to the distance from average solution. The steps of this method for n alternatives and m criteria are as follows:

i. Form decision making matrix:

$$X = \begin{bmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{nm} \end{bmatrix} \tag{15}$$

$$X_{ij} = the\ performance\ value\ of\ ith\ alternative\ on\ jth\ criterion.$$

ii. Calculation of average solution:

$$AV_j = \frac{\sum_{i=1}^{n} X_{ij}}{n} \tag{16}$$

iii. The amount of PDA and NDA matrices calculate with attention to the type of criteria (cost or benefit).

$$PDA = \left[PDA_{ij}\right] \tag{17}$$

$$NDA = \left[NDA_{ij}\right] \tag{18}$$

For beneficial criteria:

$$PDA_{ij} = \frac{\max(0,(X_{ij}-AV_j))}{AV_j} \tag{19}$$

$$NDA_{ij} = \frac{\max(0,(AV_j-X_{ij}))}{AV_j} \tag{20}$$

For cost criteria:

$$PDA_{ij} = \frac{\max(0,(AV_j-X_{ij}))}{AV_j} \tag{21}$$

$$NDA_{ij} = \frac{\max(0,(X_{ij}-AV_j))}{AV_j} \tag{22}$$

PDA_{ij}: positive distance of ith alternative from average solution in terms of jth criterion.

NDA_{ij}: negative distance of ith alternative from average solution in terms of jth criterion.

iv. Calculation of weighted sum of PDA and NDA.

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij} \tag{23}$$

$$SN_i = \sum_{j=1}^{m} w_j NDA_{ij} \tag{24}$$

w_j: the weight of jth criterion which is acquired by DEMATEL.

v. Normalization of SP and NP.

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \tag{25}$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)} \tag{26}$$

vi. Calculation of appraisal score (AS):

$$AS_i = \frac{NSP_i + NSN_i}{2} \tag{27}$$

Where $0 \leq AS_i \leq 1$

vii. Ranking of alternatives.

The alternative with high amount AS is the best for choosing. We rank alternatives in decreasing form.

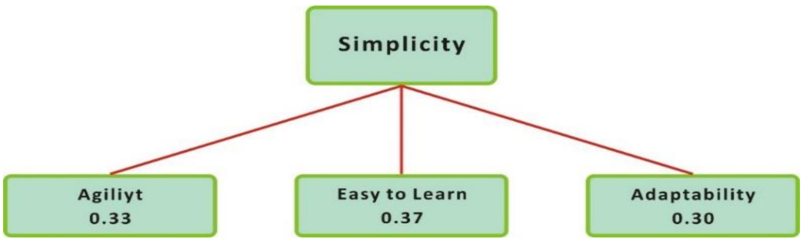

Figure 3. Hierarchy structure of Simplicity criterion and weights of sub criteria

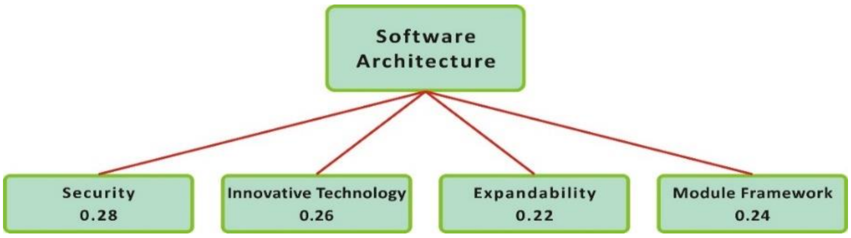

Figure 4. Hierarchy structure of Software Architecture criterion and weights of sub criteria

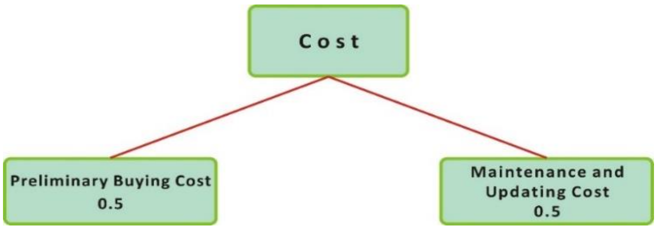

Figure 5. Hierarchy structure of Cost criterion and weights of sub criteria

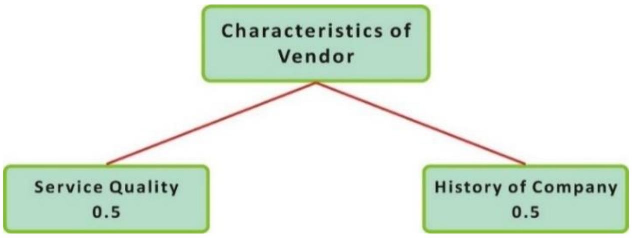

Figure 6. Hierarchy structure of Characteristics of Vendor criterion and weights of sub criteria

V. Illustrative Example and Results

Real and current data is obtained from one ERP consultant company that implements diverse ERP strategies on various furniture manufacturing companies. The level of uncertainty in the selection of ERP systems is relatively high and need to be carefully analyzed. Therefore, in order to select a proper ERP strategy, combination of fuzzy DEMATEL and evaluation based on distance from average solution (EDAs) has proposed a new useful method, in which fuzzy DEMATEL is used for calculating priority weight of criteria (sub criteria) and the EDAs is implemented for obtaining the final ranking of ERP deployment strategies. Decision making group selected four main criteria and eleven sub criteria, the group consists of managers, experts and academicians with significant background in this topic. This group also selected six eligible ERP deployment strategies as our alternatives. In calculation of EDAs method, nine degrees scale of (Saaty, 1980) is applied for comparing ERP deployment strategies based on sub criteria, which nine absolute distance and one means Equal distance (Harker and 1987:1383-1403).

Accordingly, a systematic approach based on combination of fuzzy DEMATEL with EDAs is proposed to determine the best ERP deployment strategy. The main aim of using EDAs is its comprehensive and useful outlook through conflicting criteria. Linguistic values in Table 1 (Baykasoğlu et al.,2013:899-907) are used in fuzzy DEMATEL method.

Table 1. *Criteria comparison linguistic terms*

Linguistic Terms	Triangular Fuzzy	Linguistic Values
Very High Influence (VH)	$\tilde{9}$	(8,9,9)
High Influence (H)	$\tilde{7}$	(6,7,8)
Low Influence (L)	$\tilde{5}$	(4,5,6)
Very Low Influence (VL)	$\tilde{3}$	(2,3,4)
NO Influence (NO)	$\tilde{1}$	(1,1,1)

Pairwise comparison between criteria is shown in Table 2. Normalized direct relation fuzzy matrix is calculated by Equations (2-4). Then, total relation fuzzy matrix is calculated by Equations (5, 6) and shown in Table 3. After that, the amount of $\widetilde{D}$ and $\tilde{R}$ are calculated according to Equations (7, 8). Prominence, relation and weights of criteria are calculated by Equations (9-13). Weights of sub criteria are calculated as well as criteria and shown in Table 4. Finally, overall weights of sub criteria are calculated by Equations 14 and results are presented in Table 4.

Table 2. *Pairwise comparison between criteria*

Z	Simplicity	Software Architecture	Cost	Characteristics of vendors
Simplicity	0	L	H	L
Software Architecture	H	0	H	H
Cost	L	L	0	NO
Characteristics of vendors	NO	L	NO	0

Table 3. *Total relation fuzzy matrix*

T	Simplicity	Software Architecture	Cost	Characteristics of vendors
Simplicity	(0.15,0.41,2.71)	(0.30,0.65,3.28)	(0.37,0.71,3.27)	(0.28,0.58,2.88)
Software Architecture	(0.38,0.73,3.39)	(0.19,0.54,3.46)	(0.41,0.79,3.67)	(0.38,0.72,3.32)
Cost	(0.26,0.52,2.44)	(0.26,0.54,2.68)	(0.14,0.37,2.40)	(0.155,0.37,2.2)
Characteristics of vendors	(0.12,0.27,1.47)	(0.22,0.42,1.82)	(0.13,0.29,1.60)	(0.08,0.22,1.39)

Table 4. *The overall weights of sub criteria*

Main Criteria	Weights	Sub Criteria	Weights	Overall Weights
C1	0.27	C11	0.33	0.09
		C12	0.37	0.10
		C13	0.30	0.08
C2	0.30	C21	0.28	0.09
		C22	0.26	0.08
		C23	0.22	0.07
		C24	0.24	0.07
C3	0.24	C31	0.50	0.12
		C32	0.50	0.12
C4	0.19	C41	0.50	0.09
		C42	0.50	0.09

In the second step, ERP deployment strategies are ranked by implementing EDAs method. To do this, the comparison between ERP deployment strategies are done by Saaty's nine degrees' scale, which are between one and nine; comparison is shown in Table 5. Red numbers in columns refer to sub criteria that are related to cost. After that, PDA and NDA matrices are acquired by Equations (16-22). Besides, the amounts of weighted PDA and NDA are obtained by Equations (23, 24); Normalized amounts of SP and ND are calculated by Equations (25, 26). Finally, appraisal scores (AP) are calculated by Equations 27 an all results are presented in Table 6. As a result, ERP deployment strategies for applying in a furniture company are ranked as Cloud Based, Single System, Hybrid, Multi-Level, Operational and Peer.

Table 5. *Comparison between ERP deployment strategies based on sub criteria*

	C11	C12	C13	C21	C22	C23	C24	C31	C32	C41	C42
Single-system	6	7	8	7	8	7	8	7	8	7	7
Cloud-based	8	7	9	8	8	9	9	8	8	7	8
Operational	7	7	6	5	6	6	7	6	5	6	6
Peer	5	7	6	5	6	6	7	5	5	6	5
Hybrid	6	6	6	6	7	8	8	6	5	6	7
Multi-level	8	6	7	6	7	7	8	8	7	6	6

Table 6. *The evaluation of the appraisal score.*

	SP	SN	NSP	NSN	AS	RANK
Single-System	0.99	0.05	0.92	0.92	0.92	2
Cloud-Based	1.08	0.05	1	0.90	0.95	1
Operational	0.05	0.54	0.04	0.06	0.05	5
Peer	0.06	0.57	0.05	0	0.03	6
Hybrid	0.05	0.49	0.05	0.14	0.09	3
Multi-Level	0.02	0.53	0.02	0.08	0.05	4

VI. Conclusion

The main objective of this study is to propose comprehensive criteria to evaluate ERP deployment strategies by using integrated fuzzy DEMATEL and EDAs methods. This paper contributes to ERP literature as well as the validity of developed criteria for ERP deployment strategies based on experts, managers and academicians. Furthermore, this paper proposes valuable ranking of ERP deployment strategies by using EDAs. Choosing of suitable ERP deployment strategy for a manufacturing company is a difficult MCDM problem that includes both quantitative and qualitative objectives. It is difficult to measure the performance of ERP deployment strategies, which this study managed to do that by getting help from experts of an ERP consultant company. This study, proposed a fuzzy integrated model that can assess and choose the best ERP strategies by using of fuzzy DEMATEL and EDAs methods. The Implementing of a practical decision making method for assessment and choosing ERP strategies is the major contribution of this study for the further studies. In future researches, this integrated method can be adjusted to diverse MCDM problems. The proposed model may be used to evaluate alternatives successfully through different selection problems. Future researches may try to extend this study as an integration of more "fuzzy integrated MCDM" techniques to solve many other decision making problems on various industries. Consequently, effect of criteria (sub criteria) and types of them can be changed according to area of intended industry.

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