Contents list available at JMCS
Journal of Mathematics and Computer Science
Journal Homepage: www.tjmcs.com

A Model for Selecting an ERP System with Triangular Fuzzy Numbers and Mamdani Inference

J. Vahidi
Department of Applied Mathematics, Iran University of Science and Technology, Behshahr, Iran,
jvahidi@iust.ac.ir
D. Darvishi SalooKolayi
Department of Mathematics, Payeme Noor University, Bandpey branch, Babol, Iran,
drvishidavood@yahoo.com
A. Yavari
Mazandaran University of Science and Technology
yavari@ustmb.ac.ir

Article history:
Received September 2013
Accepted October 2013
Available online October 2013

Abstract

The enterprise resource planning (ERP) is an integrated set of programs that provide support for core business processes, such as production, input and output logistics, finance and accounting, sales and marketing and resource. It is important to select an ERP that adapt with organization requirements. This paper presents a method for selecting a suitable ERP system based on fuzzy logic. This model has 3 inputs: functionality, cost and vendor support. These inputs are criteria for selecting suitable ERP for organization. We use triangular fuzzy membership function for each criterion and develop a Mamdani inference system.

Keywords: Enterprise Resource Planning Selection, Criteria, Fuzzy logic, Triangular Fuzzy Membership Function

1. Introduction

The enterprise resource planning (ERP) is an integrated set of programs that provide support for core business processes, such as production, input and output logistics, finance and accounting, sales and marketing and resource[1,2]. In other words, an ERP system is the information backbone of an organization and reaches into all areas of the business and value-chain [3]. Since it has a long and problematic implementation process, and is a very expensive investment, due to the high costs and risks in this systems it is important to select an ERP that adapt with organization requirements [4, 5].ERP

selection is a complex process that need identification criteria and choosing a suitable and reliable approach for select an alternative from the available options. On the other hand the failure of an ERP project can cause the negative effects on organizational processes and bring irreparable damage for organization [6].

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 [7]. Owing to the complexity of the business environment, the limitations in available resources, and the diversity of ERP alternatives, ERP system selection is tedious and time consuming. However, given the considerable financial investment and potential risks and benefits, the importance of a pertinent ERP system selection cannot be overemphasized. Hence, it is important to make a healthy selection about which ERP fits the organization the most [8-10].

This paper presents a method for selecting a suitable ERP system based on fuzzy logic. This model has 3 inputs and 1 output. We use triangular fuzzy membership function for each criterion. Three criteria: functionality, cost and vendor support to evaluate the alternatives was presented.

The organization of this paper is as follows: in section 2 we have a review on related works about criteria and methods for ERP selection. In section 3 we introduced proposed approach for ERP selection. In section 4 we have conclusion and future work.

2. Related Works

Recently many works in ERP selection is proposed, some of those presented a set of factors that important for ERP selection and a few of those presented methods based on mathematic approaches, fuzzy logic and AHP. In this section we introduce this works.

In [11] introduced seven criteria for ERP selection. Some of those (Reliability and Functionality) are based on quality metrics in software and some of those are related to organization such as: cost, ease of use, ease of customization and ease of implementation and vendor reputation is criteria for vendors.

In [12, 13] 13 criteria for ERP selection introduced. Functionality, reliability, fit with business process of organization, cost, level of customization, vendor support, compatibility, availability, vendor reputation, technology, module integration, fit with parent/allied organization system. This work has not an approach for ERP selection, only introduced criteria that important in ERP selection.

In [14] proposed an approach for select suitable ERP for organization based on AHP. In this method they assigned weights to criteria, finally they select ERP software from Created hierarchy. They Identified 9 attributes. Costs, implementation time, functionality, user friendliness, flexibility, reliability, vendor reputation, vendor technical capability, vendor service. Each attribute can be split into evaluation items. They use analytic hierarchy process to estimate weights for the criteria.

In [15] used analytic network process and fuzzy numbers for select a suitable ERP for organization. Their criteria are: license fee, vendor support, maintenance cost, infrastructure cost, vendor good reputation, vendor consulting performance, R&D capability, technical-support capability, training performance, upgrade ability, ease of integration, easy of in-house development, module completion, function

fitness, security level, stability, recovery ability, easy of operations, easy of learning, standardization, integration of legacy systems, easy to maintain.

In [16] a fuzzy logic approach for ERP selection is proposed. In this method they used 27 criteria such as: possibility of applying industry solutions, credibility of the system, the capacity to integrate the ERP with the current IS/IT, trust in the ERP system, modularity, adaptation of the ERP to the current system needs, capability of the ERP system to offer information on time, intuitiveness of the ERP system, software costs, consultation costs, maintenance costs, hardware requirements, specialist team requirements, high average implementation time, parameter complexity, project planning, possibility of objectively defining the concepts, employee continuing education, average age of the personnel, continuing education of the decision-making group, suggestions/recommendations made by the users, traditional organizational culture, complexity of the organizational structure, high performance, number of employees/company size, traditional organizational strategy, complexity of organizational processes.

In [17] used data envelopment analysis to evaluate mid-level ERP packages. They utilized an extensive study of the available features and functions and performance of various mid-level packages in these features and functions. Regarding the analysis, the following criteria were used: service and support, training, scalability, implementation flexibility, integration, manufacturing process, core financials, purchasing and sales, human resource process, international tax support, average cost of packages, support fees, training fees and average implementation.

In [18] used in an analytic hierarchy process model to ERP selection. They used 4 criteria: function and technology, strategic fitness, vendor's ability and vendor's reputation.

In [19] used fuzzy logic for ERP selection. In this method, recommended ERP packages and vendors were compared by a Fuzzy-AHP system.

3. Proposed Approach

First of all, we review some basic definitions of fuzzy sets.

A fuzzy set $\tilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{A}}(X)$ which associates with each element x in X a real number in the interval [0, 1]. The function value $\mu_{\tilde{A}}(X)$ is termed the grade of membership of *x* in $\tilde{A}$. Figure 1 shows a fuzzy number [20]

Definition1. A fuzzy set $\tilde{A}$ of the universe of discourse X is convex if and only if for all x_1, x_2 in X, [21]

$$\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq Min(\mu_{\tilde{A}}(x_1) + \mu_{\tilde{A}}(x_2),$$

Where $\lambda \in [0,1]$.

Definition2. A fuzzy set $\tilde{A}$ of the universe of discourse X is called a normal fuzzy set implying that [22]

$$\exists\, x_i \in X, \mu_{\tilde{A}}(x_i) = 1$$

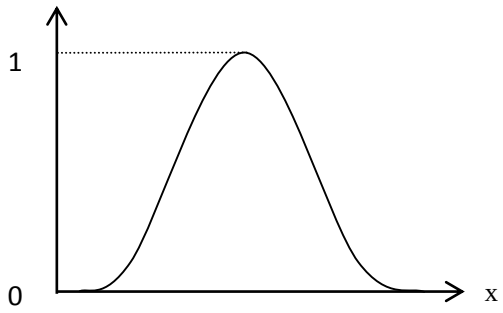
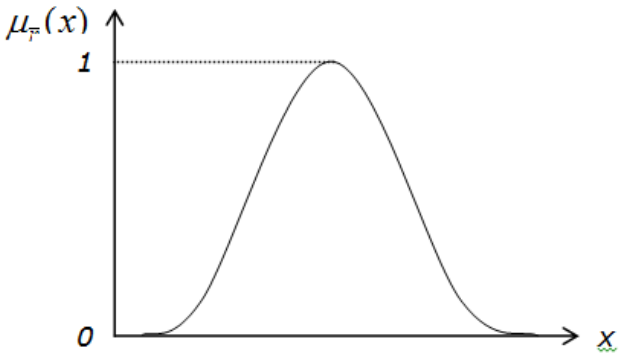


Figure1. A fuzzy number

A fuzzy number $\tilde{n}$ is a fuzzy subset in the universe of discourse X whose membership function is both Convex and normal. [23]

A triangular fuzzy number $\tilde{n}$ can be defined by a triplet (n_1, n_2, n_3) shown in Figure 2 show the membership function $\mu_{\tilde{n}}(X)$ is defined as

$$\mu_{\tilde{n}}(X) = \begin{cases} 0, & x < n_1 \\ \dfrac{x - n_1}{n_2 - n_1}, & n_1 \le x \le n_2 \\ \dfrac{x - n_3}{n_2 - n_3}, & n_2 \le x \le n_3 \\ 0, & x > n_3 \end{cases}$$



In this paper we use triangular fuzzy membership function for each criteria. Three criteria: functionality, cost and vendor support to evaluate the alternatives was chased [24, 25].

Figure 3 show the proposed model for ERP selection base on fuzzy logic. This model has 3 inputs and 1 output. Inputs are functionality, cost and vendor support. The fuzzy model consists of four modules. The fuzzification module is the first stage in working of any fuzzy model, which transforms crisp input(s) into fuzzy values. In the second stage, these values are processed in the fuzzy domain by interface engine based on production rules (knowledge base) supplied by the domain expert(s). During second stage, the fuzzy operators are applied. In third stage implication process is applied and then all outputs are aggregated. In fourth and final stage, the processed output is transformed from fuzzy domain to crisp domain by defuzzification module.

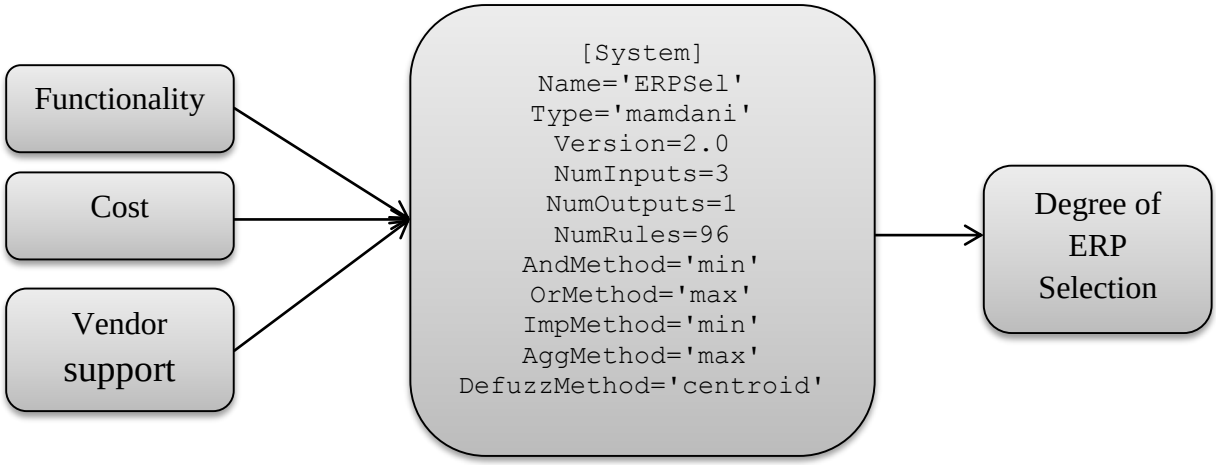


Figure 3. Proposed model for ERP selection base on fuzzy logic

In this paper, inputs (functionality, cost) have been taken in the scale of 0 to 1 and membership functions for two inputs (functionality and vendor support) as Nil, Low, Medium and high are triangular fuzzy membership function for each criteria. Table 1 shows the linguistic variable and triangular fuzzy numbers. This table has four rows. Each row shows the membership function name and range of the membership function.

Table 1. Shows the linguistic variable and triangular fuzzy numbers

Nil	0.0, 0.0, 0.0
Low(L)	0.0, 0.16,0.33
Medium(M)	0.30, 0.46, 0.66
High(H)	0.60, 0.82, 1.0

$$\mu(ERPSel) = \begin{cases} Nil & if \quad 0.0 \\ Low & if \quad 0.0 \leq ERPSel \leq 0.33 \\ Medium & if \quad 0.30 \leq ERPSel \leq 0.66 \\ High & if \quad 0.60 \leq ERPSel \leq 1.0 \end{cases}$$

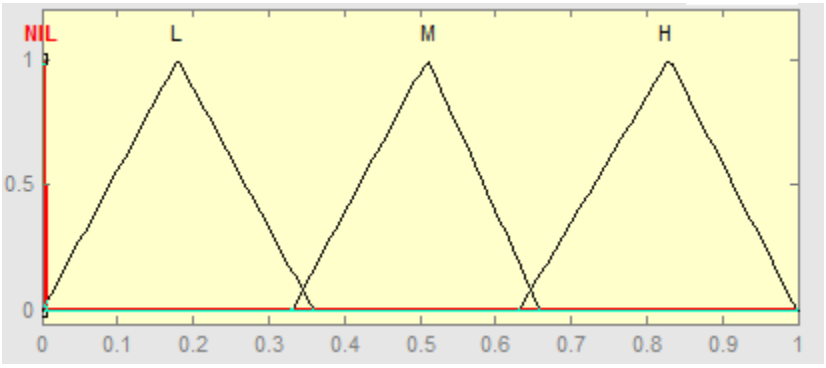


Figure 4. are triangular fuzzy membership function

Table 2 shows the range of membership functions NIL, VeryLow, Low, Medium, High and VeyHigh of input variable vendor support and output variable (ERPSel) have been considered as 0.0-0.0, 0.0-0.23, 0.2-0.43, 0.4-0.63, 0.6-0.83 and 0.8-1.00 respectively. Figure 5 shows the membership functions.

Table 2 shows the linguistic variable and triangular fuzzy numbers

Nil	0.0, 0.0, 0.0
VeryLow(VL)	0.0,0.11, 0.23
Low(L)	0.20,0.31, 0.43
Medium(M)	0.40,0.51, 0.63
High(H)	0.60,0.71, 0.83
VeryHigh(VH)	0.80,0.91, 1.00

$$\mu(ERPSel) = \begin{cases} Nil & if \quad 0.0 \\ VerLow & if \quad 0.0 \leq ERPSel \leq 0.23 \\ Low & if \quad 0.2 \leq ERPSel \leq 0.43 \\ Medium & if \quad 0.40 \leq ERPSel \leq 0.63 \\ High & if \quad 0.60 \leq ERPSel \leq 0.83 \\ VeyHigh & if \quad 0.80 \leq ERPSel \leq 1.0 \end{cases}$$

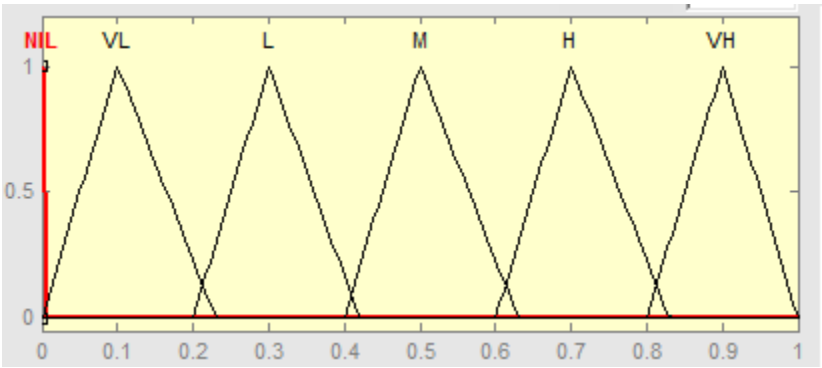


Figure 5. are triangular fuzzy membership function

In order to measure level of selected ERP (*ERPSel*), which is the main objective of our model, there three members functionality, cost and vendor support contributing in the selecting of any alternative. As a solution of this problem, we have used fuzzy logic and have designed 96 fuzzy rules (4 membership functions of functionality * 4 membership functions of *cost* * 6 membership functions of *vendor suport*). Here, mamdani method for defining fuzzy rules is used, which is used for nonlinear equations. These rules are designed on the basis of experience and expertise knowledge of the field that's why these are also known as knowledge base. For sample, some of the rules are listed in table 3. First column labeled # represent rule number, second column is for input linguistic variables, members functionality, cost and vendor support and third column is for output linguistic variable *ERPSel*.

Table3: some fuzzy rules

#	functionality	cost	*vendor suport*	output
1	Nil	Nil	Nil	Nil
12	Nil	Nil	VeryHigh	VeryHigh
25	Low	Nil	Nil	VeryLow
37	Low	Medium	Nil	Medium
45	Low	High	Low	High
57	Medium	Low	Low	Medium
65	Medium	Medium	High	VeryHigh
93	High	High	Nil	High

As an example, if *functionality* =0.573, *cost* =0.596 and *vendor suport* =0.5 are input values then *output* value is resulting as 0.692, which is high for output It is also shown in figure 6 as rule viewer.

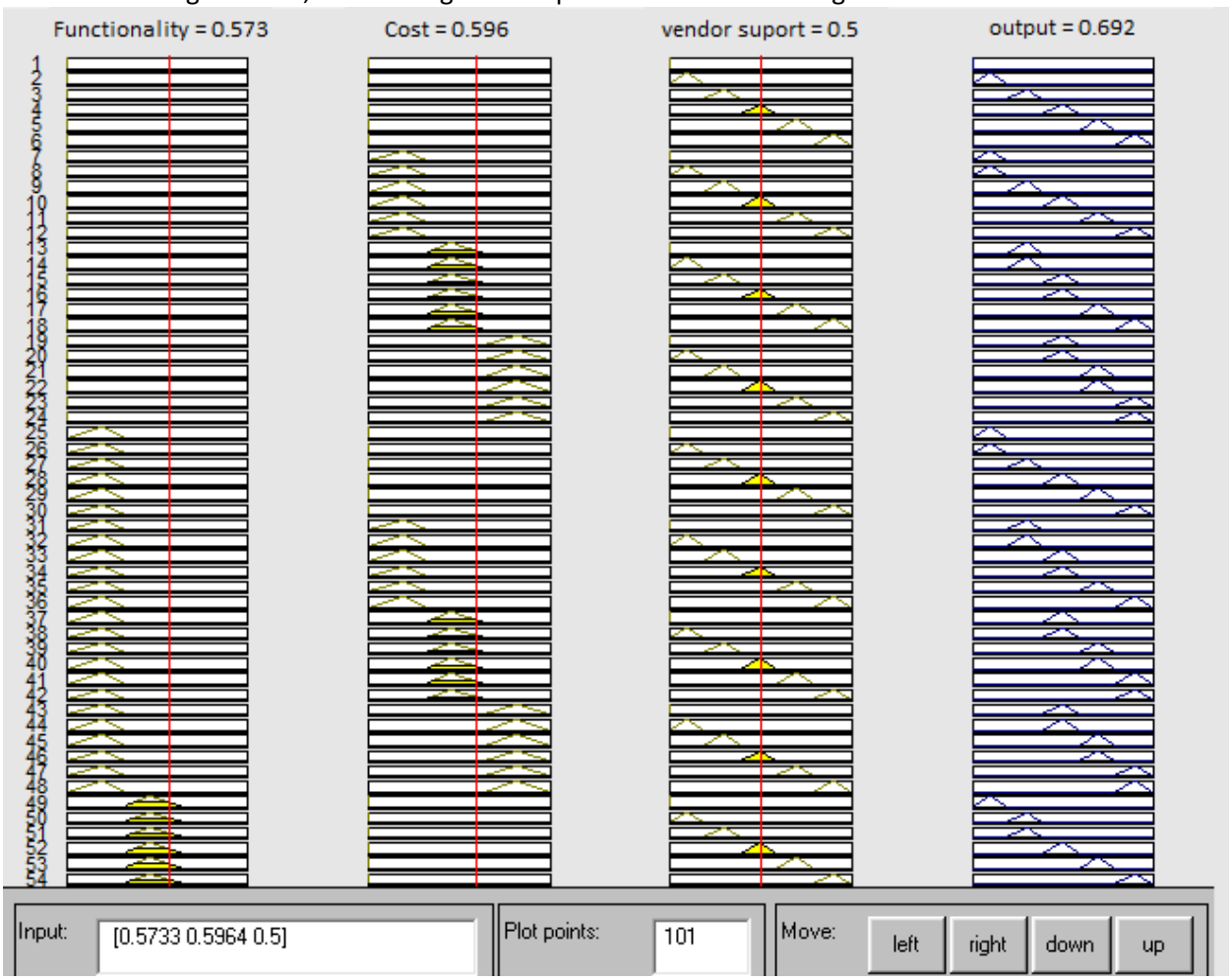


figure 6. result of test

Three dimensional surface view of this rule base is given in figure 7.

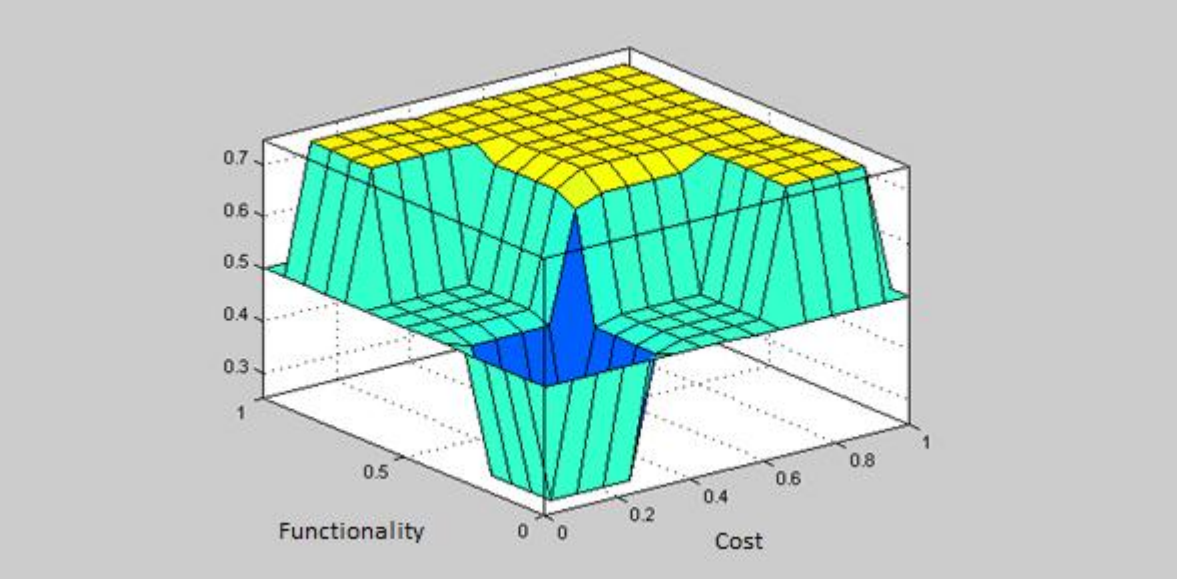


Figure 7: Three dimensional surface view of rule base.

4. CONCLUSION AND FUTURE WORK

An ERP system is the information backbone of an organization and reaches into all areas of the business and value-chain. Since it has a long and problematic implementation process, and is a very expensive investment, due to the high costs and risks in this systems it is important to select an ERP that adapt with organization requirements. This paper presents a method for selecting a suitable ERP system based on fuzzy logic. This model has 3 inputs and 1 output. We use triangular fuzzy membership function for each criterion. Three criteria: functionality, cost and vendor support to evaluate the alternatives was presented.

In future work, we want to propose a method based on Adaptive-Network-based Fuzzy Inference Systems (ANFIS) for ERP selection. ANFIS uses a hybrid learning algorithm to identify parameters of Sugeno-type fuzzy inference systems. It applies a combination of the least-squares method and the back propagation gradient descent method for training fuzzy inference system (FIS) membership function parameters to emulate a given training data set. ANFIS can also be invoked using an optional argument for model validation. The type of model validation that takes place with this option is a checking for model over fitting, and the argument is a data set called the checking data set. So, we want to develop a system based on ANFIS for ERP selection.

5. References

[1] Aladwani, Adel M. "Change management strategies for successful ERP implementation." *Business Process management journal* 7.3 (2001): 266-275.
[2] Wier, Benson, James Hunton, and Hassan R. HassabElnaby. "Enterprise resource planning systems and non-financial performance incentives: The joint impact on corporate performance." *International Journal of Accounting Information Systems* 8.3 (2007): 165-190.
[3] Kallunki, Juha-Pekka, Erkki K. Laitinen, and Hanna Silvola. "Impact of enterprise resource planning systems on management control systems and firm performance." *International Journal of Accounting Information Systems* 12.1 (2011): 20-39.
[4] Bernroider, Edward, and Stefan Koch. "ERP selection process in midsize and large organizations." *Business Process Management Journal* 7.3 (2001): 251-257.

[5] Yazgan, Harun Resit, Semra Boran, and Kerim Goztepe. "An ERP software selection process with using artificial neural network based on analytic network process approach." *Expert Systems with Applications* 36.5 (2009): 9214-9222.
[6] Falkenstein, M., et al. "Effects of crossmodal divided attention on late ERP components. II. Error processing in choice reaction tasks." *Electroencephalography and clinical neurophysiology* 78.6 (1991): 447-455.
[7] Deep, Aman, et al. "Investigating factors affecting ERP selection in made-to-order SME sector." *Journal of Manufacturing Technology Management* 19.4 (2008): 430-446.
[8] Moon, Young B. "Enterprise resource planning (ERP): a review of the literature." *International Journal of Management and Enterprise Development* 4.3 (2007): 235-264.
[9] Singla, Ashim Raj. "Enterprise resource planning systems implementation: a literature analysis." *International Journal of Business and Systems Research* 3.2 (2009): 170-185.
[10] Al-Mashari, Majed, Abdullah Al-Mudimigh, and Mohamed Zairi. "Enterprise resource planning: a taxonomy of critical factors." *European journal of operational research* 146.2 (2003): 352-364.
[11] Keil, Mark, and Amrit Tiwana. "Relative importance of evaluation criteria for enterprise systems: a conjoint study." *Information Systems Journal* 16.3 (2006): 237-262.
[12] Kumar, Vinod, B. Maheshwari, and U. Kumar. "Enterprise resource planning systems adoption process: a survey of Canadian organizations." *International Journal of Production Research* 40.3 (2002): 509-523.
[13] Kumar, Vinod, Bharat Maheshwari, and Uma Kumar. "An investigation of critical management issues in ERP implementation: emperical evidence from Canadian organizations." *Technovation* 23.10 (2003): 793-807.
[14] Wei, Chun-Chin, Chen-Fu Chien, and Mao-Jiun J. Wang. "An AHP-based approach to ERP system selection." *International journal of production economics* 96.1 (2005): 47-62.
[15] Ayağ, Z., and R. G. Özdemir. "An intelligent approach to ERP software selection through fuzzy ANP." *International Journal of Production Research* 45.10 (2007): 2169-2194.
[16] Bueno, Salvador, and Jose L. Salmeron. "Fuzzy modeling enterprise resource planning tool selection." *Computer Standards & Interfaces* 30.3 (2008): 137-147.
[17] Wang, Ying-Ming, and Kwai-Sang Chin. "A new approach for the selection of advanced manufacturing technologies: DEA with double frontiers." *International Journal of Production Research* 47.23 (2009): 6663-6679.
[18] Liao, Xiuwu, Yuan Li, and Bing Lu. "A model for selecting an ERP system based on linguistic information processing." *Information Systems* 32.7 (2007): 1005-1017.
[19] Cebeci, Ufuk. "Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard." *Expert Systems with Applications* 36.5 (2009): 8900-8909.
[20] Zadeh, Lotfi A. "Fuzzy sets." *Information and control* 8.3 (1965): 338-353.
[21] Zadeh, Lotfi A. "Toward a theory of fuzzy information granulation and its centrality in human reasoning and fuzzy logic." *Fuzzy sets and systems* 90.2 (1997): 111-127.
[22] Klir, George J., and Bo Yuan. *Fuzzy sets and fuzzy logic*. New Jersey: Prentice Hall, 1995.
[23] Kaufmann, Arnold, Madan M. Gupta, and A. Kaufmann. *Introduction to fuzzy arithmetic: theory and applications*. New York: Van Nostrand Reinhold Company, 1985.
[24] Kosko, Bart. *Fuzzy thinking: The new science of fuzzy logic*. New York: Hyperion, 1993.
[25] Lee, Chuen-Chien. "Fuzzy logic in control systems: fuzzy logic controller. I." *Systems, Man and Cybernetics, IEEE Transactions on* 20.2 (1990): 404-418.