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Research Article

Enterprise Resource Planning Selection Using Fuzzy Entropy-Based Fuzzy MOORA Method: Case Study in a Bearing Company

Bulanık Entropi Tabanlı Bulanık MOORA Yöntemi ile Kurumsal Kaynak Planlaması Seçimi: Bir Rulman Şirketinde Örnek Olay Çalışması

Beyzanur DURMUŞ	**Muhammet Enes AKPINAR**
İzmir Bakırçay Üniversitesi	Dr. Öğr. Üyesi, İzmir Bakırçay Üniversitesi
Endüstri Mühendisliği Bölümü	İşletme Bölümü
beyzanur.durmus@bakircay.edu.tr	enes.akpinar@bakircay.edu.tr
https://orcid.org/0000-0003-1637-3111	https://orcid.org/0000-0003-0328-6107

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Öz

Seçim problemleri işletmeler açısından sıklıkla karşılaşılan ve karar vermesi zor olan problem tiplerindendir. Zor problem olmasının sebebi birçok kriter ve alternatifin aynı anda dikkate alınması gerektiği içindir. Bu problemlerin çözümü için genellikle çok kriterli karar verme yaklaşımları kullanılmaktadır. Seçim problemleri hayatın her aşamasında karşılaştığı için çok fazla çeşitlilik gösterebilmektedir. Bu çalışmada bir işletmenin kurumsal kaynak planlaması (KKP) seçim süreci ele alınmıştır. Yeni bir yazılım satın almak isteyen işletmenin satın alma departmanı birçok kriter ve alternatif yazılım belirlemiştir. Bu kriterlerin en uygun düzeyde karşılandığı alternatif yazılımın seçilmesi planlanmıştır. Bu problemin çözümü için kriter ağırlıkların belirlenmesi aşamasında bulanık Entropi yöntemi kullanılmıştır. Yazılım alternatiflerinin değerlendirilmesi sürecinde bulanık Oran Analiziyle Çok Amaçlı Optimizasyon (MOORA) yöntemi kullanılmış ve yazılımlardan en uygun olanına karar verilmiştir. Çalışma sonucunda belirlenen üç yazılım sisteminden en uygun olanın üçüncü yazılım sistemi olduğu görülmüştür.

Anahtar Kelimeler: *Çok Kriterli Karar Verme, Kurumsal Kaynak Planlaması, Seçim, Bulanık Entropi Yöntemi, Bulanık MOORA Yöntemi.*

Abstract

Selection problems are one of the types of problems that are often encountered from the point of view of companies and are difficult to decide. The reason it is a difficult problem is that many criteria and alternatives must be considered at the same time. Multi-criteria decision-making approaches are often used to solve these problems. Selection problems can vary a lot because they are faced at every stage of life. In this study, the selection process of enterprise resource planning (ERP) is discussed. The purchasing department of a company that wants to buy new software has set many criteria and alternative software. It is planned to select alternative software where these criteria are met at the most appropriate level. For the solution to this problem, the fuzzy Entropy method was used at the stage of determining the criterion weights. In the process of evaluating software alternatives, the fuzzy Multi-Objective Optimization by Ratio Analysis (MOORA) method was used, and the most appropriate software was decided. As a result of the study, it was found that the third software system was the most suitable of the three software systems identified.

Keywords: *Multi-Criteria Decision Making, Enterprise Resource Planning, Selection, Fuzzy Entropy Methodology, Fuzzy MOORA Methodology.*

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1. Introduction

People are faced with many sorting, classification, and selection problems both in their private and professional lives. In these problems faced at any time, it is expected to decide among the alternatives. Decision makers should evaluate many criteria and alternatives together. The intensely competitive environment created by the effect of changing and developing technology has increased the difficulty of decision making. Multi-Criteria Decision Making (MCDM) methodologies are proposed to strengthen the decision-makers. MCDM; is concerned with the selection of the most suitable decision among the decision options based on quantitative and qualitative criteria (Cho, 2003, p. 1099). The problems that MCDM methods deal with generally include three main components: alternatives, criteria, and weights calculated for each criterion (Özcan and Ömürberk, 2020, pp.77-98). MCDM approaches provide the advantage of evaluating several criteria and alternatives at the same time (Chatterjee, Athawale, and Chakraborty, 2010, pp. 484). This advantage also provides convenience in the selection of ERP software for companies.

Companies must keep up with competitive elements such as fast customer response times, reduced product lifetimes, and globalization (Bayraktar and Efe, 2006). Technological developments enable companies to improve the competitive market conditions in their sector and develop innovative ideas. Companies use ERP software to develop strategies based on information and technology, to gain a competitive advantage over their competitors, and accordingly to increase quality and customer satisfaction. ERP is a fully acquired computer-aided companies management system that covers the entire functional area of an organization and enables these areas to gain the most competitive advantage by providing wide-scale integration (Jacobs and Whybark, 2000). ERP software is very important in terms of the benefits it provides to companies in matters such as reducing stock, raw material, and production costs, reducing lead time and production times, and increasing productivity and customer satisfaction (Perçin and Gök, 2013). Companies should determine their needs correctly and choose the ERP software that will provide the highest benefit among many alternatives in line with these needs. The study's goal is to offer a two-stage method for calculating the weights of criteria using the fuzzy Entropy method and ranking them using the MOORA method.

The rest of the study is organized as follows. Section 2 includes a literature review on enterprise resource planning. Sections 3 and 4 discuss the fuzzy entropy and fuzzy MOORA techniques, respectively. Section 5 explains how to apply these techniques to the problem. The final section contains the findings as well as potential study directions.

2. Literature Review

In this section, previous studies in the field of ERP selection are mentioned. In addition, the methods used in the study are given as a separate section of the literature.

2.1 ERP Selection Literature

Demydenko (2018) provides a method for using modeling to locate an ERP that fulfills the needs of businesses in uncertain situations. A methodological guiding system was established as part of the research. The study's method will automate the ERP selection process and allow businesses to choose ERP systems from their mobile devices. Ecer (2019), evaluated different ERP software alternatives with various ERP software selection criteria and selected the best ERP system with the ARAS method. His study showed that the ARAS method is a method that can be used to selection of the most favorable ERP software.

Jha, Saini and Jha (2018), provide a comprehensive, comparative analysis in their work. Shukla et al. (2016) suggested an approach for selecting an ERP system based on the Stepwise Weighting Ratio Analysis (SWARA) technique for evaluating the weight of criteria, along with the Preferred Ranking Organization Method (PROMETHEE) to enrich assessments for alternative ranking. Elsoud, Gawich and Hegazy (2020), will propose a model to help the ERP vendor decide to implement the ERP system and suggest appropriate ERP modules based on the factors specified. Vatansever and Uluköy (2013) used a combination of fuzzy AHP and fuzzy MOORA approaches to find the best ERP software for the manufacturing industry.

Yıldız and Yıldız (2014) give a thorough framework for using the fuzzy TOPSIS technique to identify an acceptable ERP system in their investigations. Kim et al. (2019) present in their study the factors that influence how small companies consider ERP system options when replacing a legacy system. Haddara (2018) noted the selection of an ERP in the overseas branch of an international company. The process used a simple multi-attribute grading technique (SMART) for evaluation. In his study, Haddara shows how cross-border data protection laws between core companies and branches affect the selection process. Beskese, Corum and Anolay (2019) proposed a model using AHP and TOPSIS methods for ERP selection for use in the automotive industry. They prioritized the determined criteria using the AHP approach, and they ordered ERP systems using the TOPSIS method.

Kilic, Zaim, and Delen (2014) applied a three-step method in their research. A mixed model was used in the study, using the strengths of different methods to overcome the complexity of multi-dimensional decisions. The fuzzy AHP method was used to determine the priorities of these criteria in order to select an ERP system for an airline company, and then the TOPSIS method was used to select alternative systems. Noureddine and Oualid (2018) used the conceptual findings of the ERP selection issue, as well as favorable expert recommendations, to determine the serious decisions that must be made prior to implementation. They then presented a methodology based on serious decision analysis for determining ERP selection criteria.

Based on quality function distribution (QFD), fuzzy linear regression, and zero-one goal programming, Karsak and zogul (2009) proposed a novel perspective for ERP software selection. Rouyendegh and Erkan (2011), Suggested five basic criteria for ERP system selection: Reliability, User Friendliness, Functionality, Installation, and Total Cost. Meng, Wang, and Xu (2020) used Fuzzy Neutrosophic Preference Relationships to express what decision-makers (DM) know about ERP Software selection. They have defined a multiplicative consistency concept for TFNPRs to logically rank the evaluated ERP systems. Chen, Wang, and Wang (2019) developed a novel two-step comparative method based on probabilistic linguistic word sets for evaluating cloud-based ERP systems (PLTS). To accomplish the class of cloud-based ERP suppliers, they offered multifunctional optimizations enhanced by the ratio analysis method in PLTS. They used the probabilistic linguistic Choquet integral operator to collect the ERP package assessment matrices, considering the interrelationships between the criteria.

Bal's (2020) goal was to raise awareness about the relevance of ERP, as well as to identify effective system selection criteria and explore the relationship between these factors and business characteristics. The AHP approach was used to determine the importance of selection criteria in order of importance. To determine the relationship between the criteria, a Relationship Rules Analysis was used. Using the AHP technique, Malindzakova and Puskas (2018) investigated the factors for selecting ERP software for a manufacturing organization.

Zeng, Wang, and Xu (2017) revealed the criteria for evaluating the most appropriate ERP system in China using group discussion and anonymous survey methods. A practical algorithm that combines effective and modified Delphi, Fuzzy Comprehensive Evaluation (FCE), Gray Relational Analysis (GRA), and AHP are among the methods they use to select the most ideal option in the event of uncertainty. To evaluate an adequate ERP model, Elyacoubi, Attariuas, and Aknin (2017) developed a three-stage BP neural network. Using the instances to train and examine the BP neural network, they concluded that using BP neural networks to predict the proper ERP is an effective strategy.

Efe (2016) used fuzzy AHP to determine the weights for the criteria in the software selection issue and Fuzzy TOPSIS to identify the best option in an uncertain environment. As a result, the group was able to reduce ambiguity and information loss during decision-making phase. Gürbüz, Alptekin, and Alptekin (2012), worked on a mixed MCDM method implementation related to ERP system types. They combined three methods in their work: Analytical Network Process (ANP), Choquet integral (CI), and Categorically Based Assessment Technique (MACBETH). As a result, they suggested that ignoring interactions can lead to erroneous decisions. In their ideas for a multi-criteria decision-making strategy, Hinduja and Pandey (2019) used three common MCDM techniques, DEMATEL, IF-ANP, and IF-AHP, at different stages of the process to get superior results. They carried out a case study in India on the selection of a cloud-based ERP system for SMEs, demonstrating that the proposed four-step approach efficiently handled the ERP selection challenge.

2.2. Entropy and MOORA Literature

Liu, Gao, and Fujita (2021) presented a weighting method based on the correlation coefficient for sustainable supplier selection criteria. For the ranking of the criteria, the Borda rule was developed by taking the MOORA method into account. Wu et al. (2018), presented an MDCM method with probabilistic linguistic MOORA. Zhang et al. (2019) revised the MOORA method for IFS and assumed several scenarios for endurance testing. Wang, Tian, and Wu (2021) adopted PLTS as a trust scaling method. They have considered the uncertainty and hesitation of unprofessional users when defining benchmark weights and they did the final ranking using MOORA.

Wang, Li, and Li (2021) proposed different criteria specific to the supplier selection project for the battery exchange station and solved it with the MOORA method. Fedajev et al. (2020) also used the MOORA method for ranking and classification, as well as the Shannon Entropy Index. JunPing et al. (2020) proposed for the first time a smart distribution room's health status assessment method based on AHP - Entropy weight method. Liang et al. (2019) made a proposal to the problem of radar software system security assessment based on the Entropy weight method and cloud model theory. Gong et al. (2020) determined performance indicators with the correlation method for the evaluation of football team cooperation. They used the Entropy method to weight performance indicators. Ozguner and Ozguner (2021) used the Entropy method to evaluate renewable energy alternatives. An et al. (2020) proposed a new prediction model for unstable growth load based on the Entropy weight method combined with GM and the gray Verhulst model. Karaatlı (2016), Turkey's tourism performance in the study of Entropy method for examining the criteria weights, considering economic data, has many years of use in the GRA for their performance evaluation.

As can be seen in the detailed literature review mentioned above, Entropy and MOORA methods have not been applied to ERP selection problems before. Therefore, it has been observed that there is a gap in the literature. In addition, the fact that this study is a real-life application reveals another originality of the study.

3. Fuzzy Entropy Method

The idea of entropy was developed by Shannon (1948) as the measurement of uncertainty in information. Criterion weights are calculated using the fuzzy entropy approach. The fuzzy entropy method's primary premise is that information is derived from differences between data sets. As a result, the objective weights of the criteria are decided by how distinct or distinct the alternatives' outputs are in relation to each criterion, i.e., the "intensity of their contrasts." The higher the contrast, the more information the relevant criterion covers and transmits (Çınar, 2004, p. 103-104).

3.1. Stages of Fuzzy Entropy Method

The solution of Shannon's fuzzy Entropy based on α-level clusters is explained as follows (Cavallaro, Zavadskas, and Raslanas, 2016).

Step 1. The decision matrix $\tilde{x}_{ij}$ containing fuzzy data shown in Equation 1 is converted to interval data according to cut sets.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}$$

The fuzzy variables can be expressed in the following interval form in the α section. While the fuzzy data is (a, b, c), the interval numbers are calculated according to Equation 2 (Lotfi and Fallahnejad, 2010).

$$(\tilde{x}_{ij})^L_\alpha = a + \alpha * (b - a), (\tilde{x}_{ij})^R_\alpha = c + \alpha * (b - c) \quad (1)$$

$$\left[\tilde{(x_{ij})}_{\alpha}^{L}, \tilde{(x_{ij})}_{\alpha}^{R}\right] = \left[\min_{x_{ij}}\{x_{ij} \in R\mu_{\tilde{x}_{ij}}(x_{ij}) \geq \alpha, \max_{x_{ij}}\{x_{ij} \in R\mu_{\tilde{x}_{ij}}(x_{ij}) \geq \alpha\right] 0 \leq \alpha \leq 1$$

The fuzzy data is transformed into different α-level clusters by setting different confidence levels,

$$B = \begin{bmatrix} [x_{11}^{L}, x_{11}^{R}] & [x_{11}^{L}, x_{11}^{R}] & \dots\dots & [x_{1n}^{L}, x_{1n}^{R}] \\ [x_{21}^{L}, x_{21}^{R}] & [x_{22}^{L}, x_{22}^{R}] & \dots\dots & [x_{2n}^{L}, x_{2n}^{R}] \\ \vdots & \vdots & \ddots & \vdots \\ [x_{m1}^{L}, x_{m1}^{R}] & [x_{m2}^{L}, x_{m2}^{R}] & \dots & [x_{mn}^{L}, x_{mn}^{R}] \end{bmatrix} \quad (2)$$

Step 2. The normalized values p_{ij}^{L} and p_{ij}^{R} are calculated as follows:

$$p_{ij}^{L} = \frac{x_{ij}^{L}}{\sum_{j=1}^{m} x_{ij}^{R}} j = 1,2,\dots\dots\dots m i = 1,2,\dots\dots\dots,n \quad (3)$$

$$p_{ij}^{R} = \frac{x_{ij}^{R}}{\sum_{j=1}^{m} x_{ij}^{R}} j = 1,2,\dots\dots\dots m i = 1,2,\dots\dots\dots,n \quad (4)$$

Step 3. The lower bound e_{i}^{L} and the upper limit e_{i}^{R} of intermittent entropy are calculated as follows:

$$e_{i}^{L} = min\{-e_{0}\sum_{j=1}^{m} p_{ij}^{L} \ln p_{ij}^{L}, -e_{0}\sum_{j=1}^{m} p_{ij}^{R} \ln p_{ij}^{R}\} i = 1,2,\dots\dots\dots,n \quad (5)$$

$$e_{i}^{R} = min\{-e_{0}\sum_{j=1}^{m} p_{ij}^{L} \ln p_{ij}^{L}, -e_{0}\sum_{j=1}^{m} p_{ij}^{R} \ln p_{ij}^{R}\} i = 1,2,\dots\dots\dots,n \quad (6)$$

In this equation, the product of $e_{0} = (\ln m)^{-1}$, $p_{ij}^{L} \ln p_{ij}^{L}$ and $p_{ij}^{R} \ln p_{ij}^{R}$ is 0. (If $p_{ij}^{L} = 0$ and $p_{ij}^{R} = 0$).

Step 4. The lower limit range change d_{i}^{L} and the upper limit range change d_{i}^{R} are calculated as follows:

$$d_{i}^{L} = 1 - e_{i}^{R} i = 1,2,\dots\dots\dots,n \quad (7)$$

$$d_{i}^{R} = 1 - e_{i}^{L} i = 1,2,\dots\dots\dots,n \quad (8)$$

Step 5. The lower and upper values of the criterion weights are calculated as follows:

$$w_{i}^{L} = \frac{d_{i}^{L}}{\sum_{j=1}^{n} d_{i}^{R}} i = 1,2,\dots\dots,n \quad (9)$$

$$w_{i}^{R} = \frac{d_{i}^{R}}{\sum_{j=1}^{n} d_{i}^{L}} i = 1,2,\dots\dots,n \quad (10)$$

Step 6. The arithmetic average of the lower and upper values are calculated using Equation 11.

$$w_{i} = (w_{i}^{L} + w_{i}^{R})/2 \quad (11)$$

4. Fuzzy MOORA Method

MOORA method was introduced by Willem Karel Brauers and Edmundas Kazimieras Zavadskas in 2008 with their work named "Control and Cybernetics". The feature that distinguishes this method from other methods is that it takes all criteria into the evaluation framework, considers all interactions between alternatives and criteria at the same time, and uses objective and non-directional values instead of subjective weighted normalization (Brauers and Zavadskas, 2008).

4.1. Fuzzy MOORA Method Stages

The operation steps of the fuzzy MOORA method used in evaluating the alternatives in this study are as follows:

Step 7. Constructing the fuzzy decision matrix using triangular fuzzy numbers.

$$\tilde{x}_{ij} = [x_{ij}^{l}, x_{ij}^{m}, x_{ij}^{u}]$$

where

$i = 1,2,\dots\dots\dots,m$; alternatives $j = 1,2,\dots\dots\dots,n$; criteria and $k = 1,2,\dots\dots\dots,l$ denotes the number of decision makers.

$$\tilde{X} = \tilde{x_{ij}} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \quad (12)$$

$x_{ij}^l, x_{ij}^m, x_{ij}^u$ values in the fuzzy decision matrix; j. in terms of criteria i. represent the small, medium and large values, respectively, in the triangular fuzzy number for the alternative.

Step 8. Normalizing a Fuzzy Decision Matrix (r_{ij})

$$r_{ij}^l = \frac{x_{ij}^l}{\sqrt{\sum_{i=1}^{n}\left[(x_{ij}^l)^2+(x_{ij}^m)^2+(x_{ij}^u)^2\right]}} \quad (13)$$

$$r_{ij}^m = \frac{x_{ij}^m}{\sqrt{\sum_{i=1}^{n}\left[(x_{ij}^l)^2+(x_{ij}^m)^2+(x_{ij}^u)^2\right]}} \quad (14)$$

$$r_{ij}^u = \frac{x_{ij}^u}{\sqrt{\sum_{i=1}^{n}\left[(x_{ij}^l)^2+(x_{ij}^m)^2+(x_{ij}^u)^2\right]}} \quad (15)$$

Step 9. Considering the different importance of each criterion, the weighted normalized fuzzy decision matrix is constructed using Equation 16, 17 and 18.

$$v_{ij}^l = W_j r_{ij}^l \quad (16)$$

$$v_{ij}^m = W_j r_{ij}^m \quad (17)$$

$$v_{ij}^u = W_j r_{ij}^u \quad (18)$$

Step 10. Finding normalized performance values (S) in terms of benefit (max) and cost (min) criteria.

For the benefit criterion;

$$s_i^{+l} = \sum_{j=1}^{n} v_{ij}^l \mid j \in j^{max} \quad (19)$$

$$s_i^{+m} = \sum_{j=1}^{n} v_{ij}^m \mid j \in j^{max} \quad (20)$$

$$s_i^{+u} = \sum_{j=1}^{n} v_{ij}^u \mid j \in j^{max} \quad (21)$$

For the cost criterion;

$$s_i^{-l} = \sum_{j=1}^{n} v_{ij}^l \mid j \in j^{min} \quad (22)$$

$$s_i^{-m} = \sum_{j=1}^{n} v_{ij}^m \mid j \in j^{min} \quad (23)$$

$$s_i^{-u} = \sum_{j=1}^{n} v_{ij}^u \mid j \in j^{min} \quad (24)$$

Step 11. Performance scores are calculated for all alternatives. For the performance scores, the benefit and cost criteria values for the alternatives are clarified with the help of the vertex method.

$$S_i(s_i^+, s_i^-) = \sqrt{\frac{1}{3}\left[(s_i^{+l} - s_i^{-l})^2 + (s_i^{+m} - s_i^{-m})^2 + (s_i^{+u} - s_i^{-u})^2\right]} \quad (25)$$

Step 12. Alternatives are ranked according to their performance scores. The alternative with the highest performance score is preferred (Karande and Chakraborty, 2012)

5. Application of fuzzy Entropy and fuzzy MOORA Methods

The study consists of six parts in total. In the first part, information was given about the purpose and scope of the study. In the second part, literature review has been made on the case studies on ERP selection, fuzzy Entropy method and MOORA method. In the third part of the study, the calculation steps and explanations of the fuzzy Entropy method are included. In the fourth chapter, the steps of the MOORA method are explained. The criteria selected based on the literature review and studies in the literature for the criteria selection of the study are presented in Table 1. Problem definition is provided in section 5.1. Fuzzy Entropy method has been applied and explanations are given in section 5.2. Section 5.3 contains the application steps and detailed explanations of the MOORA method. Finally, in the sixth section, the result of the study and the conclusion section where the obtained data are interpreted are included.

5.1. Problem Definition

In this part of the study, the ERP selection problem of a bearing company located in Izmir Kemalpaşa is discussed. It is difficult for companies to meet the requirements of the developing world. In order not to fall under this requirement, ERP software is important for companies. ERP selection is a very stressful and difficult process. Different departments should be involved in the selection process along with the management staff. Companies should choose software that meets their company's needs and fits their strategic plans. The criteria used in the study were determined by considering three purchasing experts' opinion and literature (Rouyendegh and Erkan, 2011; Zeng, Wang and Xu, 2017; Beskese, Corum and Anolay, 2019). These criteria and their short forms are presented in Table 1. The hierarchical presentation of the problem is presented in Figure 1. The fuzzy linguistic evaluation values are provided in Table 2. Detailed explanations of these 6 criteria are given below.

Table 1: Codes and units of the criteria

Code	Criterion	Units of
Price	C_1	Turkish Lira (TL)
Reliability	C_2	Value
Compatibility	C_3	Value
Service and Support	C_4	Value
Ease of Customization	C_5	Value
Usability	C_6	Value

Price: Price; includes software purchase, installation, training services, hardware, service and upgrade costs. Many costs will occur in the process of integrating the ERP software to the companies. Minimizing these costs is very important for companies.

Reliability: Reliability is one of the important factors in ERP software selection. Reliability refers to a system's capability to maintain its service and functionality under specified conditions for a stated period of time (Beskese, Corum and Anolay, 2019)**.**

Compatibility: This criterion is of critical importance in the selection of ERP software for companies to make the right choice according to the needs of the sector they operate in, investment success and user satisfaction. The fact that ERP software can be integrated into all departments of an enterprise positively affects future improvements.

Service and Support: Consultancy is a critical issue as it has an important role in preparation, implementation, privatization and after implementation (Cebeci, 2009; Tsai et al., 2012; Wei and Wang, 2004). The vendor should deal with potential problems encountered during the life cycle of ERP software in companies. Thus, the service life of the software will be longer. Providing the specific training required for ERP software is part of the service offered by the vendor.

Ease of Customization: This criterion can be evaluated individually for each companies. The time required for customization, the necessary development tools, budget, durability, and proven reliability of close customizations should be evaluated together with the criteria for ease of customization.

Usability: This criterion represents the ability of the employees who will use the program to run the program without difficulty. The user interface of the selected ERP software should be quite plain, understandable, and simple. Shortcuts, the fluency, and speed of the transactions will determine the productivity of the employees.

Table 2. Linguistic variable

Linguistic Expression	Code	Triangular Fuzzy Number
Extremely Hight	EH	(0.8, 1,1)
Very Hight	VH	(0.7, 0.8, 0.9)
Hight	H	(0.5, 0.7, 0.8)
Medium	M	(0.4, 0.5, 0.6)
Low	L	(0.2, 0.4, 0.5)
Very Low	VL	(0.1, 0.2, 0.3)
Extremely Low	EL	(0, 0, 0.2)

Source: Ecer, 2007

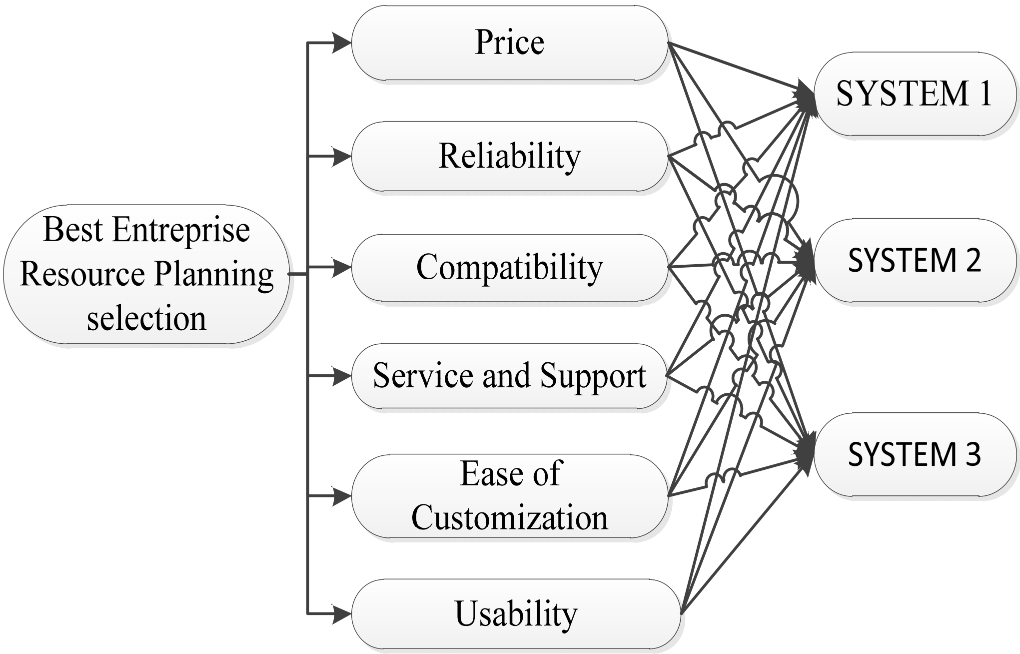

Figure 1. The hierarchical structure of the problem

5.2. Calculation of Criteria Weights by using Fuzzy Entropy Method

The calculation of the criterion weights with the fuzzy Entropy method is performed with the following steps.

Step 1. The decision matrix is created by the purchasing experts considering Table 2 and this matrix is presented in Table 3. Linguistic evaluations are also provided in Table 3.

Table 3. Evaluation of alternatives by decision-makers

Criteria	Alternatives	DM1	DM2	DM3
Price (C_1)	System 1	H	VH	M
	System 2	VH	H	H
	System 3	EH	VH	VH
Reliability (C_2)	System 1	VL	L	VL
	System 2	H	VL	M

	System 3	EH	H	EH
Compatibility (C_3)	System 1	M	M	M
	System 2	H	M	VH
	System 3	H	VL	M
Service and Support (C_4)	System 1	H	H	VH
	System 2	M	VH	L
	System 3	L	M	VL
Ease of Customization (C_5)	System 1	EH	EH	H
	System 2	VH	H	VH
	System 3	VH	EH	H
Usability (C_6)	System 1	VH	EH	VH
	System 2	EH	VH	EH
	System 3	EH	VH	EH

Triangular values are provided in Table 4. Fuzzy decision matrix is provided in Table 5 and range values are provided in Table 6.

Table 4. Triangular fuzzy numbers of alternatives

Criteria	Alternatives	D1	D2	D3
Price (C_1)	System 1	(0.5, 0.7, 0.8)	(0.7, 0.8, 0.9)	(0.4, 0.5, 0.6)
	System 2	(0.7, 0.8, 0.9)	(0.5, 0.7, 0.8)	(0.5, 0.7, 0.8)
	System 3	(0.8, 1, 1)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)
Reliability (C_2)	System 1	(0.1, 0.2, 0.3)	(0.2, 0.4, 0.5)	(0.1, 0.2, 0.3)
	System 2	(0.5, 0.7, 0.8)	(0.1, 0.2, 0.3)	(0.4, 0.5, 0.6)
	System 3	(0.8, 1, 1)	(0.5, 0.7, 0.8)	(0.8, 1, 1)
Compatibility (C_3)	System 1	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)
	System 2	(0.5, 0.7, 0.8)	(0.4, 0.5, 0.6)	(0.7, 0.8, 0.9)
	System 3	(0.5, 0.7, 0.8)	(0.1, 0.2, 0.3)	(0.4, 0.5, 0.6)
Service and Support (C_4)	System 1	(0.5, 0.7, 0.8)	(0.5, 0.7, 0.8)	(0.7, 0.8, 0.9)
	System 2	(0.4, 0.5, 0.6)	(0.7, 0.8, 0.9)	(0.2, 0.4, 0.5)
	System 3	(0.2, 0.4, 0.5)	(0.4, 0.5, 0.6)	(0.1, 0.2, 0.3)
Ease of Customization (C_5)	System 1	(0.8, 1, 1)	(0.8, 1, 1)	(0.5, 0.7, 0.8)
	System 2	(0.7, 0.8, 0.9)	(0.5, 0.7, 0.8)	(0.7, 0.8, 0.9)
	System 3	(0.7, 0.8, 0.9)	(0.8, 1, 1)	(0.5, 0.7, 0.8)
Usability (C_6)	System 1	(0.7 0.8 0.9)	(0.8, 1, 1)	(0.7, 0.8, 0.9)
	System 2	(0.8, 1, 1)	(0.7, 0.8, 0.9)	(0.8, 1, 1)
	System 3	(0.8, 1, 1)	(0.7, 0.8, 0.9)	(0.8, 1, 1)

Table 5. Fuzzy decision matrix

Criteria	System 1	System 2	System 3
C_1	0.533, 0.667, 0.767	0.567, 0.733, 0.833	0.733, 0.867, 0.933
C_2	0.133, 0.267, 0.367	0.333, 0.467, 0.567	0.700, 0.900, 0.933
C_3	0.400, 0.500, 0.600	0.533, 0.667, 0.767	0.333, 0.467, 0.567
C_4	0.567, 0.733, 0.833	0.433, 0.567, 0.667	0.233, 0.367, 0.467
C_5	0.767, 0.900, 0.867	0.667, 0.800, 0.733	0.700, 0.867, 0.867
C_6	0.733, 0.867, 0.933	0.767, 0.933, 0.967	0.767, 0.933, 0.967

Table 6. Range values

Criteria	System 1	System 2	System 3	Total
C_1	0.600, 0.717	0.650, 0.783	0.800, 0.900	2.400
C_2	0.200, 0.317	0.400, 0.517	0.800, 0.917	1.750
C_3	0.450, 0.550	0.600, 0.717	0.400, 0.517	1.783
C_4	0.650, 0.783	0.500, 0.617	0.300, 0.417	1.817
C_5	0.833, 0.883	0.733, 0.767	0.783, 0.867	2.517
C_6	0.800, 0.900	0.850, 0.950	0.850, 0.950	2.800

Step 2. To normalize fuzzy decision matrix is as shown in Table 7.

Table 7. Normalized range values

Criteria	System 1		System 2		System 3	
	P_{ij}^L	P_{ij}^R	P_{ij}^L	P_{ij}^R	P_{ij}^L	P_{ij}^R
C_1	0.250	0.299	0.271	0.326	0.333	0.375
C_2	0.114	0.181	0.229	0.295	0.457	0.524
C_3	0.252	0.308	0.336	0.402	0.224	0.290
C_4	0.358	0.431	0.275	0.339	0.165	0.229
C_5	0.331	0.351	0.291	0.305	0.311	0.344
C_6	0.286	0.321	0.304	0.339	0.304	0.339

Step 3. Calculation of lower and upper bound range Entropy values are provided in Table 8

Table 8. The fuzzy Entropy of the lower and upper bound range

Criteria	e_i^L	e_i^R
C_1	0.971	0.996
C_2	0.858	0.918
C_3	0.955	0.990
C_4	0.929	0.971
C_5	0.991	0.998
C_6	0.985	1.000

Step 4. Lower and upper limit range change values are provided in Table 9.

Table 9. Lower and upper limit range change values

Criteria	d_i^L	d_i^R
C_1	0.029	0.004
C_2	0.142	0.082
C_3	0.045	0.010
C_4	0.071	0.029
C_5	0.009	0.002
C_6	0.015	0.000

Step 5. Lower and upper values of criterion weights are provided in Table 10.

Table 10. Lower and upper values of criterion weights

Criteria	W_i^L	W_i^R
C_1	0.231	0.032
C_2	1.119	0.650
C_3	0.355	0.076
C_4	0.564	0.226
C_5	0.072	0.014
C_6	0.121	0.002

Step 6. Average criteria weight are calculated in this step and the final values are provided in Table 11.

Table 11. Values of average criterion weights

Criteria	Weight
C_1	0.131
C_2	0.884
C_3	0.216
C_4	0.395
C_5	0.043
C_6	0.062

5.3. Application of fuzzy MOORA Method

The fuzzy MOORA method application steps are provided in this section. The weights related to the criteria are calculated using the fuzzy Entropy method. The calculation steps for the solution of the fuzzy MOORA method are given below.

Step 7 and Step 8. Fuzzy decision matrix (Table 5) is normalized, and the values are provided in Table 12.

Table 12. Normalized decision matrix

Criteria	System 1	System 2	System 3
C_1	0.080, 0.101, 0.116	0.085, 0.111, 0.126	0.111, 0.131, 0.141
C_2	0.029, 0.057, 0.079	0.071, 0.100, 0.121	0.150, 0.193, 0.200
C_3	0.083, 0.103, 0.124	0.110, 0.138, 0.159	0.069, 0.097, 0.117
C_4	0.116, 0.151, 0.171	0.089, 0.116, 0.137	0.048, 0.075, 0.096
C_5	0.107, 0.126, 0.121	0.093, 0.112, 0.102	0.098, 0.121, 0.121
C_6	0.093, 0.110, 0.119	0.097, 0.119, 0.123	0.097, 0.119, 0.123

Step 9. The fuzzy Entropy criterion weights are used in order to calculate weighted fuzzy decision matrix and the obtained values are provided in Table 13.

Table 13.Creating a weighted fuzzy decision matrix

Criteria	Weight	Benefit / Cost	System 1	System 2	System 3
C_1	0.131	-1	0.011, 0.013, 0.015	0.011, 0.015, 0.016	0.015, 0.017, 0.018
C_2	0.884	1	0.025, 0.051, 0.069	0.063, 0.088, 0.107	0.133, 0.171, 0.177
C_3	0.216	1	0.018, 0.022, 0.027	0.024, 0.030, 0.034	0.015, 0.021, 0.025
C_4	0.395	1	0.046, 0.059, 0.068	0.035, 0.046, 0.054	0.019, 0.030, 0.038
C_5	0.043	1	0.005, 0.005, 0.005	0.004, 0.005, 0.004	0.004, 0.005, 0.005
C_6	0.062	1	0.006, 0.007, 0.007	0.006, 0.007, 0.008	0.006, 0.007, 0.008

Step 10, Step 11 and Step 12: All these steps are applied to Table 13 and the obtained values are provided in Table 14.

Table 14. Performance ranking of alternatives

Alternative	S^+			S^-			S	Ranking
	l	**m**	**u**	**l**	**m**	**u**		
System 1	0.099	0.145	0.176	0.011	0.013	0.015	0.131	**3**
System 2	0.132	0.176	0.208	0.011	0.015	0.016	0.161	**2**
System 3	0.177	0.234	0.253	0.015	0.017	0.018	0.207	**1**

As seen in Table 14, fuzzy MOORA results were calculated. As a result of the calculations, it was tried to decide the most suitable one among three different ERP systems. As can be seen in this table, it has been seen that System 3 is the alternative that meets all the criteria at the most appropriate level in terms of company. Secondly, System 2 can be preferred. Finally, System 1 was the alternative ERP that could be preferred.

6. Conclusion

ERP software consists of a whole system in which companies can execute all processes in a virtual environment. The fact that there are many suppliers related to the purchase process of this system reveals different alternatives. Since this software are worth millions of dollars, the initial selection stage is quite important. Accurate determination of their actual requirements at this decision stage and opinions on the extent to which the software to be selected meets these expectations in the industry are the most important elements of the decision process. The inability of most organizations in the industry to properly express their own requirements and the exaggerated expectations of software suppliers are the most important obstacles to the success of such projects, which are put forward in large numbers.

In this study, the problem of ERP software selection process faced by a company was discussed. This problem was solved by fuzzy Entropy and fuzzy MOORA methods. 6 criteria and 3 alternative software determined by purchasing experts by considering the literature review and company needs. Criterion weights were determined by the fuzzy Entropy method and the most appropriate of the software was selected by the fuzzy MOORA method. As a result of the study, the third most suitable software system was decided. The fact that the number of criteria and alternatives considered in the study is sufficient for this problem is important in terms of being a real-life application. However, these numbers may increase or decrease according to the companies. Therefore, not considering the similar problem with a complex number of alternatives and criteria can be said as a limitation of the study. This study considers a problem evaluated in a fuzzy environment. Different MCDM methods that can be used in the absence of uncertainty can be considered in terms of future studies to enlarge this study.

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Araştırma Makalesi

Enterprise Resource Planning Selection Using Fuzzy Entropy-Based Fuzzy MOORA Method: Case Study in a Bearing Company

Bulanık Entropi Tabanlı Bulanık MOORA Yöntemi ile Kurumsal Kaynak Planlaması Seçimi: Bir Rulman Şirketinde Örnek Olay Çalışması

Beyzanur DURMUŞ	Muhammet Enes AKPINAR
İzmir Bakırçay Üniversitesi	Dr. Öğr. Üyesi, İzmir Bakırçay Üniversitesi
Endüstri Mühendisliği Bölümü	İşletme Bölümü
beyzanur.durmus@bakircay.edu.tr	enes.akpinar@bakircay.edu.tr
https://orcid.org/0000-0003-1637-3111	https://orcid.org/0000-0003-0328-6107

Genişletilmiş Özet

İnsanlar hem özel hayatlarında hem de profesyonel hayatlarında birçok sıralama, sınıflandırma ve seçim problemleriyle karşı karşıya kalırlar. Her an karşı karşıya kalınan bu problemlerde alternatifler içerisinden karar verilmesi beklenir. Karar vericiler çok sayıda kriter ve alternatifi birlikte değerlendirmelidir. Değişen ve gelişen teknolojinin etkisi ile oluşan yoğun rekabet ortamı karar vermenin zorluğunu arttırmıştır. Karar vericiyi desteklemek için Çok Kriterli Karar Verme (ÇKKV) metotları geliştirilmiştir. ÇKKV metotları nitel ve nicel kriterleri dikkate alarak alternatifler arasından en uygununa karar vermeyle ilgilenir (Cho, 2003, s. 1099). ÇKKV metotları üç bileşen olarak alternatifler, kriterler ve kriterlerin her birine ait ağırlık değerlerini hesaplama aşamasını içerir. (Özcan ve Ömürberk, 2020).

İşletmeler; küreselleşme, müşteri yanıt süresi, kısalan ürün yaşam döngüleri gibi rekabet faktörlerine ayak uydurmalıdır. (Bayraktar ve Efe, 2006). Teknolojik gelişmeler, işletmelerin bulunduğu sektördeki rekabetçi piyasa koşullarını iyileştirmeye ve yenilikçi fikirlerle gelişmesine imkan sağlamaktadır. İşletmeler bilgi ve teknolojiye dayalı stratejiler geliştirebilmek, rakipleri karşısında rekabet avantajı yakalayabilmek buna bağlı olarak kalite ve müşteri memnuniyetini arttırabilmek amacıyla kurumsal kaynak planlama (ERP) yazılımları kullanmaktadırlar. ERP, bir kuruluşun tüm fonksiyonel alanlarını kapsayan, kapsamlı entegrasyonu ile en büyük rekabet avantajına sahip bilgisayar destekli bir iş yönetim sistemidir (Jacobs ve Whybark, 2000). ERP yazılımları; envanterlerin, hammaddelerin ve üretim maliyetlerinin azaltılması, teslimat ve üretim sürelerinin kısaltılması, verimlilik ve müşteri hoşnutluğunun arttırılması gibi firmalara sağladığı faydalar açısından önemlidir (Perçin ve Gök, 2013). İşletmeler ihtiyaçlarını doğru belirleyip bu ihtiyaçlar doğrultusunda çok sayıda alternatifin arasında en yüksek faydayı sağlayacak ERP yazılımını seçmesi gerekmektedir.

Çalışmanın amacı işletmelerin ERP yazılımı seçim problemlerinin çözümünde kriterlerin bulanık Entropi yöntemiyle ağırlıklarının hesaplanması ve bulanık MOORA yöntemiyle sıralanmasına ilişkin iki aşamalı bir yaklaşım sunmaktır.

Entropi fikri, bilgideki belirsizliğin ölçümü olarak Shannon (1948) tarafından geliştirilmiştir. Kriter ağırlıkları, bulanık Entropi yaklaşımı kullanılarak hesaplanır. Bu yöntemin temel dayanağı, bilginin veri kümeleri arasındaki farklılıklardan türetilmesidir. Sonuç olarak, kriterlere ait nesnel ağırlıkların, alternatiflere ait çıktıların her bir kriteri dikkate alarak farklılığına, yani "karşıtlıklarının yoğunluğuna" karar verilir. Karşıtlık ne kadar yüksekse, ilgili kriter o kadar fazla bilgiyi kapsar ve iletir (Çınar, 2004, s. 103-104).

Bulanık MOORA yöntemi ise, 2006 yılında Brauers ve Zavadskas tarafından "Kontrol ve Sibernetik" adlı çalışmalarıyla ortaya atılmıştır. Bu yöntemin diğerlerine göre avantajlarına bakılırsa, tüm kriterler

ve alternatifler arasındaki etkileşim dikkate alınması ve objektif değerlendirmenin yapılabilmesidir. Bu yöntemin uygulanma aşamasında güncel verilerle çalışılması önemlidir (Karaca, 2011, s. 24).

ERP yöntemi literaütürüne bakıldığında; Demydenko (2018), belirsiz durumlarda işletmelerin ihtiyaçlarını karşılayan bir ERP'yi bulmak için modellemeyi kullanmak için bir yöntem sağlamıştır. Araştırma kapsamında metodolojik bir yönlendirme sistemi kurulmuştur. Çalışmanın yöntemi, ERP seçim sürecini otomatikleştirecek ve işletmelerin mobil cihazlarından ERP sistemlerini seçmelerine olanak tanıyacak. Ecer (2019), farklı ERP yazılım alternatiflerini çeşitli ERP yazılım seçim kriterleri ile değerlendirmiş ve ARAS yöntemi ile en iyi ERP sistemini seçmiştir. Araştırması, ARAS yönteminin en uygun ERP yazılımının seçiminde kullanılabilecek bir yöntem olduğunu göstermiştir.

Zeng, Wang ve Xu (2017), grup tartışması ve anonim anket yöntemlerini kullanarak Çin'deki KOBİ'lerin en uygun ERP sistemini değerlendirme kriterlerini ortaya koydu. Etkili ve değiştirilmiş Delphi, Bulanık Kapsamlı Değerlendirme, Gri İlişkisel Analiz ve AHP'yi bir araya getiren pratik bir algoritma, belirsizlik durumunda en ideal seçeneği seçmek için kullandıkları yöntemler arasındadır. Yeterli bir ERP modelini değerlendirmek için Elyacoubi, Attariuas ve Aknin (2017) üç aşamalı bir BP sinir ağı geliştirdi. BP sinir ağını eğitmek ve incelemek için örnekleri kullanarak, doğru ERP'yi tahmin etmek için BP sinir ağlarını kullanmanın etkili bir strateji olduğu sonucuna vardılar.

Liu, Gao ve Fujita (2021), sürdürülebilir tedarikçi seçim kriterleri için korelasyon katsayısına dayalı bir ağırlıklandırma yöntemi sunmuştur. Kriterlerin sıralanması için MOORA yöntemi dikkate alınarak Borda kuralı geliştirilmiştir. Wu et al. (2018), olasılıksal dilbilimsel MOORA ile bir ÇKKV yöntemi sundular. Zhang et al. (2019), IFS için MOORA yöntemini revize etmiş ve dayanıklılık testi için çeşitli senaryolar üstlenmiştir. Wang, Tian ve Wu (2021), kıyaslama ağırlıklarını tanımlarken profesyonel olmayan kullanıcıların belirsizliğini ve tereddütlerini hesaba katmışlardır. Ve son sıralamayı MOORA kullanarak yaptılar.

Wang, Li ve Li (2021), pil değişim istasyonu için tedarikçi seçim projesine özel farklı kriterler önermiş ve MOORA yöntemi ile çözmüştür. Fedajev et al. (2020), Shannon Entropi Endeksinin yanı sıra sıralama ve sınıflandırma için MOORA yöntemini de kullanmışlardır. JunPing et al. (2020), ilk kez AHP-Entropi ağırlık yöntemine dayalı bir akıllı dağıtım odasının sağlık durumu değerlendirme yöntemini önerdi. Liang et al. (2019), Entropi ağırlık yöntemi ve bulut modeli teorisine dayalı olarak radar yazılımı sistem güvenlik değerlendirmesi sorununa bir öneride bulunmuştur. Gong et al. (2020) futbol takımı işbirliğinin değerlendirilmesi için korelasyon yöntemi ile performans göstergeleri belirlemiştir. Performans göstergelerini ağırlıklandırmak için Entropi yöntemini kullandılar. Özgüner ve Özgüner (2021), yenilenebilir enerji alternatiflerini değerlendirmek için entropi yöntemini kullanmışlardır. Karaatlı (2016), Türkiye'nin turizm performansının Entropi yönteminin incelenmesinde kriter ağırlıklarının ekonomik verileri dikkate alarak, performans değerlendirmeleri için GRA'da uzun yıllardır kullanılmaktadır.

Çalışmada İzmir Kemalpaşa'da bir rulman firmasının ERP seçim problemi ele alınmıştır. Şirketlerin gelişen dünyanın gereksinimlerini karşılaması zordur. Bu zorunluluğun altında kalmamak adına ERP yazılımları firmalar için önemlidir. ERP seçimi oldukça stresli ve zor bir süreçtir. Zira bu sürecin doğru bir şekilde yönetilmemesinin telafisi çok ağır olabilmektedir. Seçim sürecine yönetim kadrosu ile birlikte farklı departmanlar dahil edilmelidir. Çalışmada kullanılan kriterler satın alma uzmanlarının görüşleri ve literatür dikkate alınarak belirlenmiştir (Rouyendegh ve Erkan 2011; Zeng, Wang ve Xu, 2017; Beskese, Çorum ve Anolay, 2019). Bu kriterlerin açıklamaları aşağıda verilmiştir.

Fiyat: Fiyat; yazılım satın alma, kurulum, eğitim hizmetleri, donanım, servis ve yükseltme maliyetlerini içerir. ERP yazılımlarının firmalara entegrasyonu sürecinde birçok maliyet oluşacaktır. Bu maliyetleri minimize etmek firmalar için oldukça önemlidir.

Güvenilirlik: Güvenilirlik, ERP yazılım seçiminde önemli faktörlerden biridir. Güvenilirlik, bir sistemin belirli koşullar altında belirli bir süre boyunca hizmet ve işlevselliğini sürdürebilme kabiliyetini ifade eder (Beskese, Çorum ve Anolay, 2019).

Uyumluluk: Firmaların faaliyet gösterdikleri sektörün ihtiyaçlarına, yatırım başarısına ve kullanıcı memnuniyetine göre doğru tercih yapabilmeleri için ERP yazılımı seçiminde bu kriter kritik öneme sahiptir. ERP yazılımlarının bir işletmenin tüm departmanlarına entegre edilebilmesi, gelecekteki iyileştirmeleri olumlu etkiler.

Hizmet ve Destek: Danışmanlık, hazırlık, uygulama, özelleştirme ve uygulama sonrasında önemli bir role sahip olması nedeniyle kritik bir konudur (Cebeci, 2009; Tsai vd., 2012; Wei ve Wang, 2004). Satıcı, şirketlerde ERP yazılımının yaşam döngüsü boyunca karşılaşılan olası sorunlarla ilgilenmelidir. Böylece yazılımın hizmet ömrü daha uzun olacaktır. ERP yazılımı için gereken özel eğitimin sağlanması, satıcı tarafından sunulan hizmetin bir parçasıdır.

Özelleştirme Kolaylığı: Bu kriter her firma için ayrı ayrı değerlendirilebilir. Özelleştirme için gereken süre, gerekli geliştirme araçları, bütçe, dayanıklılık ve yakın özelleştirmelerin kanıtlanmış güvenilirliği, özelleştirme kolaylığı kriterleri ile birlikte değerlendirilmelidir.

Kullanılabilirlik: Bu kriter, programı kullanacak çalışanların programı zorlanmadan çalıştırabilme becerisini temsil eder. Seçilen ERP yazılımının kullanıcı arayüzü oldukça sade, anlaşılır ve basit olmalıdır. Kısayollar, işlemlerin akıcılığı ve hızı çalışanların verimliliğini belirleyecektir.

ERP yazılımı, şirketlerin tüm süreçlerini sanal bir ortamda yürütebilecekleri bir sistem bütününden oluşur. Bu sistemin satın alma süreci ile ilgili çok sayıda tedarikçinin olması farklı alternatifleri ortaya çıkarmaktadır. Bu yazılımlar milyonlarca dolar değerinde olduğu için ilk seçim aşaması oldukça önemlidir. Bu karar verme aşamasında en önemli unsur, gerçek gereksinimlerin doğru belirlenmesi ve seçilecek yazılımın, bölümün bu beklentilerini ne kadar karşıladığına dair görüşlerdir. Çoğu organizasyonun ihtiyaçlarını doğru bir şekilde aktaramaması ve yazılım satıcılarının abartılı beklentileri birçok projenin başarısının önündeki en büyük engellerdir.

Bu çalışmada, bir firmanın karşılaştığı ERP yazılım seçim süreci problemi ele alınmıştır. Bu problem bulanık Entropi ve bulanık MOORA yöntemleri ile çözülmüştür. Literatür taraması ve firma ihtiyaçları dikkate alınarak satın alma uzmanları tarafından belirlenen 6 kriter ve 3 alternatif yazılım belirlenmiştir. Kriter ağırlıkları bulanık Entropi yöntemi ile belirlenmiş ve yazılımlardan en uygun olanı bulanık MOORA yöntemi ile seçilmiştir. Çalışma sonucunda alternatif yazılımlardan en uygun olanının üçüncü yazılım sistemi olduğu görülmüştür. Çalışmada dikkate alınınan kriter ve alternatif sayısının bu problem için yeterli olması bir gerçek hayat uygulaması olması bakımından önemlidir. Ancak, işletmelere göre bu sayılar artabilir veya azalabilmektedir. Dolayısıyla benzerli problemin karmaşık sayıda alternatif ve kriterle dikkate alınmaması çalışmanın kısıtı olarak söylenebilir. Bu çalışma bulanık ortamda değerlendirilen bir problemi dikkate almıştır. Belirsizliği olmadığı durumlarda kullanılabilen farklı çok kriterli karar verme yöntemleri bu çalışmayı zenginleştirmek adına gelecekte yapılabilecek çalışmalar açısından dikkate alınabilir.

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