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Evaluation of ERP softwares with fuzzy AHP integrated TODIM method

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ABSTRACT

Since enterprise resource planning process is important for growing and developed private companies due to productivity, in the business world it has found effectively its place. ERP softwares have gained much importance in recent years according to doing the jobs productivity needs. In this study, a solution method is proposed for a private organization that desires to re-evaluate the distributed ERP softwares of it owns. For this, most used multi-criteria decision-making method named analytic hierarchy process is utilized for determination of criteria weights. In addition a risk involving process called TODIM (an MCDM method), which is based on prospect theory, was chosen for risky and dynamic conditions in the study. Since the Nobel prize-winning prospect theory, including risk avoidance and taking situations in decision-making behaviors, has been integrated in TODIM's decision-making process. This process involves ambiguities as well as risk. Furthermore, the company's data privacy policy has been incorporated into the solution procedure with the fuzzy logic, which takes into account these drawbacks. Besides, it has been ensured that the cost criterion is integrated in a detailed manner. In the real world application, a selection is made between the renovation of the existing system alternative consisting of the scattered and different softwares –especially stressed on built-in software that only a majority uses-; this software's cloud alternative and a completely different rival software alternatives. The result of this study, which examines ERP software selection under uncertainties by adding risk and cost measures, has been influential on enterprise's preferences about this project.

Keywords: ERP systems, Fuzzy logic, Multi-criteria decision making, AHP, TODIM, Equal uniform annual cost

1. INTRODUCTION

Enterprise resource planning (ERP) systems, which are the main subjects of industrial engineering, are systems that enable to see all the sizes of work done. Within this system, the dimensions of management, employees and equipment facilitate the process components and help to integrate them in a unique system. It

provides the right jobs and increases productivity both in growing companies and in developed companies. ERP integrates a traditionally managed company (together with tools such as accounting, finance, human resources (HR), production management and customer relationship management (CRM)) in a harmonious manner. For example, the production management tool includes inventory, procurement, sales and quality management. The sharing of information between departments is questionable in most companies.

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This problem is either ignored or the dominant section often refuses to share information in particular. In ERP systems, it is ensured that the data entered in a corporate information system can be shared with other departments. The institution becomes more effective when information is shared throughout the organization [1]. In this case, the costs resulting from inefficiency and double transaction are avoided. Thus, not only in large companies in the world today, it has also become inevitable even for midsize organizations to implement the ERP system. The evaluation of ERP systems, or software in other words, is usually done by the management and information systems (MIS) department of the companies cause it is thought only cost-based. However, evaluation of ERP system software is a much more complicated process. Since the ERP system is concerned with the whole structure, it should be a process in which not only a department is included in the company, but also all top management is in common. ERP software selection has many dimensions such as cost, scalability, adaptability and so on. Generally, business strategy evaluation is done in the direction of the way that the institutions' doing business. However, when the ERP system is applied, employees may resist because doing business will change by the new software. Therefore, in the ERP software selection process, as many departments as possible should be included in the process. A slight change of mind in the way of doing business from the beginning will ensure that the whole business strategy is carried out in a healthier way and the desired success will be achieved.

As mentioned in the previous paragraph, many dimensions influence the evaluation process. Therefore, it is obvious that there is a need for a method that can evaluate with multi-criteria. In this study, analytic hierarchy process (AHP) solution method will be used for the related multi-criteria process cause rationale of the model is very clear. This method proved to be a good alternative to many complex problems, and has understandable steps in contrast to the complexity of the process involved. In addition to these benefits, the AHP can also take into account both monetary and nonmonetary criteria. However, in order to evaluate the investments that are risky, there is a need for a more multi-criteria decision making (MCDM) method. Repetitive Multi-Criteria Decision Making (RMCDM), mostly known as Portuguese acronym TODIM (Tomada de Decisão Iterativa Multicritério), offers a

valuation involving risky situations. This model, based on the prospect theory developed by Kahnemann and Tversky [2], was introduced in 1992 by Gomes and Lima [3].

Many situations in everyday life include ambiguity and vagueness at different dimensions. In order to be able to fully evaluate the system, all information must be accessed, but in most cases there is a lack of information. Most companies usually do not want their financial data to be taken out of the company and used in a study. Zadeh [4] introduced an absolute mathematical outline with the name of fuzzy set in order to eliminate such deficiencies. Therefore, in this study, all the data will be taken as fuzzy numbers and the methods will be solved with fuzzy logic in order to come up from the above-mentioned deficiencies.

Wei et al. [5] developed a comprehensive framework for selecting the most appropriate ERP system / software using the AHP method. Perera and Costa [6] have also applied another work for production companies by using AHP method. In Karaarslan and Gundogar's [7] study, they have made appropriate analyzes for the institution's culture. They then aimed to choose the most appropriate software from the last two candidates. In the plant, ERP software those who fit within the institution assessed only and they preferred the method of AHP.

Fuzzy AHP method was applied by Cebeci [8] in the textile industry. In the mentioned work, the solution to the problem of choosing the most appropriate ERP system has been sought. In his study, the author used a balanced scorecard system that turned strategic goals into performance drivers. With this method, he seeks to determine the key success factors. Kahraman et al. [9] provided the opportunity to explain the evaluations of decision makers linguistically in their work, and implemented it in an automotive company using the fuzzy AHP method. Further in cited study, the fuzzy AHP method has been used to choose among ERP outsourcing alternatives. Oztaysi [10] used the AHP method with interval Type-2 Fuzzy numbers in his work to select ERP systems.

A number of researchers have also studied the problem of selecting ERP systems with the analytical network process (ANP) method, which is a different MCDM method. Yazgan et al. [11] suggested a method combining an ANP and an artificial neural network (ANN) models and so they easily set up an ERP software selection procedure. It was found unnecessary to take the

geometric averages of the expert responses while calculating in the related procedure. Ayag and Ozdemir [12] proposed a fuzzy ANP method that takes into account both numerical and verbal components in ERP software selection. A general structure for proper module ordering in the ERP system and a case study in a more detailed level are presented by Hallikainen et al. [13]. The priorities in practice for ranking these modules have been determined in the mentioned work. Gürbüz et al. [14] applied a hybrid model to the ERP selection problem by combining different MCDMs with the ANP method. Another hybrid study was carried out by Kilic et al. [15] for ERP software selection in the airline company. Kilic et al. [16] also combined another MCDM method with the ANP method and applied it to the ERP selection problem of small and medium-sized enterprises.

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), a method similar to TODIM but risk-neutral, has found much room for itself in the literature. Rouyendegh et al. [17] conducted a reverse application integrating AHP and TOPSIS methods to select the successful implementors of ERP system. In another study [18], a comprehensive decision support system with fuzzy TOPSIS was conducted in a real case of ERP selection before the implementation phase.

TODIM is an MCDM method based on prospect theory; although recently became one of the popular methods it is applied in different areas. Being a risk-sensitive method is also a sign that deserves this interest. Tosun and Akyuz [19] used fuzzy TODIM method in supplier valuation and selection. Fuzzy TODIM has also been used in the green supply chain valuation [20]. The authors have set benchmarks in the context of uncertainty for the green supply chain in their work and have argued that this may be the case in general. Fan et al. [21] combined the TODIM method with a fuzzy simple additive weighting method and applied them to a case study. Lourenzutti and Krohling [22] have generalized fuzzy TODIM methods in their work so that they can deal with intuitive fuzzy information. They have also developed a method that takes into account the vectors that affect the performance of the alternatives. In another study, TODIM method based on interval Type-2 fuzzy numbers was applied for green supplier selection in the automotive sector [23]. Qin et al. [24] used TODIM method based on triangular intuitive

fuzzy numbers in the selection of renewable energy alternatives.

Furthermore, integrating different multi-criteria decision making methods has been applied to different problems. Integration of fuzzy AHP and fuzzy TOPSIS methods has been applied by Kahraman et al. [25] to the problem of introducing new product development. The integration of the fuzzy VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) method with fuzzy AHP has been applied to the selection of the afforestation area in the work of Kaya and Kahraman [26]. Baykasoğlu and Gölcük [27] integrated fuzzy TOPSIS with the Fuzzy DEMATEL (Decision Making Trial and Evaluation Laboratory) method and used it to solve the strategy selection problem.

In terms of selection of ERP system software, TODIM method emerges as a need in terms of risk based evaluation. In this study, by combining the fuzzy AHP method with the fuzzy TODIM method, we will choose among the alternatives of the appropriate ERP system software, based on the weight of the expert opinion.

While there is not much work on the cost-based evaluation of ERP systems, the following interesting studies have been found in the literature. A study was conducted to calculate the weekly cash outflows, cost of consulting to shorten the duration of the project and to monitor the performance of ERP implementation [28]. A cost optimization under budget constraints is done by Ahmadi et al. [29] in order to improve the preparations of ERP system implementation

The parts of this study are structured as follows: In the second part, the criteria and the hierarchy of ERP software revaluation process are explained. In Chapter 3, the main subject of this study, fuzzy AHP and fuzzy TODIM methods are given, and then the proposed method, which consists of integration of these methods, is presented. In the fourth chapter, study done in a construction-based holding company has been tested with the proposed method. The results and discussions of this practice and the study are also explained in chapter 5.

2. THE EVALUATION AND SELECTION CRITERIA FOR ERP SOFTWARES

At first a literature survey has been done to determine the set of criteria necessary for fuzzy

multi-criteria decision-making methods in the ERP evaluation process. The criteria obtained from this study were developed by the cooperation of the professionals (ERP system consultants, MIS director, HR director). Five main criteria: culture and structures, adaptation development, solution partner, productivity and fuzzy cost are determined with the conclusion of the meetings and analyzes made. In addition, sixteen sub-criteria and nine sub-sub-criteria have been proposed in relation to the main criteria.

With special effort, the criteria are kept at these levels because otherwise the efficiency of the method is reduced. All main, sub, and sub-sub-criteria agreed by the team are seen in Table 1. Figure 1 shows the hierarchy required by the AHP method.

3. REVALUATION OF ERP SOFTWARES WITH FUZZY EUAC INTEGRATED FUZZY AHP AND TODIM METHODS

Fuzzy AHP and Fuzzy TODIM methods mentioned in the previous sections will be given

theoretically in this section and the integrated method will be proposed by using the required steps individually. This integrated; in other word hybrid method is a combination of the steps of these two methods and will be explained in detail in sub-section 3.3. The fuzzy numbers to be used in this study are trapezoidal fuzzy numbers because they are both easy to use and more suitable in uncertainty conditions. Before going into the methods the description of the trapezoidal fuzzy number and the arithmetic operations between them are briefly given below:

Any fuzzy number \tilde{A} is called the trapezoidal fuzzy number if it is shown as $\tilde{A} = (a_1, a_2, a_3, a_4)$, ($a_1 \leq a_2 \leq a_3 \leq a_4$) and if the membership function $\mu_{\tilde{A}}(x) = (a_1, a_2, a_3, a_4)$, $\mu_{\tilde{A}}(x): R \rightarrow [0,1]$ is as follows:

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1} & x \in (a_1, a_2] \\ 1 & x \in [a_2, a_3] \\ \frac{a_4-x}{a_4-a_3} & x \in [a_3, a_4) \\ 0 & \text{others} \end{cases} \quad (1)$$

Table 1. Main and Sub-criteria in Revaluation of ERP Software

ERP Main Criteria	Sub-Criteria Ölçütler	Sub-sub-Criteria	Definition
Culture and Structures (CS)	Business strategy (CB)		Ability to change the manner of doing business, describe it, and design processes on the part of the employer
	Socio-economic factors (CS)		Sufficiency of physical and environmental conditions
	Human resources (CH)		Adequacy of human resources as an institution
	Top Management Support (CT)		The commitment and support of the top management of the institution
Adaptation and Development (AD)	Flexibility (AF)	Table Personalization (AFT)	Whether or not the table is personalized
		Module Personalization (AFM)	Whether or not the module is personalized
		Code Personalization (AFK)	Whether or not the code is personalized
	Process Adaptation (AP)		Adapting the system to the process
	Implementation Time (AI)		Solution partner suggested duration of implementation
	Fast and Efficient Reporting (AE)		Fast and efficient reporting capability
	Manufacturing Structure (AM)	Manufacturing (AMM)	Suitability of production processes
		Support (AMS)	Suitability of support processes
		Commercial (AMC)	Suitability of commercial processes
	Accountability (AA)	Inner (AAI)	Compliance of the system with internal audit
		Exterior (AAE)	Compliance of the system with external (Finance, SPK) inspections
		Independent (AAN)	Compliance of the system with the audits of the independent audit firms
	Solution partner (SP)	Conceptual Design (SC)	
Service and Support (SS)			Human, financial and physical resources to be provided by the solution partner after sales service
References and Prestige (SR)			The previous works and awareness of the solution partner in the sector
Productivity (PR)	Functionality (PF)		The system's functionality, easy manageability and user-friendliness of the interface
	Scalability (PS)		The system's expandability or shrinkability
	Integration (PI)		Compatibility with environmental systems (Office, Explorer, Mozilla, etc.)
Equal uniform annual cost (EUAC)	-		Annual Cost of ERP Software Projects

The representation is shown in Figure 2 in accordance with the relevant definition. Now consider any two trapezoidal fuzzy numbers; \tilde{A} and \tilde{B} ; the basic arithmetic operations between the two are shown in the following equations:

$$\tilde{A} \oplus \tilde{B} = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4) \quad (2)$$

$$\tilde{A} \otimes \tilde{B} \cong (a_1 \times b_1, a_2 \times b_2, a_3 \times b_3, a_4 \times b_4) \quad (3)$$

$$\tilde{A} \ominus \tilde{B} = (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1) \quad (4)$$

$$\tilde{A} \oslash \tilde{B} \cong \left(\frac{a_1}{b_4}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_4}{b_1} \right), \tilde{A} > 0, \tilde{B} > 0 \quad (5)$$

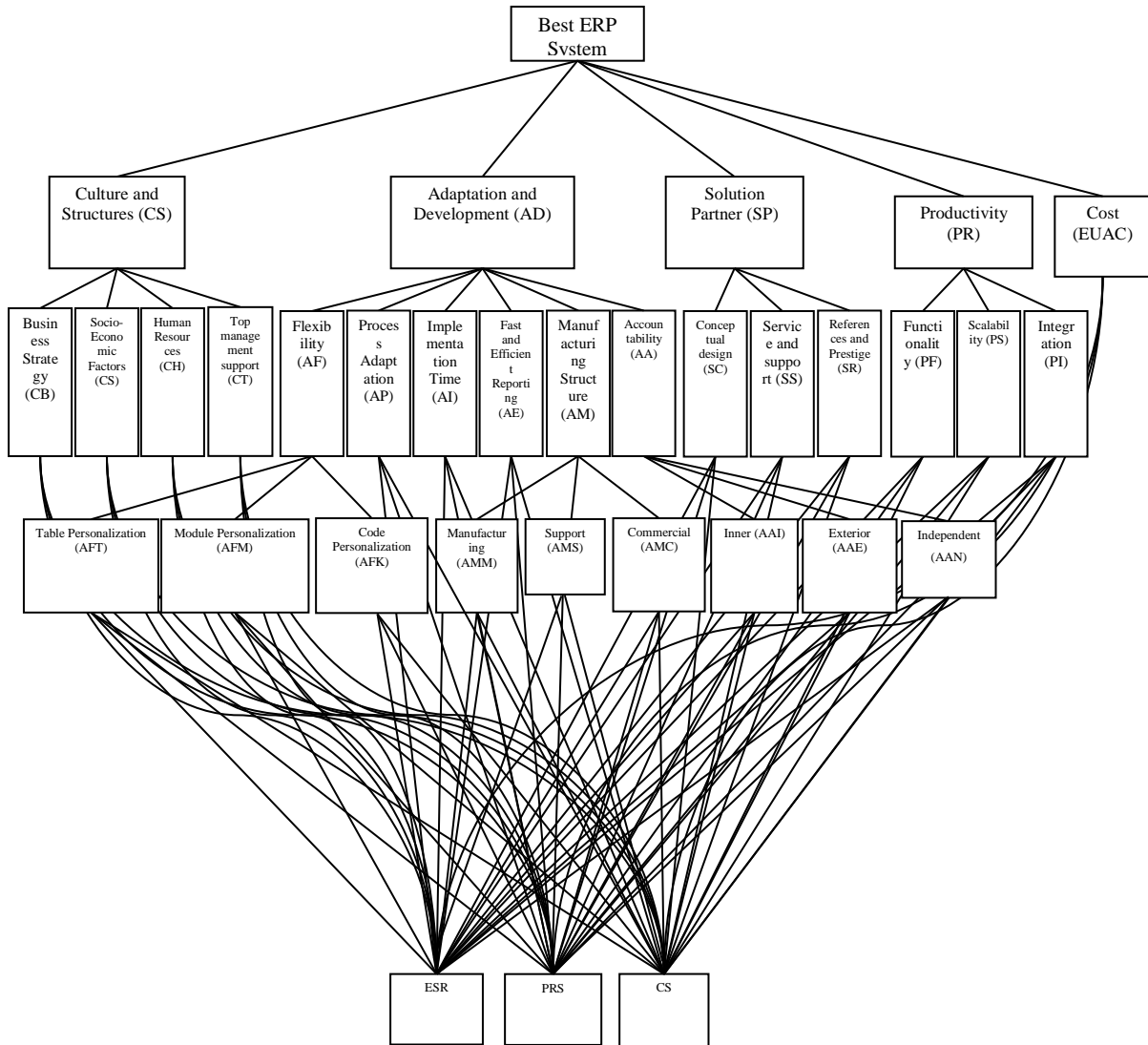


Figure 1. Hierarchy of Criteria

where, \oplus , \otimes , \ominus , and \oslash , represent fuzzy addition, fuzzy multiplication, fuzzy subtraction, and fuzzy division operations, respectively. The formula for defuzzification -called the centroid method- from Zeng et al. [30]’s study is applied as given below:

$$A = \frac{a_1 + 2a_2 + 2a_3 + a_4}{6} \quad (6)$$

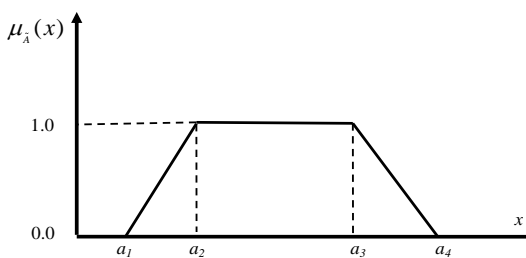


Figure 2. A Trapezoidal Fuzzy Number

The method to be used for comparison of the fuzzy numbers is proposed by Kahraman and Tolga [31].

It is advised to look at the relevant work for details because of space constraints in this study.

3.1. Fuzzy AHP Method

The AHP method developed by Saaty [32] has been used in a number of excess problems since its development. Buckley [33] has extended the classical AHP method with trapezoidal fuzzy numbers by using fuzzy comparison ratios. Buckley used this method because it is easier to expand into fuzzy numbers and, unlike the others, produces a unique solution in the reciprocal matrix. Hence, Buckley’s work was preferred because of the use of trapezoidal fuzzy numbers in this study. The steps are briefly shown below:

Step 1: After the the decision-maker’s judgement, compute the C comparison matrix whose components are $\tilde{t}_{ij} = (k_{ij}, l_{ij}, m_{ij}, n_{ij})$ (all trapezoidal fuzzy numbers for all i and j).

Step 2: Calculate the fuzzy weights (\tilde{w}_i) using the following equations. For each row, take the geometric mean as:

$$\tilde{z}_i = [\prod_{j=1}^n \tilde{t}_{ij}]^{1/n}, \forall i \quad (7)$$

where n refers to the number of criteria in the current hierarchical level. Then obtain the fuzzy weight (\tilde{w}_i) as follows:

$$\tilde{w}_i = \tilde{z}_i \oslash [\sum_{j=1}^n \tilde{z}_j] \quad (8)$$

Then repeat this step for all performance levels $\tilde{c}_{ij}, \forall i$ and j (main, sublevel, sub-sublevel).

Step 3: Combine the fuzzy performance grades with fuzzy weights: The fuzzy benefit $\tilde{U}_i, \forall i$ is calculated using the following formula:

$$\tilde{U}_i = \sum_{j=1}^n \tilde{w}_j \tilde{c}_{ij}, \forall i \quad (9)$$

A new model will be obtained by integrating the fuzzy TODIM method with the trapezoidal fuzzy AHP method's steps given above, and this model will be used to evaluate the ERP system software projects.

3.2. Fuzzy TODIM Method

The TODIM method, which can be translated as Repetitive (iterative) Multidimensional Decision Making in English, is a multi-criteria decision-making method based on prospect theory. The basic theory of the prospect theory, and the used multi-criteria method will be examined in the next subsections.

3.2.1. Prospect Theory

The prospect theory developed by Kahneman and Tversky [2] is presented as a significant model for decision makers in the presence of risky situations. Kahneman won the Nobel Prize for Economics in 2002 with this theory. According to this theory, people are reacting differently while taking risk depending on their gain or loss situation. In the event of having profits, people avoid risk; however, in case of loss, people are prone to take more risk. There is a value function in the prospect theory that expresses more tendency to risk avoidance and/or taking; it is shown as in the following equation:

$$\varphi(x) = \begin{cases} x^\alpha & \text{if } x \geq 0 \\ -\theta(-x)^\beta & \text{if } x < 0 \end{cases} \quad (10)$$

where α and β are parameters related to gains and losses, respectively. θ represents the perpendicular property for many losses from the effective gain.

It is obvious $\theta > 1$ if it is sought for risk. In the mentioned study, the use of the values $\alpha = \beta = 0,88$, and $\theta = 2.25$ was recommended by experimental methods. For different situations, they recommended that θ be between 2.0 and 2.5 [34]. This value function is S-shaped and is shown in Figure 3 below:

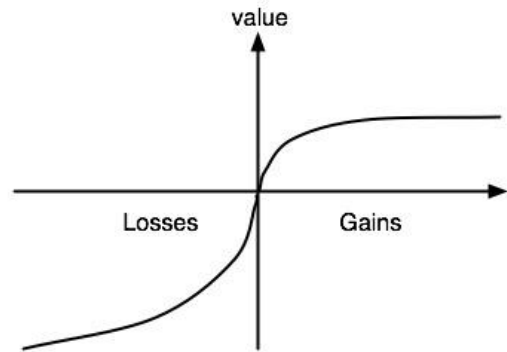


Figure 3. The value function of prospect theory

The gains are shown by a concave curve and the losses by a convex curve. The value function of the TODIM method, which is the subject of this study, is similar to the prospect theory value function and this value function is also same as shown in Figure 3.

3.2.2. Fuzzy TODIM Steps

We have already stated that Gomes and Lima [3] have established a multi-criteria decision-making method based on the prospect theory based on the crisp numbers. Fuzzy TODIM method is a method obtained by expanding the crisp numbers TODIM method with fuzzy numbers. In the method, mutual comparisons are made between the alternatives for each criterion and the losses and gains on each alternative are calculated on the other alternatives. The losses and gains of each alternative represent the degree of dominance of that alternative. In the last step, alternatives are sorted according to their normalized general values.

Suppose m be the number of alternatives and $i = 1, 2 \dots m$, n be the number of evaluation criteria and $j = 1, 2 \dots n$. Then let A_i specifies the i^{th} alternative, and C_j specifies the j^{th} criteria. Each criteria has a different weight grade and $\tilde{w} = (\tilde{w}_1, \tilde{w}_2 \dots \tilde{w}_n)^T$ is the weight vector, where \tilde{w}_j denotes the significance weight of the criteria C_j , such that $\sum_{j=1}^n w_j = 1$ and $0 \leq w_j \leq 1$. Alternatives have performance values for all criteria separately. \tilde{x}_{ij} is the i^{th} alternative's performance value according the j^{th} criteria. It

should be noted that; \tilde{w}_j and \tilde{x}_{ij} are trapezoidal fuzzy numbers, and w_j is a defuzzified crisp number.

The steps of the fuzzy TODIM method used in this study are the steps obtained by analyzing the various articles in the literature such as [35], [36], and [37] and they are presented as follows:

Step 1: Calculate criteria weights and performance values of alternatives.

In this study, fuzzy numbers were used in the fuzzy TODIM method to evaluate the performance of the alternatives according to the qualitative measure and to determine the criteria weights. There are numerical values of alternatives for quantitative criteria, and these values are provided as trapezoidal fuzzy numbers as well as institutional data confidentiality. Performance evaluation and weighting processes are carried out by decision makers. The equations are as follows:

$$\tilde{x}_{ij} = \frac{1}{k} [\sum_{e=1}^k \tilde{x}_{ij}^p] \quad i = 1, 2 \dots m \quad (11)$$

where \tilde{x}_{ij}^p is the performance ratio assessed by the p^{th} decision maker considering the criterion j for alternative i . k is the number of decision makers.

$$\tilde{w}_j = \frac{1}{k} [\sum_{p=1}^k \tilde{w}_j^p] \quad j = 1, 2 \dots n \quad (12)$$

where \tilde{w}_j^p is the weight determined by the p^{th} decision maker for j^{th} criterion. If the performance values are in different units, normalization of these values is required. The fuzzy normalized value of any $\tilde{x}_{ij} = (f_{ij}, g_{ij}, h_{ij}, o_{ij})$ is \tilde{c}_{ij} , and calculated as:

$$\bar{G}^v = [\tilde{c}_{ij}] = \begin{cases} \tilde{x}_{ij} \odot e_j^* & j \in B \\ l_j^- \odot \tilde{x}_{ij} & j \in C \end{cases} \quad (13)$$

B and C represent the sets of benefit and cost criteria, respectively. If $j \in B$: $e_j^* = \max_i \tilde{x}_{ij}$; and if $j \in C$: $l_j^- = \min_i \tilde{x}_{ij}$. This normalization method standardizes the fuzzy performance values and ensures that the value ranges are between 0 and 1, such that [0,1]. From here; the standardized values and performance matrix may be represented as follows:

$$\bar{G}^v = \begin{matrix} & C_1 & \dots & C_n \\ A_1 & \begin{bmatrix} \tilde{c}_{11} & \dots & \tilde{c}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{c}_{m1} & \dots & \tilde{c}_{mn} \end{bmatrix} & & \end{matrix} \quad \begin{matrix} j = 1, \dots, n; \\ i = 1, \dots, m \end{matrix} \quad (14)$$

The losses and gains of any alternative over other alternatives are estimated by mutual comparisons. Where \tilde{c}_{ij} and \tilde{c}_{kj} are the standardized performance values according to the criterion

C_j ($k = 1, 2 \dots m$) of the alternatives A_i and A_k , respectively. These values are; that is, \tilde{c}_{ij} and \tilde{c}_{kj} are expressed as trapezoidal fuzzy numbers. The euclidean distance between these fuzzy numbers is calculated by the following equation:

$$d(\tilde{c}_{ij}, \tilde{c}_{kj}) = \sqrt{\frac{1}{6} \left[(c_{ij}^f - c_{kj}^f)^2 + 2(c_{ij}^g - c_{kj}^g)^2 + 2(c_{ij}^h - c_{kj}^h)^2 + (c_{ij}^o - c_{kj}^o)^2 \right]} \quad (15)$$

Step 3: Calculate the relative weights w_{jr} of the criteria.

Relative weights of the criteria are calculated based on the reference criteria. The criterion with the highest weight is defined as the reference criterion. Suppose C_r is the reference criterion; the relative weight \tilde{w}_{jr} of C_j with respect to the reference criterion C_r is found as follows:

$$\tilde{w}_{jr} = \tilde{w}_j / \tilde{w}_r \quad (16)$$

where \tilde{w}_j is the weight of criterion C_j , \tilde{w}_r is the weight of reference criterion C_r , $j = 1, \dots, n$.

Step 4: Build the dominance degree matrix.

To obtain the matrix, the degree of dominance according to the criterion C_j of the alternative A_i on the alternative A_k is calculated with the following equation:

$$\tilde{\Phi}_{ik}^j = \begin{cases} \sqrt{\frac{w_{jr}}{(\sum_{j=1}^n w_{jr})}} d(\tilde{c}_{ij}, \tilde{c}_{kj}) & \text{if } \tilde{c}_{ij} \geq \tilde{c}_{kj} \\ 0 & \text{if } \tilde{c}_{ij} = \tilde{c}_{kj} \\ -\frac{1}{\theta} \sqrt{\frac{(\sum_{j=1}^n w_{jr})}{w_{jr}}} d(\tilde{c}_{ij}, \tilde{c}_{kj}) & \text{if } \tilde{c}_{ij} < \tilde{c}_{kj} \end{cases} \quad (17)$$

where θ is the weakening factor of the losses. In this case, for the criterion C_j , the dominance degree matrix $\tilde{\Phi}_j = [\tilde{\Phi}_{ik}^j]_{m \times m}$ is created.

Step 5: Calculate the general dominance degree matrix.

The general dominance rating of alternative A_i over alternative A_k is calculated as:

$$\tilde{\delta}_{ik} = \sum_{j=1}^n \tilde{\Phi}_{ik}^j \quad (18)$$

As a result of this calculation, the general dominance degree matrix Δ in $m \times m$ dimensions appears and shown as $\Delta = [\tilde{\delta}_{ik}]_{m \times m}$.

Step 6: Calculate the overall value of each alternative and list the alternatives accordingly.

On the basis of the matrix Δ , the general value of the alternative A_i can be calculated by the following equation:

$$\xi(A_i) = \frac{\sum_{k=1}^m \delta_{ik} - \min_{i \in M} \{\sum_{k=1}^m \delta_{ik}\}}{\max_{i \in M} \{\sum_{k=1}^m \delta_{ik}\} - \min_{i \in M} \{\sum_{k=1}^m \delta_{ik}\}} \quad (19)$$

where $0 \leq \xi(A_i) \leq 1$ and the larger $\xi(A_i)$ value is a better alternative. The alternatives are therefore sorted according to the decreasing order of the general value of $\xi(A_i)$. In order to find out the superiority of these trapezoidal fuzzy numbers, one can use the ranking method of Kahraman and Tolga's work [31].

3.3. Proposed Method

In this section, a new methodology's steps based on the integration of the said studies (AHP and TODIM) given in the previous subsections based on the study of Kahraman et al. [25]'s integration of the fuzzy AHP and fuzzy TOPSIS methods. Of course, some steps will be taken out because of merging, and some steps will be added to make it clearer. The steps of the recommended method is briefly as follows:

1. *Step: Create a commission of experts.* This commission should set the criteria for valuation and alternatives with K members as prescribed by the top management.
2. *Step: Decide to the basis of evaluation.* Use linguistic expressions for the weights of the measures and the performance values of the alternatives and use the data in Table 2 for this.

Table 2. Pairwise Comparison Scale

Linguistic Expression	Numeric Value
Much less important	(0.167, 0.200, 0.250, 0.333)
Less important	(0.250, 0.333, 0.500, 1.000)
Equal-to-significant	(0.500, 0.667, 0.667, 1.000)
Full equal	(1.000, 1.000, 1.000, 1.000)
Equal-excess is important	(1.000, 1.500, 1.500, 2.000)
More important	(1.000, 2.000, 3.000, 4.000)
Much more important	(3.000, 4.000, 5.000, 6.000)

3. *Step: Create the main criteria evaluation matrix.* Firstly, each decision maker is surveyed with separate questionnaires on the benchmarks of the main criteria. For each decision maker, construct the main criterion matrix (\tilde{I}_{MA}^p) and the average main criterion matrix (\tilde{I}_{MA}) as follows:

$$\tilde{I}_{MA}^p = [\tilde{w}_i^p]_{n_{MA} \times 1} = \begin{matrix} MA_1 \\ \vdots \\ MA_{n_{MA}} \end{matrix} \begin{matrix} Goal \\ \left[\begin{matrix} \tilde{w}_1^p \\ \vdots \\ \tilde{w}_{n_{MA}}^p \end{matrix} \right] \end{matrix} \quad (20)$$

$$\tilde{I}_{MA} = [\tilde{w}_i]_{n_{MA} \times 1} \quad (21)$$

where n_{MA} denotes the number of criteria in the main criterion hierarchical level; and here $1 \leq i \leq n_{MA}$ and $1 \leq p \leq k$. Hence, the decision maker should consider the main goal of selecting the best ERP system software; ask her / him to compare the generated main criteria with each other. Since there are equality in terms of k decision makers and their evaluations, compute the matrix with the formula $\tilde{w}_i = \frac{1}{k} [\sum_{p=1}^k \tilde{w}_i^p]$. Then Eq. 7 is applied to this matrix and the weight of the main criteria is found.

4. *Step: Construct subcriterion evaluation matrix.* Get thoughts related to the pair-wise comparisons of the sub-criteria decision from each decision-maker separately with the survey. For each decision maker, construct the subcriterion matrix (\tilde{I}_{SA}^p) and the average subcriterion matrix (\tilde{I}_{SA}) as follows:

$$\tilde{I}_{SA}^p = [\tilde{w}_{ij}^p] = \begin{matrix} & \tilde{w}_1 & \tilde{w}_2 & \dots & \tilde{w}_i & \dots & \tilde{w}_{n_{MA}} \\ MA_1 & MA_2 & \dots & MA_i & \dots & MA_{n_{MA}} \\ SA_{11} & \left[\begin{matrix} \tilde{w}_{11}^p & 0 & \dots & 0 & \dots & 0 \\ \tilde{w}_{12}^p & 0 & \dots & 0 & \dots & 0 \\ \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ \tilde{w}_{1r_1}^p & 0 & \dots & 0 & \dots & 0 \\ SA_{21} & 0 & \tilde{w}_{21}^p & \dots & 0 & \dots & 0 \\ SA_{22} & 0 & \tilde{w}_{22}^p & \dots & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ SA_{2r_2} & 0 & \tilde{w}_{2r_2}^p & \dots & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ SA_{ij} & 0 & \vdots & \dots & \vdots & \dots & \vdots \\ \vdots & 0 & \vdots & \dots & \tilde{w}_{ij}^p & \dots & \vdots \\ SA_{n1} & 0 & \vdots & \dots & \vdots & \dots & \vdots \\ SA_{n2} & 0 & 0 & \dots & 0 & \dots & \tilde{w}_{n1}^p \\ \vdots & 0 & 0 & \dots & 0 & \dots & \tilde{w}_{n2}^p \\ SA_{nn_{MA}} & 0 & \vdots & \dots & 0 & \vdots & \dots & \vdots \\ & 0 & 0 & \dots & 0 & \dots & \tilde{w}_{nn_{MA}}^p \end{matrix} \right] \end{matrix} \quad (22)$$

$$\tilde{I}_{SA} = [\tilde{w}_{ij}]_{nr_n \times n_{MA}} \quad (23)$$

where n_{SA} represents the number of criteria in the subcriterion hierarchical level, and here $1 \leq i \leq n$, $1 \leq j \leq n$, and $1 \leq p \leq k$. For this, while the decision-maker considering each of the created main criterion; ask her / him to compare the generated sub-criteria of each main criterion reciprocal. Since there are equality in terms of k decision makers and their evaluations, compute the matrix with the formula $\tilde{w}_{ij} = \frac{1}{k} [\sum_{p=1}^k \tilde{w}_{ij}^p]$. Then Eq. 7 is applied to this matrix and the weight of the sub-criteria is found. Repeat this fourth step for the sub-sub-criteria, if they exist.

5. *Step: Construct the weight matrix.* In order to calculate the weight matrix, the sub-criteria for the main criterion weights are multiplied, if any, by the weights of the respective sub-sub-criteria, and are calculated by the following general formula:

$$\tilde{W}_G = [\tilde{w}_i \otimes \tilde{w}_{ij} \otimes \tilde{v}_{ij}]_{nn_{MA} \times 1} \quad (24)$$

where \tilde{v}_{ij} is the term that is taken the average of decision maker and is applied with Eq. 7 to sub-sub-criteria, if they exist. In addition, the matrix created here can not be multiplied by the weights

$$\tilde{I}_A^p = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} \tilde{w}_{11} & \tilde{w}_{12} & \cdots & \tilde{w}_{1r_1} & \cdots & \tilde{w}_{ij} & \cdots & \tilde{w}_{nn_{MA}} \\ SA_{11} & SA_{12} & \cdots & SA_{1r_1} & \cdots & SA_{ij} & \cdots & SA_{nn_{MA}} \\ \tilde{c}^p_{111} & \tilde{c}^p_{112} & \cdots & \tilde{c}^p_{11r_1} & \cdots & \tilde{c}^p_{ij} & \cdots & \tilde{c}^p_{1nn_{MA}} \\ \tilde{c}^p_{211} & \tilde{c}^p_{212} & \cdots & \tilde{c}^p_{21r_1} & \cdots & \tilde{c}^p_{ij} & \cdots & \tilde{c}^p_{2nn_{MA}} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{c}^p_{i11} & \tilde{c}^p_{i12} & \cdots & \tilde{c}^p_{i1r_1} & \cdots & \tilde{c}^p_{ij} & \cdots & \tilde{c}^p_{inn_{MA}} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{c}^p_{m11} & \tilde{c}^p_{m12} & \cdots & \tilde{c}^p_{m1r_1} & \cdots & \tilde{c}^p_{mij} & \cdots & \tilde{c}^p_{mnn_{MA}} \end{bmatrix} \quad (25)$$

Make the evaluation for each alternative with respect to each criterion according to the scale in Table 3.

Since there are equality in terms of k decision makers and their evaluations, compute the matrix \tilde{I}_A with the formula $\tilde{I}_A = \frac{1}{k} [\sum_{p=1}^k \tilde{c}^p_{ij}]$.

7. *Step: Compute performance values of alternatives.* Each criteria weights were determined in step 5, so on the contrary to the fuzzy TODIM steps we only calculate performance values in this step. We compute the fuzzy normalized values of performance values of alternatives by Eq. 13. The distances between the standardized performance values are calculated by Eq. 15. With the method used in the study of Kahraman and Tolga these fuzzy values are compared with each other.

Table 3. Evaluation Scale

Linguistic Expression	Numeric Value
Very bad	(0.167, 0.200, 0.250, 0.333)
Bad	(0.250, 0.333, 0.500, 1.000)
Medium Bad	(0.500, 0.667, 0.667, 1.000)
Medium	(1.000, 1.000, 1.000, 1.000)
Moderate	(1.000, 1.500, 1.500, 2.000)
Good	(1.000, 2.000, 3.000, 4.000)
Very good	(3.000, 4.000, 5.000, 6.000)

8. *Step: Obtain the relative weights.* Eq. 16 is applied to the weight matrix established in step 6 and relative weights (\tilde{w}_{jr}) are found.

9. *Step: Construct the dominance degree matrix.* Using the values obtained in the previous steps

of the performance evaluations in the fuzzy TODIM method, so the transpose of the matrix is utilized.

6. *Step: Find performance evaluations:* In this step, decision-makers are asked to rate alternatives (\tilde{c}_{ij}) according to the relevant sub-criteria or sub-sub-criteria if necessary. If there exists quantitative criteria, the related data collected are integrated into this step. Apply Eq. 13 to form the performance matrix \tilde{G}^v in Eq. 14 and replace the result in Eq. 25.

and Eq. 17, calculate the matrix $\tilde{\Phi}_j$ for each criterion j .

10. *Step: Compute the general dominance degree matrix.* The dominance of the alternatives over each other is calculated at this stage and Eq. 18 is used to obtain the general dominance degree matrix " Δ ".

11. *Step: Find the overall value of the alternatives.* Obtain the general values ($\tilde{\xi}(A_i)$) for each alternative by Eq. 19. Defuzzify the general values with Eq. 6 and then sort them in descending order. The alternative to be selected is the alternate with the highest overall value.

4. AN APPLICATION ON CONSTRUCTION ORIGIN ENTERPRISE

This application was carried out in Turkey on an enhanced holding company that is based on construction. Founded in the construction sector for nearly 50 years, the group also houses 10 different companies in energy, casting and cement fields. To describe the annual turnover with a trapezoidal fuzzy number; it is (800, 900, 1000, 1100) million Turkish Lira. Having a dynamic human resource of 1300 people and performing successful projects, the group has set annual goals to re-evaluate its ERP system to secure the foundations of the growth. With this study, the basic ERP system to be applied in all companies of the related institution will be renewed. The

companies of the enterprise are using different ERP systems and cannot provide a comprehensive report.

The top management has taken the decision to transform this disorganized structure into a single and whole. Therefore, the management is also in the view of renewing the system of the holding company according to its needs. A working team has been created for this project and they have participated in this revaluation and selection process, with a Director of Management, Director of Human Resources, corporate adviser, finance director, and a faculty member specializing in universities. A survey of the literature on the subject was made and also given in the introduction section. Then process-related work team has held several meetings.

The Delphi method has been applied with the support of team members and the set of criteria given in Table 1 has been decided to be implemented in the revaluation and selection process. The current system is the system used in four out of ten companies and will be called this manner as an alternative. The first alternative is to renew and restructure the existing system to include all companies. Though the licensing of the current system has been over 10 years since the beginning of the license, the price of establishing the system from scratch has been given in negotiations with the supplier company. However, as a result of negotiations, necessary discounts have been provided due to being an old customer and these prices are given below. In addition, there are alternative ERP softwares those have important points on the market. One of these alternatives has been included in valuation process with the opinions of the team members. The alternative called the proposed rival software is thought to be purchased completely and the new system will be installed and operated entirely instead of the old systems on the servers within the company. In this case, additional servers, trainings and support will be needed if necessary. On the other hand, the last alternative is the cloud alternative of the existing ERP system, which serves in the part of the organization. Then whole system should be transitioned to the cloud system and activated in the entire holding company. In this instance, there will be training costs for employees and of companies using different systems in the organization but the costs of transactions and housings belonging to the servers will decrease. For this reason, the number of employees who will

use the software within the institution should be determined. The number of users in the past has been checked. This is regarded as the average value; the predicted number of users is given by the trapezoidal fuzzy number (65, 75, 85, 95). It is predicted as this number because there can be decrease in number with the increase in the productivity that would occur in the future or increase when the number of the company grows.

This decision is of great risk because the existing and functioning system will be renewed. In the event of a system failure, doing business may be totally affected. Therefore, for the solution the related enterprise needs exactly the proposed method, which includes both the viewpoint of the related team, adds cost to the account and also takes into account the risks.

4.1. Application with Proposed Method

The first and second steps of the proposed method were carried out as described in the previous section and started to be valued with five decision-makers. At first, questionnaires created were presented to the members of the team. Because of space constraints, only the decision makers' overall evaluations will be given for the first step. In the rest of the steps, just a decision maker's valuation will tell the method. The evaluations of decision makers for the third step are given in Table A 1. The main criteria matrix (\tilde{I}_{MA}) obtained by these valuations is given in Table 4.

In the fourth step, main criterion -the evaluation of the adaptation and development-, which has the largest criterion number of the sub-criteria, is given in Table A 2 for only one decision maker. Other sub-criteria and sub-sub-criteria assessments created in this step are not given due to space constraints (if requested, account table will be shared the private).

In the fifth step, the weight matrix is found by applying Eq. 24 and the results are given in In the sixth step, a questionnaire was presented to the decision makers using the linguistic expressions in Table 3. Corresponding numerical values will be input for the matrix shown in Eq. 25. Finding the cost calculations and then integrating them into the system is discussed in this step. For this purpose, one of the topics in engineering economy -the cost comparison method- named Equal Uniform Annual Cost (EUAC) method will be used. This cost value is calculated by the following equation:

$$EUAC = P * \left[\frac{i*(1+i)^N}{(1+i)^N - 1} \right] \quad (26)$$

where P is the present value of the investment, i is the annual nominal interest rate (13%, taken from the InterBank markets), N (set by the team as 10 years) is the investment life of the investment to be made. The Euro/T.Lira rate was taken as 4.3196. The resulting cost data are presented in

Table 6.

Table 5.

Table 4. Average value of decision makers

\bar{I}_{MA}	Decision makers average				
The best ERP	CS	AD	SP	PR	EUAC
CS	(1, 1, 1)	(1.30, 2.03, 2.63, 3.40)	(1.40, 1.90, 2.10, 2.60)	(0.90, 1.33, 1.53, 2.00)	(1.10, 1.50, 1.70, 2.20)
AD	(0.29, 0.38, 0.49, 0.77)	(1, 1, 1)	(1.00, 1.40, 1.80, 2.20)	(0.90, 1.53, 1.93, 2.60)	(0.80, 1.17, 1.37, 1.80)
SP	(0.38, 0.48, 0.53, 0.71)	(0.45, 0.56, 0.71, 1.00)	(1, 1, 1)	(0.90, 1.33, 1.53, 2.00)	(0.70, 1.03, 1.30, 1.80)
PR	(0.50, 0.65, 0.75, 1.11)	(0.38, 0.52, 0.65, 1.11)	(0.50, 0.65, 0.75, 1.11)	(1, 1, 1)	(0.90, 1.13, 1.13, 1.40)
EUAC	(0.45, 0.59, 0.67, 0.91)	(0.56, 0.73, 0.86, 1.25)	(0.71, 0.88, 0.88, 1.11)	(0.71, 0.88, 0.88, 1.11)	(1, 1, 1, 1)

In the sixth step, a questionnaire was presented to the decision makers using the linguistic expressions in Table 3. Corresponding numerical values will be input for the matrix shown in Eq. 25. Finding the cost calculations and then integrating them into the system is discussed in this step. For this purpose, one of the topics in engineering economy -the cost comparison method- named Equal Uniform Annual Cost (EUAC) method will be used. This cost value is calculated by the following equation:

$$EUAC = P * \left[\frac{i*(1+i)^N}{(1+i)^N - 1} \right] \tag{26}$$

where P is the present value of the investment, i is the annual nominal interest rate (13%, taken from the InterBank markets), N (set by the team as 10 years) is the investment life of the investment to be made. The Euro/T.Lira rate was taken as 4.3196. The resulting cost data are presented in

Table 6.

Table 5. Weight Matrix

	CB	CS	CH	CT	AFT
\bar{W}_G	(0.02, 0.07, 0.12, 0.29)	(0.02, 0.05, 0.07, 0.21)	(0.03, 0.07, 0.12, 0.28)	(0.02, 0.05, 0.09, 0.24)	(0.00, 0.01, 0.02, 0.07)
	AFM	AFK	AP	AI	AE
\bar{W}_G	(0.00, 0.01, 0.02, 0.06)	(0.00, 0.01, 0.02, 0.05)	(0.01, 0.03, 0.05, 0.13)	(0.01, 0.02, 0.04, 0.10)	(0.01, 0.03, 0.04, 0.12)
	AMM	AMS	AMC	AAI	AAE
\bar{W}_G	(0.00, 0.01, 0.02, 0.07)	(0.00, 0.01, 0.01, 0.04)	(0.00, 0.01, 0.02, 0.06)	(0.00, 0.01, 0.01, 0.05)	(0.00, 0.01, 0.01, 0.06)
	AAN	SC	SS	SR	PF
\bar{W}_G	(0.00, 0.01, 0.02, 0.06)	(0.02, 0.06, 0.09, 0.22)	(0.01, 0.03, 0.05, 0.13)	(0.02, 0.04, 0.07, 0.17)	(0.02, 0.06, 0.07, 0.18)
	PS	PI	EUAC		
\bar{W}_G	(0.01, 0.03, 0.04, 0.11)	(0.02, 0.05, 0.06, 0.15)	(0.09, 0.15, 0.17, 0.28)		

The values for each alternative are calculated in Table 7 by taking the average of the responses from the questionnaires presented to the decision makers. The results from the previous

Table 6 for the EUAC criterion have been included by this way.

Then, in the seventh step, Eq.s 12-13 are applied to obtain the gain-loss matrix \bar{G}^v . The results are given in Table 8.

In the eighth step, relative weights can easily be calculated by applying Eq. 16 to the weights obtained with AHP in In the sixth step, a questionnaire was presented to the decision makers using the linguistic expressions in Table 3. Corresponding numerical values will be input for the matrix shown in Eq. 25. Finding the cost calculations and then integrating them into the system is discussed in this step. For this purpose, one of the topics in engineering economy -the cost comparison method- named Equal Uniform Annual Cost (EUAC) method will be used. This cost value is calculated by the following equation:

$$EUAC = P * \left[\frac{i*(1+i)^N}{(1+i)^N - 1} \right] \tag{26}$$

where P is the present value of the investment, i is the annual nominal interest rate (13%, taken from the InterBank markets), N (set by the team as 10 years) is the investment life of the investment to be made. The Euro/T.Lira rate was taken as 4.3196. The resulting cost data are presented in

Table 6.

Table 5. These calculated relative weights are shown in Table 9.

With ninth step, the dominance degree matrix is calculated by Eq. 17. The corresponding calculation result is given in Table A 3.

In the tenth step, the general dominance degree matrix is obtained using Eq. 18. made as described in the theoretical section and the sequence is obtained as follows: $A_1 > A_3 > A_2$. In this case, while the restructuring of the existing system is preferred in the first place, the cloud alternative of the same system is preferred in the second place. The alternative to other rival software is at the last order.

Table 10 below shows the results obtained.

In the last step, the general values of the alternatives ($\tilde{\xi}(A_i)$) are found. The defuzzified results are as given in Table 11. Comparisons are

Table 6. Cost Data

Total Annual Turnover (Million TL)	(800, 900, 1000, 1100)		
Number of Users (Expected)	(65, 75, 85, 95)		
	Existing System Restructuring	Proposed Rival System	Cloud System
Initial Costs			
1. Consulting and Training Cost (€)	(65000, 82500, 110500, 133000)	(58350, 65963, 73575, 81188)	(62400, 74250, 89250, 102600)
2. Equipment Cost (If required) (€)	(30000, 40000, 50000, 60000)	(30000, 40000, 50000, 6.000)	(0, 0, 0, 0)
3. Software Cost (€)	(65000, 82500, 110500, 133000)	(77800, 87950, 98100, 108250)	(0, 0, 0, 0)
TOTAL (TL)	(691136, 885518, 1170612, 1408190)	(717701, 837624, 957547, 1077470)	(269543, 320730, 385524, 443191)
During Usage Costs (Annual)			
1. Software Maintenance Cost (€)	(13000, 16500, 22100, 26600)	(11670, 13193, 14715, 16238)	(0, 0, 0, 0)
2. Hardware Maintenance Cost (€)	(4000, 4500, 5500, 6000)	(4000, 4500, 5500, 6000)	(0, 0, 0, 0)
3. Software Maintenance Cost wrt User # (€)	(6500, 8250, 11050, 13300)	(5835, 6596, 7358, 8119)	(0, 0, 0, 0)
4. Cost Per User Per Month (€)	(0, 0, 0, 0)	(0, 0, 0, 0)	(160, 165, 175, 180)
5. Server Operational Cost (TL)	(4000, 4500, 5000, 5500)	(4000, 4500, 5000, 5500)	(0, 0, 0, 0)
TOTAL (TL)	(105511, 130848, 171953, 203770)	(96893, 109418, 124102, 136627)	(539086, 641461, 771049, 886382)
EUAC (TL)	(232880, 294040, 387684, 463284)	(229158, 263783, 300568, 335193)	(588760, 700568, 842097, 968057)

Table 7. Performance evaluation for alternatives

	CB	CS	CH	CT
Existing System Restructring	(2.10, 2.83, 3.43, 4.20)	(0.40, 0.57, 0.70, 1.20)	(0.90, 1.43, 1.63, 2.20)	(1.07, 1.28, 1.50, 1.73)
Proposed Rival System	(1.00, 1.60, 2.00, 2.60)	(0.85, 1.47, 1.90, 2.60)	(0.80, 1.07, 1.07, 1.40)	(0.70, 0.93, 1.20, 1.60)
Cloud System	(0.33, 0.44, 0.52, 0.87)	(1.00, 1.40, 1.80, 2.20)	(0.68, 0.71, 0.75, 0.87)	(1.40, 1.60, 1.80, 2.00)
	AFT	AFM	AFK	AP
Existing System Restructring	(0.70, 1.33, 2.00, 2.80)	(1.00, 1.40, 1.60, 2.00)	(0.83, 0.94, 0.95, 1.07)	(0.70, 0.93, 1.00, 1.40)
Proposed Rival System	(2.60, 3.50, 4.30, 5.20)	(1.00, 1.30, 1.30, 1.60)	(1.00, 1.00, 1.00, 1.00)	(0.85, 1.07, 1.10, 1.40)
Cloud System	(1.00, 1.20, 1.40, 1.60)	(0.80, 1.37, 1.77, 2.40)	(0.40, 0.53, 0.60, 1.00)	(0.90, 1.13, 1.13, 1.40)
	AI	AE	AMM	AMS
Existing System Restructring	(0.93, 1.37, 1.85, 2.47)	(1.50, 2.13, 2.80, 3.60)	(1.40, 1.90, 2.30, 2.80)	(1.40, 2.00, 2.60, 3.20)
Proposed Rival System	(1.00, 1.40, 1.60, 2.00)	(1.80, 2.50, 2.90, 3.60)	(1.00, 1.70, 2.30, 3.00)	(1.00, 1.50, 1.90, 2.40)
Cloud System	(0.50, 0.70, 0.77, 1.20)	(1.80, 2.60, 3.20, 4.00)	(1.40, 2.00, 2.60, 3.20)	(1.00, 1.90, 2.70, 3.60)
	AMC	AAI	AAE	AAN
Existing System Restructring	(1.30, 1.63, 1.83, 2.20)	(1.00, 1.30, 1.50, 1.80)	(1.60, 2.17, 2.57, 3.20)	(1.80, 2.30, 2.70, 3.20)
Proposed Rival System	(1.00, 1.30, 1.50, 1.80)	(0.90, 1.33, 1.53, 2.00)	(1.00, 1.30, 1.50, 1.80)	(0.85, 0.97, 1.00, 1.20)
Cloud System	(1.40, 1.70, 1.90, 2.20)	(1.40, 1.80, 2.20, 2.60)	(1.80, 2.30, 2.70, 3.20)	(1.80, 2.20, 2.60, 3.00)
	SC	SS	SR	PF
Existing System Restructring	(2.00, 2.67, 3.27, 4.00)	(1.25, 1.67, 2.10, 2.60)	(1.00, 1.70, 2.10, 2.80)	(0.85, 1.27, 1.70, 2.20)
Proposed Rival System	(1.00, 1.50, 1.70, 2.20)	(1.00, 1.50, 1.90, 2.40)	(1.00, 1.70, 2.10, 2.80)	(1.00, 1.70, 2.10, 2.80)
Cloud System	(1.65, 2.07, 2.50, 3.00)	(1.40, 2.00, 2.60, 3.20)	(1.00, 1.60, 2.20, 2.80)	(0.40, 0.57, 0.70, 1.20)
	PS	PI	EUAC	
Existing System Restructring	(2.20, 2.80, 3.40, 4.00)	(1.50, 2.03, 2.50, 3.20)	(232879.75, 294040.02, 387684.03, 463284.28)	
Proposed Rival System	(1.00, 1.50, 1.50, 2.00)	(0.90, 1.33, 1.73, 2.20)	(229157.90, 263783.12, 300568.14, 335193.37)	
Cloud System	(1.65, 2.07, 2.50, 3.00)	(1.00, 1.70, 2.10, 2.80)	(588760.05, 700567.84, 842096.70, 968057.39)	

Table 8. Gain loss matrix

	CB	CS	CH	CT
Existing System Restructring	(0.50, 0.83, 1.21, 2.00)	(0.15, 0.30, 0.48, 1.20)	(0.41, 0.88, 1.14, 2.44)	(0.53, 0.71, 0.94, 1.24)
Proposed Rival System	(0.24, 0.47, 0.71, 1.24)	(0.33, 0.77, 1.30, 2.60)	(0.36, 0.65, 0.74, 1.56)	(0.35, 0.52, 0.75, 1.14)
Cloud System	(0.08, 0.13, 0.18, 0.41)	(0.38, 0.74, 1.23, 2.20)	(0.31, 0.43, 0.52, 0.96)	(0.70, 0.89, 1.13, 1.43)
	AFT	AFM	AFK	AP
Existing System Restructring	(0.13, 0.31, 0.57, 1.08)	(0.42, 0.79, 1.14, 2.00)	(0.78, 0.94, 0.95, 1.07)	(0.50, 0.82, 0.88, 1.56)
Proposed Rival System	(0.50, 0.81, 1.23, 2.00)	(0.42, 0.74, 0.93, 1.60)	(0.94, 1.00, 1.00, 1.00)	(0.61, 0.94, 0.97, 1.56)
Cloud System	(0.19, 0.28, 0.40, 0.62)	(0.33, 0.77, 1.26, 2.40)	(0.38, 0.53, 0.60, 1.00)	(0.64, 1.00, 1.00, 1.56)
	AI	AE	AMM	AMS
Existing System Restructring	(0.38, 0.74, 1.32, 2.47)	(0.38, 0.6, 1.08, 2.00)	(0.44, 0.73, 1.15, 2.00)	(0.39, 0.74, 1.30, 2.29)
Proposed Rival System	(0.41, 0.76, 1.14, 2.00)	(0.45, 0.78, 1.12, 2.00)	(0.31, 0.65, 1.15, 2.14)	(0.28, 0.56, 0.95, 1.71)
Cloud System	(0.20, 0.38, 0.55, 1.20)	(0.45, 0.81, 1.23, 2.22)	(0.44, 0.77, 1.30, 2.29)	(0.28, 0.70, 1.35, 2.57)
	AMC	AAI	AAE	AAN
Existing System Restructring	(0.59, 0.86, 1.08, 1.57)	(0.38, 0.59, 0.83, 1.29)	(0.50, 0.80, 1.12, 1.78)	(0.56, 0.85, 1.17, 1.78)
Proposed Rival System	(0.45, 0.68, 0.88, 1.29)	(0.35, 0.61, 0.85, 1.43)	(0.31, 0.48, 0.65, 1.00)	(0.27, 0.36, 0.43, 0.67)
Cloud System	(0.64, 0.89, 1.12, 1.57)	(0.54, 0.82, 1.22, 1.86)	(0.56, 0.85, 1.17, 1.78)	(0.56, 0.81, 1.13, 1.67)
	SC	SS	SR	PF
Existing System Restructring	(0.50, 0.82, 1.23, 2.00)	(0.39, 0.64, 1.05, 1.86)	(0.36, 0.77, 1.24, 2.80)	(0.30, 0.60, 1.00, 2.20)
Proposed Rival System	(0.25, 0.46, 0.64, 1.10)	(0.31, 0.58, 0.95, 1.71)	(0.36, 0.77, 1.24, 2.80)	(0.36, 0.81, 1.24, 2.80)
Cloud System	(0.41, 0.63, 0.94, 1.50)	(0.44, 0.77, 1.30, 2.29)	(0.36, 0.73, 1.29, 2.80)	(0.14, 0.27, 0.41, 1.20)
	PS	PI	EUAC	
Existing System Restructring	(0.55, 0.82, 1.21, 1.82)	(0.47, 0.81, 1.23, 2.13)	(0.69, 0.98, 1.47, 2.02)	
Proposed Rival System	(0.25, 0.44, 0.54, 0.91)	(0.28, 0.53, 0.85, 1.47)	(0.68, 0.88, 1.14, 1.46)	
Cloud System	(0.41, 0.61, 0.89, 1.36)	(0.31, 0.68, 1.03, 1.87)	(1.76, 2.33, 3.19, 4.22)	

Table 9. Relative weights

	CB	CS	CH	CT	AFT
\tilde{w}_{jr}	(0.09, 0.40, 0.81, 3.08)	(0.06, 0.27, 0.51, 2.18)	(0.09, 0.42, 0.80, 2.91)	(0.07, 0.29, 0.59, 2.49)	(0.01, 0.06, 0.13, 0.78)
	AFM	AFK	AP	AI	AE
\tilde{w}_{jr}	(0.01, 0.05, 0.11, 0.64)	(0.01, 0.04, 0.09, 0.53)	(0.04, 0.18, 0.34, 1.35)	(0.03, 0.13, 0.25, 1.11)	(0.04, 0.16, 0.30, 1.23)
	AMM	AMS	AMC	AAI	AAE
\tilde{w}_{jr}	(0.01, 0.06, 0.12, 0.71)	(0.01, 0.03, 0.07, 0.46)	(0.01, 0.05, 0.11, 0.58)	(0.01, 0.05, 0.09, 0.55)	(0.01, 0.05, 0.10, 0.58)
	AAN	SC	SS	SR	PF
\tilde{w}_{jr}	(0.01, 0.05, 0.11, 0.59)	(0.09, 0.33, 0.63, 2.28)	(0.05, 0.19, 0.34, 1.33)	(0.07, 0.26, 0.47, 1.75)	(0.09, 0.32, 0.51, 1.88)
	PS	PI	EUAC		
\tilde{w}_{jr}	(0.05, 0.18, 0.29, 1.18)	(0.07, 0.27, 0.41, 1.61)	(0.33, 0.83, 1.20, 2.99)		

made as described in the theoretical section and the sequence is obtained as follows: $A_1 > A_3 > A_2$. In this case, while the restructuring of the existing system is preferred in the first place, the cloud alternative of the same system is preferred in the second place. The alternative to other rival software is at the last order.

Table 10. General dominance degree matrix

	$\delta(A_i, A_1)$	$\delta(A_i, A_2)$	$\delta(A_i, A_3)$
$\delta(A_1, A_i)$	(0.00, 0.00, 0.00, 0.00)	(-131.47, -26.56, -12.85, 5.59)	(-224.62, -48.28, -24.87, 1.01)
$\delta(A_2, A_i)$	(-325.64, -71.03, -37.84, -5.55)	(0.00, 0.00, 0.00, 0.00)	(-369.52, -79.45, -42.10, -4.54)
$\delta(A_3, A_i)$	(-194.32, -42.92, -22.37, 0.84)	(-173.65, -36.11, -17.95, 4.25)	(0.00, 0.00, 0.00, 0.00)

The solution described so far only gives the results where θ equals to 1.

Table 11. General values

$\tilde{\xi}(A_1)$	6.970
$\tilde{\xi}(A_2)$	3.913
$\tilde{\xi}(A_3)$	6.785

4.2. Sensitivity Analysis

One of the important features of the TODIM method is the calculation of the risk situation. As it will be understood from the formula the risk factor is expressed with different values of the variable θ . The results for different values of θ variable in the TODIM method and the analysis with only EUAC model are given in Table 12 below. The θ values smaller than one show the results risk-averse conditions; θ values greater than one indicate results of the risk-seeker person or team. The fact that the sorting does not change

in any case shows that the decision makers remain on the very safe side.

Table 12. Ranking Results

	1	2	3
EUAC	Proposed Rival System	Existing System Restructuring	Cloud System
$\theta = 0.50$	Existing System Restructuring	Cloud System	Proposed Rival System
$\theta = 0.88$	Existing System Restructuring	Cloud System	Proposed Rival System
$\theta = 1$	Existing System Restructuring	Cloud System	Proposed Rival System
$\theta = 2$	Existing System Restructuring	Cloud System	Proposed Rival System
$\theta = 2.25$	Existing System Restructuring	Cloud System	Proposed Rival System
$\theta = 3$	Existing System Restructuring	Cloud System	Proposed Rival System
$\theta = 4$	Existing System Restructuring	Cloud System	Proposed Rival System
$\theta = 5$	Existing System Restructuring	Cloud System	Proposed Rival System

As can be seen, when sorting according to only the cost; "the proposed rival system" alternative is the first place, while it is found in the last place with the fuzzy EUAC integrated fuzzy TODIM method. This has been a sign that decision-makers do not want to take the very big risks involved at the beginning of the application study.

As the value of θ increase, for example the values of 5, 6, or 7, the loss's real effect decreases and it is expected that the method should provide risk-seeking solutions, while on the contrary since θ decreases the real effect of the loss increases and one seeks to averse from risk. Indeed this happened and in some studies in the literature, it is stated that such a situation assures to the accuracy of conclusion. As a result of the analysis: it seems that the decision makers think that the possible damage in "doing business" or a slight disruption in production has more effect than the cost between the alternative systems. There is also a risk of losing customers who are found in supply, not disruption just in production. That's why the DMs are very conservative in their responses to the questionnaires. This protectionist instinct is so high that even the cloud system, which is a very

expensive alternative to the existing system, is ahead of the proposed rival system. Another consequence of this is the need for alternative rival systems to underline the simplicity and ease of use of their interfaces and their use.

5. CONCLUSIONS

Private institutions are becoming difficult to manage as they grow however thanks to ERP systems increasing the manageability. ERP systems ensure that every detail from highest to lowest level is known and available, and provide ease of management. At the same time, profitability is increasing due to proper business operations and increase in productivity. That is why it is very important for the big companies to decide which software to choose. Since it is a system that directly affects profitability, this study evaluated the ERP software selection process in a construction-based organization.

This evaluation process is a risky process because it could impress all business processes. A disruption in these processes would affect doing business and employee motivation, and so productivity will decrease; then profitability is likely to fall. Therefore, the TODIM method, which takes into account the risky situations, is preferred in this study. Furthermore, since it is necessary to include the uncertainties present in the model, in addition to the necessity of data security; the more suitable TODIM method was processed with fuzzy numbers. Since cost estimates are of great importance for decision makers in this method, how much the amount of annually will cost to the company is calculated by an equally uniform annual cost model.

The fact that there is no study that involves risky situations in the selection of ERP software and the evaluation of this subject with fuzzy multi-criteria decision method in this study have been an effective contribution to the literature. In addition, such a detailed cost calculation in ERP software is a difficult task. This study has made a significant contribution to the literature through the integration of the said methods and topics, and taking into account of the risky situations.

The findings obtained in the study include significant details regarding the selection of ERP software or revaluation. Even though very different and in pieces softwares are used in actual, this construction company uses a very old version

of major and existing software mostly. As a result of the application, it is very natural to choose the renewal of the existing system alternative. Because there may be other possible disruptions in the transition process; which can lead to loss of service, sales and productivity; in this case too much damage can be caused while cost saving is desired. Decision makers may therefore be on the more conservative side and have brought the alternative having existing knowledge to the forefront.

For the proposals of possible future studies on the subject are; the relevant criteria have been determined by looking at the general framework and although the sector has not been determined to be a criterion, it is possible to raise or lower the criteria for different sectors if deemed necessary. The work was done for the big company; it can be applied with the necessary adaptation for small and medium sized companies. This problem can be applied by risk-free multi-criteria decision-making alternatives including risks in different ways. The related method(s) of Type-2 fuzzy numbers, which better express(es) uncertainty situations, can also be used.

APPENDICE

Table A 1. Evaluation of decision makers for main criteria

DM 1						DM 2					
ERP Software	CS	AD	SP	PR	EUAC	ERP Software	CS	AD	SP	PR	EUAC
CS	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.50, 1.50, 2.00)	CS	(1.00, 1.00, 1.00, 1.00)	(1.00, 2.00, 3.00, 4.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.50, 1.50, 2.00)	(0.50, 0.67, 0.67, 1.00)
AD	(0.50, 0.67, 0.67, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 2.00, 3.00, 4.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 2.00, 3.00, 4.00)	AD	(0.25, 0.33, 0.50, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 2.00, 3.00, 4.00)	(1.00, 2.00, 3.00, 4.00)	(0.50, 0.67, 0.67, 1.00)
SP	(0.50, 0.67, 0.67, 1.00)	(0.25, 0.33, 0.50, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 2.00, 3.00, 4.00)	(1.00, 1.50, 1.50, 2.00)	SP	(0.50, 0.67, 0.67, 1.00)	(0.25, 0.33, 0.50, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.00, 1.00, 1.00)
PR	(1.00, 1.00, 1.00, 1.00)	(0.50, 0.67, 0.67, 1.00)	(0.25, 0.33, 0.50, 1.00)	(1.00, 1.00, 1.00, 1.00)	(0.50, 0.67, 0.67, 1.00)	PR	(0.50, 0.67, 0.67, 1.00)	(0.25, 0.33, 0.50, 1.00)	(0.50, 0.67, 0.67, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)
EUAC	(0.50, 0.67, 0.67, 1.00)	(0.25, 0.33, 0.50, 1.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.00, 1.00, 1.00)	EUAC	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)

DM 3						DM 4					
ERP Software	CS	AD	SP	PR	EUAC	ERP Software	CS	AD	SP	PR	EUAC
CS	(1.00, 1.00, 1.00, 1.00)	(1.00, 2.00, 3.00, 4.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.50, 1.50, 2.00)	(0.50, 0.67, 0.67, 1.00)	CS	(1.00, 1.00, 1.00, 1.00)	(0.50, 0.67, 0.67, 1.00)	(1.00, 1.00, 1.00, 1.00)	(0.50, 0.67, 0.67, 1.00)	(0.50, 0.67, 0.67, 1.00)
AD	(0.25, 0.33, 0.50, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 2.00, 3.00, 4.00)	(1.00, 1.50, 1.50, 2.00)	AD	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.00, 1.00, 1.00)
SP	(0.50, 0.67, 0.67, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(0.50, 0.67, 0.67, 1.00)	(0.25, 0.33, 0.50, 1.00)	SP	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 2.00, 3.00, 4.00)
PR	(0.50, 0.67, 0.67, 1.00)	(0.25, 0.33, 0.50, 1.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	PR	(1.00, 1.50, 1.50, 2.00)	(0.50, 0.67, 0.67, 1.00)	(0.50, 0.67, 0.67, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)
EUAC	(1.00, 1.50, 1.50, 2.00)	(0.50, 0.67, 0.67, 1.00)	(0.50, 0.67, 0.67, 1.00)	(0.50, 0.67, 0.67, 1.00)	(1.00, 1.00, 1.00, 1.00)	EUAC	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)

DM 5					
ERP Software	CS	AD	SP	PR	EUAC
CS	(1.00, 1.00, 1.00, 1.00)	(3.00, 4.00, 5.00, 6.00)	(3.00, 4.00, 5.00, 6.00)	(1.00, 1.00, 1.00, 1.00)	(3.00, 4.00, 5.00, 6.00)
AD	(0.17, 0.20, 0.25, 0.33)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.50, 1.50, 2.00)	(0.50, 0.67, 0.67, 1.00)
SP	(0.17, 0.20, 0.25, 0.33)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 2.00, 3.00, 4.00)	(0.25, 0.33, 0.50, 1.00)
PR	(0.25, 0.33, 0.50, 1.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.50, 1.50, 2.00)
EUAC	(0.17, 0.20, 0.25, 0.33)	(1.00, 1.50, 1.50, 2.00)	(0.50, 0.67, 0.67, 1.00)	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.00, 1.00, 1.00)

Table A 2. Evaluation of AD main criterion against each sub-criteria

DM 1							
For UG	AF	AP	AI	AE	AM	AA	
AF	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(0.50, 0.67, 0.67, 1.00)	(1.00, 1.50, 1.50, 2.00)	(0.25, 0.33, 0.50, 1.00)	(1.00, 1.00, 1.00, 1.00)	
AP	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.50, 1.50, 2.00)	(0.25, 0.33, 0.50, 1.00)	(1.00, 1.00, 1.00, 1.00)	
AI	(1.00, 1.50, 1.50, 2.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(0.25, 0.33, 0.50, 1.00)	(0.25, 0.33, 0.50, 1.00)	(0.50, 0.67, 0.67, 1.00)	
AE	(0.50, 0.67, 0.67, 1.00)	(0.50, 0.67, 0.67, 1.00)	(1.00, 2.00, 3.00, 4.00)	(1.00, 1.00, 1.00, 1.00)	(0.17, 0.20, 0.25, 0.33)	(0.50, 0.67, 0.67, 1.00)	
AM	(1.00, 2.00, 3.00, 4.00)	(1.00, 2.00, 3.00, 4.00)	(1.00, 2.00, 3.00, 4.00)	(3.00, 4.00, 5.00, 6.00)	(1.00, 1.00, 1.00, 1.00)	(0.50, 0.67, 0.67, 1.00)	
AA	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.00, 1.00, 1.00)	(1.00, 1.50, 1.50, 2.00)	(0.17, 0.20, 0.25, 0.33)	(0.17, 0.20, 0.25, 0.33)	(1.00, 1.00, 1.00, 1.00)	

Table A 3. Fuzzy dominance degree matrix

	ϕ_1	ϕ_2	ϕ_3	ϕ_4	ϕ_5	ϕ_6
(A1, A2)	(0.04, 0.20, 0.29, 1.10)	(-20.41, -4.96, -2.69, -0.67)	(0.04, 0.20, 0.28, 1.03)	(0.02, 0.10, 0.15, 0.60)	(-47.08, -9.09, -4.67, -1.00)	(0.01, 0.05, 0.07, 0.33)
(A1, A3)	(0.05, 0.29, 0.41, 1.57)	(-18.52, -4.50, -2.44, -0.61)	(0.05, 0.26, 0.36, 1.33)	(-9.52, -2.30, -1.20, -0.30)	(0.01, 0.05, 0.08, 0.37)	(-27.88, -5.50, -2.83, -0.59)
(A2, A1)	(-13.62, -3.17, -1.68, -0.44)	(0.04, 0.21, 0.29, 1.18)	(-12.45, -2.98, -1.62, -0.44)	(-9.39, -2.27, -1.19, -0.30)	(0.01, 0.09, 0.13, 0.63)	(-29.87, -5.89, -3.03, -0.63)
(A2, A3)	(0.04, 0.21, 0.29, 1.12)	(0.02, 0.10, 0.14, 0.55)	(0.03, 0.16, 0.23, 0.84)	(-13.33, -3.22, -1.68, -0.42)	(0.01, 0.09, 0.13, 0.63)	(-40.49, -7.99, -4.11, -0.86)
(A3, A1)	(-19.35, -4.51, -2.39, -0.63)	(0.04, 0.19, 0.27, 1.08)	(-16.09, -3.86, -2.10, -0.56)	(0.02, 0.11, 0.15, 0.61)	(-27.56, -5.32, -2.74, -0.58)	(0.01, 0.04, 0.06, 0.31)
(A3, A2)	(-13.77, -3.21, -1.70, -0.45)	(-9.47, -2.30, -1.25, -0.31)	(-10.23, -2.45, -1.33, -0.36)	(0.03, 0.15, 0.21, 0.85)	(-53.59, -10.35, -5.32, -1.13)	(0.01, 0.06, 0.09, 0.44)
	ϕ_7	ϕ_8	ϕ_9	ϕ_{10}	ϕ_{11}	ϕ_{12}
(A1, A2)	(-19.65, -3.95, 2.08, -0.44)	(-9.01, -2.14, -1.15, -0.29)	(0.01, 0.08, 0.11, 0.44)	(-8.34, -1.97, -1.08, -0.28)	(0.00, 0.03, 0.05, 0.23)	(0.01, 0.05, 0.07, 0.35)
(A1, A3)	(0.01, 0.06, 0.08, 0.39)	(-10.73, -2.55, -1.38, -0.35)	(0.03, 0.14, 0.20, 0.80)	(-11.92, -2.82, -1.55, -0.39)	(-23.42, -4.65, -2.36, -0.51)	(-27.41, -5.66, -2.87, -0.59)
(A2, A1)	(0.00, 0.03, 0.04, 0.19)	(0.01, 0.06, 0.08, 0.32)	(-15.69, -3.75, -2.02, -0.49)	(0.01, 0.05, 0.07, 0.28)	(-18.26, -3.63, -1.84, -0.39)	(-43.63, -9.01, -4.57, -0.94)
(A2, A3)	(0.01, 0.06, 0.09, 0.43)	(-5.88, -1.40, -0.75, -0.19)	(0.02, 0.12, 0.17, 0.69)	(-10.21, -2.41, -1.33, -0.34)	(-22.36, -4.44, -2.26, -0.48)	(-49.70, -10.26, -5.20, -1.07)
(A3, A1)	(-40.57, -8.15, -4.29, -0.91)	(0.01, 0.07, 0.10, 0.39)	(-28.54, -6.82, -3.68, -0.89)	(0.01, 0.07, 0.10, 0.39)	(0.01, 0.04, 0.06, 0.29)	(0.00, 0.03, 0.05, 0.22)
(A3, A2)	(-44.43, -8.93, -4.70, -0.99)	(0.01, 0.04, 0.05, 0.21)	(-24.48, -5.85, -3.15, -0.77)	(0.01, 0.07, 0.10, 0.39)	(0.01, 0.04, 0.06, 0.28)	(0.01, 0.06, 0.08, 0.40)
	ϕ_{13}	ϕ_{14}	ϕ_{15}	ϕ_{16}	ϕ_{17}	ϕ_{18}
(A1, A2)	(0.01, 0.05, 0.07, 0.31)	(-16.62, -3.33, -1.80, -0.37)	(0.01, 0.07, 0.10, 0.47)	(0.01, 0.09, 0.12, 0.58)	(0.04, 0.20, 0.27, 1.01)	(0.01, 0.06, 0.08, 0.32)
(A1, A3)	(-11.40, -2.37, -1.25, -0.27)	(-39.77, -7.97, -4.31, -0.90)	(-14.67, -2.92, -1.58, -0.33)	(0.00, 0.03, 0.04, 0.16)	(0.03, 0.14, 0.20, 0.73)	(-12.44, -3.22, -1.80, -0.47)
(A2, A1)	(-26.99, -5.60, -2.95, -0.65)	(0.00, 0.02, 0.03, 0.17)	(-44.19, 8.80, -4.76, -0.99)	(-50.96, -10.30, -5.57, -1.20)	(-14.41, -3.74, -2.03, -0.55)	(-7.86, -2.03, -1.14, -0.30)
(A2, A3)	(-28.91, -6.00, -3.16, -0.69)	(-37.30, -7.47, -4.04, -0.84)	(-45.90, -9.14, -4.95, -1.02)	(-48.96, -9.89, -5.35, -1.16)	(-10.03, -2.60, -1.41, -0.38)	(-14.65, -3.79, -2.12, -0.55)
(A3, A1)	(0.00, 0.02, 0.03, 0.13)	(0.01, 0.06, 0.08, 0.40)	(0.00, 0.02, 0.03, 0.16)	(-14.47, -2.92, -1.58, -0.34)	(-10.39, -2.69, -1.46, -0.39)	(0.02, 0.10, 0.13, 0.51)
(A3, A2)	(0.01, 0.05, 0.07, 0.33)	(0.01, 0.06, 0.08, 0.37)	(0.01, 0.07, 0.10, 0.49)	(0.01, 0.09, 0.12, 0.56)	(0.03, 0.14, 0.19, 0.70)	(0.02, 0.12, 0.16, 0.60)
	ϕ_{19}	ϕ_{20}	ϕ_{21}	ϕ_{22}	ϕ_{23}	
(A1, A2)	(0.00, 0.00, 0.00, 0.00)	(-10.68, -2.85, -1.68, -0.45)	(0.03, 0.15, 0.19, 0.75)	(0.03, 0.15, 0.19, 0.71)	(0.06, 0.23, 0.28, 0.86)	
(A1, A3)	(-4.60, -1.18, -0.65, -0.17)	(0.04, 0.20, 0.25, 0.93)	(0.02, 0.11, 0.14, 0.53)	(0.02, 0.10, 0.13, 0.49)	(-12.57, -4.03, -2.51, -0.81)	
(A2, A1)	(0.00, 0.00, 0.00, 0.00)	(0.03, 0.14, 0.18, 0.68)	(-19.69, -5.22, -3.08, -0.79)	(-13.28, -3.51, -2.11, -0.55)	(-5.45, -1.75, -1.09, -0.35)	
(A2, A3)	(-4.60, -1.18, -0.65, -0.17)	(0.05, 0.24, 0.31, 1.15)	(-14.00, -3.71, -2.19, -0.56)	(-9.77, -2.58, -1.55, -0.40)	(-13.61, -4.36, -2.72, -0.88)	
(A3, A1)	(0.01, 0.05, 0.07, 0.25)	(-14.58, -3.88, -2.29, -0.61)	(-13.88, -3.68, -2.17, -0.56)	(-9.16, -2.42, -1.45, -0.38)	(0.13, 0.54, 0.64, 1.98)	
(A3, A2)	(0.01, 0.05, 0.07, 0.25)	(-18.04, -4.81, -2.84, -0.76)	(0.02, 0.11, 0.14, 0.54)	(0.02, 0.11, 0.14, 0.53)	(0.14, 0.58, 0.70, 2.14)	

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