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Warehouse Location selection for an electricity distribution company by KEMIRA-M method

Bir elektrik dağıtım firması için KEMIRA-M yöntemi ile depo yeri seçimi

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Abstract

In this study, by using Modified Kemeny Median Indicator Ranks Accordance (KEMIRA-M) approach which begins to become popular in recent times for solution of Multi criteria Decision Making (MCDM) problems, warehouse location selection for an electricity distribution company is performed. KEMIRA-M logically distinguishes criteria into two groups and it computes criteria importance weights by including interactions between both groups. KEMIRA-M considers both decision makers' preferences related to the priorities of criteria and quantitative or qualitative values of these criteria in decision making process. Decision makers can change importance weights of criteria based on median priority component representing expected rankings of criteria importance weights and they can see the effect of this variability on rankings of alternatives. In warehouse location selection problem investigated in this study, it is aimed to choose the favorable location considering different criteria and these criteria were grouped firm related and environmental criteria to evaluate 20 alternative warehouse locations. In this context, as firm related criteria; Operation Center-Meeting Point (OC-MP) transportation cost per month, main warehouses' transportation costs per month, number of connected OC-MP, consumption amounts of OC-MP were considered. Population, distance to the closest main road, average distance to main supplier, mobility, investment amounts in 2018, average delivery time and land cost were taken into account as environmental criteria group.

Keywords: KEMIRA, Warehouse, Location selection, Electricity distribution, MCDM

Öz

Bu çalışmada, Çok Kriterli Karar Verme (ÇKKV) problemlerinin çözümü için son zamanlarda popüler hale gelen Modifiye Edilmiş Kemeny Medyan Gösterge Sıralaması Uygunluk Yaklaşımı (Modified KEmeny Median Indicator Ranks Accordance, KEMIRA-M) kullanılarak; bir elektrik dağıtım şirketi için depo yeri seçimi gerçekleştirilmiştir. KEMIRA-M, kriterleri mantıksal olarak iki gruba ayırmakta ve her iki grup arasındaki etkileşimleri de kapsayarak kriter önem ağırlıklarını hesaplamaktadır. KEMIRA-M, karar vericilerin hem kriter öncelikleriyle ilgili tercihlerini hem de kriterlerin nicel veya nitel değerlerini dikkate almaktadır. Karar vericiler, kriterlerin önem ağırlıklarını medyan bileşen öncelikleri temelinde değiştirebilirler ve bu değişkenliğin etkilerini alternatiflerin sıralaması üzerinde görebilirler. Bu çalışmada incelenen depo yeri seçim probleminde farklı kriterler göz önünde bulundurularak en uygun yerin seçilmesi amaçlanmıştır. Bu kriterler 20 depo yeri alternatifinin değerlendirilmesi için çevresel ve firma ile ilişkili kriterler olmak üzere iki gruba ayrılmıştır. Bu kapsamda, firma ilişkili kriterler olarak; Operasyon Merkezi-Buluşma Noktası Depolarının (OC-MP) aylık ulaşım maliyetleri, 2018 yatırım tutarları, aylık ana depolar arası ulaşım maliyetleri, bağlı OC-MP sayısı ve OC-MP tüketim tutarları dikkate alınmıştır. Çevresel kriterler olarak; nüfus, en yakın ana yola uzaklık, ana tedarikçiye ortalama uzaklık, hareket esnekliği, ortalama teslimat süresi ve arazi maliyeti göz önünde bulundurulmuştur.

Anahtar kelimeler: KEMIRA, Depo, Yer seçimi, Elektrik dağıtımı, ÇKKV

1 Introduction

Effective supply chain management is needed for companies to meet continuously changing requirements in the marketplace. By reducing supply chain risk and uncertainty, companies can enhance customer service, optimize inventory levels, improve business processes and reduce cycle times, resulting in increased competitiveness and profitability. Warehouse location selection is one of the most critical decisions in supply chain design and management.

In today's competitive market environment, companies are continuously forced to improve their warehousing operations [1]. Many companies have also customized their value proposition to increase their customer service levels, which has led to changes in the role of warehouses [1]. Warehousing also affects the total logistics costs of a company, as reducing warehousing costs can lead to an increase in transportation costs [2]. Choosing the right location for a warehouse can prevent an increase of the total logistics costs and its positive effects may only become apparent over time [2].

Suitable warehouse location selection is also very significance part of the logistics systems for an Electricity Distribution Company, because energy is indispensable for a city. Electrical materials which maintain the electricity grid of the city are stored at these warehouses. Warehouse location is a long-term decision and is influenced by many quantitative and qualitative factors [3]. Hence, warehouse location selection is a Multi-Criteria Decision Making (MCDM) problem. MCDM is an approach to rank and select the best from a set of feasible alternatives.

Among supply chain studies, many papers on location selection problem have been published. The existing literature does not indicate a systematic fashion of location selection research. However, the study of location selection has a long and extensive history spanning many general research fields including operations research (or management science), industrial engineering, geography, economics, computer science, mathematics, marketing, electrical engineering, urban planning [4]. Brief information for warehouse location selection studies is given below.

Han et al. [5] studied the supply location selection and routing (SLSR) problem via considering uncertain demand and formulating as a probabilistic constrained integer programming (PCIP) model. Cao et al. [6] analyzed the inevitable trend of cooperation between estate logistic, logistic enterprise, manufacturing firm and retail. They constructed the simulated annealing (SA) model with the comprehensive consideration of estate logistics firm and customers' profit. Liang and Tu [7] investigated how to select the warehouse location for time limited aeronautical emergency material. A warehouse location selection model for aeronautical emergency material has been established based on the set-covering theory. Feng et al. [8] used index system for location evaluation of logistics center constructed by analyzing influencing factors of logistics center location. Then, the fuzzy-matter element model based on Grey Relation Analysis (GRA) was built in view of the fuzziness and incompatibility of evaluation index in evaluation of logistics center location and the model was used to choose the best scheme. Demirel and Kahraman [3] applied multi-criteria Choquet integral to a real warehouse location selection problem of a big Turkish logistic firm. Özcan et al. [9] compared the results of Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Elimination and Choice Expressing Reality (ELECTRE) and GRA for the warehouse selection problem, which is one of the main topics of logistics management in retail sector. Natarajan et al. [10] implemented TOPSIS, Elemination and Choice Translating Reality English (ELECTRE) and GRA for warehouse selection for mobile phone industry in special economic zone. Public Bonded warehouse was found as a best warehouse among the alternatives and comparative analysis were done by using C++ programming software. Uysal and Tosun [11] considered labor, transportation, environment and geographical location as decision criteria and used GRA under the sustainability basis for the warehouse location selection problem. This method is appropriate for solving the group decision-making problem in an uncertain and inconsistent environment. Warehouse location alternatives for the supply chain of the medical companies are evaluated in this study. Aktepe and Ersöz [12] solved warehouse site selection problem by using three different methods as AHP, Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) and Multi-Objective Optimization by Ratio Analysis (MOORA). AHP method was used for determining the importance weights of criteria. VIKOR and MOORA methods were used for ranking alternatives. Erbaş et al. [13] performed spatial analysis of the Geographical Information Systems (GIS) for warehouse location selection for hazardous materials. Jayant [14] selected the most appropriate warehouse location for a manufacturing organization. Here, three MCDM techniques VIKOR, TOPSIS, GRA were used to facilitate decision making in the selection of a warehouse. The model proposed in this paper determines the most appropriate warehouse location alternative through maximization of objectives. A case study of manufacturing company was presented to illustrate these three MCDM techniques for the selection of warehouse facility. Malmir et al. [15] proposed a new balancing and ranking method combined with an interval data approach for solving a warehouse location selection problem. This method involves a three-step procedure to derive an overall complete final order of the warehouses which are already selected for the decision making. Dey et al. [16] proposed three new extended fuzzy MCDM methodologies capable of handling subjective and objective factors for the evaluation and selection of warehouse location. The concept of fuzzy set theory was integrated with the TOPSIS, Simple Additive Weight (SAW) and MOORA to assess subjective criteria in terms of subjective factor measures. Mangalan, et al. [17] calculated the personal preference for criteria using Simos' procedure (1990) for the ware house location. Then, MOORA used to optimize the rankings of warehouse sites. Zhu et al. [18] used probabilistic model checking to provide a formal way to select the best express delivery storage locations. Probabilistic Computation Tree Logic (PCTL) was employed to specify the requirements of delivery system. The Probabilistic Symbolic Model Checker (PRISM) was used to the qualitative verification and probabilistic simulation of each step in delivery fetches process. Devangan [19] developed an integrated production and distribution planning (IPDP) optimization model for a multi-product, multi-plant, multi-location and multi-echelon supply chain environment with multiple transport options including railways and roads. Özbek and Erol [20] developed a model to select the best place for storage. The study utilized AHP, SAW, Complex Proportional Assessment (COPRAS) and MOORA to form an integrated model. Cömert and Yener [21] determined an optimal warehouse location of a food company using the Fuzzy AHP. Sezer et al. [22] proposed a multiple criteria decision problem for hazardous material warehouse selection. In particularly, for the explosives storage among other hazardous materials, necessary criteria are determined according to expert's consultant. The determined criteria are weighted according to DMs' consultancies and the alternatives were evaluated by fuzzy Multi-Objective Optimization by Ratio Analysis (MULTIMOORA) under uncertainty. Dey et al. [23] proposed a new Multi criteria Group Decision Making (GDM) approach in adroit exploitation of the group heterogeneity during evaluation process and restrict the biasness of information while decision making. To overcome the biasness, the consistency check mechanism of AHP was employed. He et. al [24] identified key effectiveness-oriented criteria used to evaluate the alternative emergency warehouse locations and made an attempt to propose a new multi criteria ranking method to solve the problem of inaccurate or uncertain weight information based on stochastic pairwise dominant relations and the pruning procedure of ELECTRE-II method. Gül and Eren [25] developed a multi criteria optimization approach by combining AHP and goal programming (GP) model for warehouse location selection process in a public sector. Shukla et al. [26] solved location selection problem for a modern agri-warehouse using Fuzzy AHP. Büyüközkan and Uztürk [27] proposed group decision-making (GDM) technique based on 2-tuple linguistic model, quality function deployment (QFD) and the TOPSIS method. This proposed framework was then applied to a green warehouse selection problem. Chen et. al [28] provided a data-smart approach for addressing the connected capacitated warehouse location problem (CCWL), which searches for the minimum total transportation cost of the warehouse network including supplier-warehouses shipping cost, warehouse customer delivering cost and the cost of warehouse-warehouse inter-transportation. Izdebski et al. [29] developed the genetic algorithm in order to solve the multi-criteria warehouse location problem in the logistics network. Jha et al. [30] identified and modeled critical success factors (CSFs) for the selection of sustainable warehouse for Indian chemical industries. Through literature survey and experts' opinions, 14 critical factors were identified, and the interpretive structural modeling (ISM) approach was used to establish interrelationship among the defined parameters and to determine the key criteria having high driving power. Lin and Wanga [31] resolved the problems of deciding the optimal warehouse location for multiple markets and determining warehouse configuration design against stochastic demands. An appropriate inventory policy with owned and rented warehouses for deteriorating items was further designed. Brunaud et al. [32] proposed a Mixed-integer Linear Programming model to determine the optimal number location and capacity of the warehouses required to support a long-term forecast with seasonal demand. Kabak and Keskin [33] determined the most suitable location for an explosive and ammunition warehouse to be established in the Marmara Region of Turkey, with an aim to minimize the transportation costs from the point of origin (warehouse) to the distribution point and simultaneously minimize or eliminate impact to the environment and living beings. A hybrid methodology of a mathematical model, AHP and GIS are proposed for the solution of this problem. Foroozesh et al. [34] selected the most optimal location from a number of potential sustainable warehouse candidates and presented a novel MCDM model by a group of supply chain experts with interval-valued fuzzy setting and asymmetric uncertainty information. Emeç [35] developed a stochastic MCDM approach to solve the warehouse location problem in the stochastic environment which contains uncertain condition. Singha et al. [36] found the most optimal location for a warehouse in Special Economic Zones (SEZs) and Free Trade Zones (FTZs) of Iran on the basis of different criteria derived from literature. Guo et al. [37] applied a Monte Carlo simulation to simulate future well locations, Then they selected several suitable candidates using a continuous location model and finally they used discrete location optimization to determine the optimal solution while also considering the distribution interruption problem. In the context of literature review study, 97 numbers of studies in between 2009-2018 focusing on location selection problem are analyzed. There are 38 studies are related about warehouse selection problem. The distribution of these studies including warehouse location selection by years is given in Figure 1.

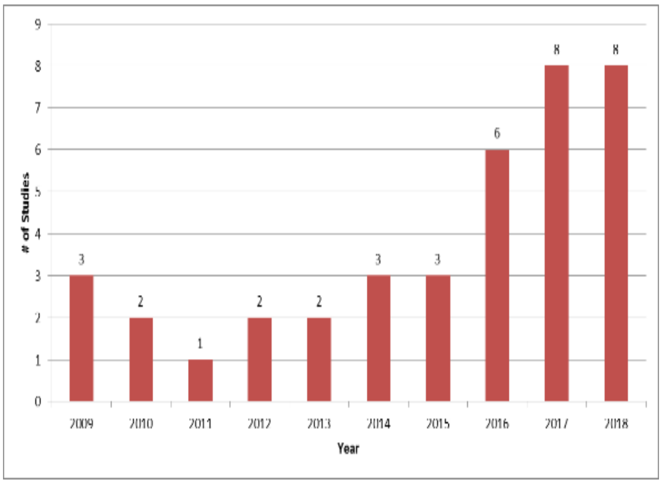

Figure 1: Distribution of warehouse location selection problems between 2009-2018.

In Figure 2, distribution of sectors where warehouse location selection is performed can also be seen.

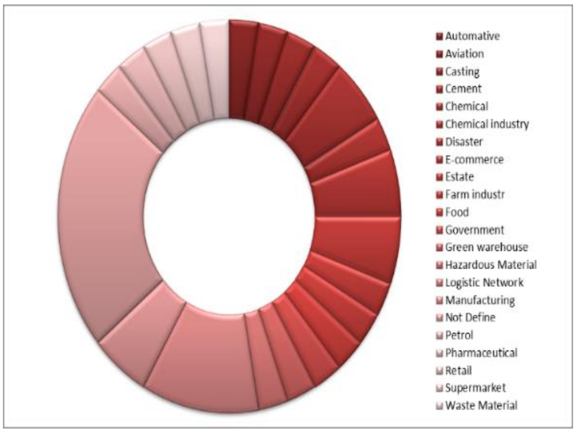

Figure 2: Distribution of sectors.

Figure 3 shows the methodologies used for location selection in these 38 studies.

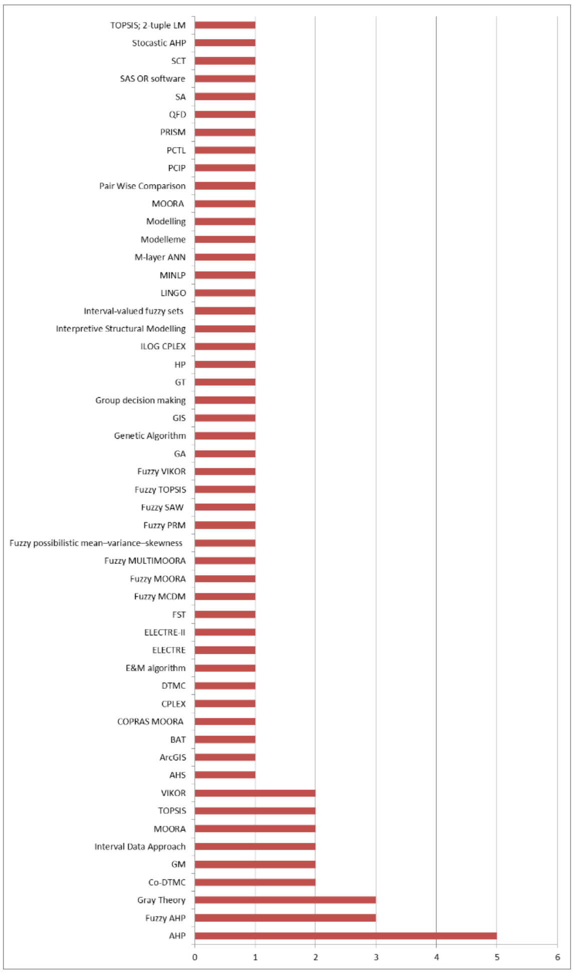

Figure 3: Methodologies used in studies.

As seen from the literature, ware house location selection is the popular topic for researchers. However, KEMIRA-M has not been used for this problem. Therefore, it is a hot topic to use KEMIRA-M to determine the most suitable warehouse location alternative. In this study, the most suitable location is aimed to determine for an electrical material warehouse to be established for the Electricity Distribution Company domain.

Warehouse location selection is an important decision that directly affects logistics management. One of the factors increasing or decreasing costs in logistics activities is the selection of warehouse locations. Today, a positive or negative competition environment depends on a good settlement decision. Competition shows itself through the prices determined as the basis for the cost expenses. A good placement makes creating a location that will provide an affordable cost and a bad settlement has reverse effect. The choice of warehouse location is a decision requiring a long-term strategic planning level that includes the size, geographical location and number of warehouses etc.. Because of considering many different criteria to evaluate different numbers of location multi criteria decision making (MCDM) approaches provide flexibility in decision process. Among MCDM approaches, KEMIRA-M which is a new generation and powerful methodology can model location selection decision in a detailed manner.

The decision process in KEMIRA-M is carried out considering both the decision makers' opinions and the qualitative-quantitative values that the alternatives take for the criteria simultaneously. Additionally, KEMIRA-M is based on the fact that decision makers create a priority order instead of using a scale when determining criteria weight. Final criteria rankings are obtained via aggregating these different priorities of decision makers. The combined priority of the criteria is determined to be the least difference between the decision makers. According to this order, the decision makers have the flexibility to make different weightings with a total of 1. In addition, the method can show changes in alternative rankings for different criteria weights given by decision makers in its inner procedure.

"KEMIRA-M uses two heuristics as prioritizing criteria groups separately and determining criteria weights according to the median priority components. In KEMIRA-M procedure, the differences between the priorities of decision makers in terms of criteria are considered and median priority component forms a decision rule for criteria weights' rankings. Decision makers have to assign criteria weights based on median priority component. This provides a systematic and flexible approach for determining criteria weights. Median priority component is the aggregation of different rankings of decision makers in terms of criteria. In location selection problem, different decision makers may have different priorities for different location alternatives. Additionally, KEMIRA-M can reflect qualitative and quantitative values of criteria and priorities of decision makers for criteria in solution process at the same time. The increase in the number of alternatives does not create any problems in the evaluation for KEMIRA-M. This also applies to cases where the number of criteria increases. Because KEMIRA-M separates criteria in to sub sets according to their structural similarities. KEMIRA-M categorizes criteria according to their features. In this way, criteria for querying similar information about alternatives can be gathered. This feature is very usable for location selection problem because location selection is a decision process including different criteria in different natures. Each criterion group allows decision makers to evaluate location alternatives from different perspectives." The combination of all these features shows the greatest differences between the KEMIRA-M method and the other MCDM approaches. The rest of the paper is organized as follows: In the second section, explanation of KEMIRA-M Method is given. In the third section, KEMIRA-M application for Warehouse Location Selection is represented. The last section includes conclusions and discussions.

2 Modified Kemeny median ındicator ranks accordance (KEMIRA-M) method

Modified Kemeny Median Indicator Ranks Accordance (KEMIRA-M) allows simultaneous identification of the criteria weights and accomplishes ranking procedure of alternatives [11]. This method is especially efficient when there are separate groups of criteria and the criteria weights must be computed for each group [11].

The decision process is carried out considering both the decision makers' opinions and the qualitative-quantitative values that the alternatives take according to the criteria simultaneously. Additionally, the method is based on the fact that decision makers create a priority order instead of using a scale when determining criteria weight. Final criteria rankings are obtained via aggregating these different priorities of DMs. The combined priority of the criteria is determined to be the least difference between the DMs. According to this order, the decision makers have the flexibility to make different weightings with a total of 1. In addition, the method can show different alternative rankings in which different weights are reflected to DMs. The combination of all these features shows the greatest differences between the KEMIRA-M method and the other MCDM approaches.". Krylovas et al. [38] performed KEMIRA-M for solving specific task of elite selection from security personnel. Krylovas et. al [39] applied KEMIRA-M Method which is an extend version of KEMIRA for the case study of construction site selection for non-hazardous waste incineration plant. Toktaş and Can [40] used KEMIRA-M to rank risk levels of construction worksites in terms of work health and safety. They combined Quality Function Deployment with KEMIRA-M to obtain the ranks of risk criteria based on risk degrees of risk types. They considered two criteria groups as quantitative indicators and precaution indicators related to nine construction worksites. They modeled relations between risk types encountered in worksites and indicators. Delice and Arslan [41] performed KEMIRA-M to select the best drone among seven alternatives according to seven criteria as camera quality, control distance, flight time, weight, cost, aesthetic and usability. They grouped these criteria into two classes as internal criteria group and external criteria group. Toktaş and Can [42] used KEMIRA-M to select the best SM in Ankara, Turkey. They considered two criteria groups as technical and universal design. As seen from the KEMIRA-M literature, KEMIRA-M has been tried to combine different approaches like Entropy, QFD and it has also been used for different decision areas. This shows increasing attention for KEMIRA-M. Additionally, researchers are trying to implement KEMIRA-M for more than two dimensions. KEMIRA-M algorithm consists of the following steps:

Step 1. Determine the criteria, alternatives and form expert group.

Criteria are denoted as $x_i; i = 1, \dots, m$ and $y_j; j = 1, \dots, n$. x_i and y_j form two different criteria groups with different nature such as subjective and objective or internal and external. Alternatives are denoted as $A_k; k = 1, \dots, K$. Experts are shown as $E_s, s = 1, \dots, S$.

Step 2. Categorize the criteria as cost and benefit type.

All criteria in decision process in KEMIRA-M should be transformed into benefit type [43]. The benefit type criteria are always wanted to have higher values. If the value of the criterion for an alternative is higher, this means that the respective alternative has the better performance for this criterion than the other alternatives. If criterion x_i is cost type criterion, the value of this criterion is transformed into the benefit type criterion by implementing $\frac{1}{x_i}$ [43]. This conversion is also applied for y_j.

Step 3. Form the initial decision matrix.

Initial decision matrix is indicated as $[D]$. The elements of $[D]$ consist of $x_i^{(k)}$ and $y_j^{(k)}$as in Eq. (1).

$$D=\begin{bmatrix} x_1^{(1)} \dots x_1^{(1)} \dots x_m^{(1)} & y_1^{(1)} \dots y_1^{(1)} \dots y_n^{(1)} \\ \dots \quad \dots & \dots \quad \dots \\ x_1^{(i)} \dots x_1^{(i)} \dots x_m^{(i)} & y_1^{(i)} \dots y_1^{(i)} \dots y_n^{(i)} \\ \dots \quad \dots & \dots \quad \dots \\ x_1^{(K)} \dots x_1^{(K)} \dots x_m^{(K)} & y_1^{(K)} \dots y_1^{(K)} \dots y_n^{(K)} \end{bmatrix} \tag{1}$$

where;

$x_i^{(k)}$ is the ith criterion value in the first criterion group for the kth alternative.

$y_j^{(k)}$ is the jth criterion value in the second criterion group for the kth alternative.

Step 4. Normalize initial decision matrix.

Criteria values in $[D]$ are normalized according to the Eq. (2).

$$x_i^{(k)*} = \frac{x_i^{(k)} - x_{min}^{(k)}}{x_{max}^{(k)} - x_{min}^{(k)}}, \quad y_j^{(k)*} = \frac{y_j^{(k)} - y_{min}^{(k)}}{y_{max}^{(k)} - y_{min}^{(k)}} \tag{2}$$

where;

$x_i^{(k)*}$ is the normalized value of ith criterion in the first criterion group for the kth alternative.

$y_j^{(k)*}$ is the normalized value of jth criterion in the second criterion group for the kth alternative.

$x_{min}^{(k)}$ is the criterion value which is minimum in the first criterion group for all alternatives.

$y_{min}^{(k)}$ is the criterion value which is minimum in the second criterion group for all alternatives.

$x_{max}^{(k)}$ is the criterion value which is maximum in the first criterion group for all alternatives.

$y_{max}^{(k)}$ is the criterion value which is maximum in the second criterion group for all alternatives.

Before normalization process, all cost type criteria should be turned into benefit type criteria as $1/x_i^{(k)}$ and $1/y_j^{(k)}$ respectively.

Step 5. Determine the priority of criteria for each expert.

Each expert ($E_s, s = 1, \dots, S$) prioritizes criteria in the first and second group independently and separately as in Table 1.

If a criterion in any of two groups is assigned a value as "1", it means that it is the most important criterion among the others in the same group. The rank of ith criterion in the first group determined by sth expert is denoted as $(x_i)_r^s$ providing $(x_i)_r^s \epsilon \{1,2,\dots,m\}$. The rank of jth criterion in the second group determined by sth expert is denoted as $(y_j)_r^s$ providing $(y_j)_r^s \epsilon \{1,2,\dots,n\}$.

Table 1: Priorities established by experts for the first and second group criteria.

E_s	x_1	⋯	x_i	⋯	x_I	y_1	⋯	y_j	⋯	y_J
1	$(x_1)_r^1$	⋯	$(x_i)_r^1$	⋯	$(x_I)_r^1$	$(y_1)_r^1$	⋯	$(y_j)_r^1$	⋯	$(y_J)_r^1$
…	…	…	…	…	…	…	…	…	…	…
s	$(x_1)_r^s$	⋯	$(x_i)_r^s$	⋯	$(x_I)_r^s$	$(y_1)_r^s$	⋯	$(y_j)_r^s$	⋯	$(y_J)_r^s$
…	…	…	…	…	…	…	…	…	…	…
S	$(x_1)_r^S$	⋯	$(x_i)_r^S$	⋯	$(x_I)_r^S$	$(y_1)_r^S$	⋯	$(y_j)_r^S$	⋯	$(y_J)_r^S$

Step 6. Form the priority matrix for each expert for each criterion.

$x_{(i)}^s$ defines the ith importance order of x_i for sth expert. For expert s, $x_{(1)}^s$ shows the most important criterion among $x_i, i = 1,2,\dots,m$ and $x_{(m)}^s$ represents the least important criterion among $x_i, i = 1,2,\dots,m$. Then, $x_{(1)}^s \succ x_{(2)}^s \succ \dots \succ x_{(i)}^s \succ \dots \succ x_{(m)}^s$ presents the priorities of x_i (first criteria group) determined by sth expert.

The elements of priority matrix $[P_X^S]_{m\times m}$ for the first criteria group for each expert are denoted as $(p_{it})^s, i = 1,2,\dots,m, t = 1,2,\dots,m$. $(p_{it})^s$ given in Eq.(3) defines the priority of ith criterion in the first group according to tth criterion in the first group for sth expert.

$$(p_{it})^s = \begin{cases} 0, & if\ x_{(i)}^s \prec x_{(t)}^s \\ 1, & if\ x_{(i)}^s \succ x_{(t)}^s \end{cases} \tag{3}$$

Similarly, the elements of priority matrix $[P_Y^S]_{n\times n}$ for the first criteria group for each decision maker are indicated as $(p_{jz})^s, j = 1,2,\dots,n; z = 1,2,\dots,n$. $(p_{jz})^s$ given in Eq.(4) defines the priority of jth criterion in the second criterion group according to zth criterion in the second criterion group for sth expert.

$$(p_{jz})^s = \begin{cases} 0, & if\ y_{(j)}^s \prec y_{(z)}^s \\ 1, & if\ y_{(j)}^s \succ y_{(z)}^s \end{cases} \tag{4}$$

Step 7. Find the distance between each expert's priority.

Priority distance $\rho_X^s, l = 1,\dots,m$ for each expert for the first criterion group $X = \{x_1, x_2, \dots, x_i, \dots, x_m\}$ are computed as in Eq.(5).

$$\rho_X^1 = \sum_{s=1}^{S}\sum_{i=1}^{m}\sum_{t=1}^{m} |(p_{it})^1 - (p_{it})^s|$$
$$\rho_X^2 = \sum_{s=1}^{S}\sum_{i=1}^{m}\sum_{t=1}^{m} |(p_{it})^2 - (p_{it})^s| \vdots \tag{5}$$
$$\rho_X^S = \sum_{s=1}^{S}\sum_{i=1}^{m}\sum_{t=1}^{m} |(p_{it})^S - (p_{it})^s|$$

Then, the minimum value of $\rho_X^s, s = 1,2,\dots,S$ is obtained as in Eq. (6).

$$\rho_X = min\{\rho_X^1, \rho_X^2, \dots, \rho_X^S\} \tag{6}$$

$x^s_{(1)}$ is the most important among $x_i, i = 1, \dots, m$ and $x^s_{(I)}$ is the least important among $x_i, i = 1,2, \dots, m$ for expert sth. s^* is an expert whose priority ranking providing ρ_X is defined as $x^{s^*}_{(1)} \succ x^{s^*}_{(2)} \succ \cdots \succ x^{s^*}_{(I)}$. Then, this priority ranking is named as priority median components for the first criterion group. In the same manner, priority distance $\rho^s_Y, j = 1, \dots, n$ for each expert for the second criterion group $Y = \{y_1, y_2, \dots, y_j, \dots, y_n\}$ is computed as in Eq.(7).

$$\rho_Y^1 = \sum_{s=1}^{S}\sum_{z=1}^{n}\sum_{j=1}^{n}\left|(p_{jz})^1 - (p_{jz})^s\right|$$
$$\rho_Y^2 = \sum_{l=1}^{S}\sum_{z=1}^{n}\sum_{j=1}^{n}\left|(p_{jz})^2 - (p_{jz})^s\right| \quad (7)$$
$$\rho_Y^L = \sum_{s=1}^{S}\sum_{z=1}^{n}\sum_{j=1}^{n}\left|(p_{jz})^S - (p_{jz})^s\right| \vdots$$

Then, the minimum value of $\rho^s_Y, l = 1,2, \dots, S$ is computed as in Eq.(8).

$$\rho_Y = min\{\rho_Y^1, \rho_Y^2, \dots, \rho_Y^L\} \quad (8)$$

$y^s_{(1)}$ is the most important among $y_j, j = 1,2, \dots, n$ and $y^s_{(J)}$ is the least important among $y_j, j = 1,2, \dots, n$ for expert sth. s^* is an expert whose priority ranking providing ρ_Y is defined as $y^{s^*}_{(1)} \succ y^{s^*}_{(2)} \succ \cdots \succ y^{s^*}_{(J)}$. Then, this priority ranking is named as priority median components for the second criterion group.

Step 8. Assign criteria weights according to the median priority components.

Each expert determines criteria weights according to the median priority components for each criterion group. The conditions for weights are given below:

$w_{x_1} + w_{x_2} + w_{x_{3+}} \dots + w_{x_n} = 1, w_{y_1} + w_{y_2} + w_{y_{3+}} \dots + w_{y_4} = 1.$

Step 9. Form the weighted normalized vector of alternatives for each weight set.

The decision on alternatives' rankings is made according to the values of sums of linear combinations $v_x + v_Y$, calculated for each alternative [43]. v_x is the weighted normalized vector of alternatives for the first group criteria. It is obtained via multiplying w_X with the first group criteria part of $[D]$ as in Eq.(9). The element of v_x is represented as $v_X^{(k)};\ k = 1,2, \dots, K$.

$$v_x = \begin{bmatrix} v_X^{(1)} \\ v_X^{(2)} \\ \vdots \\ v_X^{(K)} \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^{m}\left(x_i^{(1)}\right)'.w_{x_i} \\ \sum_{i=1}^{m}\left(x_i^{(2)}\right)'.w_{x_i} \\ \vdots \\ \sum_{i=1}^{m}\left(x_i^{(K)}\right)'.w_{x_i} \end{bmatrix} \quad (9)$$

Weighted normalized vector of alternatives for the second criterion group v_Y is obtained by multiplying w_Y with second criteria group part of $[D]$ as in Eq.(10). The element of v_Y is represented as $v_Y^{(k)}, k = 1,2, \dots, K$.

$$v_Y = \begin{bmatrix} v_Y^{(1)} \\ v_Y^{(2)} \\ \vdots \\ v_Y^{(K)} \end{bmatrix} = \begin{bmatrix} \sum_{j=1}^{n}\left(y_j^{(1)}\right)'.w_{y_j} \\ \sum_{j=1}^{n}\left(y_j^{(2)}\right)'.w_j \\ \vdots \\ \sum_{j=1}^{n}\left(y_j^{(K)}\right)'.w_{y_j} \end{bmatrix} \quad (10)$$

Step 10. Rank the alternatives.

To rank alternatives Eq.(11) and Eq.(12) are implemented.

$$F_{(X,Y)} = \sum_{k=1}^{K}\left|v_X^{(K)} - v_Y^{(K)}\right| \quad (11)$$

$$F_{(X^*,Y^*)} = min\, F_{(X,Y)} \quad (12)$$

Weights satisfying Eq.(12) denoted as $w_x^* = (w_{x_1}^*, \dots, w_{x_m}^*)$ for the first criterion group and $w_y^* = (w_{y_1}^*, \dots, w_{y_n}^*)$ for the second criterion group are used to rank the alternatives. To find the final ranks of the alternatives Eq.(13) is used.

$$S = v_X + v_Y \quad (13)$$

where v_X and v_Y are calculated as in Eq. (9) and Eq. (10) using w_x^* and w_y^*. The elements of S denoted as $s^{(k)}$ are the sum of the weighted normalized values of alternatives $s^{(k)} = v_X{}^{(k)} + v_Y{}^{(k)}, k = 1,2, \dots, K$. The highest value of $s^{(k)}$ shows the best alternative.

3 KEMIRA-M application for warehouse location selection

This study focuses on warehouse location selection problem for an electricity distribution company by using KEMIRA-M. Company where the application was performed has three main warehouses for continuing their logistics activity as seen in Figure 4. They want to open more than one main warehouse to increase customer satisfaction and decrease delivery time and transportation costs. Therefore, they determined 20 alternative warehouse locations for this aim. The 20 possible alternative locations for a new warehouse are presented in Table 2. The implementation steps of KEMIRA-M given in Section 2 were utilized for this problem as below.

Step 1. Determine the criteria, alternatives and form expert group.

To select the best warehouse location, two criteria groups were determined as firm related criterion group and environmental criterion group. Firm related criterion group consists of five criteria as the number of connected OC-MP (x_1), consumption amounts of OC-MP (x_2), investment amounts for 2018 (x_3), OC-MP transportation cost per month (x_4), main warehouses' transportation cost per month (x_5). Environmental criterion group includes six different criteria as population (y_1), distance to the closest main road (y_2), average distance to main supplier (y_3), mobility (y_4), average delivery time (y_5) and land cost (y_6). Among these criteria, mobility is evaluated in a qualitative manner by using 1-5 scale changing between "least mobile and most mobile". 20 numbers of alternative warehouse locations $A_k; k = 1, \dots, 20$ were evaluated according to these criteria. Opinions of five experts $E_s, s = 1, \dots, 5$ are considered for the evaluation. Two warehouse specialists, one planning and logistics team leader, one strategic supply chain team leader and one supply chain manager whose experiences in this sector are average 5-10 years evaluated the priorities of criteria.

Step 2. Categorize the criteria as cost and benefit type.

Number of connected OC-MP (x_1), consumption amounts of OC-MP (x_2), investment amounts of 2018 (x_3), population (y_1) and mobility (y_4) are benefit type criteria and OC-MP transportation cost per month (x_4), main warehouses' transportation costs per month (x_5), distance to the closest main road (y_2), average distance to main supplier (y_3), average delivery time (y_5), land cost (y_6) are cost type criteria.

Step 3. Form the initial decision matrix.

Initial decision matrix $[D]$ is shown in Table 3.

Step 4. Normalize initial decision matrix.

Criteria values in $[D]$ are normalized by using Eq.(2) as seen in Table 4.

Step 5. Determine the priority of criteria for each expert.

Priority rankings for the firm related criteria group and environmental criteria group for each expert are given in Table 5. As seen from Table 6, according to the first expert, first criterion in the firm related criteria group is the most important, fifth criterion in the same group is the least important.

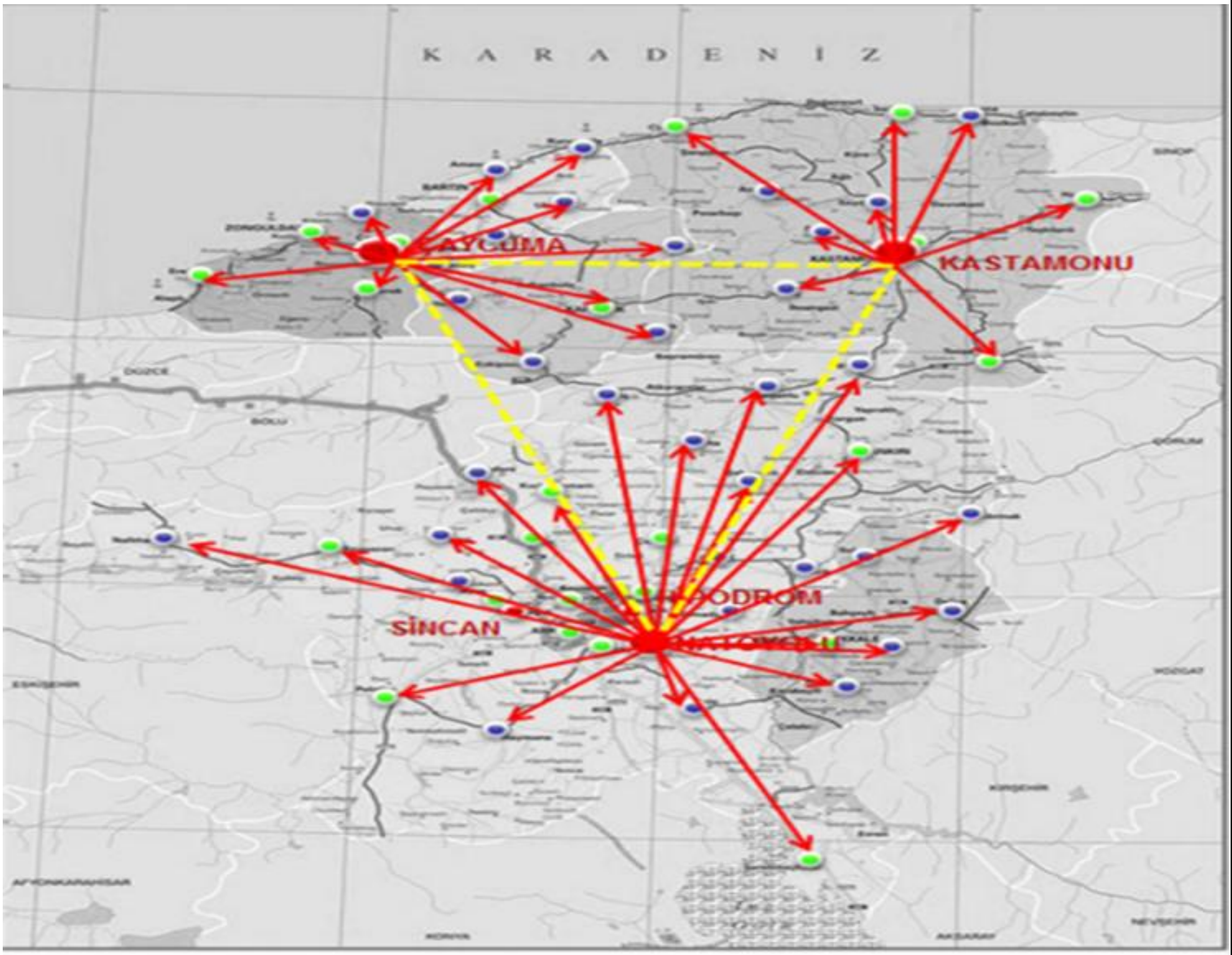

Figure 4: Present logistic network.

Table 2: 20 location alternatives for new warehouse.

A_i $i = 1, \dots, 20$	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
Location	Taşköprü	Tosya	Cide	İnebolu	Çankırı	Zonguldak	Ereğli	Devrek	Karabük	Bartın
A_i $i = 1, \dots, 20$	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}	A_{17}	A_{18}	A_{19}	A_{20}
Location	Çankaya	Beypazarı	Sincan	Kızılcahamam	Kazan	Kırıkkale	Polatlı	Şereflikoçhisar	Çubuk	Gölbaşı

Table 3: Initial decision matrix.

A_k	Firm related criteria group					Environmental criteria group					
	x_1	x_2	x_3	x_4	x_5	y_1	y_2	y_3	y_4	y_5	y_6
A_1	1	2	55	24	600	38171	5	465	5	5	66
A_2	4	13	66	2330	618	40280	2	389	5	43	48
A_3	5	4	108	1524	677	22212	4	484	2	43	110
A_4	4	6	83	1943	738	21716	4	524	4	62	80
A_5	5	12	123	3571	512	95444	7	324	3	49	139
A_6	2	24	251	582	580	126303	11	351	4	30	178
A_7	1	11	82	24	711	175351	14	345	2	5	3
A_8	5	29	143	1731	484	56558	14	329	3	56	65
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
A_{17}	4	17	151	3548	736	124464	5	318	3	64	20
A_{18}	1	3	37	24	932	33599	1	379	3	5	22
A_{19}	9	26	296	2530	547	90063	22	285	5	53	67
A_{20}	5	23	301	2201	587	130363	4	276	5	50	50

Table 4: Normalized criteria values for twenty alternative warehouse locations.

A_k	$x_1^{(k)*}$	$x_2^{(k)*}$	$x_3^{(k)*}$	$x_4^{(k)*}$	$x_5^{(k)*}$	$y_1^{(k)*}$	$y_2^{(k)*}$	$y_3^{(k)*}$	$y_4^{(k)*}$	$y_5^{(k)*}$	$y_6^{(k)*}$
A_1	0.88	0.00	0.05	0.20	0.52	0.02	0.16	0.11	1.00	1.00	0.04
A_2	3.88	0.16	0.07	0.00	0.48	0.02	0.57	0.30	1.00	0.04	0.06
A_3	4.88	0.03	0.16	0.00	0.36	0.00	0.20	0.07	0.25	0.04	0.02
A_4	3.88	0.06	0.11	0.00	0.25	0.00	0.20	0.00	0.75	0.00	0.03
A_5	4.88	0.16	0.19	0.00	0.78	0.08	0.11	0.53	0.50	0.03	0.02
A_6	1.88	0.33	0.46	0.01	0.57	0.12	0.05	0.43	0.75	0.10	0.01
A_7	0.88	0.14	0.11	0.20	0.29	0.17	0.03	0.45	0.25	1.00	1.00
A_8	4.88	0.40	0.23	0.00	0.88	0.04	0.03	0.52	0.50	0.01	0.04
....	....	...	.....	.....	.....	....	...	.....	.....	.....	....
....	....	...	.....	.....	.....	....	...	.....	.....	.....	.....
....	....	...	.....	.....	.....	....	...	.....	.....	.....	.....
A_{17}	3.88	0.22	0.25	0.00	0.25	0.11	0.19	0.56	0.50	0.00	0.15
A_{18}	0.88	0.02	0.01	0.20	0.00	0.01	1.00	0.33	0.50	1.00	0.13
A_{19}	8.88	0.36	0.55	0.00	0.67	0.08	0.00	0.73	1.00	0.02	0.04
A_{20}	4.88	0.31	0.56	0.00	0.56	0.12	0.25	0.78	1.00	0.02	0.06

Table 5: Expert priorities.

E_s	$(x_1)_r^s$	$(x_2)_r^s$	$(x_3)_r^s$	$(x_4)_r^s$	$(x_5)_r^s$	$(y_1)_r^s$	$(y_2)_r^s$	$(y_3)_r^s$	$(y_4)_r^s$	$(y_5)_r^s$	$(y_6)_r^s$
E_1	1	4	3	2	5	1	3	6	5	2	4
E_2	3	4	2	1	5	1	6	2	3	4	5
E_3	2	3	1	4	5	1	2	3	4	5	6
E_4	5	1	4	2	3	3	4	6	2	1	5
E_5	5	1	3	2	4	6	3	4	2	1	5

Table 6: Priority rankings of criteria for each expert.

E_s	$(p_{it})^s$	$(p_{jz})^s$
E_1	$x^1_{(1)} \succ x^1_{(4)} \succ x^1_{(3)} \succ x^1_{(2)} \succ x^1_{(5)}$	$y^1_{(1)} \succ y^1_{(5)} \succ y^1_{(2)} \succ y^1_{(6)} \succ y^1_{(4)} \succ y^1_{(3)}$
E_2	$x^2_{(4)} \succ x^2_{(3)} \succ x^2_{(1)} \succ x^2_{(2)} \succ x^2_{(5)}$	$y^2_{(1)} \succ y^2_{(3)} \succ y^2_{(4)} \succ y^2_{(5)} \succ y^2_{(6)} \succ y^2_{(2)}$
E_3	$x^3_{(3)} \succ x^3_{(1)} \succ x^3_{(2)} \succ x^3_{(4)} \succ x^3_{(5)}$	$y^3_{(1)} \succ y^3_{(2)} \succ y^3_{(3)} \succ y^3_{(4)} \succ y^3_{(5)} \succ y^3_{(6)}$
E_4	$x^4_{(2)} \succ x^4_{(4)} \succ x^4_{(5)} \succ x^4_{(3)} \succ x^4_{(1)}$	$y^4_{(5)} \succ y^4_{(4)} \succ y^4_{(1)} \succ y^4_{(2)} \succ y^4_{(6)} \succ y^4_{(3)}$
E_5	$x^5_{(2)} \succ x^5_{(4)} \succ x^5_{(3)} \succ x^5_{(5)} \succ x^5_{(1)}$	$y^1_{(5)} \succ y^1_{(4)} \succ y^1_{(2)} \succ y^1_{(3)} \succ y^1_{(6)} \succ y^1_{(1)}$

Priority matrix for each expert for the firm related criteria group is formed according to the rankings given in Table 6 as seen in Eq. (14), (15), (16), (17), (18) as an example. Same matrices are established for the environmental criteria group.

$$[P_X^1]_{5\times5} = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (14)$$

$$[P_X^2]_{5\times5} = \begin{bmatrix} 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (15)$$

$$[P_X^3]_{5\times5} = \begin{bmatrix} 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (16)$$

$$[P_X^4]_{5\times5} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 \end{bmatrix} \quad (17)$$

$$[P_X^5]_{5\times5} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (18)$$

Step 6. Form the priority matrix for each expert for each criterion.

The priority matrix for each expert is given in Table 6. For example, for the first expert (E_1), x_1 is at the first rank, x_4 is at the second rank, x_3 is at the third rank, x_2 is at the fourth rank and x_5 is at the fifth rank. Ranking of environmental criteria group can be interpreted in a same manner.

Step 7. Find the distance between each expert's priority.

Priority distance for each expert for the firm related criteria group are computed as in Eq.(6) and ρ_X^1 is given in Eq.(19) as an example.

$$\rho_X^1 = \sum_{s=1}^{5}\sum_{i=1}^{6}\sum_{t=1}^{6} |(p_{it})^1 - (p_{it})^s| = 5 \quad (19)$$

Since, the second expert provides the minimum value obtained as in Eq.(6) ($\rho_X = 28$), the priority ranking of the second expert is accepted as the priority median component for the firm related criteria group as $x_4 \succ x_3 \succ x_1 \succ x_2 \succ x_5$. Additionally, fourth expert provides the minimum value obtained as in Eq.(8) ($\rho_Y = 50$). Therefore, the priority ranking of the fourth expert is accepted as the priority median component for environmental criteria group as $y_5 \succ y_4 \succ y_1 \succ y_2 \succ y_6 \succ y_3$.

Step 8. Assign criteria weights according to the median priority components.

Each expert determines weights of criteria according to the median priority component for each criterion group satisfying median priority ranking and $w_{x_1} + w_{x_2} + w_{x_{3+}} \dots + w_{x_n} = 1$, $w_{y_1} + w_{y_2} + w_{y_{3+}} \dots + w_{y_4} = 1$.

There are 25 weight combinations satisfying condition $w_{x4} \geq w_{x3} \geq w_{x1} \geq w_{x2} \geq w_{x5}$ and 25 weight combinations satisfying condition $w_{y5} \geq w_{y4} \geq w_{y1} \geq w_{y2} \geq w_{y6} \geq w_{y3}$. These weights are presented in Table 7 for firm related criteria group and Table 8 for environmental criteria group. Weight combinations are determined by the authors randomly.

Step 9. Form the weighted normalized vector of alternatives for each weight set.

Weighted normalized vector of alternatives for the firm related criteria group v_X and for environmental criteria group v_Y are obtained using Eq.(9) and Eq.(10) as in Table 9 and Table 10 respectively.

Step 10. Rank the alternatives.

Totally, 625 (25×25) cases were evaluated in terms of $s^{(k)}$ values. As seen in Table 11, $s^{(k)}$ gains its minimum value as 2.77. This value was obtained from the fifth column of X criteria, eleventh row of Y criteria. According to this column and this row, weights are obtained as follows:

$$w_{x1} = 0, w_{x2} = 0, w_{x3} = 0{,}3\,, w_{x4} = 0{,}7\,, w_{x5} = 0$$

$$w_{y1} = 0.1\,, w_{y2} = 0.1\,, w_{y3} = 0\,, w_{y4} = 0.1\,, w_{y5} = 0.6\,, w_{y6} = 0.1$$

Final ranking of the alternatives were obtained as in Table 12. Alternative 11 is the best warehouse location for the electricity distribution company.

As seen from Table 12, ranking order of the alternatives is $A_{11} \succ A_7 \succ A_{18} \succ A_1 \succ A_{20} \succ A_{13} \succ A_6 \succ A_{15} \succ A_{19} \succ A_{12} \succ A_{14} \succ A_9 \succ A_2 \succ A_{10} \succ A_{16} \succ A_{17} \succ A_5 \succ A_8 \succ A_4 \succ A_3$.

Table 7: Weight combinations for firm related criteria group according to E_2.

Weight Combination Number	$x_4 \succ x_3 \succ x_1 \succ x_2 \succ x_5$ (second expert's ranking)					
	$w_{x_4} \geq w_{x_3} \geq w_{x_1} \geq w_{x_2} \geq w_{x_5}$					
	w_{x_1}	w_{x_2}	w_{x_3}	w_{x_4}	w_{x_5}	Sum
1	0.0	0.0	0.0	1.0	0.0	1.0
2	0.0	0.0	0.1	0.9	0.0	1.0
3	0.1	0.0	0.1	0.8	0.0	1.0
4	0.0	0.0	0.2	0.8	0.0	1.0
5	0.0	0.0	0.3	0.7	0.0	1.0
6	0.1	0.1	0.1	0.7	0.0	1.0
7	0.1	0.0	0.2	0.7	0.0	1.0
...	....	....	....	...	...	...
...	....	....	....	...	...	...
...	....	....	....	...	...	...
...	....	....	....	...	...	...
22	0.2	0.2	0.2	0.4	0.0	1.0
23	0.2	0.1	0.2	0.4	0.1	1.0
24	0.3	0.1	0.3	0.3	0.0	1.0
25	0.2	0.2	0.3	0.3	0.0	1.0

Table 8: Weight combinations for environmental criteria group according to E_4.

Weight Combination Number	$y_5 \succ y_4 \succ y_1 \succ y_2 \succ y_6 \succ y_3$ (fourth expert's ranking)						
	$w_{y_5} \geq w_{y_4} \geq w_{y_1} \geq w_{y_2} \geq w_{y_6} \geq w_{y_3}$						
	w_{y_1}	w_{y_2}	w_{y_3}	w_{y_4}	w_{y_5}	w_{y_6}	Sum
1	0.0	0.0	0.0	1.0	0.0	0.0	1.0
2	0.0	0.0	0.1	0.9	0.0	0.0	1.0
3	0.1	0.0	0.1	0.8	0.0	0.0	1.0
4	0.0	0.0	0.2	0.8	0.0	0.0	1.0
5	0.0	0.0	0.3	0.7	0.0	0.0	1.0
6	0.1	0.1	0.1	0.7	0.0	0.0	1.0
7	0.1	0.0	0.2	0.7	0.0	0.0	1.0
...	....	....	....	...	...	...	...
...	....	....	....	...	...	...	...
...	....	....	....	...	...	...	...
...	....	....	....	...	...	...	...
22	0.2	0.2	0.2	0.4	0.0	0.0	1.0
23	0.2	0.1	0.2	0.4	0.1	0.1	1.0
24	0.3	0.1	0.3	0.3	0.0	0.1	1.0
25	0.2	0.2	0.3	0.3	0.0	0.0	1.0

Table 9: Values of v_x.

	Weight Combination Numbers									
A_k	1	2	3	4	5	...	22	23	24	25
A_1	0.20	0.18	0.25	0,17	0.15	...	0.26	0.32	0.34	0.25
A_2	0.00	0.01	0.40	0,01	0.02	...	0.82	0.85	1.20	0.83
A_3	0.00	0.02	0.50	0.03	0.05	...	1.01	1.05	1.51	1.03
A_4	0.00	0.01	0.40	0.02	0.03	...	0.81	0.83	1.20	0.82
A_5	0.00	0.02	0.51	0.04	0.06	...	1.04	1.11	1.54	1.06
A_6	0.01	0.05	0.24	0.10	0.14	...	0.53	0.56	0.73	0.58
...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
A_{12}	0.00	0.02	0.61	0.05	0.07	...	1.25	1.27	1.85	1.27
A_{13}	0.00	0.06	0.65	0.12	0.17	...	1,39	1.38	1.99	1.45
A_{14}	0.00	0.04	0.73	0.09	0.13	...	1.49	1.57	2.20	1.53
A_{15}	0.00	0.05	0.94	0.10	0.15	...	1,93	1.98	2.84	1.98
A_{16}	0.00	0.03	0.72	0.06	0.08	...	1.49	1.50	2.17	1.52
A_{17}	0.00	0.02	0.41	0.05	0.07	...	0.87	0.87	1.26	0.89
A_{18}	0.20	0.18	0.25	0.16	0.14	...	0.26	0.26	0.33	0.24

Table 9: Continued.

A_k	Weight Combination Numbers								
	1	2	3	4	5	...	22	23	24	25
A_{19}	0.00	0.06	0.94	0.11	0.17	...	1.96	1.99	2.86	2.01
A_{20}	0.00	0.06	0.54	0.11	0.17	...	1.15	1.17	1.66	1.21

Table 10: Values of v_y.

A_k	Weight Combination Numbers									
	1	2	3	4	5	...	22	23	24	25
A_1	1.00	1.00	1.00	0.90	0.82	...	0.71	0.71	0.72	0.64
A_2	0.04	0.14	0.23	0.13	0.19	...	0.32	0.33	0.38	0.33
A_3	0.04	0.06	0.08	0.06	0.07	...	0.09	0.09	0.11	0.11
A_4	0.00	0.08	0.15	0.08	0.10	...	0.23	0.23	0.25	0.19
A_5	0.03	0.07	0.12	0.08	0.09	...	0.18	0.18	0.18	0.15
A_6	0.10	0.16	0.23	0.17	0.16	...	0.30	0.29	0.28	0.22
...	...	...	...	...	...	...	...	...	...	...
A_{12}	0.03	0.13	0.22	0.13	0.17	...	0.32	0.34	0.38	0.31
A_{13}	0.02	0.07	0.11	0.12	0.13	...	0.32	0.27	0.22	0.24
A_{14}	0.03	0.10	0.18	0.10	0.11	...	0.24	0.25	0.26	0.19
A_{15}	0.01	0.11	0.21	0.11	0.13	...	0.32	0.32	0.34	0.25
A_{16}	0.03	0.05	0.07	0.07	0.07	...	0.15	0.15	0.14	0.12
A_{17}	0.00	0.05	0.10	0.06	0.08	...	0.18	0.19	0.19	0.16
A_{18}	1.00	0.95	0.90	0.85	0.85	...	0.55	0.57	0.66	0.70
A_{19}	0.02	0.11	0.21	0.12	0.12	...	0.33	0.33	0.32	0.22
A_{20}	0.02	0.12	0.22	0.13	0.15	...	0.35	0.34	0.35	0.28

Table 11: $s^{(k)}$ values for all possible weights combinations.

Weight combinations y/x	1	2	3	4	5	...	22	23	24	25
1	2.85	2.84	10.79	3.21	3.71	...	20.46	20.99	28.88	20.99
2	3.81	3.38	9.66	3.11	3.29	...	19.30	19.79	27.70	19.83
3	4.76	4.34	8.56	3.96	3.72	...	18.20	18.66	26.60	18.73
4	3.65	3.20	9.26	2.81	2.91	...	18.90	19.39	27.30	19.43
5	3.86	3.42	8.83	2.97	2.86	...	18.47	18.93	26.87	19.00
6	4.60	4.16	8.16	3.77	3.40	...	17.80	18.26	26.20	18.33
7	5.71	5.30	7.57	4.91	4.56	...	17.10	17.55	25.50	17.63
8	6.67	6.26	6.65	5.87	5.49	...	15.99	16.45	24.39	16.52
9	5.55	5.11	7.17	4.73	4.35	...	16.70	17.16	25.10	17.23
10	4.44	3.99	7.76	3.59	3.21	...	17.40	17.86	25.80	17.93
11	3.84	3.40	8.68	2.95	**2.77**	...	18.32	18.78	26.72	18.85
...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
22	5.23	4.79	6.38	4.36	3.98	...	15.90	16.36	24.30	16.43
23	5.37	4.93	6.61	4.52	4.14	...	16.15	16.61	24.55	16.68
24	5.75	5.30	6.56	4.86	4.44	...	16.12	16.58	24.52	16.65
25	4.87	4.42	6.89	3.98	3.54	...	16.53	16.99	24.93	17.06

Table 12: Final ranking of alternatives setting the optimal solution.

A_k	Weights											$v_x^{(k)}$	$v_y^{(k)}$	$v_x^{(k)} + v_y^{(k)}$	Rank
	0	0	0.3	0.7	0	0.1	0.1	0	0.1	0.6	0.1				
	x_1	x_2	x_3	x_4	x_5	y_1	y_2	y_3	y_4	y_5	y_6				
A_{11}	0.88	1.00	1.00	1.00	0.59	1.00	0.28	1.00	0.50	1.00	0.00	1.00	0.78	1.78	1
A_7	0.88	0.14	0.11	0.20	0.29	0.17	0.03	0.45	0.25	1.00	1.00	0.17	0.74	0.92	2
A_{18}	0.88	0.02	0.01	0.20	0.00	0.01	1.00	0.33	0.50	1.00	0.13	0.14	0.76	0.91	3
A_1	0.88	0.00	0.05	0.20	0.52	0.02	0.16	0.11	1.00	1.00	0.04	0.15	0.72	0.88	4
A_{20}	4.88	0.31	0.56	0.00	0.56	0.12	0.25	0.78	1.00	0.02	0.06	0.17	0.16	0.33	5
A_{13}	5.88	0.51	0.58	0.00	0.41	0.56	0.10	0.98	0.50	0.02	0.01	0.17	0.13	0.30	6
A_6	1.88	0.33	0.46	0.01	0.57	0.12	0.05	0.43	0.75	0.10	0.01	0.14	0.15	0.29	7
A_{15}	8.88	0.30	0.50	0.00	0.80	0.03	0.20	0.91	1.00	0.01	0.12	0.15	0.14	0.29	8
A_{19}	8.88	0.36	0.55	0.00	0.67	0.08	0.00	0.73	1.00	0.02	0.04	0.17	0.12	0.29	9
A_{12}	5.88	0.15	0.23	0.00	0.36	0.03	0.45	0.88	1.00	0.03	0.20	0.07	0.19	0.25	10
A_{14}	6.88	0.12	0.43	0.00	0.93	0.00	0.15	0.91	0.75	0.03	0.07	0.13	0.12	0.25	11
A_9	4.88	0.15	0.00	0.00	1.00	0.13	0.61	0.45	1.00	0.06	0.00	0.00	0.21	0.21	12
A_2	3.88	0.16	0.07	0.00	0.48	0.02	0.57	0.30	1.00	0.04	0.06	0.02	0.19	0.21	13
A_{10}	3.88	0.15	0.31	0.00	0.62	0.14	0.53	0.24	0.00	0.03	0.06	0.09	0.09	0.18	14
A_{16}	6.88	0.29	0.27	0.00	0.45	0.20	0.09	0.38	0.25	0.03	0.21	0.08	0.09	0.17	15

Table 12: Continued.

A_k	Weights											$v_X^{(k)}$	$v_y^{(k)}$	$v_x^{(k)}+v_y^{(k)}$	Rank
	0	0	0.3	0.7	0	0.1	0.1	0	0.1	0.6	0.1				
	x_1	x_2	x_3	x_4	x_5	y_1	y_2	y_3	y_4	y_5	y_6				
A_{17}	3.88	0.22	0.25	0.00	0.25	0.11	0.19	0.56	0.50	0.00	0.15	0.07	0.09	0.17	16
A_5	4.88	0.16	0.19	0.00	0.78	0.08	0.11	0.53	0.50	0.03	0.02	0.06	0.09	0.14	17
A_8	4.88	0.40	0.23	0.00	0.88	0.04	0.03	0.52	0.50	0.01	0.04	0.07	0.07	0.14	18
A_4	3.88	0.06	0.11	0.00	0.25	0.00	0.20	0.00	0.75	0.00	0.03	0.03	0.10	0.13	19
A_3	4.88	0.03	0.16	0.00	0.36	0.00	0.20	0.07	0.25	0.04	0.02	0.05	0.07	0.12	20

4 Conclusion and discussion

Warehouse location is very significance issue for Electricity Distribution Companies, because energy is indispensable for a city. Materials which maintain the electricity grid are stored at this warehouse.

In this study, a new approach for Electricity Distribution Companies based on KEMIRA-M is proposed for warehouse location selection. KEMIRA-M is a powerful tool when alternatives are evaluated by two groups of criteria (or more) having different origin. There are 20 alternative warehouse locations which are determined by Electricity Distribution Company. According to the two groups (5 Firm Related and 6 Environmental factors) of evaluation criteria, the best alternative was determined as A_{11}. This alternative is Çankaya region where has large population, high consumption of material, high investment amounts. This result is eligible for the expert group.

Warehouse location is very significance issue for Electricity Distribution Companies, because energy is indispensable for a city. Materials which maintain the electricity grid are stored at this warehouse.

Çankaya contains the most important region in area of electricity distribution company activity territory.

It is the center of Ankara which is the capital city of the Republic of Turkey. It is also more crowded and developing part of the region. Moreover, Presidential Complex is also located in this region. Due to the reasons mentioned, continuous energy is a significant part of the electricity distribution service. In order to provide this, to establish a new electricity material warehouse location is necessary for this.

It is seen that KEMIRA-M is convenient for location selection problems. There is no restriction related to the numbers of criteria and alternatives in this method. Additionally, decision is not only based on experts' own opinions but also criteria' quantitative and qualitative values for alternatives. Moreover, it provides decision makers ranking flexibility.

For the future studies, subjectivity in weighting procedure of KEMIRA-M may be improved. This weighting procedure can be performed in a more systematic way. Rules for assigning weights can be advanced. Additionally, KEMIRA-M can be implemented for different decision areas.

The main limitation of the proposed approach is increasing number of decision makers. If the number of decision makers increase the number of comparisons for criteria rankings is increase and this leads to spend much more time. To overcome this disadvantages, stochastic processes and coding systems may be used.

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