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A Comparative Assesment of Facility Location Problem via fuzzy TOPSIS and fuzzy VIKOR: A Case Study on Security Services

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ABSTRACT

Today, law enforcement and security services are critically important for peace and prosperity of communities. The law enforcement forces serve citizens using security materials. The distribution of security materials is the dominant factor in determining the outcome of law enforcement duties. Failing to supply the required amounts of security materials properly, when and where it is needed, can lead to chaos. In this study, it is aimed to provide a decision support tool that can help to select the most appropriate location of security materials distribution center. The distribution center location problem is a complex multi-criteria problem including both quantitative and qualitative factors which may be in conflict and may also be uncertain. We proposed a comparative analysis that exploits fuzzy TOPSIS and fuzzy VIKOR techniques. Fuzzy weights of the 20 criteria and fuzzy judgments about 4 potential locations of distribution center as alternatives are employed to compute evaluation scores and ranking. Based on the evaluation criteria, Konya has been found the best alternative accourding to both techniques as well.

Keywords: Fuzzy TOPSIS, fuzzy VIKOR, law enforcement.
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1.0 INTRODUCTION AND PROBLEM DESCRIPTION

The facility location problem is also a highly important issue for Law Enforcement Forces (LEF). The LEF units need security materials (SMs) to fight terrorism and perform law enforcement duties. Distribution Center (DC) must be deployed so as to respond to the needs of the LEF units as soon as possible with no interruptions.

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While in times of crisis, conflict and social events, in terms of ensuring the distribution of SMs, only time and amount constraints are effective, during times of stability safety and cost constraints should be taken into consideration.

The SMs management including supply, storage, classification and distribution is being implemented as follows. All supplied SMs are primarily being implemented in the parsing, grouping and classification process in DC. After this stage, the SMs are transported to the LEF units, deployed in 81 cities.

The current DC has been met the requirements of the LEF units for a long time. In recent years, DC location of the LEF, because of the region where intensive construction takes place, is almost nested. This is why, to prevent the possible losses of lives and properties, redeployment of DC is the top priority on the agenda.

Currently, there is no scientific-based decision support system that is established in order to provide scientific decision support for locating the DC in use. In addition, there is no standards or methods for locating the DC in either national or international LEF documents. Aforementioned reasons show that the DC location must be reevaluated according to scientific principles. In this study, a comparative assesment is proposed to select the best DC location, according to the experiences and considerations of experts.

Thus, face to face interviews were carried out with the experts responsible for/with the procurement, storage, planning and distribution processes of SMs in order to determine the criteria affected the location problem and the potential DC locations. It was clarified that only the units deployed in Afyon, Ankara, Konya, and Sivas have large enough building site to construct new DC. And the criteria affecting the DC location problem have been determined. Through the determination process of the evaluation criteria, it is benefited from Erdal (2013)'s study. The evaluation criteria are demonstrated in Table 1.

Table 1: Evaluation criteria.

A. Disaster Risks	**C. Security**	C_{16}. Train Crash
C_1. Earthquake	C_9. Possibility of Attack/Sabotage	**F. Location**
C_2. Flood	C_{10}. Possibility of Air Strike	C_{17}. Proximity to Supply Points
C_3. Avalanche	C_{11}. Population Density	C_{18}. Proximity to Demand Points
C_4. Landslide	**D. Transportation**	C_{19}. Proximity to Extraction and Separation Facility
B. Climatic Risks	C_{12}. Proximity to Freight Station	C_{20}. Proximity to Borderline
C_5. Hail	C_{13}. Proximity to Airport	
C_6. Snow	**E. Accident Risk**	
C_7. Storm	C_{14}. Traffic Accident	
C_8.Thunderbolt	C_{15}. Plane Crash	

The DC must meet the all LEF units' demands in a timely manner, complete and rapidly. In this context, the possibility of damage of DC or transportation infrastructure of the cities where the DC is established, should be minimized.

The disasters and climatic risks, can cause damage of the DC and/or explosion of the SMs as a result of physical damage or can damage the transportation infrastructure. Therefore, it is vital to minimize these risks.

A DC for the continuation of the law enforcement duties and fighting against terrorism, due to critical facilities, is assessed as a priority target. It is not desired to establish DC in the cities which are close to borderline, just because of the closeness to the borderline of the cities are too risky, since they can easily be destroyed during off-border attacks. As the distance of locations to establish the DC to the border line increases, the risk will be decreases.

There are many ways to solve multi-criteria decision-making (MCDM) location problems, such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Vise Kriterijumska Optimizacija I

Kompromisno Resenje (VIKOR), Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Data Envelop Analysis (DEA), ELimination and Choice Expressing Reality (ELECTRE), etc. When making decisions from the available site alternatives, comparing, ranking or picking over all the locations, they all involve uncertainty and imperfect information processing to some extent, such as randomicity, fuzzy, roughness. Zadeh (1965) presented the concept of fuzzy sets, Bellman & Zadeh (1970) presented together with the basic model of fuzzy decision.

In this study, we proposed a comparative fuzzy multi-criteria analysis that exploits fuzzy TOPSIS and fuzzy VIKOR techniques. The proposed methods use fuzzy sets in describing uncertainties in the different criteria involved in selection of DC location. Since some uncertainties involved in the decision process, each related factor is represented by a linguistic variable.

TOPSIS and VIKOR are compromise solutions which are closest to the ideal scheme (Opricovic & Tzeng, 2004).

The fuzzy TOPSIS proposed by Tsao & Chu (2001). The reason behind the selection of fuzzy TOPSIS for analysis is that it considers both positive-ideal and negative-ideal concepts, has good computational efficiency and has the ability to measure the relative performance of each of the potential DC locations in a simple mathematical form and is one of the most popular MCDM methods.

The fuzzy VIKOR proposed by Opricovic & Tzeng (2002). The unique advantage associated with fuzzy VIKOR is that it focuses on ranking and selection from a set of alternatives in the presence of conflicting criteria. Moreover, it also offers a solution that can be accepted by the decision makers since it provides a maximum group utility for the "majority", and a minimum of individual regret for the "opponent". It also introduces the ranking index based on the particular measure of "closeness" to the ideal solution.

Our main contribution is to provide a comparative fuzzy multi-criteria assesment to a real world security service location problem.

The rest of this article is organized as follows: In Section 2: The location problems dealth with fuzzy TOPSIS and fuzzy VIKOR, and also the studies about security materials location problem are reviewed. In Section 3: An overview of the methods, used in this study, is given. The application of the comparative assesment to case study is discussed in Section 4. Finally, In Section 5: The conclusion is given.

2.0 RELATED LITERATURE

Facility location problem has been a well established research area within operations research (OR) and management (Melo, Nickel & Saldanha-Da-Gama, 2009). In the literature, there are a large number of facility location evaluation and selection methods via MCDM methods.

Because of many real world problems' nature of consisting of tangible and intangible criteria that should be taken into consideration together or/and consisting of criteria required to be consult to the experts has led the authors to the MCDM techniques.

Chu (2002) implemented fuzzy-TOPSIS for facility location problem under group decisions. Yong (2006)'s study, in which a new fuzzy TOPSIS was proposed for selecting a plant location under linguistic terms. Onut & Soner (2008) utilized fuzzy TOPSIS for transshipment site selection. A comparison of fuzzy AHP and fuzzy TOPSIS was handled by Ertugrul & Karakasoglu (2008) and implemented in a facility location of a textile company. Another study for the utilization of fuzzy TOPSIS is Wadhwa, Madaan & Chan (2009)'s study in which they coped with a reverse manufacturing chain. Cinar & Ahiska (2010) presented a fuzzy TOPSIS model in order to select the most appropriate city for opening a bank branch. Another study is presented by Verma, Verma & Mahanti (2010). The aim of their study is to select the best location with interval valued intuitionistic fuzzy information in which the information about attribute weights is completely known and the attribute values take the form of interval valued intuitionistic fuzzy numbers.

Boran (2011) presented the integration of intuitionistic fuzzy preference relation aiming to compute weights of criteria and intuitionistic fuzzy TOPSIS method aiming to rank alternatives for dealing with imprecise information on selecting the most preferable facility location. Kavitha & Vijayalakshmi (2010) handled with the selection of call center location using fuzzy VIKOR and fuzzy TOPSIS. Li, Liu & Chen (2011) demonstrated a comprehensive methodology for the selection of logistic center location. The demonstrated methodology consists of fuzzy set clustering method, and TOPSIS. Momeni, Fathi & Kashef (2011) presented a fuzzy VIKOR for plant location selection. Dag & Onder (2013) proposed a AHP-VIKOR methodology for facility location problem for a label company. Applicability of the methods of fuzzy VIKOR and fuzzy TOPSIS for the problem of selecting the appropriate airport location was investigated by Uludag & Deveci (2013).

It is observed that the the most studied topic on SMs has been the distribution network design and the most common solving method has been the simulation.

Just 3 studies (Bell, 2003; Cagrici, 2007; Erdal, 2013) have been determined on SMs facility locating problem. Contrary to our MCDM solution, they used heuristics and exact formulations.

Some authors handled the SMs facility location problem as a sub-problem of distribution network desinging (Gue, 2003; Toyoglu, Karasan & Kara, 2011). Sabuncuoglu & Utku (2002), examined whether the facility location should change, during the evaluating prosess of SMs supply system.

Sahin (2006) developed an optimization model for determining the optimal route of SMs vehicles on road network with two objectives consisting of minimizing the total transportation costs and risks.

Erdal (2013)'s study, to the best of authors' knowledge, is the most comprehensive study on SMs literature. He proposed a model and developed a solution methodology which consist of mixed integer programming (MIP), geographical information systems (GIS) and MCDM methods for solving the SMs distribution network design problem with considering facility locations. The MIP model determines the locations and numbers of the main and the regional depots and unit-depot assignments by taking the cost and risk factors into consideration. The potential depot locations have been determined by spatial queries and analyses using a GIS. The risk coefficients of potential depot locations have been determined through AHP and TOPSIS methods based on expert opinions.

Based on the literature review, it is quite clear that few works were carried out on the facility location of SMs. There is no literature, which uses multi-criteria group decision-making problem in fuzzy environment for the selection of DC location for SMs.

3.0 METHODS

3.01 FUZZY SETS AND TRIANGULAR FUZZY NUMBERS

Fuzzy set theory is a mathematical theory first introduced by Zadeh (1965), designed to model the vagueness or imprecision of human cognitive processes. In this paper, we used triangular fuzzy numbers (TFNs) for fuzzy TOPSIS and fuzzy VIKOR because of ease using of TFNs for the decision-makers to calculate (Giachetti & Young, 1997; Moon & Kang, 2001) and TFNs are useful in promoting representation and information processing in a fuzzy environment (Liang & Wang, 1993; Tang, 2009). Furthermore, it has verified that modeling with TFNs is an effective way for formulating decision problems where the information available is subjective and inaccurate (Kahraman et al., 2004; Chang et al., 2007). In addition, the TFNs best suits the nature of experts' linguistic evaluations, and they are the most utilized in fuzzy MCDM studies (e.g., Ayag & Ozdemir, 2012; Liu, Wu & Li, 2013; Patil & Kant, 2014).

Basic definitions of fuzzy sets, fuzzy numbers and linguistic variables are reviewed from Chen (1996), Cheng & Lin (2002), and Amiri (2010) and given below:

Definition 1. A TFN $\tilde{a}$ can be defined by a triplet (a_1, a_2, a_3). The membership function $\mu_{\tilde{a}}(x)$ defined as:

$$\mu_{\tilde{a}}(x) = \begin{cases} 0 & x < a_1 \\ \dfrac{x - a_1}{a_2 - a_1} & a_1 < x < a_2 \\ \dfrac{x - a_3}{a_2 - a_3} & a_2 < x < a_3 \\ 0 & x > a_3 \end{cases}$$

Definition 2. If $\tilde{a}$ and $\tilde{b}$ were two TFNs that has been presented by the triplet (a_1, a_2, a_3) and (b_1, b_2, b_3), respectively, and then the operational laws of these two TFNs are as below:

$$\tilde{a} + \tilde{b} = (a_1, a_2, a_3)(+)(b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3) \quad (1)$$

$$\tilde{a} - \tilde{b} = (a_1, a_2, a_3)(-)(b_1, b_2, b_3) = (a_1 - b_1, a_2 - b_2, a_3 - b_3) \quad (2)$$

$$\tilde{a} \times \tilde{b} = (a_1, a_2, a_3)(\times)(b_1, b_2, b_3) = (a_1 \times b_1, a_2 \times b_2, a_3 \times b_3) \quad (3)$$

$$\tilde{a} / \tilde{b} = (a_1, a_2, a_3)(/)(b_1, b_2, b_3) = (a_1 / b_1, a_2 / b_2, a_3 / b_3) \quad (4)$$

$$\tilde{a} = (ka_1, ka_2, ka_3) \quad (5)$$

Definition 3. A linguistic variable which present by terms like very low, low, etc. use to describe complex condition (Zadeh, 1974). These linguistic values might also be demonstrated by fuzzy numbers (Amiri, 2010).

Definition 4. The vertex method is used to find out the distance between $\tilde{a}$ and $\tilde{b}$:

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}\left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2\right]} \quad (6)$$

Definition 5. The weighted normalized fuzzy-decision matrix can be obtained from below formula:

$$\tilde{v} = [\tilde{v}_{ij}]_{n \times j}, \qquad i = 1,2,\ldots,n, \quad j = 1,2,\ldots,m \quad (7)$$

$$\tilde{v}_{ij} = \tilde{x}_{ij} \times W_i$$

3.02 THE FUZZY TOPSIS METHOD

In many real world problems, the human preference model is uncertain and decision-makers could be hesitant or unable to assign crisp values for judgments (Chan & Kumar, 2007; Shyur & Shih, 2006) and decision-makers often are interested in interval judgments than pointing out their judgments in crisp values (Amiri, 2010). So, one of the problems of traditional TOPSIS is using crisp values in the evaluation process. Another difficulty for using crisp values is that some criteria are difficult to measure by crisp values, so during the evaluation these criteria usually ignored.

Chen (2000) extended the TOPSIS model to the fuzzy environment. Opricovic & Tzeng (2004) pointed out the TOPSIS did not take account of the relative importance of the distance from each point to positive-ideal and negative-ideal solutions.

Thus, fuzzy TOPSIS is developed to solve ranking problems (Wang & Elhag, 2006; Chen & Tsao, 2008; Onut & Soner, 2008; Buyukozkan, Feyzioglu & Nebol, 2008).

A set of demonstration rating of $A_j = (j = 1,2,\ldots,m)$ concerning to criteria $C_i = (i = 1,2,\ldots,n)$ named $\tilde{x} = (\tilde{x}_{ij}, i = 1,2\ldots,n, \quad j = 1,2,\ldots m)$. A set of importance weights of each criterion $W_i = (i = 1,2,\ldots,n)$. The computational steps of fuzzy TOPSIS method can be summarized as follows:

Step 1: Choose the linguistic values $(x_{ij}, i=1,2...,n, \quad j=1,2,...m)$ for alternatives concerning to criteria. The fuzzy linguistic rating (x_{ij}) keeps the ranges of normalized triangular fuzzy numbers belong to [0, 1]; so, it wouldn't be necessary to normalize.
Step 2: Calculate the weighted normalized fuzzy-decision matrix by Eq. (7).
Step 3: Determine positive-ideal ($FPIS, A^*$) and negative-ideal ($FNIS, A^-$) solutions by the following Eqs. (Ω_b are the sets of benefit criteria and Ω_c are the sets of cost criteria):

$$A^* = \{v_1^*,...,v_i^*\} = \left\{(\max_j v_{ij} | i \in \Omega_b), (\min_j v_{ij} | i \in \Omega_c),\right\} \quad (8)$$

$$A^- = \{v_1^-,...,v_i^-\} = \left\{(\min_j x v_{ij} | i \in \Omega_b), (\max_j v_{ij} | i \in \Omega_c),\right\} \quad (9)$$

Step 4: Compute the distance of each alternative from A^* and A^- by the following Eqs.:

$$D_i^* = \sum_{j=1}^{m} d(\tilde{V}_{ij}, \tilde{V}_i) \qquad i = 1,2,...,n \quad (10)$$

$$D_i^- = \sum_{j=1}^{m} d(\tilde{V}_{ij}, \tilde{V}_i) \qquad i = 1,2,...,n \quad (11)$$

Step 5: Compute similarities to ideal solution:

$$CC_i = \frac{D_i^-}{D_i^- + D_i^*} \quad (12)$$

3.03 THE FUZZY VIKOR METHOD

The VIKOR method was first proposed by Opricovic (1998) for multi-criteria optimization of complex systems with the Serbian name: VIseKriterijumska Optimizacija i Kompromisno Resenje (meaning multi-criteria optimization and compromise solution) (Opricovic & Tzeng, 2002). The VIKOR method is convenient for the selection problems because of its stability and ease of use with cardinal information. Another advantage is that it considers the lowest performance rating with respect to a specified criterion (Tsai, Chou & Leu, 2011). The method focuses on ranking and selecting from a set of alternatives against various, and in most cases conflicting and non-commensurable, decision criteria and determines compromise solutions for a problem. Here, the compromise solution is a feasible solution which is the closest to the ideal, and a compromise means an agreement established by mutual concessions. The obtained compromise solution can be accepted by the decision-makers, because it provides a maximum group utility of the majority and a minimum of the individual regret of the opponent. The compromise solution can be the basis for negotiations containing the decision-makers' preference by criteria weights (Opricovic & Tzeng, 2004).

Opricovic & Tzeng (2007) extended VIKOR in fuzzy environments to solve the problem of uncertainty in expressing the decision-makers' preferences.

The fuzzy VIKOR method can be summarized as the following steps (Opricovic & Tzeng, 2004, 2007; Tzeng, Lin & Opricovic, 2005):

The first two steps are the same with fuzzy TOPSIS, so we initiated the computational steps with third step.

Step 3: Determine the best $(FBV, \tilde{f}_j^*)$ and the worst $(FWV, \tilde{f}_j^-)$ values of all criterion ratings, $j = 1,2,...,n$.

$$\tilde{f}_j^* = \begin{Bmatrix} \max_i x_{ij}, & \text{for benefit criteria} \\ \min_i x_{ij}, & \text{for cost criteria} \end{Bmatrix}, \qquad i = 1,2,\ldots,m \tag{13}$$

$$\tilde{f}_j^- = \begin{Bmatrix} \min_i x_{ij}, & \text{for benefit criteria} \\ \max_i x_{ij}, & \text{for cost criteria} \end{Bmatrix}, \qquad i = 1,2,\ldots,m \tag{14}$$

Step 4: Compute the values $\tilde{S}_i$ and $\tilde{R}_i$, $i = 1,2,\ldots,m$, by the relations

$$\tilde{S}_i = \sum_{j=1}^{n} \frac{w_j(\tilde{f}_j^* - \tilde{x}_{ij})}{\tilde{f}_j^* - \tilde{f}_j^-} \tag{15}$$

$$\tilde{R}_i = \max_j \left(\frac{w_j(\tilde{f}_j^* - \tilde{x}_{ij})}{\tilde{f}_j^* - \tilde{f}_j^-} \right) \tag{16}$$

Step 5: Compute the values $\tilde{Q}_i$, $i = 1,2,\ldots,m$, by the relation

$$\tilde{Q}_i = v \frac{\tilde{S}_i - \tilde{S}^*}{\tilde{S}^- - \tilde{S}^*} + (1-v) \frac{\tilde{R}_i - \tilde{R}^*}{\tilde{R}^- - \tilde{R}^*} \tag{17}$$

where $\tilde{S}^* = \min_i \tilde{S}_i$, $\tilde{S}^- = \max_i \tilde{S}_i$, $\tilde{R}^* = \min_i \tilde{R}_i$, $\tilde{R}^- = \max_i \tilde{R}_i$, and v is introduced as a weight for the strategy of maximum group utility, whereas $1-v$ is the weight of the individual regret. The value of v is set to 0.5 in this study.

Step 6: Rank the alternatives, sorting by the values S, R and Q in decreasing order. The results are three ranking lists.

Step 7: Determine a compromise solution, the alternative $(A^{(1th)})$, which is the best ranked by the measure Q (min.) if the following two conditions are satisfied:

C1. Acceptable advantage: $Q(A^{(2th)}) - (A^{(1th)}) \geq DQ$, where $A^{(2th)}$ is the alternative with second position accourding to the ranking list by Q; $DQ = 1/(m-1)$ $(DQ = 0.25 \ \mathit{if} \ \ m \leq 4)$.

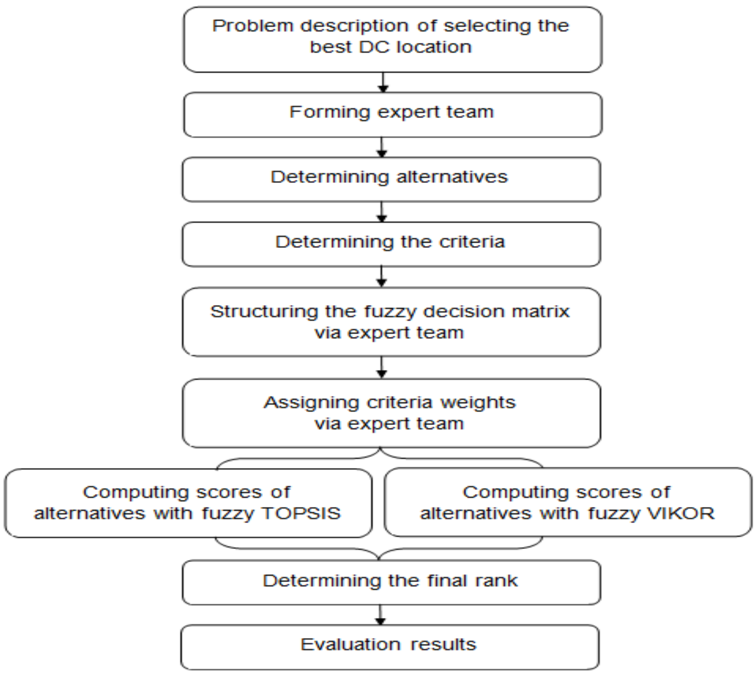
C2. Acceptable stability in decision making: The alternative $A^{(1th)}$ must also be the best ranked by S or/and R. This compromise solution is stable within a decision making process, which could be: "voting by majority rule" (when $v > 0.5$ is needed), or "by consensus" $v \approx 0.5$, or "with veto" ($v < 0.5$).

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of: (a) alternatives $A^{(1th)}$ and $A^{(2th)}$ if only the condition C2 is not satisfied or (b) alternatives $A^{(1th)}$, $A^{(2th)}$,..., $A^{(mth)}$ if the condition C1 is not satisfied; $A^{(mth)}$ is determined by the relation $Q(A^{(mth)}) - Q(A^{(1th)}) < DQ$ for max. m.

4.0 COMPARATIVE ASSESMENT OF SELECTION OF THE MOST APPROPRIATE DISTRIBUTION CENTER LOCATION

In this paper, fuzzy TOPSIS and fuzzy VIKOR have been used to select the best DC location with respect to criteria demonstrated in Table 1. The schematic representation of the proposed comparative analysis is illustrated in Figure 1.

Figure 1: Schematic representation of the proposed comparative analysis.



4.01 IDENTIFICATION OF ALTERNATIVES AND CRITERIA

In the first stage, four cities which are elected as potential DC locations named as A_1 (Afyon), A_2 (Ankara), A_3 (Konya), and A_4 (Sivas), respectively for easy tracking. After determining the alternatives, all 20 evaluation criteria which introduced in the previous section, are determined that can be seen in Table 1 and named $C_1, C_2, \ldots, C_{20}$. Linguistic values have been used for evaluation of potential DC locations and weights of criteria. The membership functions of these linguistic values and the TFNs related with these variables are presented in Table 2.

Table 2: Linguistic variables.

Linguistic variables for the importance weight of each criterion		Linguistic variables for the ratings	
Linguistic variables	**Triangular fuzzy number**	**Linguistic variables**	**Triangular fuzzy number**
Very low	(0, 0, 0.1)	Very low	(0, 0, 1)
Low	(0, 0.1, 0.3)	Low	(0, 1, 3)
Medium low	(0.1, 0.3, 0.5)	Medium low	(1, 3, 5)
Medium	(0.3, 0.5, 0.7)	Medium	(3, 5, 7)
Medium high	(0.5, 0.7, 0.9)	Medium high	(5, 7, 9)
High	(0.7, 0.9, 1)	High	(7, 9, 10)
Very high	(0.9, 1, 1)	Very high	(9, 10, 10)

4.02 THE FUZZY TOPSIS CALCULATIONS

Based on linguistic variables (Table 2.), alternatives with regards to criteria were assessed by experts. They assigned appropriate weights to each criterion. Fuzzy decision averages matrix for potential DC locations was constructed based on expert opinions and their recent experiences. According to the experts opinions "Proximity to Supply Points", "Proximity to Demand Points", and "Possibility of Attack/Sabotage" are the most important evaluation criteria, respectively.

After constructing the fuzzy decision matrix, we compute the fuzzy weighted decision matrix that is depicted in Table 3.

Table 3: Weighted normalized fuzzy-decision matrix.

Alternatives	C1	C2	C3	C4	C5
A1	(0.12,0.32,0.55)	(0.28,0.54,0.81)	(0.03,0.16,0.37)	(0.03,0.16,0.37)	(0.00,0.09,0.30)
A2	(0.35,0.61,0.87)	(0.25,0.49,0.78)	(0.03,0.16,0.37)	(0.02,0.12,0.33)	(0.00,0.07,0.27)
A3	(0.49,0.78,0.97)	(0.42,0.68,0.87)	(0.03,0.16,0.37)	(0.03,0.16,0.37)	(0.00,0.08,0.27)
A4	(0.16,0.38,0.61)	(0.05,0.16,0.38)	(0.02,0.14,0.35)	(0.00,0.04,0.16)	(0.00,0.06,0.25)
	C6	C7	C8	C9	C10
A1	(0.03,0.16,0.37)	(0.00,0.06,0.25)	(0.05,0.20,0.42)	(0.54,0.81,0.97)	(0.32,0.59,0.87)
A2	(0.03,0.17,0.37)	(0.00,0.07,0.27)	(0.05,0.22,0.43)	(0.54,0.81,0.97)	(0.43,0.72,0.93)
A3	(0.02,0.15,0.37)	(0.00,0.07,0.26)	(0.05,0.22,0.43)	(0.59,0.87,1.00)	(0.47,0.74,0.93)
A4	(0.01,0.11,0.31)	(0.00,0.02,0.13)	(0.06,0.23,0.43)	(0.33,0.59,0.83)	(0.32,0.59,0.87)
	C11	C12	C13	C14	C15
A1	(0.35,0.61,0.84)	(0.23,0.47,0.74)	(0.05,0.22,0.43)	(0.23,0.47,0.70)	(0.03,0.16,0.37)
A2	(0.15,0.35,0.61)	(0.26,0.51,0.77)	(0.05,0.21,0.43)	(0.17,0.38,0.65)	(0.02,0.12,0.32)
A3	(0.32,0.58,0.84)	(0.28,0.51,0.74)	(0.05,0.20,0.42)	(0.19,0.42,0.68)	(0.03,0.16,0.37)
A4	(0.38,0.65,0.87)	(0.21,0.43,0.72)	(0.04,0.19,0.42)	(0.19,0.42,0.68)	(0.03,0.16,0.37)
	C16	C17	C18	C19	C20
A1	(0.03,0.16,0.37)	(0.53,0.81,0.97)	(0.43,0.72,0.93)	(0.13,0.33,0.59)	(0.21,0.43,0.68)
A2	(0.02,0.12,0.32)	(0.69,0.93,1.00)	(0.59,0.87,1.00)	(0.19,0.42,0.63)	(0.28,0.53,0.73)
A3	(0.03,0.16,0.37)	(0.64,0.90,1.00)	(0.59,0.87,1.00)	(0.15,0.36,0.61)	(0.31,0.55,0.73)
A4	(0.03,0.16,0.37)	(0.53,0.81,0.97)	(0.59,0.87,1.00)	(0.13,0.33,0.59)	(0.23,0.47,0.71)

This matrix is computed with Eq. (7). After that, we defined the fuzzy positive-ideal solution $(FPIS, A^*)$ and negative-ideal solution $(FNIS, A^-)$ by Eqs. (8) and (9). Only the twentieth criterion is a benefit criterion and the others are cost criteria. So, we defined $(FPIS, A^*)$ and $(FNIS, A^-)$ as $\tilde{v}_i^* = (0,0,0)$ and $\tilde{v}_i^- = (1,1,1)$ for twentieth criterion, and $\tilde{v}_i^* = (1,1,1)$ and $\tilde{v}_i^- = (0,0,0)$ for all the other criteria.

The Euclidean distance of each alternative from A^* and A^- is computed by Eqs. (10) and (11). Subsequently, the similarities to ideal solution are computed by Eq. (12). Consequently, the final ranking of each alternative is obtained and illustrated in Table 4.

Table 4: Final computation results.

Alternatives	D_i^*	D_i^-	CC_i	Ranking
A1	12,949	8,472	0,396	3
A2	12,601	8,789	0,411	2
A3	12,035	9,357	0,437	1
A4	13,494	7,829	0,367	4

4.03 THE FUZZY VIKOR CALCULATIONS

We construct the weighted normalized fuzzy decision matrix in previous section. The determinants of (FBV, f_j^*) and (FWV, f_j^-) are presented in Table 5., based on Eqs. (13) and (14).

Table 5: Fuzzy best value and fuzzy worst value.

FBV and FWV	C1	C2	C3	C4	C5
f_j^*	(7.0,9.0,10.0)	(8.3,9.7,10.0)	(8.3,9.7,10.0)	(7.7,9.3,10.0)	(7.0,9.0,10.0)
f_j^-	(1.7,3.7,5.7)	(1.0,2.3,4.3)	(7.0,8.7,9.7)	(1.0,2.3,4.3)	(4.3,6.3,8.3)
	C6	C7	C8	C9	C10
f_j^*	(9.0,10.0,10.0)	(5.0,7.0,9.0)	(8.3,9.7,10.0)	(7.7,9.3,10.0)	(8.3,9.7,10.0)
f_j^-	(4.3,6.3,8.3)	(1.0,2.3,4.3)	(7.0,8.7,9.7)	(4.3,6.3,8.3)	(5.7,7.7,9.3)
	C11	C12	C13	C14	C15

f_j^*	(7.7,9.3,10.0)	(7.7,9.0,10.0)	(7.7,9.3,10.0)	(7.7,9.3,10.0)	(8.3,9.7,10.0)
f_j^-	(3.0,5.0,7.0)	(5.7,7.7,9.3)	(6.3,8.3,9.7)	(5.7,7.7,9.3)	(5.0,7.0,8.7)
	C16	**C17**	**C18**	**C19**	**C20**
f_j^*	(8.3,9.7,10.0)	(8.3,9.7,10.0)	(7.7,9.3,10.0)	(8.3,9.7,10.0)	(8.3,9.7,10.0)
f_j^-	(5.0,7.0,8.7)	(6.3,8.3,9.7)	(5.7,7.7,9.3)	(5.7,7.7,9.3)	(5.7,7.7,9.3)

By using Eqs. (15) and (16), the values S_i, R_i, S^*, S^-, R^* and R^- can be calculated, and are demonstrated in Tables 6 and 7.

Table 6: S_i and R_i.

	S_i			R_i		
A1	4.189	5.585	6.524	0.833	0.967	1.000
A2	1.945	2.829	3.121	0.500	0.700	0.867
A3	0.893	1.376	1.781	0.278	0.300	0.433
A4	4.521	6.736	8.868	0.833	0.967	1.000

Table 7: S^*, S^-, R^* and R^-.

S^*	0.893	1.376	1.781
S^-	4.521	6.736	8.868
R^*	0.278	0.300	0.433
R^-	0.833	0.967	1.000

With Eq. (17), the Q_i value and can be computed and after defuzzification as demonstrated in Table 8.

Table 8: The rating of Q_i and rank of each alternative.

	$\widetilde{Q}_i$			Q_i	Rank
A1	0,954	0,893	0,835	0,894	3
A2	0,345	0,435	0,477	0,419	2
A3	0,000	0,000	0,000	0,000	1
A4	1,000	1,000	1,000	1,000	4

Consequently, a compromise solution is determined as follows: C1 acceptable advantage by using Eq. $Q(A^{(2th)}) - (A^{(1th)}) \geq DQ$, we can obtain $0.419 - 0.000 \cong 0.42 \geq 0.25$ (C1 Accept) and C2 acceptable stability in decision making. The obtained results are presented in Table 9 (C2 Accept). Both C1 and C2 are acceptable. Therefore, we use Q_i to select the most appropriate alternative A3(Konya) as DC location.

Table 9: Acceptable stability in decision making.

Q_i	A3>A2>A1>A4
S_i	A3>A2>A1>A4
R_i	A3>A2>A1=A4

5.0 RESULTS AND DISCUSSIONS

For the fuzzy TOPSIS, Table 4. demonstrates the closeness index and the rank of potential DC locations. The alternative A_3 is closer to the positive-ideal and farter from negative-ideal solutions. So, as shown in Table 4, A_3 is the most appropriate DC location.

For the fuzzy VIKOR, alternative DC locations are sorted by the values S, R and Q in ascending order, in order to rank the potential DC locations as shown in Table 9. According to Table 9, A_3 and A_2 are the best locations. Considering the compromise conditions C1 and C2, which in our case the alternative A_3 satisfies both. Therefore, A_3 is selected as the most appropriate DC location.

According to the results from Table 4 and 9, Sivas (A_4) is ranked very low, reflecting the need for an alternative DC location. We can conclude that the Konya (A_3) is the most suitable location for the SMs distribution center with respect to both fuzzy TOPSIS and fuzzy VIKOR techniques. It seems that the experts have unanimously agreed that the Konya (A_3) is the most appropriate location alternative.

It is quite evident from the results (rankings of alternative locations) that both ranking algorithms generated the same set of output. Hence it can be concluded that the similarity in their working principle has primarily resulted in same rankings.

Konya (A_3) is selected the most appropriate DC location in both methods. That is why, besides all supply points are very close to this city, Konya has the highest expert score according to the Disaster Risk, Climatic Risks, Possibility of Air Strike, Proximity to Freight Station, Plane Crash, and Proximity to Borderline. The aforementioned reasons make this city the most preferable alternative.

Ankara (A_2) is selected the second most appropriate DC location in both methods. Because of the fact that the most flow is provided between the supply points and DC, Proximity to Supply Points criteria is distinguishing factor affecting the results. However, Ankara (A_2) is the nearest alternative to the supply points. İts capital status quo effects the population density and accidents risks. But, if the importance of "Population Density" or "Accident Risks" criteria can be reduced to an acceptable range, Ankara (A_2) could be the best location alternative.

Although Afyon (A_1) is the third preferable alternative and relatively the least risky alternative, it's location and relative farnest leave this city behind Konya and Ankara.

Sivas (A_4) is selected last preferable alternative. İts relatively farnest location and risky assessments among expert judgements caused this city not to be preferable.

6.0 CONCLUSION

The facility location problem is also a highly important issue for LEF units. The distribution center location problem for SMs is a complex multi-criteria problem including both quantitative and qualitative factors which may be in conflict and may also be uncertain. Fuzzy methods can handle with ambiguities, uncertainties, and vagueness that can not be dealed by crisp values. In other words, using linguistic preferences can be very useful for uncertain situations. For this reason, we proposed a comparative analysis that exploits fuzzy TOPSIS and fuzzy VIKOR techniques. Fuzzy weights of the 20 criteria and fuzzy judgments about 4 potential locations of distribution center as alternatives are employed to compute evaluation scores and ranking. Based on the evaluation criteria, Konya (A_3) has been found the best alternative accourding to the both techniques as well. Doubtlessly, the application of the both fuzzy MCDM techniques was successful to cope with the real-world security service location problem, handled in this study.

For further research, different hierarchical and detailed objectives can be incorporated into the study. Also, mathematical models or meta-heuristics can be combined with the MCDM methods. This study can be extended to the degree that exact locations for DCs to be placed in cities can be determined. In-depth studies can be carried out to any other location problem involving multiple and conflicting criteria with comprehensive criteria.

To decide which method to use, matching techniques with classes of proper problems are crucial. The validation procedures have to be developed, and application feasibility should be explored. The conceptual and operational validation of the application of a technique in real-world problems is indispensable. Authors are challenged to provide a guide for selecting the technique that is both theoretically well founded and practically operational to figure out real-world problems.

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