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Research Article

Fuzzy Entropy Based COPRAS Method in Determining the Investment Priorities of Logistics Centers in Survey and Planning Stage in Turkey

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Abstract

The logistics center is a logistics region that is connected to all kinds of transportation networks, have low-cost, fast, and safe transfer equipment between different transportation modes, and have a direct impact on the country's economy and operational efficiency. Since Turkey is geographically located on logistics routes, the establishment of logistics centers are important in terms of economic development. However, the establishment of logistics centers requires serious costs, and the return of costs takes a long time. In this respect, it is necessary to determine the investment priority of the regions that are candidates for establishing a logistics center. Considering the costs of establishing a logistics center, it is significant to research which logistics center investment priority will be given. In this study, the fuzzy entropy-based COPRAS method was used to determine the order of investment priority, considering 5 logistics centers in the survey and planning stage of Turkish State Railways, and 17 criteria. According to the results, the first four most important criteria in logistics center investment priority are proximity to the port, foreign trade potential, number of transport modes, and proximity to the railway. The investment priority order of logistics centers in Istanbul/Yeşilbayır, İzmir/Çandarlı, Mardin, Zonguldak/Filyos, and Şırnak/Habur.

Keywords: Logistic center, fuzzy entropy, COPRAS, investment priorities, sensitivity analysis

Türkiye’de Etüt ve Planlama Aşamasındaki Lojistik Merkezlerin Yatırım Önceliklerinin Belirlenmesinde Bulanık Entropi Temelli COPRAS yöntemi

Öz

Lojistik merkez, her türlü ulaşım ağına bağlı, farklı ulaşım modları arasında düşük maliyetli, hızlı ve güvenli transfer ekipmanlarına sahip, ülke ekonomisine ve operasyonel verimliliğe doğrudan etki eden lojistik bölgelerdir. Türkiye coğrafik olarak lojistik güzergahlar üzerinde yer aldığından lojistik merkezlerin kurulması ekonomik kalkınma açısından önemlidir. Ancak lojistik merkezlerin kurulması ciddi maliyetler gerektirmekte ve maliyetlerin geri dönüşü uzun zaman almaktadır. Bu doğrultuda lojistik merkez kurmaya aday bölgelerin yatırım önceliğinin belirlenmesi gerekmektedir. Lojistik merkez kurmanın maliyetleri düşünüldüğünde hangi lojistik merkeze yatırım önceliğinin verileceğinin araştırılması önemlidir. Bu çalışmada, Türkiye Cumhuriyeti Devlet Demiryolları’nın etüt ve planlama aşamasında yer alan 5 lojistik merkez ve 17 kriter dikkate alınarak yatırım öncelik sırasının belirlenmesi için bulanık entropi tabanlı COPRAS yöntemi kullanılmıştır. Elde edilen sonuçlara göre, lojistik merkez yatırım önceliğinde en önemli ilk dört kriter limana yakınlık, dış ticaret potansiyeli, taşıma modlarının sayısı ve demiryoluna yakınlıktır. Lojistik merkezlerin yatırım öncelik sıralaması İstanbul/Yeşilbayır, İzmir/Çandarlı, Mardin, Zonguldak/Filyos ve Şırnak/Habur'dur.

Anahtar Kelimeler: Lojistik merkez, bulanık entropi, COPRAS, yatırım öncelikleri, duyarlılık analizi

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1. Introduction

The increase in the level of international trade throughout the world, the globalization of production, the timely delivery of products to the user, and the requirements for good management of transportation, storage, and distribution centers have increased the interest in the logistics sector. Providing goods to reach all over the world with globalization has led to an increase in logistics movements and the emergence of fields such as intermodal transportation, combined transportation, multi-type transportation, warehouse, and stock management, 3PL logistics enterprises, customs, and insurance management. It has revealed that all these services should be provided with quality, fast, integrated, and at the least cost by making use of economies of scale. All these logistics activities and service areas that have emerged to realize this led to the emergence of logistics centers [1].

A logistics center is an area where all activities related to national and international transportation, logistics, and distribution of goods are carried out by various operators. These are the centers where many integrated logistics activities such as transportation, distribution, warehousing, handling, consolidation, separation, customs clearance, export, import and transit operations, infrastructure services, insurance and banking, consultancy, and production, have effective connections to all modes of transportation, are carried out by businesses in a certain area on a commercial basis [1-2]. Logistics centers make a significant contribution to the country's economy by enabling transportation modes to be used more efficiently and by ensuring that the transportation modes are used at the points where they are most economical. By increasing the interaction between logistics centers, highways, and railways, the use of the railway for long-distance transport and the use of the railway for short-distance transportation, and by intensifying the traffic on the railways, reduce noise and environmental pollution and providing relief in terms of freight traffic on the highways. Thus, logistics centers provide an effective competitive advantage in the growth of the region where they are established, increase business volume, reduce carbon emissions, etc. [3-5].

The concept of a logistics center is very popular today and its definitions in some countries are as follows; FreightVillage (England), Transport Center (Denmark), Kombiterminal (Hungary), Interporto (Italy), Terminal Multimodal (Portugal), Güterverkehrzentrum (Germany), Platesforme Logistique, Centres Logistiques de FRET, (France), Inland port, Disicenters, Global Freight Villages (United States), Rail Service Center (RSC) and Tradesports (Netherlands), Dry port (Northern European countries), CentroIntegrado de Mercancias, Zona Activitades Logistica (Spain). In Turkey, the concepts of a logistics village, logistics center, logistics base, freight village, and logistics specialized organized industrial zone are preferred [6], [7]. In this study, the nomenclature "Logistics center" was used.

Logistics centers first came to the fore in Europe as a "freight village" phenomenon in the late 1960s. Turkish State Railways (TSR) "Logistics Centers" project was initiated in line with the understanding of the importance of railway transportation in freight transportation in the transportation system and the plan to gradually shift the weight from highways to railroads [8]. Later, a logistics center was established by the private sector. The total project amount of the logistics centers built by TSR between 2007 and 2023 is 1 785 038 Turkish liras [9]. Logistics centers were established primarily in İstanbul (Halkalı), İzmit (Köseköy), Eskişehir (Hasanbey), Balıkesir (Gökköy), Samsun (Gelemen), Denizli (Kaklık), Mersin (Yenice), Erzurum (Palandöken), Uşak, Konya (Kayacık), Kahramanmaraş (Türkoğlu) ve Kars', where the load carrying potential is intense, in connection with the organized industrial zones. There are 3 ongoing constructions in Sivas, Rize (Iyidere), and Izmir (Kemelpasa); there are logistics centers with 3 completed projects in Bilecik (Bozüyük), Kayseri (Boğazköprü) and Tekirdağ (Çerkezköy). Five surveys and logistics centers with ongoing planning stages have been planned in Istanbul (Yeşilbayır), İzmir (Çandarlı), Zonguldak (Filyos), Mardin, Şırnak (Habur). In this case, it is aimed to reach a total of 23 logistics centers.

There are many different criteria in the selection of the logistics center locations that are functional, environmentally friendly, and in compliance with the legislation. The main factors when choosing the location of the logistics center are the intense logistics flow in the region and the proximity of the region to a wide variety of dense transportation networks. In addition, the suitability of the land and infrastructure, the suitability of its geographical location, the natural structure and current use of the land, its geological structure, the availability of quality transportation, intermodal transportation opportunities, social structure, cultural, historical, and natural assets, current urbanization situation and prospective planning, the economic development of the immediate environment, the annual development of the population, the diversity and number of industries in the region, and demographic factors [10].

The selection of logistics center locations is a decision-making problem that includes many criteria. By using Multi-Criteria Decision-Making Methods (MCDM), the investment priorities of logistics centers can be determined for which the location of the logistics center and the location of the organization are determined. The purpose of using MCDM methods is to keep the decision-making mechanism under control and to obtain the decision result as easily and quickly as possible in case of many situations and alternatives containing both qualitative and quantitative criteria.

The establishment of logistics center locations in Turkey is carried out by both the public and private sectors. Good planning of the logistics centers established in Turkey (functional, size, location, etc.), the establishment of some of them as logistics centers and the establishment of some of them at the scale of the transfer terminal, and the establishment of them without considering the current and future potential needs of the region cause inefficient investments [11]. Considering the input costs of logistics centers, it is seen that they consist of expropriation, excavation, coating, infrastructure, road construction, environment and security area, and superstructure costs. These costs are approximately 181 257 657 US$ for a logistics center of 1

500 000 m^2 [12]. Due to the high input costs, it is important to determine the investment priority of the places determined for the logistics center establishment. In addition, since logistics centers are long-term investments, it is not attractive to invest in the private sector in this area in the first place [7]. In this respect, the decision to establish a logistics center is mostly made by using public capital. When using public capital, it is necessary to decide in which region this capital will be allocated for the logistics center first. In the study, in Turkey, the survey and planning stage are ongoing in Istanbul/Yeşilbayır, İzmir/Çandarlı, Zonguldak/Filyos, Mardin, and Şırnak/Habur logistics centers were evaluated with the fuzzy entropy based COPRAS (COmplex PRoportional ASsessment) method to determine investment priorities under 17 criteria.

Most of the studies for Turkey are on the logistics center installation location selection. This study, it is aimed to determine the investment priority ranking of the logistics centers whose establishment locations have been determined by TSR and which are in the survey and planning stage. The COPRAS method, which has never been used in the literature, was used for the first time in this study in order the alternatives to determine the investment priority. In the following parts of the study, some of the literature review, the explanation of the method, the application, and the conclusion are included.

2. Literature Review

Ballis and Mavrotas (2007) used the PROMETHEE method, which is one of the MCDM methods, to determine the order of preference for three alternative locations nominated for a logistics center to be established in the Thrasio region near Athens [13]. Wang and Lui (2007) used fuzzy AHP and TOPSIS methods to determine the most suitable logistic center using fuzzy triangle numbers [14]. Baohua and Shiwei (2009), focus on the logistics center location and allocation problem under an uncertain environment. To solve the problem in the study, a genetic algorithm has been developed for the stochastic optimization model [15]. Kayıkçı (2010) developed a conceptual model from the combination of AHP and artificial neural networks (ANN) methods to determine the most appropriate logistics center location [16]. Turskis and Zavadskas (2010) developed the ARAS-F method for the selection of the logistics center location [17]. Boile et al., (2011) used a different methodology in the valuation of logistics centers by making use of the Delphi method, which includes both qualitative and quantitative evaluations [18]. Karadeniz and Akpınar (2011) determined the position of Trabzon in national and international transportation, and a new proposal was developed for the establishment of a logistics center in Trabzon [19]. Hong and Xiaohua (2011) used AHP, one of the MCDM methods, to select the logistics center location and conducted a simulation study in Matlab to measure the effectiveness of the model [20]. Notteboom (2011) used MCA (multi-criteria analysis) method for the select three container hub port locations in South Africa [21]. Elgün and Elitaş (2011) applied the model used by Boile et al (2010) to determine the establishment locations of logistics centers in Turkey. Candidates and potential candidates in Turkey's North-

South logistics line were compared with the model they proposed. Ranking of places to be nominated; Mersin, Konya, Bilecik, and Eskişehir [22]. Erkayman et al (2011), using the Fuzzy TOPSIS method, selected the logistics center location of Erzurum, Diyarbakır, and Malatya provinces. Erzurum, Diyarbakır, and Malatya came out as the most suitable ranking [23]. Bayraktutan and Özbilgin (2014), with classical and fuzzy logic methods, evaluated the basis of foreign trade volume, transportation infrastructure, and freight traffic parameters of provinces in Turkey and compared the results [24]. Tomić et al., (2014) used the Greedy Heuristics Algorithm and AHP, one of the MCDM methods, for the selection of the most suitable logistics center located in the Balkan Peninsula [25]. Hamzaçebi et al., (2016) used the MOORA method, one of the MCDM methods, for the selection of the most suitable logistics center located in the Black Sea region [26]. Aydın (2016) compared the performance of three logistic center locations by applying negative fuzzy numbers to the AHP method [11]. Elgün and Aşıkoğlu (2016) used TOPSIS, one of the MCDM methods, to determine the suitability of candidate places to establish logistics centers. They aimed to determine the most suitable center or centers to become a logistics center in Turkey. As the most suitable places to establish logistics centers in Turkey; are found in Mersin, Konya, and Bilecik (Bozüyük) [10]. Karaşan (2016) used the intuitive fuzzy DEMATEL, fuzzy ANP, and fuzzy TOPSIS methods in his study and chose the most suitable logistics center location for Istanbul. He found that the most suitable location was the Pendik-Orhanlı location [27]. Pham et al., (2017) used Fuzzy Delphi TOPSIS to locate a logistics center to be established in Vietnam [28]. Yazdani et al., (2020) used Data Envelopment Analysis (DEA), FUCOM, and CoCoSo methods to determine the priority order of five candidate locations for the logistics center in Spain [29]. Özdemir et al., (2020) evaluated 6 logistics center locations determined by the Turkish state railways with AHP and TOPSIS methods from MCDM methods in line with the criteria determined in the Logistics Master Plan [9]. Shahparvari et al., (2020), to determine the location of a logistics center to be established in the Northwest region of Iran, firstly used GIS to identify potential regions and applied VIKOR and PROMETHEE methods to prioritize these potential regions [30]. Demirkıran and Öztürkoğlu (2020) used the PROMETHEE II method, one of the MCDM methods, in terms of establishing Logistics Centers for 26 regions in Turkey in NUTS-Level 2. Istanbul has emerged as the most suitable region for the logistics center located in all scenarios [31]. Dumlu and Wolff (2021) used the MOORA method, one of the MCDM methods, to determine the efficiency of 11 logistics centers whose construction was completed by the Turkish state railways [32]. Çakmak et al., (2021) proposed a method by combining the Binary Particle Swarm Optimization algorithm and GIS to determine the location of a logistics center to be established in Istanbul [33]. Nong (2021) used ANP and TOPSIS methods to determine the most suitable logistics center located in Dong Nai, Vietnam [34]. Türkmen (2021), using AHP and TOPSIS, tried to determine which of the provinces of İzmir, Samsun, Kocaeli, İstanbul, and Balıkesir would be the most appropriate logistics center. Respectively, Istanbul, Kocaeli, Samsun, Izmir, and Balıkesir came out [35]. Tumenbatur (2021), using AHP and Center Gravity Method, aimed to evaluate which railway line to carry to Europe over Turkey in freight transportation by the Baku-Tbilisi-Kars railway line and to determine a logistics center location to be created on the line. Erzincan and Osmaniye were determined as the most suitable location for the logistics center [36].

Most of the studies for Turkey are on the logistics center installation location selection. This study, it is aimed to determine the investment priority ranking of the logistics centers whose establishment locations have been determined by TSR and which are in the survey and planning stage. The intensity of the input costs of logistics centers; expropriation, excavation, coating, infrastructure, road construction, environmental and safety belt, superstructure, etc. It is predicted that for a logistics center of 1,500,000 m^2, including costs, it will be approximately 181 257 657 US$ [12]. Since the Turkish economy has the status of a developing country, it is not possible to establish all the logistics village centers that are in the survey and planning stage at the same time. In this respect, the main subject of this study is which center should be given investment priority. When the 2nd Revised investment plan of TSR for 2022 is examined, the project amount of 2,662,295,127 TL should be used from 2007 to 2025 under the title of “establishment of logistics and load centers”. It is seen that 205.012.000 TL of this amount is distributed in different amounts to 9 cities (Kars, Sivas, Istanbul, Mardin, Kayseri, Bilecik, Erzurum, Kahramanmaraş, Niğde) [37]. As can be seen in the 2022 investment plan, it has not been possible to allocate a budget to all the logistics centers planned to be built. In this respect, it is important to determine the investment priorities of logistics centers, whose survey and planning work has been completed, to use the limited budget most efficiently.

In studies conducted in this area, the criteria to be considered in determining the investment priority of logistics centers are also important. When the studies in this field are examined, it has been observed that the criteria have been chosen by considering the expert opinion or the criteria used in previous studies. However, in this study, the criteria obtained by Pekkaya and Keleş (2021) [38] by conducting qualitative research were used to determine the criteria considered in the selection of logistics locations, since they were more inclusive and were found because of research. Expert opinion is needed to determine the weights of the criteria discussed. Expert opinions are usually expressed verbally. In the study, Fuzzy Logic was used for the analysis of verbal expressions. The COPRAS method, which has never been used in the literature, was used for the first time in this study in order the alternatives to determine the investment priority. The reasons for the use of the COPRAS method in this study are that it was used first in this field, it is easy to apply and understand compared to other MCDM techniques, and it can evaluate both minimize and maximize criteria. It also compares the decision options with each other and gives a percentage of how good or bad it is from other alternatives [39].

As given in the literature review above, it has been observed that 8 studies are using MCDM techniques related to the determination of logistics center locations in Turkey. These articles are summarized in Table 1.

Table 1. MCDM techniques related to the determination of logistics center locations in Turkey

Author/year	MCDM method	The purpose of the article	Findings
Erkayman et al (2011),[23]	Fuzzy TOPSIS	Erzurum, Diyarbakir, and Malatya provinces are ranked for logistics village location selection.	According to the authors, the logistics center establishment location is Erzurum, Diyarbakır, and Malatya, respectively.
Elgün and Elitaş (2011), [22]	Model proposal	Candidates and potential candidates in Turkey's North-South logistics line were compared with their proposed model.	According to the authors, the most suitable places for the logistics center are Mersin, Konya, Bilecik, and Eskişehir.
Karaşan (2016), [27]	Intuitionistic fuzzy DEMATEL, Fuzzy ANP, and Fuzzy TOPSIS	The most suitable logistics center location in Istanbul has been determined.	According to the author, the most suitable location for the logistics center is the Pendik-Orhanlı location.
Elgün and Aşıkoğlu (2016), [10]	TOPSIS	Determining the most suitable center or centers to be a logistics center in Turkey	According to the authors, the most suitable places for the logistics center are Mersin, Konya, and Bilecik (Bozüyük).
Özdemir et al (2020), [9]	AHS and TOPSIS	Six logistics center investments were evaluated.	According to the authors, the most suitable logistics center locations for investments were Istanbul (Yeşilbayır), Bilecik (Bozüyük), Kayseri (Boğazköprü), Karaman, Mardin, Bitlis (Tatvan).
Demirkıran and Öztürkoğlu (2020), [30]	Promethee II	NUTS 2 levels in Turkey 26 regions were compared for logistics center location selection.	According to the authors, Istanbul was the most suitable region for the logistics center located in all scenarios.
Türkmen (2021), [34]	AHP and TOPSIS	It has been tried to determine which of the provinces of Izmir, Samsun, Kocaeli, Istanbul, and Balıkesir can be the most suitable logistics center.	According to the authors, the most suitable places for the logistics center are İstanbul, Kocaeli, Samsun, İzmir, and Balıkesir.
Tümenbatur (2021), [35]	AHP and Centre Gravity Method	With the Baku-Tbilisi-Kars railway line, freight transport to Europe via Turkey It was evaluated which railway line would be good to transport. In addition, it is aimed to determine a logistics center to be created on the line.	Erzincan and Osmaniye were determined as the most suitable location for the logistics center.

3. Methodology

Multi-Criteria Decision Methods began to be used in the 1960s to help solve decision-making problems. More than one criterion is considered when making a decision. In multi-criteria decision-making, the criteria are primarily weighted, and the priority order of the alternatives is determined according to the weighted criteria. Many methods have been developed in the literature to solve multi-criteria decision-making problems. In this study, COmplex PRoportional ASsessment (COPRAS) method, which was developed in 1996, will be used to determine the investment priority of logistics centers. In the COPRAS method, no method is given to determine the criterion weights. In the study, the fuzzy entropy method was used to determine the criterion weights. The COPRAS method has been used in the literature in the performance ranking of construction companies using financial ratios, in the performance evaluation of Turkish Coal enterprises between 2008-2012, in the performance ranking of the Mechanical Chemistry Institute between 2008-2012, in the evaluation of different learning management systems, in material selection problems, in hotels' performance rankings and in many areas such as evaluating the environmental sustainability of construction projects [39].

3.1. Fuzzy Shanon's entropy based on alpha-level sets

Zadeh (1965) developed the theory of fuzzy sets to be able to express linguistic terms in the decision-making process and eliminate the uncertainty and subjectivity in human decisions and be precise. In the concept of a fuzzy set, membership degrees ranging from *0* to *1* are mentioned. In a fuzzy set, the number *0* indicates that the relevant object is not a member of the set, the number *1* indicates that the relevant object is a full member of the set, and any number between these two values indicates the degree of membership or partial membership of the related object to the set [40-43].

The fuzzy number is expressed as a fuzzy set describing a fuzzy range in the real number R. The range is also a fuzzy set because the boundaries of this range are indefinite. Among the various fuzzy numbers, the most popular is the triangular fuzzy numbers (TFNs) [44]. Generally, the triangular fuzzy number *A* is the number with the starting point *l*, the ending point *u*, and the vertex *m* and is shown as [l, m, u] [41].

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-l}{m-l} & a \le x \le b \\ \frac{u-x}{u-m} & b \le x \le c \\ 0 & other \end{cases} \tag{1}$$

For the fuzzy number equivalent of linguistic expressions, the values given in Table 2 will be used.

Table 2. Linguistic expressions and triangle fuzzy number value [45]

Linguistic Expressions	Triangle Fuzzy number value
very little important	(0.0,0.1,0.3)
less important	(0.1,0.3,0.5)
moderately important	(0.3,0.5,0.7)
too important	(0.5,0.7,0.9)
too much important	(0.7,0.9,1)

The entropy concept, which was firstly proposed by Shanon in 1948 [46], was developed by Wang and Lee as a weighting method in 2009. For α cut sets covering interval data, Lotfi and

Fallahnejad (2010) extended Shannon's application of entropy. The solution of Shannon's fuzzy Entropy based on α-level clusters is calculated with the following steps [47].

Step 1) Fuzzy data $\tilde{x}_{ij}$ comprising the decision matrix which is shown as Equation (2) is transformed into interval data according to different α-level sets.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \dots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \dots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \dots & \tilde{x}_{mn} \end{bmatrix}_{mxn} \quad (2)$$

The α-level set of fuzzy variables $\tilde{x}_{ij}$ can be expressed in the following interval form:

$$\left[(\tilde{x}_{ij})^L_{\propto}, (\tilde{x}_{ij})^R_{\propto}\right] = \left[\min_{x_{ij}}\left\{x_{ij} \in R \middle| \mu_{\tilde{x}_{ij}}(x_{ij}) \geq \propto\right\}, \max_{x_{ij}}\left\{x_{ij} \in R \middle| \mu_{\tilde{x}_{ij}}(x_{ij}) \geq \propto\right\}\right], \qquad 0 < \propto < 1 \quad (3)$$

Fuzzy data are transformed into different α-level sets by setting different levels of confidence, namely 1-α. Then the matrix composed of interval data is obtained as follows:

$$\tilde{B} = \begin{bmatrix} [x^L_{11}, x^R_{11}] & [x^L_{12}, x^R_{12}] & \dots & [x^L_{1n}, x^R_{1n}] \\ [x^L_{21}, x^R_{21}] & [x^L_{22}, x^R_{22}] & \dots & [x^L_{2n}, x^R_{2n}] \\ \vdots & \vdots & \ddots & \vdots \\ [x^L_{m1}, x^R_{m1}] & [x^L_{m2}, x^R_{m2}] & \dots & [x^L_{mn}, x^R_{mn}] \end{bmatrix}_{mxn} \quad (4)$$

Step 2) The normalized values p^L_{ij} and p^R_{ij} are calculated as follows:

$$p^L_{ij} = \frac{x^L_{ij}}{\sum_{j=1}^m x^R_{ij}} \qquad j = 1,2,\dots,m, \quad i = 1,2,\dots n \quad (5)$$

$$p^R_{ij} = \frac{x^L_{ij}}{\sum_{j=1}^m x^R_{ij}} \qquad j = 1,2,\dots,m, \quad i = 1,2,\dots n \quad (6)$$

Step 3) The lower bound e^L_i and upper bound e^R_i of interval entropy are calculated as follows:

$$e^L_i = min\left\{-e_0 \sum_{j=1}^m p^L_{ij} lnp^L_{ij} - e_0 \sum_{j=1}^m p^R_{ij} lnp^R_{ij}\right\}, i = 1,2,\dots,n \quad (7)$$

$$e^R_i = max\left\{-e_0 \sum_{j=1}^m p^L_{ij} lnp^L_{ij} - e_0 \sum_{j=1}^m p^R_{ij} lnp^R_{ij}\right\}, i = 1,2,\dots,n \quad (8)$$

Where e_0 is equal to $(lnm)^{-1}$ and $p^L_{ij}.\, lnp^L_{ij}$ or $p^R_{ij}.\, lnp^R_{ij}$ is equal to 0 if $p^L_{ij} = 0$ or $p^R_{ij} = 0$.

Step 4) The lower bound d^L_i and upper bound d^R_i of interval diversification are computed as follows:

$$d^L_i = 1 - e^R_i \qquad i = 1,2,\dots,n \quad (9)$$

$$d^R_i = 1 - e^L_i \qquad i = 1,2,\dots,n \quad (10)$$

Step 5) The lower bound w^L_i and upper bound w^R_i of interval weight of criterion i are calculated as follows:

$$w^L_i = \frac{d^L_i}{\sum_{s=1}^n d^L_s} \qquad i = 1,2,\dots,n \quad (11)$$

$$w_i^R = \frac{d_i^R}{\sum_{s=1}^{n} d_s^R} \qquad i = 1,2,\ldots,n \qquad (12)$$

Step 6) To calculate the average criterion weight, the arithmetic mean of the lower and upper values is taken.

3.2. COPRAS (COmplex PRoportional ASsessment) Method

The "Complex Proportional Assessment" or COPRAS method was introduced by Zavadskas and Kaklauskas. This method can be applied to maximize or minimize criteria in an assessment where more than one criterion should be considered. The steps of the COPRAS method are as follows [48].

Step 1) Decision matrix $F = [x_{ij}]_{mxn}$ is normalized using Eq. (13).

The normalized decision matrix is denoted by $G = [g_{ij}]_{mxn}$. The purpose of normalization is to obtain different dimensionless values to compare all criteria.

$$g_{ij} = {x_{ij}}\Big/{\sum_{i=1}^{m} x_{ij}} \qquad i = 1,2,\ldots,m; \qquad j = 1,2,\ldots,n \qquad (13)$$

Step 2) The weighted normalized decision matrix $Y = [y_{ij}]_{nxm}$ was determined using Eq. (14).

$$y_{ij} = w_j g_{ij} \qquad i = 1,2,\ldots,m; \qquad j = 1,2,\ldots,n \qquad (14)$$

Where g_{ij} is the normalized value of *i th* alternative according to *j th* criterion.

Step 3) The sums of the weighted normalized values were calculated for both the beneficial and non-benefical criteria. These sums were calculated using Eq. (15) and (16).

$$K_{+i} = \sum_{i=1}^{n} y_{+ij} \qquad (15)$$

$$K_{-i} = \sum_{i=1}^{n} y_{-ij} \qquad (16)$$

where y_{+ij} and y_{-ij} are the weighted normalised values of the beneficial and non-beneficial criteria, respectively. The larger the K_{+j} value and the lower the K_{-j} value, the better the alternative. The values of K_{+j} and K_{-j} indicate the degree of goals reached by each alternative.

Step 4) The significance of the alternatives is determined by defining the characteristics of the positive alternatives K_{+j} and negative alternatives K_{-j}.

Step 5) The relative significance or priorities of the alternativeswere determined. The relative significance value of the *j*th alternative, C_j, was calcu-lated using Eq. (17).

$$C_j = K_{+i}\left(\left(K_{-min}\sum_{i=1}^{m} K_{-i}\right)\Big/\left(K_{-i}\sum_{i=1}^{m}(K_{-min}/K_{-i})\right)\right) \qquad i = 1,2,\ldots,m \qquad (17)$$

where K_{-min} is the minimum value of K_{-i}. C_j is ordered from largest to smallest. The higher the C_i, the greater its relative importance.

Step 6) The degree of utility of an alternative, determining the rank of the alternative, is determined by comparing the priorities of all alternatives for efficiency. It is calculated using Eq. (18).

$$U_i = \left[\frac{C_i}{C_{max}}\right] x100 \qquad (18)$$

where C_{max} is the maximum relative significance value.

4. Application and Findings

In the study, 5 logistics centers in the survey and planning stage of TSR; İstanbul/Yeşilbayır, İzmir/Çandarlı, Zonguldak/Filyos, Mardin, Şırnak/Habur are discussed. These five logistics centers were taken as alternatives and the criteria considered to determine the investment priority of these alternatives were taken from the criteria determined by the benchmarking approach, to be used in the selection of logistics center locations, discussed by Pekkaya and Keleş (2021) [38]. These criteria are shown in Table 3.

Table 3. Criteria considered in determining the investment priority of the logistics center location

Short name	Criteria name	Description	
C1	Foreign trade potential	Total import and export amount in the province (thousand $)	max
C2	Number of companies operating	Number of corporate taxpayers in the province	max
C3	Number of transport modes	Number of transport modes used in the province (Modes: Road, sea, air, rail, oil pipeline)	max
C4	Proximity to the port	Average proximity of the place to the port (km)	min
C5	Proximity to the airway	Average proximity of the place to the port (km)	min
C6	Proximity to the railway	Average proximity of the location to the railway (km)	min
C7	The possibility of expansion of the land	Expansion status of the land in the future (valued from 1 to 5 and weighted for this criterion)	max
C8	Land cost	Land prices per square meter in the province/region (₺/m2)	min
C9	Rivalry	Distance to the nearest logistics village (km)	max
C10	Government incentive	Provincial incentive level	max
C11	Traffic	Traffic density of the province (number of cars/thousand people)	min
C12	Solid waste disposal	The ratio of municipality population to total municipal population (%)	max
C13	Education	Enrollment rate at the secondary level of the province (%)	max
C14	Population density	Number of people per square kilometer in the province	max
C15	Business climate	The unemployment rate in the province (%)	min
C17	Life Quality	GDP per capita ($)	max
C17	Presence of experienced workers	Labor force participation rate (%)	max

Fuzzy entropy was used to determine criterion weights. For the data to be considered in determining the criterion weights with Fuzzy Entropy, 5 experts working in private and public, who are experts in the field of logistics, were consulted. The scale given in Table 1 was used to evaluate the opinions of the experts. In Table 4, the triangular fuzzy number equivalent of expert (Expert, Exp.) opinions are given.

Table 4. Fuzzy evaluation matrix

	Exp1	Exp2	Exp3	Exp4	Exp5
C1	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
C2	(0,0.1,0.3)	(0.1,0.3,0.5)	(0,0.1,0.3)	(0.5,0.7,0.9)	(0.3,0.5,0.7)
C3	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.7,0.9,1)
C4	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
C5	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
C6	(0.7,0.9,1)	(0.7,0.9,1)	(0.3,0.5,0.7)	(0.7,0.9,1)	(0.7,0.9,1)
C7	(0.7,0.9,1)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.1,0.3,0.5)	(0.3,0.5,0.7)
C8	(0.3,0.5,0.7)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.3,0.5,0.7)
C9	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.1,0.3,0.5)	(0,0.1,0.3)	(0,0.1,0.3)
C10	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0,0.1,0.3)	(0.7,0.9,1)	(0,0.1,0.3)
C11	(0.1,0.3,0.5)	(0.7,0.9,1)	(0.1,0.3,0.5)	(0.5,0.7,0.9)	(0.1,0.3,0.5)
C12	(0.1,0.3,0.5)	(0.1,0.3,0.5)	(0,0.1,0.3)	(0.3,0.5,0.7)	(0.1,0.3,0.5)
C13	(0,0.1,0.3)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0.3,0.5,0.7)
C14	(0,0.1,0.3)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0,0.1,0.3)	(0.3,0.5,0.7)
C15	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.1,0.3,0.5)
C16	(0.1,0.3,0.5)	(0.7,0.9,1)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0.1,0.3,0.5)
C17	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0.7,0.9,1)

After the fuzzy decision matrix was created, the normalized interval decision matrix given in Table 4 was obtained by using Equations (3), (4), and (5). The segment set α, A_{α}, consists of members whose memberships are not less than α. α is an arbitrary value and is expressed by Equation (19).

$$A_{\alpha} = \{x \in E | \mu_A(x) \geq \alpha\} \qquad (19)$$

α is a probability value, for example, if α=0.3, it means a set containing 0.3 and higher probability values [49]. In the order of the criteria, the value of α takes a value between 0-1. In studies conducted in the literature, α = 0.5 was generally taken. In the study, the α cutoff value for weighting the criteria/alternatives was handled at three different levels (α=0.1;0.5;0.9) and sensitivity analysis was performed. The lower and upper bound of interval entrophy (e_i^L *and* e_i^R) and interval diversification (d_i^L*and* d_i^R) values are computed and shown in Table 5.

Table 5. The values $e_i^L, e_i^R, d_i^L and\ d_i^R$

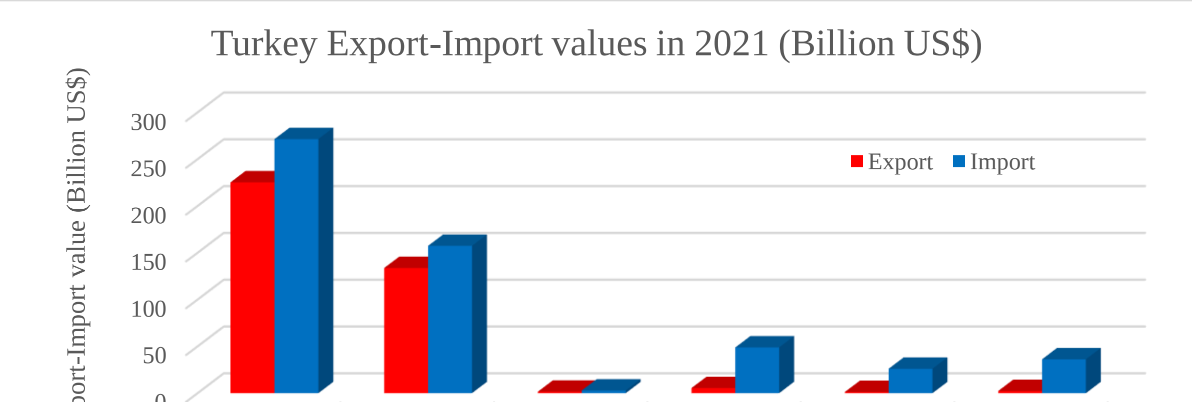
	α=0,1		α=0,5		α=0,9	
	e_i^L, e_i^R	d_i^L, d_i^R	e_i^L, e_i^R	d_i^L, d_i^R	e_i^L, e_i^R	d_i^L, d_i^R
C1	[0.871,1.00]	[0.078,0.17]	[0.932,1.00]	[0.00,0.068]	[0.987,1.00]	[0.00,0.013]
C2	[0.475,0.938]	[0.042,0.16]	[0.655,0.910]	[0.090,0.345]	[0.813,0.870]	[0.13,0.187]
C3	[0.836,0.999]	[0.074,0.17]	[0.911,1.00]	[0.00,0.089]	[0.979,1.00]	[0.00,0.021]
C4	[0.871,1.00]	[0.078,0.17]	[0.932,1.00]	[0.00,0.068]	[0.987,1.00]	[0.00,0.013]
C5	[0.666,0.989]	[0.059,0.17]	[0.812,0.990]	[0.010,0.187]	[0.948,0.980]	[0.020,0.052]
C6	[0.833,0.994]	[0.074,0.17]	[0.906,0.990]	[0.010,0.094]	[0.971,0.990]	[0.010,0.029]
C7	[0.737,0.980]	[0.066,0.17]	[0.842,0.970]	[0.030,0.158]	[0.936,0.960]	[0.040,0.064]
C8	[0.762,0.993]	[0.068,0.17]	[0.866,0.990]	[0.010,0.134]	[0.962,0.990]	[0.010,0.038]
C9	[0.497,0.926]	[0.044,0.16]	[0.660,0.90]	[0.10,0.340]	[0.800,0.850]	[0.150,0.200]
C10	[0.589,.0922]	[0.052,0.16]	[0.708,.0890]	[0.110,0.292]	[0.809,.0850]	[0.150,0.191]
C11	[0.647,.0900]	[0.058,0.16]	[0.881,.0880]	[0.120,0.119]	[0.918,.0920]	[0.080,0.082]
C12	[0.460,0.978]	[0.041,0.17]	[0.687,0.970]	[0.030,0.314]	[0.894,0.950]	[0.050,0.106]
C13	[0.558,.0972]	[0.050,0.17]	[0.735,.0960]	[0.040,0.265]	[0.896,.0940]	[0.060,0.104]
C14	[0.527,0.939]	[0.047,0.16]	[0.629,0.940]	[0.060,0.371]	[0.715,0.940]	[0.060,0.285]
C15	[0.666,0.989]	[0.059,0.17]	[0.813,0.990]	[0.010,0.187]	[0.948,0.990]	[0.020,0.052]
C16	[0.541,0.948]	[0.048,0.16]	[0.703,0.930]	[0.070,0.298]	[0.843,0.890]	[0.110,0.157]
C17	[0.70,0.982]	[0.062,0.17]	[0.824,0.970]	[0.030,0.176]	[0.936,0.960]	[0.040,0.064]

In the last stage, the arithmetic average of the lower and upper entropy values was taken to determine the criterion weights and it is shown in Table 6.

Table 6. Weights of criteria

	Weights				
	α=0,1		**α=0,5**		**α=0,9**
Proximity to the port	0.7997	**Foreign trade potential**	**0.6520**	**Foreign trade potential**	**0.5267**
Foreign trade potential	0.7997	**Proximity to the port**	**0.6510**	**Proximity to the port**	**0.5267**
Number of transport modes	0.7726	**Number of transport modes**	**0.6420**	**Number of transport modes**	**0.5265**
Proximity to the railway	0.7702	**Proximity to the railway**	0.6420	**Proximity to the airway**	0.5258
Land cost	0.7104	Traffic	0.6360	Business climate	0.5258
The possibility of expansion of the land	0.6934	Land cost	0.6190	Proximity to the railway	0.5213
Presence of experienced workers	0.6599	The possibility of expansion of the land	0.6040	Land cost	0.5210
Proximity to the airway	0.6340	Presence of experienced workers	0.5910	The possibility of expansion of the land	0.5156
Business climate	0.6340	Proximity to the airway	0.5880	Presence of experienced workers	0.5156
Traffic	0.6163	Business climate	0.5600	Traffic	0.5102
Government incentive	0.5692	Education	0.5500	Education	0.5097
Education	0.5462	Government incentive	0.5240	Solid waste disposal	0.5095
Life Quality	0.5305	Life Quality	0.5220	Life Quality	0.4784
Population density	0.5180	Solid waste disposal	0.5200	Population density	0.4732
Rivalry	0.4959	Population density	0.5150	Number of companies operating	0.4678
Number of companies operating	0.4756	Number of companies operating	0.5000	Rivalry	0.4625
Solid waste disposal	0.4623	Rivalry	0.5000	Government incentive	0.4578

In the study, the weights of criteria according to three different cut-off levels, at α=0.1, were the first four most important criteria, proximity to the port, foreign trade potential, number of transport modes, and proximity to the railway. The first four most important criteria at α=0.5 were foreign trade potential, proximity to the port, number of transport modes, and proximity to the railway. At α=0.9, the first four most important criteria were foreign trade potential, proximity to the port, number of transport modes, and proximity to the railway. The first four criteria at all three alpha cut levels were proximity to the port, foreign trade potential, number of transport modes, and proximity to the railway. When we look at the literature, Pekkaya, and Keleş (2021) [38], in their study to determine the criteria weights in determining the logistics center location, according to the opinion of 46 experts, "foreign trade potential", "proximity to the port", "market opportunities" and "proximity to the" railway" was found to be the most important criteria. Therefore, it has been seen that the criterion importance order determined in the study is in harmony with the literature. When looking at the distribution of import-export values in Turkey in 2021 by transport modes, the values in Figure 1 are observed.



	Total	Seaway	Railway	Highway	Airline	Other
Export	225	134	2	5	1	2
Import	271	157	3	49	26	36

Figure 1. Column chart of Turkey's import-export values in 2021 according to transport modes [50]

As can be seen in Figure 1, Turkey's import and export values are made by using the seaway, which is one of the transportation modes most frequently. In this case, proximity to the port of the logistics center will increase its efficiency. Logistics centers are places where intermodal transportation is carried out intensively. In Turkey, which is surrounded by seas on four sides, intermodal transportation by using the maritime route and the railroad in the terrestrial part will reduce costs and increase the efficiency of logistics centers. When looking at the importance level of the criteria, the proximity of the logistics center to be established to the sea and railway is important. When looking at the weights of the criteria, the first criterion is the proximity to the port, the second is the foreign trade potential, and then the number of transport modes and proximity to the railway. The criteria in order of weight are different α cutting levels, with little change in the rankings; land cost, the possibility of expansion of the land, presence of experienced workers, proximity to the airway, business climate, traffic, government incentive, education, life quality, population density, rivalry, number of companies operating and solid waste disposal. After determining the criteria weights, the values of 17 criteria for logistics center locations were determined (a decision matrix was created) and given in Table 7, to determine the investment priority of logistics center locations.

Table 7. Values of logistics center locations according to criteria

Criteria Shortname	Criteria	İstanbul/Yeşilbayır (A1)	Zonguldak/Filyos (A2)	İzmir /Çandarlı (A3)	Şırnak/Habur (A4)	Mardin (A5)
C1	Foreign trade potential	236.185.264	2.708.000	22.183.510	764.845	1.608.477
C2	Number of companies operating	950.836	13.564	208.471	7.597	16.581
C3	Number of transport modes	4	4	4	3	4
C4	Proximity to the port	20	5	50	670	480
C5	Proximity to the airway	27	10	100	50	15
C6	Proximity to the railway	20	5	50	180	10
C7	The possibility of expansion of the land	1	1	2	5	5
C8	Land cost	450	1.000	130	50	50
C9	Rivalry	30	280	100	610	420
C10	Government incentive	1	3	1	6	6
C11	Traffic	200	168	195	10	28
C12	Solid waste disposal	100	100	100	97	91
C13	Education	91,26	94,20	91,53	72,52	75,23
C14	Population density	3.048,67	178,48	368,45	76,42	97,97
C15	Business climate	14,70	9,30	17,10	33,50	33,50
C17	Life Quality	15.285	Quality	10.663	5.083	4.804
C17	Presence of experienced workers	52,60	47,20	51,70	39,10	39,10

The data in Table 6 are taken from the websites of TSI (Turkish Statistical Institute), BOTAŞ, TSR, and National Consultancy.

A normalized decision matrix was created by using the created decision matrix Eq. 13. The normalized decision matrix is given in Table 8.

Table 8. The normalized decision matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17
A1	0,897	0,794	0,211	0,016	0,134	0,075	0,071	0,268	0,021	0,059	0,333	0,205	0,215	0,809	0,136	0,361	0,229
A2	0,010	0,011	0,211	0,004	0,050	0,019	0,071	0,595	0,194	0,176	0,280	0,205	0,222	0,047	0,086	0,153	0,205
A3	0,084	0,174	0,211	0,041	0,495	0,189	0,143	0,077	0,069	0,059	0,324	0,205	0,215	0,098	0,158	0,252	0,225
A4	0,003	0,006	0,158	0,547	0,248	0,679	0,357	0,030	0,424	0,353	0,017	0,199	0,171	0,020	0,310	0,120	0,170
A5	0,006	0,014	0,211	0,392	0,074	0,038	0,357	0,030	0,292	0,353	0,047	0,186	0,177	0,026	0,310	0,114	0,170

According to equation 14, the weighted normalized decision matrix is obtained for α=0.1, α=0.5, and α=0.9 levels. It is given in Table 9.

Table 9. The weighted normalized decision matrix

	MAX C1	MAX C2	MAX C3	MİN C4	MİN C5	MİN C6	MAX C7	MİN C8	MAX C9	MİN C10	MİN C11	MAX C12	MAX C13	MAX C14	MİN C15	MAX C17	MAX C17
	α=0,1																
A1	0,7169	0,3777	0,1626	0,0131	0,0847	0,0581	0,0495	0,1903	0,0103	0,0335	0,2051	0,0947	0,1174	0,4189	0,0862	0,1917	0,1511
A2	0,0082	0,0054	0,1626	0,0033	0,0314	0,0145	0,0495	0,4229	0,0964	0,1004	0,1723	0,0947	0,1211	0,0245	0,0545	0,0810	0,1356
A3	0,0673	0,0828	0,1626	0,0326	0,3139	0,1453	0,0991	0,0550	0,0344	0,0335	0,2000	0,0947	0,1177	0,0506	0,1003	0,1337	0,1485
A4	0,0023	0,0030	0,1220	0,4374	0,1569	0,5232	0,2477	0,0211	0,2101	0,2009	0,0103	0,0919	0,0933	0,0105	0,1965	0,0637	0,1123
A5	0,0049	0,0066	0,1626	0,3134	0,0471	0,0291	0,2477	0,0211	0,1446	0,2009	0,0287	0,0862	0,0967	0,0135	0,1965	0,0602	0,1123
	α=0,5																
A1	0,5846	0,3969	0,1351	0,0106	0,0786	0,0484	0,0431	0,1659	0,0104	0,0308	0,2117	0,1066	0,1181	0,4167	0,0762	0,1887	0,1351
A2	0,0067	0,0057	0,1351	0,0027	0,0291	0,0121	0,0431	0,3687	0,0972	0,0925	0,1778	0,1066	0,1219	0,0244	0,0482	0,0798	0,1212
A3	0,0549	0,0870	0,1351	0,0266	0,2911	0,1211	0,0862	0,0479	0,0347	0,0308	0,2064	0,1066	0,1185	0,0504	0,0887	0,1317	0,1328
A4	0,0019	0,0032	0,1014	0,3559	0,1455	0,4360	0,2156	0,0184	0,2117	0,1850	0,0106	0,1034	0,0939	0,0104	0,1737	0,0628	0,1004
A5	0,0040	0,0069	0,1351	0,2550	0,0437	0,0242	0,2156	0,0184	0,1457	0,1850	0,0296	0,0970	0,0974	0,0134	0,1737	0,0593	0,1004
	α=0,9																
A1	0,4722	0,3715	0,1108	0,0086	0,0703	0,0393	0,0368	0,1396	0,0096	0,0269	0,1698	0,1044	0,1095	0,3827	0,0715	0,1729	0,1181
A2	0,0054	0,0053	0,1108	0,0021	0,0260	0,0098	0,0368	0,3101	0,0899	0,0808	0,1426	0,1044	0,1130	0,0224	0,0452	0,0731	0,1059
A3	0,0444	0,0815	0,1108	0,0215	0,2603	0,0984	0,0737	0,0403	0,0321	0,0269	0,1655	0,1044	0,1098	0,0462	0,0832	0,1206	0,1161
A4	0,0015	0,0030	0,0831	0,2881	0,1302	0,3541	0,1841	0,0155	0,1959	0,1616	0,0085	0,1013	0,0870	0,0096	0,1630	0,0575	0,0878
A5	0,0032	0,0065	0,1108	0,2064	0,0390	0,0197	0,1841	0,0155	0,1349	0,1616	0,0238	0,0950	0,0903	0,0123	0,1630	0,0543	0,0878

Using equations 15, 16, and 17, the performance levels of the alternatives (logistics centers) were determined for the three alpha levels.

Table 10. Performance values of alternatives

	α=0,1 K+i	K-i	K-min	K-i-Sum	K-min/K-i	K-min/K-i Sum	Ci	Ui	
İstanbul/Yeşilbayır	2.291	0.671	0.671	4.734	1.000	3.837	3.525	1.000	1

Zonguldak/Filyos	0.779	0.799			0.839		1.815	0.515	4
İzmir /Çandarlı	0.992	0.881			0.762		1.932	0.548	2
Şırnak/Habur	0.957	1.546			0.434		1.492	0.423	5
Mardin	0.935	0.837			0.802		1.925	0.546	3
	α=0.5								
İstanbul/Yeşilbayır	2.372	0.622	0.622	4.221	1.000	3.940	3.443	1.000	1
Zonguldak/Filyos	0.986	0.731			0.851		1.898	0.551	4
İzmir /Çandarlı	1.175	0.813			0.766		1.995	0.580	2
Şırnak/Habur	1.092	1.325			0.470		1.595	0.463	5
Mardin	1.070	0.730			0.853		1.983	0.576	3
	α=0.9								
İstanbul/Yeşilbayır	2.108	0.526	0.526	3.589	1.000	3.914	3.024	1.000	1
Zonguldak/Filyos	0.893	0.617			0.853		1.675	0.554	4
İzmir /Çandarlı	1.059	0.696			0.756		1.752	0.579	2
Şırnak/Habur	0.985	1.121			0.469		1.415	0.468	5
Mardin	0.960	0.629			0.836		1.727	0.571	3

The order of investment priority for the 5 logistics center locations, which are in the survey and planning stage, is the same at all three α levels (Table 10). According to the results, the order of investment priority for logistics center locations was Istanbul/Yeşilbayır, İzmir/Çandarlı, Mardin, Zonguldak/Filyos, and Şırnak/Habur. Istanbul/Yeşilbayır logistics center, which is one of these logistics centers in the survey and planning stage, is planned to have an area of 1 million m^2 and a carrying capacity of 6 million tons. The logistics center to be built in Zonguldak/Filyos is planned to be established with a capacity of 1 million tons of cargo and 25 million tons of cargo [7]. Information about the capacities of the logistics centers to be established in İzmir/Çandarlı and Şırnak/Habur could not be obtained from the literature.

5. Results and Discussion

Turkey is a bridge between Asia and Europe, the Black Sea, and the Mediterranean, and is at the intersection of three continents. Turkey is the distribution and collection (transfer) center for European, Balkans, Black Sea, Caucasus, Caspian, Central Asian, Middle Eastern, and North African countries. Turkey established the first public-owned Samsun/Gelemen logistics center in 2006 to gain the advantage of being on the logistics routes. In addition, logistics centers are planned to be built in 25 different places, and when all of them are opened, it is aimed to gain 12.8 million m^2 open area, stock area, container stock, and handling area with 35.6 million tons of additional transportation [7]. The establishment of these logistics centers is a necessity for Turkey’s economic development in the short, medium, and long term. While determining the priority order of establishment from the logistics centers to be established, it is important to obtain the targeted benefit as soon as possible. The establishment of logistics centers requires serious costs and investment costs are expected to return in a short time. Because, in a feasibility report prepared for the establishment of a logistics center, the payback period of the investment was calculated as 18 years, considering the economic life of 55 years [12]. On the other hand, when the gross domestic product in Turkey is evaluated according to the economic activity codes (A21) at current prices, as the transport and storage logistics sector data, the share of the logistics sector in GDP is 7.9% for 2020. The logistics sector constitutes 10%-12% of the GDP in developed countries [51]. In this respect, a value of 7.9% is a low value for a country that aims to be a logistics epicenter. The establishment of effective logistics centers that will recycle the investment costs in a short time is important for the production and commercial development of the country. According to the research on the subject of logistics, no matter what the job is, logistics costs constitute 10% of the cost of that job [52]. International competition is increasing in the logistics sector as well as in all areas.

In this study, investment priority rankings were determined under 17 criteria determined from the literature in 5 logistics centers that are in the survey and planning stage. The problem of determining the investment priority of the Logistics Center location is in the structure of the decision problem. Such problems with criteria and alternatives can be solved by multi-criteria decision analysis methods. In the study, fuzzy entropy was used to determine the criterion weights, namely the order of importance, and the COPRAS method was used for the investment priority ranking of the alternatives, namely the logistics center locations.

Considering the priority order of 17 criteria, when expert opinions are analyzed according to the fuzzy entropy method, the first four criteria for three alpha levels (α=0.1; 0.5; 0.9) are proximity to the port, foreign trade potential, number of transport modes, proximity to the railway. It is important to establish logistics centers in places close to railways, where foreign trade potential is high, close to the port, where all types of transportation modes are available and accessible, and since railways are more economical than other land transportation modes in terms of transportation costs. Turkey's import and export values are made by using the most common maritime transport modes. In this case, the proximity of the logistics center to the port will increase its efficiency. Logistics centers are places where intermodal transportation is carried out intensively. The realization of intermodal transportation by using the maritime route and the railroad on the land side in Turkey, which is surrounded by seas on all four sides, will provide development in a way that reduces costs and increases the efficiency of logistics centers. When we look at the importance level of the criteria, the proximity of the logistics center to be established to the sea and railway is important. In the ranking of the criteria, the first criterion was the proximity to the port, the second was the foreign trade potential, and then the number of transport modes and proximity to the railway. According to the criteria weights, the criteria in the last four of the 17 criteria are population density, rivalry, number of companies operating, solid waste disposal, and government incentive. When these criteria are examined, it is noteworthy that there are criteria that are mostly related to the environment.

6. Conclusion

It is important to establish logistics centers in places close to railways, where foreign trade potential is high, close to the port, where all types of transportation modes are available and accessible, and since railways are more economical than other land transportation modes in terms of transportation costs. In the ranking of the criteria, the first criterion was the proximity to the port, the second was the foreign trade potential, and then the number of transport modes and proximity to the railway. According to the criteria weights, the criteria in the last four of the 17 criteria are population density, rivalry, number of companies operating, solid waste disposal, and government incentive. When these criteria are examined, it is noteworthy that there are criteria that are mostly related to the environment.

In the selection of the logistics center location, the variables that have a direct relationship with the logistics activities came to the fore, and the weight of the variables that had an indirect relationship was relatively low. When the criteria weights are used to rank the investment priorities of the logistics center locations according to the COPRAS method, in the performance ranking of the three alpha levels of the five logistics centers that have been studied and planned, Istanbul/Yeşilbayır is in the first place, followed by İzmir/Çandarlı, Mardin, Zonguldak/Filyos, Şırnak/Habur. Considering the weights of the criteria, foreign trade potential took place in the first place. According to the result of this evaluation under 17 criteria, Istanbul/Yeşilbayır and İzmir/Çandarlı, which have a considerably higher foreign trade potential compared to other regions and yet are close to the port, took the first two places. Although the main objective is to make all these 5 logistics center locations, whose survey and planning stages have been completed, operational as soon as possible, this is not possible. According to the results of the study in 2023 investment planning of TSR, it is recommended to focus on logistics center locations in Istanbul/Yeşilbayır and İzmir/Çandarlı regions.

The result obtained in the study is a recommendation. The weights of the criteria were determined by taking the opinions of 5 experts in the study. Expert opinions are personal judgments. Suggestions can be developed by increasing the number of expert opinions, consulting different experts, considering different criteria, and using different MCDM methods.

Ethics in Publishing

There are no ethical issues regarding the publication of this study.

Author Contributions

In the study carried out, Ümran ŞENGÜL contributed to the determination of the analysis method of the data, the analysis, the literature review, and the evaluation of the results. Ahmet Bilal ŞENGÜL contributed to the creation of the idea, obtaining the data, evaluating the data and the results, and literature review studies.

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