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Assessment of the Performance of Logistics Villages Operated by the Turkish State Railways Using MCDM and DEA Methods

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ABSTRACT

Increasing competition with globalization brought along the cost problem arising from logistics activities. In this context, logistics villages play an active role in reducing costs. Logistics villages provide significant benefits to users as areas where goods from different modes of transport are transferred, arranged and prepared for transportation, and all logistics-related activities are gathered in one region. Logistics villages have begun to be established by The Turkish State Railways (TSR-Türkiye Cumhuriyeti Devlet Demiryolları) using government resources after 2006 in Turkey. The aim of this study is to assess the logistics performances of the eight logistics villages in operation by analyzing their efficiencies using Multi Criteria Decision Making (MCDM) and Data Envelopment Analysis (DEA) methods. In the study, Entropy-based EDAS, MAUT and MOOSRA methods have been used. The efficiency scores of logistics villages were calculated using output-oriented DEA models. According to CCR and BCC models, İstanbul (Halkalı) and Uşak logistics villages were found to be efficient.

Key Words: Logistics Village, Entropy, MAUT, EDAS, MOOSRA, DEA.

JEL Classification Codes: B23, B27, C67.

1. INTRODUCTION

Tremendously increasing world trade creates an environment where supply chains compete more than companies. Today, the spatial distribution of production and consumption has spread to wider areas (Theo et al., 2017). Although the companies vary according to the content of the product they produce, they supply raw materials from many suppliers located in different geographies. In addition, they have to deliver their products to customers in different locations around the world. They need a network of distributors and retailers to carry out these activities. In this context, a supply chain refers to a network of interconnected businesses from the first point to the end consumer. Logistics is the most important part of the supply chain, and with the effect of globalization, managing the logistics activities demanded by customers has become a very complex and costly process. On the other hand, by the right logistics management, businesses save time and money while providing customer satisfaction (AMCO, 2018).

This change, experienced by globalization has led businesses to seek different solutions in the logistics industry. Because, companies that perform their logistics processes at the lowest cost gain a sustainable competitive advantage. The concept of logistics center or logistics village is a business model that emerged in order to reduce costs and accelerate processes by gathering different logistics activities in one area (Sezen and Gürsev, 2014). These areas which have been very popular in recent years, operate under different names from country to country. Logistics villages are named Freight Village in England, Logistics Centers in the US, Logistics Centers in China, Freight Center in Germany, Logistics Platform or Multimodal Platforms in France, Multimodal Industrial Park in South Korea, and Interport in Italy (Meidute, 2005; Ahi, 2015).

Logistics villages are the areas where logistics and transportation companies and related public institutions are located and have efficient connections to all kinds of transport modes. These areas have the opportunity to perform many logistics activities such as handling, weighing, consolidation, packaging, and maintenance & repair. Materials and equipment required to carry out all these activities are available in these areas (TCDD, 2012). Logistics villages are regions that bring together businesses that offer both

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national and international logistics-related solutions, helping to create coordination, cooperation and synergy between them. At the same time, logistics villages provide the most favorable conditions for the establishment of intermodal transport chains as a hub between transport modes. As a result of this situation, companies provide cost advantages (Baydar et al., 2017).

With the effect of globalization, the historical background of logistics villages, whose importance gradually increased in the 21st century, dates back to the 1960s (Mircetic et al., 2014). The first logistics villages emerged with the development of the industry in the US. On the other hand, it has been suggested to establish logistics villages in order to improve urban logistics in Japan. The traffic problem caused by the increasing population in crowded cities has been tried to be overcome with logistics villages. The first examples of logistics villages in Europe started to be established in Garanor and Sogoris in the France-Paris region. In the 1970s, logistics villages, which attracted the attention of other EU countries, started to be established in Germany and Italy. In those years, logistics villages served as transfer centers, mostly used for road-rail integration. In the 1980s and 1990s, logistics villages started to be adopted much more in Europe and their number gradually increased (Postiguillo et al., 2015).

Logistics village project in Turkey dates back to the early 2000s which is much later than in Europe. In this context, TSR has started to make logistics village investments as of 2006 (Karadeniz and Akpınar, 2013). Logistics villages established by TSR are shown in Figure 1.

Samsun (Gelemen) logistics village, which was activated in 2007, is the first project that is completed in Turkey. After that, İzmit (Köseköy) logistics village started operations in 2010, Uşak logistics village in 2012, Istanbul (Halkalı) logistics village in 2013, Eskişehir (Hasanbey) logistics village in 2014, Balıkesir (Gökköy) logistics village in 2014, Denizli (Kaklık) logistics village in 2014, Kahramanmaraş (Türkoğlu) logistics village in 2017, and Erzurum (Palandöken) logistics village in 2018. When the construction of 21 logistics villages shown in Fig.1 is completed, 35.6 million tons of transportation will be possible annually from the total area of 12.8 million m^2 (Uygun, 2019).

The importance of logistics villages in both global trade and logistics sector is increasing day by day. Turkey is a country with a high potential in terms of logistics sector due to its geographical location. When the literature is reviewed, it is seen that most of the studies focus on the determination of the location of the logistics villages. In this study, the performances of the logistics villages operated by TSR were evaluated using the MCDM and DEA approaches. While ranking the performances of the logistics villages have been conducted using MCDM methods, the DEA method was utilized to find out the relative efficiencies of the logistics villages. In this respect, it is aimed that the study will contribute to the literature. On the other hand, the findings of the study would contribute to the efficiency of the operations of the logistics villages, planned to be established in the future.

The rest of this study is organized as follows: In the subsequent section a brief literature review is given.

Fig. 1: TSR Logistics Villages

Table 1: Literature Review

Recent Studies Conducted by Entropy Method	
Risk assessment for dangerous substance transportation in China	Huang et al. (2021)
Evaluation of development potential of ports in China	Mou et al. (2020)
Assessing the risks of ports' container terminals	Khorram (2020)
Analyzing the impact of regional logistics activities in China	Li (2020)
Planning express freight train service sites in China	Huang et al. (2019)
Recent Studies Conducted by MAUT Method	
Sustainable highway alignment selection for China Pakistan economic corridor	Zafar et al. (2020)
Planning warehouse locations for sustainable disaster logistics in Turkey	Ergün et al. (2020)
Developing a transit system selection model for Thailand	Sirikijpanichkul et al. (2017)
Comparison of transport corridors	Zietsman et al. (2006)
Recent Studies Conducted by EDAS Method	
Choosing a logistics center in Turkey	Özmen and Aydoğan (2020)
Determining the best practice for business balance of passenger rail operator	Veskovic et al. (2020)
Evaluation of the third-party logistics companies in Turkey	Yürüyen and Ulutaş (2020)
Analyzing the logistics performances of OECD member countries	Gök Kısa & Ayçin (2019)
Evaluating the suitability of different transportation methods for mine transfer	Maksimović et al. (2017)
Recent Studies Conducted by MOOSRA Method	
Logistics village location selection	Ulutaş et al. (2018)
Recent Studies Conducted by DEA Method	
Evaluation of the efficiencies of container terminals in India	Iyer and Nanyam (2021)
Evaluation of the efficiencies of the EU ports	Quintano et al. (2020)
Measuring the efficiency of freight transport railway undertakings	Blagojevic et al. (2020)
Examining the efficiencies of airports in Greece	Fragoudaki and Giokas (2020)
Evaluation of the efficiency of Vietnam ports	Kuo et al. (2020)

In section 3, detailed explanations are given about the MCDM and DEA approaches. In section 4, the data are described and the ranking and efficiency analyses are made. Finally, the analysis results were evaluated and suggestions for further studies were presented.

2. LITERATURE REVIEW

When the literature is searched, it is seen that many studies on the logistics sector have been carried out using MCDM and DEA methods. Some studies on Entropy, MAUT (Multi-Attribute Utility Theory), EDAS (Evaluation Based on Distance from Average Solution), MOOSRA (Multi-Objective Optimization on the basis of Simple Ratio Analysis) and DEA methods used in the study are summarized in Table 1.

3. RESEARCH METHODOLOGY

The aim of the study is to evaluate the performance of the logistics villages operated by TSR. In Turkey in 2019, eight logistics villages (İzmit (Köseköy), Uşak, İstanbul (Halkalı), Eskişehir (Hasanbey), Balıkesir (Gökköy), Denizli (Kaklık), Kahramanmaraş (Türkoğlu) ve Erzurum (Palandöken) operated. In order to evaluate the performances of logistics villages, seven criteria have been determined: investment cost, total area, distance to the nearest port, distance to the nearest airport, amount of loaded / unloaded goods, number of incoming / outgoing wagons and total annual income.

MCDM methods consist of the methods in which objective and non-objective factors are evaluated together, as a different way from statistical analysis techniques. Analyzes are made within the framework of expert opinions and the study can be developed by taking the opinion of a single expert or a group of experts (Korucuk, 2021).

Since the 1970s, MCDM research has developed rapidly and many MCDM methods have been developed to measure tangible/intangible conflicting criteria and to make a decision among alternatives according to these criteria (Saaty and Ergu, 2015). In the study, the weights were calculated by using the Entropy and Critic methods, which are among the objective weight determination methods in determining the criterion weights. However, it has been concluded that the weight values calculated using the Entropy method are more appropriate by taking the expert opinion.

In MCDM problems, fuzzy logic arises when more than one option is available to choose the best alternative. Fuzzy MCDM methods are more preferred to be used in solving MCDM problems that include both quantitative and qualitative factors (Aruldoss et al., 2013). Since all of the criteria determined in the study were quantitative, classical MCDM methods were used. Considering the determined criteria, the performances of the logistics villages were ranked using EDAS, MOOSRA and MAUT methods. Then, the relative efficiency scores of the logistics villages were calculated using the DEA method and the results were evaluated.

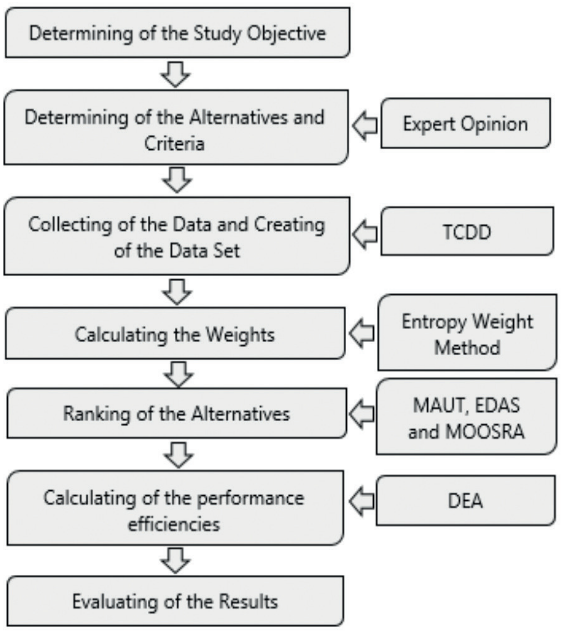

Fig. 2. Methodological Framework

3.1. Entropy Method

Weighting criteria has a significant effect on problem solving and the ranking of alternatives. The Entropy method is one of the most frequently used objective weighting methods. It was first developed by Rudolph in the field of thermodynamics in 1865. This method has been used in many studies in social sciences. Since subjective evaluations of decision makers are not required in the Entropy method, more objective results are obtained. Hence, the criterion weights in the study were made by the Entropy method and the steps of the method are shown below (Shemshadi et al., 2011).

Step 1: First, a decision matrix is constructed.

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

Step 2: In the second step, the decision matrix which was created in the first step is normalized. This calculation is done using Eq. (2) below.

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{j} x_{ij}} \quad (2)$$

Descriptions of the terms used in Eq. (2) are as follows:

i: Alternatives,

j: Criteria,

$r_{ij:}$ Normalized values,

x_{ij}: Utility values for the j. criterion of the i. alternative.

Step 3: In this step, the Entropy values of the criteria are found using Eq. (3) below.

$$e_j = -k\sum_{j=1}^{n} r_{ij} . ln\left(r_{ij}\right) \quad (i = 1, 2, \ldots, m \;\; and \;\; j = 1, 2, \ldots, n) \quad (3)$$

Descriptions of the terms used in Eq. (3) are as follows:

k: Entropy coefficient {(ln(n))-1},

r_{ij}: Normalized values,

e_j: Entropy values.

Step 4: In this step, the degree of divergence (dj) of the information is calculated. The high (dj) values obtained by using Equation (4) indicate that the deviation between the alternative scores for the criteria is high.

$$dj = 1 - ej \qquad (i = 1, 2, \ldots, m \;\; and \;\; j = 1, 2, \ldots, n) \quad (4)$$

Step 5: In the last step, the weight values of the criteria (wj) are found with Eq. (5). As a result, the sum of the obtained Entropy values must be 1.

$$w_j = \frac{1 - e_j}{\sum_{i=1}^{n}\left(1 - e_j\right)} \quad (5)$$

3.2. MAUT Method

The MAUT method, which was first found by Fishburn (1967) and Keeney (1974), is one of the most used MCDM methods (Velasquez and Hester, 2013:57). The MAUT method, developed by Loken in 2007, tries to assemble risk preferences and uncertainty using multi-criteria decision support methods (Loken, 2007:1587). The application steps of the MAUT method are as follows (Zietsman et al., 2006:259).

Step 1: Criteria, sub-criteria, and alternatives for solving the problem are defined and determined.

Step 2: The weights (wj) of the criteria and sub-criteria are determined for the evaluation of alternatives. The sum of the (wj) values must be 1.

$$\sum_{1}^{m} w_i = 1 \quad (6)$$

Step 3: In this step, the criterion weights are multiplied by the criterion values and then the decision matrix (X) is created.

$$X = [x_{ij}]_{m\text{x}n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (7)$$
$$(i = 1,2\ldots,m \; and \; j = 1,2\ldots,n)$$

Step 4: In order to normalize the decision matrix, the utility function is determined for each criterion. Values of 1 are assigned to the best value for the utility criterion and 0 to the worst value for the cost criterion. Equations (8) and (9) are used to normalize the other criterion values.

$$u_j\left(x_{ij}\right) = \frac{x_{ij} - \min\left(x_{ij}\right)}{\max\left(x_{ij}\right) - \min\left(x_{ij}\right)} \quad (i = 1, 2\ldots,\ m \; and \; j = 1, 2\ldots,\ n) \quad (8)$$

$$u_j\left(x_{ij}\right) = \frac{\max\left(x_{ij}\right) - x_{ij}}{\max\left(x_{ij}\right) - \min\left(x_{ij}\right)} \quad (i = 1, 2\ldots,\ m \; and \; j = 1, 2\ldots,\ n) \quad (9)$$

Step 5: In this step, the utility values of the criteria are calculated using equation (10).

$$U(A_i) = \sum_{j=1}^{n} u_j(x_{ij}) * w_i \quad (10)$$

Step 6: In the last step, the best alternative is determined by ranking the utility values of the alternatives in descending order.

3.3. EDAS Method

The EDAS, developed by Ghorabaee et al. (2015), is a simple and efficient MCDM method. The basic idea of the EDAS method is based on two types of distance calculations PDA (positive distance to average) and NDA (negative distance to average) for determining the best alternative (Stanujkic et al., 2017). The steps of the EDAS method are as follows (Ghorabaee et al., 2015).

Step 1: In the first step, the decision matrix consisting of (n) criteria and (m) alternatives is created.

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

Step 2: In this step, the average solution matrix (AV) is created as follows by calculating the average of all criterion values.

$$AV = [AV_j]_{1\text{x}m} \quad (12)$$

AVj values shows the average of the j^{th} criterion and are computed using Eq. (13).

$$AV_j = \frac{\sum_{i=1}^{n} X_{ij}}{\text{n}} \quad (13)$$

Step 3: Then, distances from mean matrices are obtained for each criterion. Distances from mean are divided into positive distance from the mean (PDA) and negative distance from the mean (NDA).

$$PDA = [PDA_{ij}]_{n\text{xm}} \quad (14)$$

$$NDA = [NDA_{ij}]_{\text{nxm}} \quad (15)$$

For utility-criteria, positive and negative distance values from the mean are calculated by using Equation (16) and (17).

$$PDA_{ij} = \frac{max\left(0,\ \left(X_{ij} - AV_j\right)\right)}{AV_j} \quad (16)$$

$$NDA_{ij} = \frac{max\left(0,\ \left(AV_j - X_{ij}\right)\right)}{AV_j} \quad (17)$$

For cost-oriented criteria, positive and negative distance values from the mean are calculated by using Equations (18) and (19).

$$PDA_{ij} = \frac{max\left(0,\ \left(AV_j - X_{ij}\right)\right)}{AV_j} \quad (18)$$

$$NDA_{ij} = \frac{max\left(0,\ \left(X_{ij} - AV_j\right)\right)}{AV_j} \quad (19)$$

Step 4: In this step, weighted total positive values (SPi) and weighted total negative values (SNi) for all decision alternatives are calculated using Equations (20) and (21).

$$SP_i = \sum_{j=1}^{m} w_j . \; PDA_{ij} \quad (20)$$

$$SN_i = \sum_{j=1}^{m} w_j . \; NDA_{ij} \quad (21)$$

The W_j value in Eq. (20) and (21) shows the weights of the criteria. The sum of all W_j values must be 1.

Step 5: In this step, the SP_i and SN_i values which were calculated in the previous step are normalized by using Eq. (22) and (23).

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \quad (22)$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)} \quad (23)$$

Step 6: After normalization, the appraisal scores (ASi) are calculated using Eq. (24). Then the appraisal scores (ASi) are ranked in descending rank. The highest (ASi) refers to the best alternative.

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \quad (24)$$

3.4. MOOSRA Method

The MOOSRA method was first proposed by Das et al. (2012) as an MCDM method. Having a simple structure in terms of the steps, the method is a frequently preferred MCDM method. (Demircioğlu and Coşkun, 2018). There are similar features between the MOOSRA and the MOORA methods. However, the MOOSRA method has two superior advantages over the MOORA. First, the negative performance score in the MOORA method does not occur in this method. The other is that this method is less sensitive at criterion values with large variations. The application steps of the MOOSRA method are shown below (Jagadish and Ray, 2014):

Step 1: In the first step, the decision matrix (X) is created.

$$X = [X_{ij}]_{m\text{x}n} = \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ \vdots & \vdots & \dots & \vdots \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix} \quad (25)$$

Step 2: In the second step, the decision matrix (X) is normalized. The normalization process in the MOOSRA method is performed using Eq. (26).

$$X_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} X^2_{ij}}} \quad (26)$$

Where, the value X_{ij} represents the normalized performance of i^{th} alternative on the j^{th} objective for $i=1,2,3, \ldots. n$ and $j= 1, 2, 3, \ldots. m$.

Step 3: In this step, performance scores (Y_i) are calculated using the ratio of the weighted sum of the benefit criteria to the weighted sum of the cost criteria. Performance scores (Y_i) of all alternatives are obtained by using equation (27).

$$Y_i = \frac{\sum_{j=1}^{g} w_j . X_{ij}}{\sum_{j=g+1}^{n} w_j . X_{ij}} \quad (27)$$

In Eq. (27), g is the number of attributes to be maximized, (n - g) is the number of attributes to be minimized, w_j is an associated weight of the j^{th} attributes.

Step 4: In the final step, the alternatives are ranked according to their scores (Y_i) in descending rank.

3.5. DEA

The foundations of the DEA method are based on Farrell's study in 1957. Farrell (1957), measured efficiency by linear programming using multiple inputs and single outputs. This model was later extended by Charnes et al. (1978). Today, it is a non-parametric method that is frequently used in performance and efficiency measurement (Bilişik and Elibol, 2017).

It is possible to collect DEA models into two main groups as input and output-oriented approaches. If control is low (or not) on the outputs, then input-oriented models should be used. In input-oriented models, it is aimed to use the least input to produce the current output value. In output-oriented models, the maximum output value is tried to be obtained with the current input value (Dinç and Haynes, 1999). Regardless of which models for input or output are used, the DEA model can be expressed in linear programming form and solved with linear programming solution methods (Seiford and Thrall, 1990).

Overall efficiency can be calculated by the CCR model based on the assumption of constant return to scale (CRS). In Eq. (28), the output oriented dual (envelopment) CCR model based on the CRS assumption is defined (Luptacik, 2010).

$$\max h_0 = \phi + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \varepsilon \sum_{r=1}^{s} s_r^+\right) \quad (28)$$

Subjected to:

$$\sum_{j=1}^{n} x_{ij}\beta_j - x_{i0} + s_i^- = 0 \quad (29)$$

$$-\sum_{j=1}^{n} y_{rj}\beta_j + \phi y_{r0} + s_i^+ = 0 \quad (30)$$

$$\beta_j, s_i^-, s_r^+ \geq 0, \quad j= 1, 2, \ldots, n, \quad r= 1, 2, \ldots, s, \quad i= 1, 2, \ldots, m \quad \phi: \text{free}$$

Technical and scale efficiencies can be calculated by the BCC model, which is based on the assumption of variable returns to scale (VRS). In Eq. (31), the dual BCC model for output based on VRS assumption is defined (Cooper et al., 2000).

$$\max h_0 = \varphi + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \quad (31)$$

Subjected to:

$$\sum_{j=1}^{n} x_{ij}\beta_j - x_{i0} + s_i^- = 0 \qquad i = 1, 2, \ldots, m \quad (32)$$

$$\sum_{j=1}^{n} y_{rj}\beta_j - \varphi y_{r0} - s_r^+ = 0 \qquad r = 1, 2, \ldots, s \quad (32)$$

$$\sum_{j=1}^{n} \beta_j = 1 \quad (33)$$

$$\beta_j, s_i^-, s_r^+, \qquad j \geq 0 = 1, 2, \ldots, n, \qquad r = 1, 2, \ldots, s, \qquad i = 1, 2, \ldots, m$$

If an enterprise is technical and scale efficient according to the BCC model based on the VRS assumption, it is also overall efficient according to the CCR model based on the CRS assumption. However, the reverse is not necessarily true.

4. APPLICATION

In this section, the evaluations are made about the purpose of the study, alternatives, criteria, weight values of criteria, rankings obtained by MCDM methods and the DEA scores.

4.1. Purpose of Research and Data

Efforts to establish logistics villages in Turkey began in 2006 which is much later than the developed countries. Later, important logistics village projects and plans were set up in various regions of the country. However, the continuing loss of TSR in recent years has brought up the issue of efficient use of logistics villages. In this study, it was aimed to rank the TSR logistics villages based on their performance levels using MCDM methods, to measure their efficiency by the DEA method and offer solutions within the scope of the findings.

In the study, first of all, the alternatives and criteria were determined by the MCDM method. For this purpose, eight logistics villages established by TSR and operating in 2019 constitute the data set of the study. Logistics villages included in the data set are shown in Table 2.

Criteria used in the study were determined by taking a literature review and expert opinions. In this context, seven criteria were determined to be suitable for the purpose of the study. Criteria and descriptions of criteria were shown in Table 3.

In the study, the data of 2019 TSR Logistics Department were used. The decision matrix created using the data obtained was shown in Table 4.

Table 2: Alternatives

Abbreviations	*Logistics Village Name*
A1	İzmit (Köseköy)
A2	Uşak
A3	İstanbul (Halkalı)
A4	Eskişehir (Hasanbey)
A5	Balıkesir (Gökköy)
A6	Denizli (Kaklık)
A7	Kahramanmaraş (Türkoğlu)
A8	Erzurum (Palandöken)

4.2. Ranking of Performance of Logistics Villages using MAUT, EDAS, MOOSRA Methods

Criteria weights of the alternatives were calculated with the Entropy method before ranking by MCDM methods. Entropy weights of the criteria are shown in Table 5 and the most important criterion is C7 (annual income) with a weight value of 0.36. Other criteria are listed as the amount of loaded / unloaded goods (0.17), the number of incoming / outgoing wagons (0.16), the investment value (0.12), the distance to the nearest port (0.08), the total area (0.07), and the distance to the nearest airport (0.04) according to weight values.

After the criterion weights were determined, the performance rankings of the alternatives were made by MAUT, EDAS, and MOOSRA methods. Then the ranking results were combined by applying the absolute dominance method, and these results were shown in Table 6. The Absolute Dominance means that an alternative or project dominates in ranking all other alternatives or solutions which are all being dominated (Brauer and Zavadskas, 2011). According to these results, the logistics villages with the best three performance values were determined as İstanbul (Halkalı), İzmit (Köseköy) and Balıkesir (Gökköy). Other logistics villages were ranked as Eskisehir (Hasanbey), Denizli (Kaklık), Kahramanmaraş (Türkoğlu), Uşak and Erzurum (Palandöken).

4.3. Measuring Efficiency of Logistics Villages by DEA Method

The selection of input and output variables is very important in DEA application. The selected input and output values affect the validity of the results. The input and output variables and the data related to these variables, which were determined by making a literature review and taking expert opinions, are shown in Table 7.

Table 3: Descriptions of Criteria

Abbreviations	*Criterion Name*	*Unit*	*Description*
C1	Investment Value	Turkish Lira (TL)	It shows the total amount of money spent for the establishment of the logistics village in national currency. In the establishment of a logistics village, it should be aimed to provide maximum benefit with minimum cost in terms of efficiency. For this reason, the investment cost was determined as a cost criterion and it was requested to be the minimum amount.
C2	Total Area	$x1000m^2$	It refers to the total area where the logistics village is established. Despite being established in a small area, the efficiency of logistics villages that provide high freight transport volumes is more than others. Therefore, it was deemed appropriate to use the total area criterion as a cost criterion.
C3	Distance to the Nearest Port	Km	It shows the distance of the area where the logistics village is located to the nearest seaport. Most of the world trade is carried out by seaway. For this reason, logistics villages established near the ports will be more efficient. Therefore, this criterion was used as a cost criterion in the study.
C4	Distance to the Nearest Airport	Km	It shows the distance of the area where the logistics village is located, from the nearest airport. In recent years, air transport has shown a significant development in the world and also in Turkey. It is thought that airline transportation, which is the best solution to the speed problem in transportation, will be preferred more by reducing the costs. For this reason, logistics villages established closer to airports have the potential to be more efficient than the others. Therefore, this criterion was used as a cost criterion in the study.
C5	Amount of Loaded / Unloaded Goods	Tonne	It refers to the total amount of goods loaded and unloaded in the logistics village within a year. The amount of goods loaded and unloaded in the logistics villages is an indicator of how much the logistics village is efficient. Therefore, the amount of goods loaded and unloaded in logistics villages is expected to be at high levels. For this reason, this criterion was used as a benefit criterion in the study.
C6	Number of Incoming / Outgoing Wagons	Piece	It shows the number of wagons Incoming/Outgoing to the logistics village in a year. The high number of wagons coming / going to the logistics village shows that the logistics village is operating efficiently. For this reason, this criterion was used as a benefit criterion in the study.
C7	Total Annual Income	Turkish Lira (TL)	It refers to the total monetary amount that the logistics village has obtained in a year. This amount includes the income earned from transportation and other services provided by the logistics village. The high amount of money earned is important for the profitability and efficiency of the logistics village. For this reason, this criterion was used as a benefit criterion in the study.

Table 4: Decision Matrix

Criteria / Alternatives	C1 (min)	C2 (min)	C3 (min)	C4 (min)	C5 (max)	C6 (max)	C7 (max)
A1	199,662,062	694	15	12	285,699	8,719	3,117,156
A2	860,328	140	215	8	28,025	681	789,562
A3	26,115,685	220	10	19	596,814	17,668	38,369,451
A4	258,434,785	541	237	10	65,787	1,896	15,011,470
A5	129,084,885	211	187	17	198,950	5,999	1,469,004
A6	36,187,071	125	250	30	79,086	2,500	692,291
A7	160,452,151	805	156	30	102,640	5,396	685,331
A8	144,796,933	350	232	16	22,499	760	1,369,103

Table 5: Entropy Weights of Criteria (w_j)

	C1	C2	C3	C4	C5	C6	C7
w_j	0.12	0.07	0.08	0.04	0.17	0.16	0.36

Table 6: Ranking Alternatives by MAUT, EDAS and MOOSRA Methods

	Alternatives	MAUT	EDAS	MOOSRA	Absolute Dominance
A1	İzmit (Köseköy)	2	2	4	2
A2	Uşak	4	7	7	7
A3	İstanbul (Halkalı)	1	1	1	1
A4	Eskişehir (Hasanbey)	5	4	3	4
A5	Balıkesir (Gökköy)	3	3	2	3
A6	Denizli (Kaklık)	6	5	5	5
A7	Kahramanmaraş (Türkoğlu)	7	6	6	6
A8	Erzurum (Palandöken)	8	8	8	8

Table 7: Input and Output Values

DMU	Inputs				Outputs		
	C1	C2	C3	C4	C5	C6	C7
A1	199,662,062	694	15	12	285,699	8,719	3,117,156
A2	860,328	140	215	8	28,025	681	789,562
A3	26,115,685	220	10	19	596,814	17,668	38,369,451
A4	258,434,785	541	237	10	65,787	1,896	15,011,470
A5	129,084,885	211	187	17	198,950	5,999	1,469,004
A6	36,187,071	125	250	30	79,086	2,500	692,291
A7	160,452,151	805	156	30	102,640	5,396	685,331
A8	144,796,933	350	232	16	22,499	760	1,369,103

Table 8: Efficiency Scores of Output-Oriented CCR and BCC Models

DMU	Overall Efficiency Scores (CCR)	CCR Benchmarks	Technical Efficiency Scores (BCC)	BCC Benchmarks	Scale Efficiency (CCR / BCC)
A1	1.28	3 (0,63)	1	-	1.28
A2	1	-	1	-	1
A3	1	-	1	-	1
A4	1.35	3 (0,53)	1	-	1.35
A5	2.64	3 (0,89)	2.43	1 (0,01) 2 (0,18) 3 (0,81)	1.08
A6	4.02	3 (0,57)	1	-	4.02
A7	5.17	3 (1,58)	3.27	3 (1,00)	1.58
A8	9.58	3 (0,84)	7.86	1 (0,29) 2 (0,09) 3 (0,62)	1.22

It was appropriate to use output oriented CCR and BCC models on the grounds that it is not possible to control the inputs in measuring the efficiency of the logistics villages in DEA application. In output-oriented models, the aim is to obtain the most output with a certain amount of input. EMS (Efficiency Measurement System) program was used to get DEA results. Efficiency scores were shown in Table 8.

When Table 8 is examined, it is determined that according to the output oriented CCR model, İstanbul (Halkalı-A3) and Uşak (A2) logistics villages are efficient due to their scores (1). İzmit (Köseköy-A1), Eskişehir (Hasanbey-A3), Balıkesir (Gökköy-A4), Denizli (Kaklık-A5), Kahramanmaraş (Türkoğlu-A6) and Erzurum (Palandöken-A7) logistics villages are inefficient decision-making units. According to the technical efficiency scores, only Denizli (Kaklık-A5) logistics village is not efficient. According to the scale efficiency scores, it was determined that the logistics villages of Istanbul (Halkalı-A3) and Uşak (A2) are efficient.

5. DISCUSSION

Istanbul (Halkalı-A3) logistics village takes the first place in the rankings obtained by MAUT, EDAS and MOOSRA methods. Erzurum (Palandöken-A8) logistics village ranks in last place. The fact that Istanbul has the largest trade volume in the country plays a significant role in the logistics village of Istanbul (Halkalı-A3)'s taking the first place. Izmit (Köseköy-A1) logistics village is in the second place in Kocaeli city where some of the very important industrial organizations of the country take place. Another feature for both of these cities is that the railways are connected to many ports. Therefore, it can be concluded that logistics villages perform better if they are located close to industrial and commercial centers. In addition, it is seen that especially the logistics villages providing seaway connection are at higher ranks. So, it is an undeniable fact that the variety of transport modes significantly affects the performance of the logistics villages.

According to the CCR model scores for the output oriented by DEA, it is concluded that the logistics villages of Istanbul (Halkalı-A3) and Uşak (A2) are efficient. When the values of the output variables of the Istanbul (Halkalı-A3) logistics village are examined, it is seen that more goods are handled (C5), more wagons are transported (C6) and more income is obtained (C7) compared to the other logistics villages. Therefore, this situation enabled the logistics village of Istanbul (Halkalı-A3) to be efficient and be referred to other logistics villages. On the other hand, the efficiency score of Istanbul (Halkalı-A3) logistics village supported the ranking results obtained by MCDM methods.

When the values of the input variables of Uşak (A2) logistics village are examined, it is observed that the investment cost (C1) of this logistics village is much lower than the other logistics villages. Although it is in the lower ranks according to MCDM rankings, the logistics village of Uşak (A2) is efficient according to DEA results. The reason for this is that the investment cost (C1) of the Uşak (A2) logistics village is the lowest among the decision-making units.

6. CONCLUSION

In this paper, the performance of eight villages logistics operations in Turkey in 2019 was evaluated by MCDA and DEA methods. First, rankings were obtained by Entropy-based MAUT, EDAS and MOOSRA methods. Then, the efficiency of the logistics villages was evaluated by DEA method. Istanbul (Halkalı-A3) logistics village ranked first in three MCDM methods and it was concluded that its performance was also efficient according to DEA method.

In Turkey in 2019, there were eight operating logistics villages operated by TSR except for Samsun (Gelemen). Additionally, two logistics villages are ready to operate, two more are under construction, and eight others are also in the project phase. Evaluating the efficiency of the existing logistics villages and taking efficient logistics villages as models for new projects will yield more successful results. Therefore, according to DEA results Uşak and Istanbul (Halkalı) logistics villages are recommended to be taken as models for future projects. The Uşak logistics village can be taken as a model for low-cost projects in regions with development potential. Istanbul (Halkalı) logistics village can also be taken as a model for big cities where the industry is developed.

Demirkıran and Öztürkoğlu (2020) reached the conclusion that TR10 (Istanbul) is the region with the greatest potential in Turkey for new logistics village projects. In parallel with this result in the study, the logistics village of Istanbul (Halkalı) is in the first place according to the three methods (MAUT, EDAS and MOOSRA). In addition, there is a logistics village project in Istanbul (Avrupa Yakası) to meet this potential.

Turkey should consider the advantages of its strategic position better and increase the amount of investment and the number of logistics villages in this area. In addition to public investments, private sector investments should also be encouraged. It is thought that encouraging private sector investments will accelerate the development process in this area. In this respect, efficiency comparisons of logistics villages operated by the private sector and TSR can be made in future studies.

On the other hand, the findings obtained in the study are valid within the input-output variables and criteria used. These input-output variables and criteria can be developed in future studies. In addition, the performances of logistics villages can be examined using different MCDM methods and the results obtained can be evaluated using sensitivity analysis.

REFERENCES

Ahi, T. (2015). Demiryollarında lojistik merkezler. Demiryolu Mühendisliği, 2, 32-35.

AMCO. (2018). Why is logistics management important?, Available at: https://www.amcoservices.co.uk/why-is-logistics-management-important/, (Accessed May 12, 2020).

Aruldoss, M., Lakshmi, T.M. and Venkatesan, V.P. (2013). A survey on multi criteria decision making methods and its applications. American Journal of Information Systems, 1(1), 31-43.

Baydar, A. M., Süral, H., & Çelik, M. (2017). Freight villages: a literature review from the sustainability and societal equity perspective. Journal of Cleaner Production, 167(20), 1208-1221.

Bilisik, M. T., & Elibol, G. O. (2017). Efficiency research with total factor productivity and determination of improvement targets. Journal of Business Economics and Finance. 6(3), 246-253.

Blagojevic, A., Veskovic, S., Kasalica, S., Gojic, A., & Allamani, A. (2020). The application of the fuzzy ahp and dea for measuring the efficiency of freight transport railway undertakings. Operational Research in Engineering Sciences: Theory and Applications. 3(2), 1-23.

Brauer, W.K.M. and Zavadskas, E.K. (2011). MULTIMOORA optimization used to decide on

a bank loan to buy property. Technological and Economic Development of Economy. 17(1), 174-188.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. European Journal of Operational Research, 2(6), 429-444.

Cooper, W. W., Seiford, L. M., & Tone, K. (2007). Alternative DEA models. Data envelopment analysis a comprehensive text with models, references, and DEA-solver software. (p.p. 87-120). Springer, NY, USA.

Das, M. C., Sarkar, B., & Ray, S. (2012). Decision making under conflicting environment: a new MCDM method. International Journal of Applied Decision Sciences, 5(2), 142-162.

Demirkıran, Y. and Öztürkoğlu, Ö. (2020). Türkiye'deki bölgelerin lojistik köy kurulması açısından potansiyelinin PROMETHEE II yöntemi ile incelenmesi. Journal of Yasar University, 15(58), 347-367.

Dinc, M., & Haynes, K. E. (1999). Sources of regional inefficiency an integrated shift-share, data envelopment analysis and input-output approach. The Annals of Regional Science, 33(4), 469-489.

Farrell, M. J. (1957). The measurement of productive efficiency. Journal of the Royal Statistical Society: Series A (General), 120(3), 253-281.

Fragoudaki, A., & Giokas, D. (2020). Airport efficiency in the dawn of privatization: the case of Greece. Journal of Air Transport Management, 86, 1-14.

Ergün, M., Korucuk, S., & Memiş, S. (2020). Sürdürülebilir afet lojistiğine yönelik ideal afet depo yeri seçimi: Giresun ili örneği. Çanakkale Onsekiz Mart Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 6(1), 144-165.

Gök Kısa, A., & Ayçin, E., (2019), ''OECD Ülkelerinin Lojistik Performanslarının SWARA Tabanlı EDAS Yöntemi ile Değerlendirilmesi", Çankırı Karatekin Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, C.9, S.1, (301-325).

Huang, W., Shuai, B., Xu, Y., Zhang, S., & Mao, B. (2019). Railway express freight train service sites planning: a two-stage entropy-TOPSIS approach. Transportmetrica A: Transport Science, 15(2), 807-823.

Huang, W., Zhang, Y., Yu, Y., Xu, Y., Xu, M., Zhang, R., Deieu, G. J. D., Yin, D., & Liu, Z. (2021). Historical data-driven risk assessment of railway dangerous goods transportation system: comparisons between Entropy weight method and Scatter Degree method. Reliability Engineering & System Safety, 205, 1-8.

Iyer, K. C., & Nanyam, V.P.S. N. (2021). Technical efficiency analysis of container terminals in India. The Asian Journal of Shipping and Logistics, 37(1), 61-72.

Karadeniz, V., & Akpınar, E. (2011). Türkiye'de lojistik köy uygulamalari ve yeni bir lojistik köy önerisi. Marmara Coğrafya Dergisi, 24, 49-71.

Keshavarz Ghorabaee, M., Zavadskas, E. K., Olfat, L., & Turskis, Z. (2015). Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS). Informatica, 26(3), 435-451.

Khorram, S. (2020). A novel approach for ports' container terminals' risk management based on formal safety assessment: FAHPentropy measure-VIKOR model. Natural Hazards, 103, 1671-1707.

Korucuk, S. (2021). Ordu ve Giresun illerinde kentsel lojistik performans unsurlarına yönelik karşılaştırmalı bir analiz. Dicle Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 26, 141-155.

Kuo, K.-C., Lu, W.-M., & Le, M.-H. (2020). Exploring the performance and competitiveness of Vietnam port industry using DEA. The Asian Journal of Shipping and Logistics, 36(3), 136-144.

Li, J. (2020). The structure of the overall network of research on spatial correlation network structure and effects of regional logistics. Design Engineering, 11, 783-802.

Loken, E., (2007). Use of multicriteria decision analysis methods for energy planning problems. Renewable and Sustainable Energy Reviews, 11(7), 1584-1595.

Luptacik, M. (2010). Data envelopment analysis. Mathematical optimization and economic analysis (p.p. 135-186). Springer, NY, USA.

Maksimovic, M., Brzakovic, M., Grahovac, M., & Jovanovic, I. (2017). An approach for evaluation the safety and quality of transport at the open pit mines, based on the EDAS method. Mining and Metallurgy Engineering Bor, 3-4, 139-144.

Meidute, I. (2005). Comparative analysis of the definitions of logistics centres. Transport, 20(3), 106-110.

Mircetic, D., Nikolicic, S., & Maslaric, M. (2014). Logistic centers: Literature review and papers classification. The Fifth International Conference Transport and Logistics.

Mou, N., Wang, C., Yang, T., & Zhang, L. (2020). Evaluation of development potential of ports in the Yangtze River Delta using FAHP-Entropy model. Sustainability, 12(2), 1-24.

Özmen, M., & Kızılkaya Aydoğan, E. (2020). Robust multi-criteria decision making methodology for real life logistics center location problem. Artificial Intelligence Review, 53(1), 725-751.

Postiguillo, J. R., Campo, J. M. & Santamera, J. A. (2015). Areas of logistics activity evolution and tendencies criteria and parameters of design to implementation and organization. International Journal of Innovation, Management and Technology, 6(2), 126-129.

Saaty, T.L. and Ergu, D. (2015). When is a decision-making method trustworthy? criteria for evaluating multi-criteria decision-making methods. International Journal of Information Technology & Decision Making, 14(6), 1171-1187.

Quintano, C., Mazzocchi, P., & Rocca, A. (2020). A competitive analysis of EU ports by fixing spatial and economic dimensions. Journal of Shipping and Trade, 5, 1-19.

Seiford, L. M., & Thrall, R. M. (1990). Recent developments in DEA: the mathematical programming approach to frontier analysis. Journal of Econometrics, 46(1-2), 7-38.

Sezen, B., & Gürsev, S. (2014). Türkiye'de kurulması planlanan lojistik merkezler hakkında bir analiz çalışması. Maramara Üniversitesi Öneri Dergisi, 11(42), 105-126.

Shemshadi, A., Shirazi, H., Toreihi, M., & Tarokh, M. J. (2011). A fuzzy VIKOR method for supplier selection based on entropy measure for objective weighting. Expert Systems with Applications, 38(10), 12160-12167.

Sirikijpanichkul, A., Winyoopadit, S., & Jenpanitsub, A. (2017). A multi-actor multi-criteria transit system selection model: a case study of Bangkok feeder system, Transportation Research Procedia, 25, 3736-3755.

TCDD (2012). Lojistik Merkezler, Available at: http://www.lojistikhatti.com/haber /2012/09/ lojistikmerkezler, (Accessed Feb 25, 2020).

Theo, N., Francesco, P., Giovanni, S. & Marcello, R., (2017), A taxonomy of logistics centres: overcoming conceptual ambiguity. Transport Reviews, 37(3), 276-299.

Ulutaş, A., Karaköy, Ç., Arıç, K. H., & Cengiz, E. (2018). Çok kriterli karar verme yöntemleri ile lojistik merkezi yeri seçimi. İktisadi Yenilik Dergisi, 5(2), 45-53.

Uygun, A. İ. (2019). TCDD Genel Müdürlüğü lojistik merkez projeleri sunumu, Available at: www.tcdd.gov.tr, (Accessed Jun 20, 2020).

Velasquez, M., & Hester, P.T. (2013). An analysis of multi criteria decision making methods. International Journal of Operations Research, 10(2), 56-66.

Veskovic, S., Stevic, Z., Karabasevic, D., Rajilic, S., Milinkovic, S., & Stojic, G. (2020). A new integrated fuzzy approach to selecting the best solution for business balance of passenger rail operator: fuzzy PIPRECIA-fuzzy EDAS model. Symmetry, 12(5), 1-20.

Yürüyen, A. A., & Ulutaş, A. (2020). Bulanık AHP ve bulanık EDAS yöntemleri ile üçüncü parti lojistik firması seçimi, Anemon Muş Alparslan Üniversitesi Sosyal Bilimler Dergisi (İİB), 8, 283-294.

Zafar, I., Wuni, I. Y., Shen, G. Q., Zahoor, H. & Xue, J. (2020). A decision support framework for sustainable highway alignment embracing variant preferences of stakeholders: case of China Pakistan economic corridor, Journal of Environmental Planning and Management, 63(9), 1550-1584.

Zietsman, J., Rilett, L. R., & Kim, S. J. (2006). Transportation corridor decision-making with multi-attribute utility theory. International Journal of Management and Decision Making, 7(2-3), 254-266.