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Logistics Center Location Optimisation in Thrace: A Hybrid Approach Using AHP and TOPSIS Methods

Trakya'da Lojistik Köy Yerseçimi: AHP ve TOPSIS Yöntemleriyle Hibrit Model Yaklaşımı

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ABSTRACT

The region of Thrace, its proximity to Istanbul, the strong industrial infrastructure, and road transport in the region, due to the fact that our country is the gateway to Europe, are subject to strong mobility of loads. The load transport facilities in the area have an imbalanced relationship with one another. Unplanned and uncontrolled development of logistical components compromises logistical performance and jeopardizes the region's planned integrity. As a result of similar failures with living industrial towns, logistics villages have been created. The purpose of this paper is to choose the best location for the envisaged logistics community in Thrace. The location of the logistics village should be chosen using a system that is affordable, simple to grasp, quick, qualitative, adaptable, and universal. This model was developed by combining data from field research and book reviews at the same time. According to the literature review, the two most preferred methods for multi-criteria decision-making in logistics center siting are AHP and TOPSIS. Based on this data, our study provides a comparative interpretation of these methods. Literature In addition to the survey, a field study was conducted, site selection criteria, in-depth interviews with experts on sub-criteria, and options were developed. The criteria of accessibility, costs, land characteristics, and social benefit criteria were taken into account. Tekirdağ, Çerkezköy, Marmara Ereğlisi, and Havsa were identified as options. The results of the study showed that the AHP and TOPSIS applications provided consistent and uniform results.

Keywords: AHP; logistics center; multiple criteria decision making; TOPSIS; Thrace.

ÖZ

Trakya Bölgesi, İstanbul'a olan yakınlığı, güçlü sanayi altyapısı ve ülkemizin batıya açılan kapısı olması nedenleriyle, yoğun yük hareketliliğine konu olmaktadır. Bölgede karayolu taşımacılığının dengesiz hakimiyeti söz konusudur. Lojistik unsurlar plansız ve kontrolsüz gelişmekte, bölgenin plan bütünlüğünü tehdit etmekte ve lojistik performansını zayıflatmaktadır. Benzer deneyimler yaşayan bölgelerde, çözüm olarak lojistik köyleri geliştirmişlerdir. Bu bağlamda, çalışmamız Trakya'da yapılması düşünülen lojistik köy için en uygun yeri tespit etmeyi amaçlamaktadır. Lojistik köy yer seçimi için; ekonomik, kolay anlaşılabilir, hızlı, kalitatif ve kantitatif verilerin birlikte kullanılabildiği esnek ve evrensel bir modelin oluşturması hedeflenmiştir. Bu modelin oluşturulması sürecinde literatür taraması ve alan çalışması verileri eş zamanlı olarak sürece katılmıştır. Literatürde, lojistik köy yerseçimi için çok kriterli karar verme teknikleri arasında yer alan AHP ve TOPSIS yöntemlerinin en çok tercih edilen iki yöntem olduğu tespit edilmiştir. Bu veriden hareketle, çalışmamız bu iki yöntemi karşılaştırmalı bir biçimde yorumlamaktadır. Literatür taramasına ek olarak alan çalışması yapılmış, yerseçimi ölçütleri, alt ölçütleri ve seçenekleri uzmanlarla derinlemesine mülakatlar geliştirilmiştir. Lojistik köy yerseçimi için erişilebilirlik, maliyetler, arazi özellikleri ve sosyal fayda ölçütleri dikkate alınmıştır. Seçenekler; Tekirdağ, Çerkezköy, Marmara Ereğlisi ve Havsa olarak belirlenmiştir. Araştırmanın bulguları, AHP ve TOPSIS uygulamalarının uyumlu ve tutarlı sonuçlar verdiğini göstermiştir.

Anahtar sözcükler: AHP; lojistik köy; çok kriterli karar teknikleri; TOPSIS; Trakya.

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TMMOB Şehir Plancıları Odası

1. Introduction

Thrace Region is the one which stands out with its strong industry besides its fertile agricultural lands, nature, and history. Its closeness to Istanbul and being on the route to Europe also make Thrace Region significant. The advantages of both being close to Istanbul and to the border crossing to Europe; determine the destiny of the region. These advantages strengthen its industrial profile, add value in service sectors and improve technological capacity level. Thrace has attractiveness for local and global investors, and its capacity develops constantly with its strong transport networks. The region has goals such as gaining more progress in opening up to the West and overcoming crises with its adaptation capacity. Yet Thrace Region has several logistics issues. Although the region has high potential, logistical chaotic region is observed, because of logistics supply and demand mismanagement (Thrace Development Agency, 2009; Thrace Development Agency, 2011; Thrace Development Agency, 2013; İBB, 2009). Considering that the current industrial production will continue to increase, it is clearly seen that logistics sector in the region needs to be well organized. With the right planning strategies, it is possible to provide a sustainable logistics system in the region.

The main problem bases on unbalanced transportation mode distribution. Despite three separate coasts, qualified ports, and a railway infrastructure; nearly 90% of freight is transported by road. This level of agglomeration causes monopoly of the road transport in accessing to terminals from the industrial production cores. As a natural consequence of this situation, intermodality is also quite weak. Besides, it is observed that freight cargo generally handle in urban areas and threaten the citizens' health, quality of life and environment. In addition, the lack of the logistics center in the region causes significant problems.

Under these conditions the question occurs: How will the Region deal with basic logistics problems? Literature survey and first findings of the field study led to focus on the absence of logistics center. After identifying this problem, we focused on determining the appropriate location for the logistics center. A logistics center in region provides a structural transformation, which is required. And this solution would make possible to reach the desired positive level in logistics. Considering the current economic and spatial structure of the region, **the research question is determined as: where should the logistics center be located?** In this context, the aim of the article is to determine the most suitable location of logistics center by considering it as a whole with its national and international axes. It is aimed to realize a concrete spatial proposal among the options so that the logistics center would be selected in the most suitable location.

In the literature, as a reflection of the emerging number of logistics investments, an increasing number of studies have been prepared for the problems related to the location selection of logistics centers (Uyanık et al., 2018). Naturally, location selection problems require the consideration of multiple criteria and multi criteria decision-making techniques are the most widely used methods for this research area. In most of the studies for this problem, initial step is the determination of decision criteria for the evaluation of alternatives. It is a well-known fact that determination of evaluation criteria and their weights are very important for decision-making processes since it directly effects the final ranking. As far as seen in literature, Analytic Hierarchy Process (AHP) is the most preferred technique (Fig. 1). AHP is one of the most convenient methodologies in order to evaluate logistics and transport related issues due to its various advantages. Planning, location selection, prioritization, evaluation, resource allocation, demand determination, forecasting the effects, designing the system, measuring the performance, optimization, benchmarking, quality management, public policy, health care, strategic planning are some of those various topics. For instance; Das and Tyagi (1997), Tudela et al. (2006), Vreeker et al. (2002), Gerçek, Karpak and Kılınçaslan (2004), Zhang et al. (2016) did their research on transport and logistics with AHP methodology. Similarly; Khalili et al. (1992), Ferrari (2003), Yelda et al. (2003), Song and Yeo (2004), Nir et al. (2003), Haralambides and Yang (2003) preferred AHP methodology for the selection of project, invest or terminal project.

On the other hand, the method of TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) has been using for various topics including logistics. TOPSIS method was proven to give the most reliable outcome compared to the others in the method Convenience Test at the assessment stage. For instance, Bao et al. (2012), Elevli (2014), Liu et al. (2011), Zak and Weglinski (2014), Wang and Liu (2007), Li and Liu (2011) and Chen et al. (2014) mentioned logistics issues using TOPSIS methodology. Erkayman et al. (2011) proposed TOPSIS approach to logistics center location selection in the Eastern Anatolian region of Turkey. Li et al. (2011) proposed an approach combining of clustering method and the TOPSIS method to select the best location selection. Özceylan et al. (2016) proposed a methodology based on a combination of the GIS, ANP and TOPSIS methods for location selection in Ankara (Oğuztimur, 2011).

Recently in literature, it is observed that authors favor to compare findings with some other techniques. Lately, qualitative academic studies regarding with logistics mainly focus on the comparison of two qualitative methods. The reason for using two methods at the same time is that comparison gives more reliable results. AHP and TOPSIS methods are the most preferred methods in logistics village location selection. Ertuğrul and Karakaşoğlu (2008) are one of the scholar applied the AHP and TOPSIS methods respectively to select op-

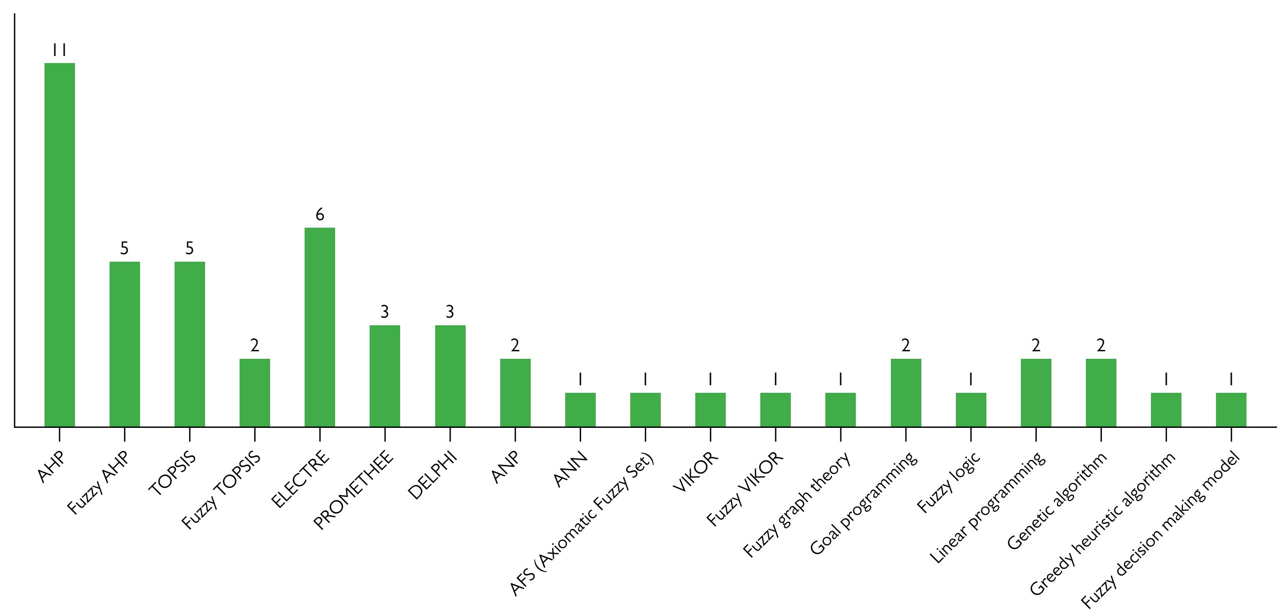

Figure 1. The most preferred methods in logistics village location selection (Uyanık et al. 2018).

AHP: Analytic Hierarchy Process; TOPSIS: Technique for Order Preference by Similarity to Ideal Solution; ELECTRE: Elemination and Choice Translating Reality English; PROMETHEE: The Preference Ranking Organization Method for Enrichment Evaluation; ANP: Analytic Network Process; ANN: Artificial Neural Network; VIKOR: VIseKriterijumsa Optimizacija I Kompromisno Resenje.

timal location. Furthermore, Wang and Liu (2007), Sirisawat & Kiatcharoenpol (2018), Prakash & Barua (2015), Naseem et al. (2021), Jayant et al. (2014), Li et al. (2020) used the AHP and TOPSIS methods to handle the location decision problem within given selection alternatives.

In real life, the evaluation of location suitability for various subjective criteria and the weights of the criteria are usually expressed in linguistic terms. Additionally, multi criteria decision techniques have been utilized to create decision in order to effectively resolve the ambiguity that commonly arises in the information that is provided and to better reflect the inherent fuzziness in human judgment and preference. Thus in this paper, AHP and TOPSIS methods are proposed for facility location selection, where the ratings of various alternative locations under various subjective criteria and the weights of all criteria are represented by numbers.

The purpose of this paper is to offer a contribution to a real life problem in Thrace that arises from logistics disorganization. The specific focus is on four options that were also mentioned in Regional Plans and Logistics Sector Analysis of the region. This article focuses on what is going on inside Thrace. For sure, İstanbul, with its great hinterland, has a certain effect on whole country. A city of this much huge size will definitely have an impact on the economic activities in its nearby surroundings. However, the scope of our study is spatially limited with Thrace Region. Therefore, the criteria and sub-criteria, which effect the location selection, are designed by taking into account of the regions specialties. In order to determine scenarios for the logistics center's location, besides a detailed secondary source research, experts' opinions were taken into consideration. The results of the study conducted with two different methodologies are compatible with each other.

The remainder of this paper is organized as follows. Methodology is expressed in Section 2. AHP procedure is followed by TOPSIS procedure explanation. Steps of both methodologies are summarized, the model of the research is presented. Then the design of the research is detailed. In section 3, the results that are gained with these methods are submitted. The same systematic is followed: Firstly AHP findings detailed, then TOPSIS. The weights main criteria, and evaluation of sub-criteria and finally the weights of options have taken place. And at last in section 4, discusses and concludes the paper.

2. Methodology

It has been clearly seen from the reports and regional plan documents that (Thrace Development Agency, 2009; Thrace Development Agency, 2011; Thrace Development Agency, 2013; İBB, et al. 2009) the Region has weaknesses in terms of logistics infrastructure. After seeing the existence of the problem, a detailed literature review is done. Along with secondary resource survey, a study was carried out in the field, in-depth interviews were conducted with experts. Experts were selected because of their ties to the logistics sector. In order to evaluate the general logistics view of the Region, interviews were made with Tekirdağ Chamber of Commerce and Industry, Thrace Development Agency and Asyaport experts. Local governments and representatives of some of the central government ie. Turkish State Railways, Regional Highway Directorate were also involved into the study. These representatives have been preferred due to their wide representation capacity for the problems and solution proposals in the logistics sector.

To summarize briefly; Tekirdağ province carries out more than 80% of the foreign trade in the Thrace region. A significant part of this foreign trade is carried out by sea. Asyaport is the only container terminal in Thrace. It is the hub port of the region. Asyaport connects the region to the world thanks to its connection with global maritime networks. In addition, since it is the 4th largest terminal of our country, it has a wide hinterland. Thrace Development Agency is a public institution that provides services with the participation of the administrative representatives of all three provinces in the Thrace Region. Representatives from the local and central administrations of all three provinces take part in the management of the development agency. In this respect, Thrace Development Agency has been accepted as the key institution that has knowledge of the current situation, economic conditions and trends of all three provinces regarding the logistics center. We evaluated investments in the context of both public and private sectors, the capacity of foreign capital, the projects of terminals. Thus, various dimensions of the subject were expressed in this study with the opinions of experts including non-governmental organizations, public institutions and private sector. In addition to the meetings held with these institutions, joint studies were conducted with the academicians from Yıldız Technical University, Department of City and Regional Planning and Industrial Engineering. So that an academic perspective was also included in the study. As a result, interviews were held with the most appropriate private sector, public institutions and non-governmental organizations in order to obtain expert opinions required for AHP and TOPSIS.

Logistics center location selection requires a high-cost investment. Moreover, it is a dominating decision, which applies to a large area as an irreversible decision. For this reason, decisions should be rational, digitized and taking into account all the affecting parameters. Various methods are preferred in numerous academic studies due to the location selection of logistics centers (Uyanık et al., 2018; Taniguchi et al., 1999). In academic studies carried out until the 2000s, multi-criteria decision-making techniques were generally chosen and applied. (Dyer, 1990; Mardani et al., 2015). Two most preferred methods in the literature review are AHP and TOPSIS. As in Figure 1, in 16 out of 36 studies AHP techniques were preferred. TOPSIS and ELECTRE, among other techniques, come to the forefront by being used in respectively 7 and 6 studies. In 10 publications, criteria weights are found by AHP and Fuzzy-AHP methods and then selections/evaluations are made among the alternatives by implementing the other techniques. Due to this literature in this article, Thrace logistics center location selection problem is evaluated by AHP and TOPSIS comparatively as well (Fig. 1).

2.1. AHP Procedure

In the 1970s Saaty developed AHP. This is a decision-making method that helps to make complex decisions with both qualitative and quantitative factors. Therefore, it enables to make decisions in a way that is more suitable (Dyer, 1999; Gerçek et al., 2004; Song and Yeo, 2004). AHP is a decision making method, expressing distribution percentage of factors affecting the decision. AHP has a wide application area and is used effectively in many decision problems: investment decisions (Boucher et al., 1997), project selection (Khalili-Damghani et al., 2019; Liberatore, 1987), economic planning, marketing and management decisions (Liberatore and Nydick, 2008; Wind and Saaty, 1980; Olson et al., 1986), various transport problems (Gupta et al., 2018; Oiha et al., 2010; Gümüş, 2009; Postorino and Pratico, 2012). AHP provides a way to rank the alternatives of a problem by deriving priorities. AHP gives a proven, effective means to deal with complex decision making and can assist with identifying and weighting selection criteria, analyzing the data collected and expediting the decision making process. AHP is a methodology to rank alternative courses of action based on the decision maker's judgments concerning the importance of the criteria and the extent to which they are met by each alternative (Saaty, 2000). AHP has been shown to be a robust method of eliciting and using multi criteria preference relationships in a range of applications. It is designed for situations in which ideas, feelings, and emotions are quantified based on subjective judgment to provide a numeric scale for prioritizing decision alternatives. This method is based on a matrix of pair wise comparisons between criteria, and it can be used to evaluate the relative performance of decision alternatives (for example products and services) with respect to the relevant criteria. AHP is seen to be a suitable tool for the purpose here, as it is a robust method that is particularly suited to decisions made with limited information.

AHP has been one of the most advantageous methods for the application of the field data obtained in this study. The most important advantages is the possibility of making general inferences with limited expert opinion. Because AHP, regardless of its number, focuses on expert opinion and claims that the strongest inferences on the subject under investigation will be formed in this way (Saaty, 2000). In this field study; it is aimed to reach the most competent people and institutions in terms of revealing their widespread influence and tendencies. Thanks to AHP, it was possible to produce generalizable scientific knowledge. Another advantage that AHP offers is

Table 1. Saaty's relative importance scale

Importance level	Value definition	Explanation
1	Equal importance	Both elements agree equally with the goal or there is no indifference between the two alternatives
3	Moderate importance	Experience and judgment make item 1 slightly preferable to item 2
5	Strong importance	Experience and judgment make item 1 more preferable than 2
7	Very strong importance	The 1st item is much more preferred than the 2nd
9	Extremely importance	Judgment in which the influence of the first element is least and the second element has absolute supremacy

Gerçek et al. 2004, Song and Yeo 2004, Saaty, 2000.

that it provides the opportunity to perform a consistency analysis after performing the mathematical analysis of the views. Thus, a self-control system comes into play and guarantees the reliability of the results.

Briefly, AHP has a clearly defined process: (Step 1 and 2) structuring the hierarchy, (Step 3) pair-wise comparisons (determining the weights) and (Step 4 and 5) decision phase (selection of the best alternative among the others).

Step 1: Defining the hierarchy: The top level of the hierarchy is the objective function. The criteria that the objective function depends on are in the middle level of the hierarchy as the main criteria. When necessary, sub-criteria expansion of each main criterion can also be provided. At the bottom of the hierarchy are the options. Options are the answers to the question of how many elements the decision inquiry will be made on.

Step 2: Creating Inter-Factor Comparison Matrices: The inter-factor comparison matrix creates an nxn square matrix for n factors. Comparisons of factors are made one-to-one and mutually according to their importance values relative to each other.

Step 3: Determining the Weights of the Criteria: After the pairwise comparisons are made, the priority (relative importance) of each compared element is calculated. Linear algebra techniques are used to construct priority vectors. It includes the calculation and normalization of the largest eigenvalue and the corresponding eigenvector. After the hierarchy is established, pairwise comparisons are made using the Satty importance scale shown in Table 1. It is expected that the more important factor will take the more weighted share.

Step 4: Evaluation of Consistency: Generally, as people's level of knowledge about a problem increases, they are expected to construct the problem more consistently. AHP does not expect perfect consistency; it accepts some inconsistency (Saaty, 2000; Özdemir and Gasimov, 2004). If the consistency index is above the acceptable value, it is determined that the judgments that make up the pairwise comparisons are inconsistent. The AHS uses a consistency ratio recommended by (Saaty, 2000; Singh et al., 2018), which provides a measure of inconsistency in each trial. With the Consistency Ratio obtained, it provides the opportunity to test the consistency of the priority vector found and therefore the one-to-one comparisons between the factors.

Step 5: Concluding Decision: The last stage of AHP is the stage of solving the decision problem. A hybrid advantage that demonstrates the usefulness of decision making in achieving the main goal of the problem at this stage. In order to benefit from this abstraction, it is necessary to measure every meaning. That is, its one factor is the importance of the points of decision points determined. For this, comparisons and matrices are repeated as many times as the number of multipliers (n times).

2.2. TOPSIS Procedure

It is a MCDM method developed by Hwang and Yoon in 1980 and has found the opportunity to be applied in many areas. The basic principle in the TOPSIS method is that the chosen alternative should have the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution (Jahanshahloo et al., 2006; Shih et al., 2007). A positive ideal solution is one that maximizes benefit criteria and minimizes cost criteria; where the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria (Yang et al., 2007). The TOPSIS method reveals the distances from the positive and negative ideal solutions, and also reveals the ideal and non-ideal solutions. In order to applicate the method, there must be at least two decision options. The TOPSIS method, which has an analysis process that does not contain complex algorithms and mathematical models, finds application in many fields due to its ease of use and easy understanding and interpretation of the results (Roszkowska, 2011).

The reason why TOPSIS is preferred in this study is that it provides the benefit of simplicity, rationality, comprehensibility, good computational skills and ability to measure the relative performance for each alternative in a simple mathematical form. Reaching the result easily with the possibilities offered by our data sets and options gave the opportunity to interpret the field study findings with a mathematical model.

The closeness of the decision points to the ideal solution is based on the main principle. TOPSIS method consists of 6 steps (Singh et al., 2018, Demirtaş et al., 2011).

Step 1: Creation of the Decision Matrix: Decision matrix rows contain the decision points whose superiority is desired to be listed, and evaluation factors to be used in decision making in the columns. Matrix A is the initial matrix created by the decision maker.

Step 2: Constructing the Standard Decision Matrix: The standard decision matrix is obtained by taking the square root of the sum of the squares of the values of each criterion of the decision matrix (the sum of the squares of the column values) and dividing the relevant element of the column by this resulting value.

Step 3: Creating the Weighted Standard Decision Matrix: First, the weight values of the evaluation factors are determined. Then, the elements in each column of the matrix are multiplied by their respective values. This weighting approach reveals the subjective aspect of the TOPSIS method in the decision-making phase.

Step 4: Establishing Ideal and Negative Ideal Solutions: The TOPSIS method assumes that each evaluation factor has a monotonically increasing or decreasing trend. In order to create the ideal solution set, the largest of the weighted evaluation factors, ie column values, in the matrix (the smallest if the relevant evaluation factor is minimization-oriented) is selected. Using this matrix, positive ideal and negative ideal solution sets are obtained for each criterion according to the purpose of the evaluation criterion of interest.

Step 5: Calculation of Discrimination Measures: The Euclidian Distance Approach is used to find the deviations of the evaluation factor value for each decision point from the ideal and negative ideal solution set. The deviation values of the decision points obtained from here are called Ideal Discrimination (S^*) and Negative Ideal Discrimination (S) Measure. Accordingly, distance values are calculated as much as the number of decision options.

Step 6: Calculation of Relative Closeness to the Ideal Solution: The distances from the positive ideal and negative ideal solution values are used to calculate the relative closeness coefficients of each decision option to the ideal solution. Ideal and negative ideal separation measures are used to calculate the relative closeness (C^*) of each decision point to the ideal solution. The criterion here is the share of the negative ideal discrimination measure in the total discrimination measure (Li et al. 2011, Sirisawa 2009).

2.3. Designing the research model

The issue of location selection of logistics centers has been the subject of multidisciplinary studies to a large extent. The common feature of these studies is besides being strong quantitative studies, they are theoretically weak. The lack of a strong theorical framework constitutes the critical side of the relevant literature.

There is a wide literature on logistics village location selection (Grant et al, 2006; Jarzemskis, 2007; Meyer and Miller 2001, Weiqing 2014, Yıldırım and Önder 2014). Studies on logistics centers' location selection have some common features. It is observed that similar criteria are discussed in almost all publications examined in this context. This is because logistics centers must meet certain standards in order to join global freight mobility, and the rules and standards are global. Just like location selection of seaports and airports… Another determining factor in criteria selection in this study is the existing international logistics centers. For example; in Bologna, Zaragoza, Berlin Logistics Center cases; it is deeply searched and observed that global acceptances regarding with location selection are valid. There are some common aspects regardless of in which country and what kind of geography it is established in (Aksoy and Özyörük, 2015; Boile 2010, Chen et al., 2014). In this context, the issues, which are related with the logistics sector, were evaluated in the upper-scale plans prepared for the Thrace Region. As a result, both the explanations in the literature and world examples as well as the local possibilities and potentials of the region were taken into account in the selection of the criteria and sub-criteria.

As a result of all the search; it has been determined that logistics center in Thrace must locate economically, have suitable physical conditions, have strong supply chain relationship with the market and industries and take social responsibilities into account. Physical factors are an important issue discussed in almost all articles on logistics center location selection. Physical factors, in essence, express the geographical possibilities of the area. In this study, one aspect of the physical elements is about the existence of the area and the other is about accessibility. The ownership of the land, the possibility of expansion and the size of the area were evaluated within this framework. Accessibility, on the other hand, provides an idea about which transportation arteries will connect the logistics center with its surroundings. Accessibility also gives us an idea of direct and indirect economic costs (Fagaraşan and Cristea 2015; Kayikci 2010).

Economic factors refer to both direct costs and indirect costs. The cost includes the expropriation cost of the land, infrastructure and operating (Peker et al., 2016; Regmi and Hanaoka, 2013; Taniguchi et al., 1999).

The social aspect of the issue, in addition to the features mentioned above, is about how citizens in the city will be affected by the logistics center. Evaluation of the pollutant effect of logistics and its effect on traffic and congestion also includes the social dimension of the issue.

To briefly explain how alternatives are developed, the most basic element while creating alternatives within the Thrace Region is the regional plans of the region. The current land use situation and development trends have taken into account. Population, transportation connections and industrial production capacities of the settlements were essential. Because logistics center alternatives should have regular and continuous freight flows as well as being at an acceptable distance from the settlement centers and terminals.

It is possible to determine many options that provide these objective conditions in the Thrace Region. In order to appoint the strongest of the options; we received information from research reports, projects and regional plans. Besides Ministry of Transportation and Infrastructure documents, the regional-scale plans prepared by the Thrace Development Agency, the Ministry of Environment, Urbanization and Climate Change have been instructive.

As a result of the examined plans; It is seen that Marmara Ereğlisi is located near the most important transportation axes. D100 Highway, which connects Istanbul to Edirne, passes through the north of the district. Tekirdağ Istanbul Highway (D110-E84) extends along the coastal axis, passes along the coastal axis from the district center. In addition, apart from the highway advantage, local ports: Martaş and Botaş are located in Marmara Ereğlisi. In addition, it also has the advantage as being close to the Çorlu Airport. Muratlı and Havsa are suggested as logistics centers in the 1/100,000 scaled Thrace Environmental Plan. Due to its location, Muratlı logistics center is planned to provide services to the ports and industrial zones in the south of the region, and to establish a connection with Çorlu Airport and Istanbul-Bulgaria, Istanbul-Greece highways. These locations have also advantage of having connection with railway system. Due to its proximity to the border gates and being at the focal point of agricultural production areas, it is predicted that Havsa will expand to the foreign markets. It is anticipated that Çerkezköy, which has a strong industrial infrastructure today, will maintain its industrial identity. In the plans, service and logistics functions that complement the industrial functions were given to the Çerkezköy in order to limit the industrial development. It was stated that the industrial agglomeration in this area will be supported by the port areas, logistics areas, railway and sea transportation connections foreseen in regional plans. According to the regional plans, Tekirdağ, on the other hand, is actually an invisible logistics hub. It is seen that the plans are superior in terms of logistics due to the intersection point of transportation modes and proximity to production areas. In addition, in field study, the options were evaluated on site and the most suitable alternatives were determined as Tekirdağ, Çerkezköy, Marmara Ereğlisi and Havsa, and added to the research model.

3. Results

In the field study, we organized in depth oral interviews in a long period of time with experts of Tekirdağ Chamber of Commerce and Industry, Thrace Development Agency, Turkish State Railway, General Directorate of Highways, Asyaport and municipatilies. In addition, focus group meetings were held with academics in this field. This diversity of opinions enriched the study. Then after field observations and literature survey, main criteria, sub criteria and four possible options appeared (Fig. 2). Each interviewee gave their opinions of their institutional perspective.

3.1. Results of AHP

According to the findings of the evaluation of the main criteria, *Accessibility* has emerged as the most important criterion for the location selection of logistics centers. This is followed by cost and *social benefit. The land features* appear to be of such a low weight that it can be neglected (Table 2).

Findings Related to Sub-Criteria

The second step of the study, which was established with the AHP method, continued with the evaluations of the sub-criteria under their own headings. At this step, the experts were asked to evaluate each of the sub-headings of the four criteria that effect choosing the location of the logistics center with pairwise comparisons.

- Evaluation of Accessibility Criteria:
  Accessibility was determined as the most important issue in the location selection of the logistics center with the weight of 0.597. Only accessibility is superior to the other three criteria. Considering this degree importance; undoubtedly, accessibility is the most important pillar of the logistics industry. The weight of 6 sub-criteria is presented in Table 3.

  The most important sub-criteria in the comparison of this criterion within itself are respectively; proximity to seaports, proximity to supply chain points and proximity to markets. These criteria have gained close weights to each other. Supply and demand points are the subject of the products reaching the logistics center as raw/semi-finished materials or the access of the products to the markets. When considered on a national scale, the most

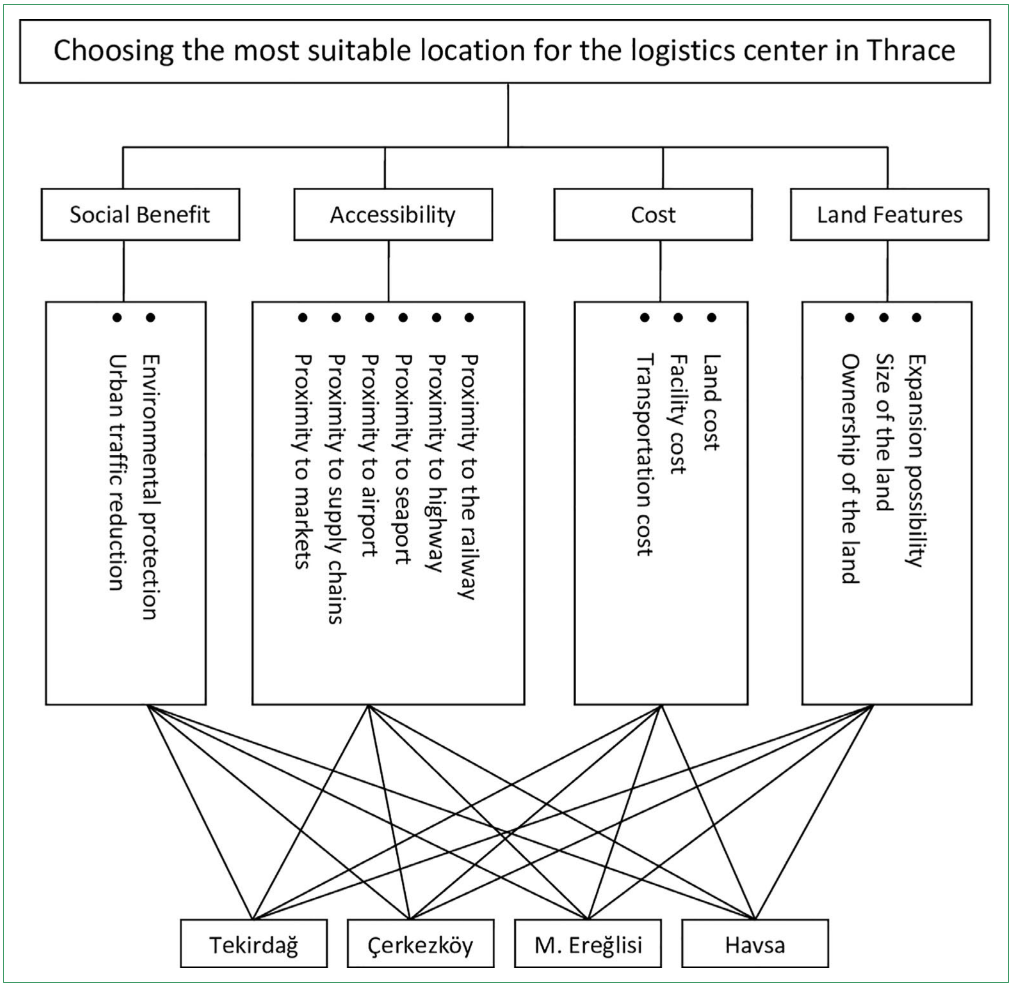

Figure 2. Logistics center location selection model.

important economic and social center is Istanbul. Accessibility to demand points in Istanbul is the most important transportation line in the region. On an international scale; in terms of providing access to European countries, the Thrace is a prominent region in general.

Proximity to the railway, which has the closest weight to these three sub-criteria, is quite behind in terms of score. Then the criteria of proximity to highway and finally proximity to airports comes. Being close to the highway is actually a very important issue. However, since almost every settlement in the Thrace region can receive road service with a certain standard, the weight of this sub-criterion remained low. Airport gained relatively the lowest weight because it does not provide suitable service due to the characteristics of the cargo in the region.

- Evaluation of Costs Criteria:
  The cost criteria expresses the cost that the public will undertake for the establishment of logistics centers. It is the second most prominent criterion after accessibility. Land cost, facility cost and transportation cost were determined as sub-criteria. The result of the comparisons, their relative and global weights are as follows (Table 4):

  Evaluation of the sub-criteria on costs differs in one respect from the evaluation of all other sub-criteria. The reason of the low share of land and facility costs is: The logistics center alternatives are physically close to each other and it is (probably) thought that it will not make an appreciable difference while creating a logistics set up in the region. In particular, the facility cost got the lowest in weight among all sub-criteria. On the other hand, transportation cost is dominantly prominent sub-criteria in this study. It was ranked as third among all the sub-criteria evaluated. This result proves the need to minimize costs.

- Evaluation of Social Benefit Criteria:
  The main criterion of social benefit was determined as the third important criterion with a weight of 0.109 of the total. Environmental protection, one of its sub-criteria, has been accepted 5 times more important than

Table 2. Findings relating to the main criteria

Main criteria	Weight
Accessibility	0.597
Cost	0.245
Social benefit	0.109
Land features	0.049

Table 3. Evaluation of accessibility sub-criteria

Accessibility	Relative weight	Global weight
Proximity to the railway	0.102	0.061
Proximity to highway	0.044	0.026
Proximity to seaports	0.291	0.174
Proximity to airport	0.019	0.011
Proximity to supply chains	0.284	0.169
Proximity to markets	0.260	0.155

Table 4. Evaluation of costs sub-criteria

Costs	Relative weight	Global weight
Land cost	0.233	0.056
Facility cost	0.091	0.022
Transportation cost	0.676	0.168

Table 5. Evaluation of social benefit sub-criteria

Social benefit	Relative weight	Global weight
Environmental protection	0.833	0.091
Urban traffic reduction	0.167	0.018

Table 6. Evaluation of the land features sub-criteria

Land features	Relative weight	Global weight
Expansion possibility	0.102	0.005
Size of the land	0.211	0.010
Ownership of the land	0.686	0.034

Table 7. Evaluation of options

	Detailed relative weight	Global weight
Tekirdağ		0.407
Social benefit	0.062	
Accessibility	0.319	
Cost	0.012	
Land features	0.014	
Çerkezköy		0.222
Social benefit	0.032	
Accessibility	0.156	
Cost	0.020	
Land features	0.014	
M. Ereğlisi		0.185
Social benefit	0.010	
Accessibility	0.097	
Cost	0.064	
Land features	0.014	
Havsa		0.186
Social benefit	0.004	
Accessibility	0.025	
Cost	0.150	
Land features	0.007	

the criterion of its impact on urban traffic. Their relative and global weights are as follows (Table 5):

Considering the urban practice; The fact that an urban functional area causes traffic in the city is not a subject that is taken into consideration at the beginning. However, after the traffic in the city is turned upside down, it is seen how important problems are caused by the wrong location selection of such large functional areas.

- Evaluation of Land Features Criteria:
  Land features are the least weighted criterion with 0.049 weight. Being weighted with the lowest weight level should not mean that the land features are considered as the least importance. It is because of a certain standard that has been reached in terms of the characteristics of the land. However, the criterion should be taken into consideration and given importance. The weights, as a result of the comparisons in the context of all criteria and sub-criteria, are presented in Table 6.

Findings Relating to Options

Experts' opinions were also taken in the comparison of the options at the lowest level of the hierarchy. As mentioned before, experts were asked to compare each of the 14 sub-criteria for four alternatives. The distribution of the weights obtained as a result of this evaluation and the relative and global weights are presented in Table 7.

Table 8. Overall weights of AHP findings

Order	Main criteria	Relative weight	Sub-criteria	Relative weight	Options	Relative weight
1	Accessibility	0.597	Prox. to the port	0.174	Tekirdağ	0.407
2	Cost	0.245	Prox. to s. points	0.169	Çerkezköy	0.222
3	Social ben.	0.109	Transp. cost	0.168	M. Ereğlisi	0.186
4	Land feat.	0.049	Prox.to demand p	0.155	Havsa	0.185
	Total	100	Enviro. Protection	0.091	Total	100
5	Prox. to railway			0.061		
6	Land cost			0.056		
7	Owners. of land			0.034		
8	Prox. to highway			0.026		
9	Facility cost			0.022		
10	Effects urban traf.			0.018		
11	Prox. to airport			0.011		
12	Field size			0.010		
13	Expan.possibility			0.005		
14	Total			100		

AHP: Analytic Hierarchy Process

Within the scope of this study, Tekirdağ is the most suitable alternative. Çerkezköy is the second best option, and Havsa and Marmara Ereğli are the third and fourth in order. Expansions of the options evaluated for the logistics center are as follows:

Tekirdağ: Tekirdağ was determined as the best location as two times weighted than second best option Çerkezköy. The main reason of this difference comes from Tekirdağ's high accessibility criteria. It gained the highest weight in the evaluation of all sub-criteria based on all options. Although the share of the social benefit criterion in the whole is not very high, it still has the highest share when compared to Havsa, Marmara Ereğli and Çerkezköy. The weakest aspect of Tekirdağ is its high costs.

Çerkezköy: The feature that makes the establishment of a logistics center in Çerkezköy a strong option is its high accessibility. Although it is behind Tekirdağ, it is very advantageous in terms of accessibility. Another sub-criterion that makes Çerkezköy second best is its social benefit. However, it has been noted that the costs will be very high in Çerkezköy.

Havsa: Havsa and Marmara Ereğli were weighted with almost the same score. However, these two options differ from each other with an important difference. Although Havsa's distance from the port and main transportation axes causes a disadvantage in terms of accessibility, it is expected to have the lowest costs. In other words, the strongest aspect of Havsa is that the costs are lower than any other options.

Table 9. Decision matrix

	Cost	Accessibility	Social benefit	Land features
Tekirdağ	9	9	8.5	5
Çerkezköy	6.5	6.5	7.5	5
M. Ereğlisi	5.5	5.5	5	5
Havsa	3	3	3	3

Marmara Ereğli: Marmara Ereğli is in the most disadvantageous position as a result of the evaluation. It is not a very bright choice in terms of location, but its strongest feature is its accessibility. Within the expectation of low land prices, it seems to be more advantageous than Tekirdağ and Çerkezköy in terms of costs. The overall findings of the AHP study are presented in Table 8 below.

3.2. Results of TOPSIS

In TOPSIS method, the main criteria determined according to the expert choises and the suggested locations for the logistics center were weighted as presented in Table 9. While creating the decision matrix, the averages of the calculated values based on expert opinions were taken into account. The values of main criteria and options are determined according with 3, 5, 7 and 9 importance levels are given as below.

Table 10. Standard decision matrix

	Cost	Accessibility	Social benefit	Land features
Tekirdağ	0.706	0.706	0.667	0.546
Çerkezköy	0.510	0.510	0.588	0.546
M. Ereğlisi	0.432	0.432	0.392	0.546
Havsa	0.235	0.235	0.235	0.327

Table 11. Weights of main criteria

Main criteria	Weight
Accessibility	0.354
Cost	0.313
Social benefit	0.167
Land features	0.167

In the second step, the standard decision matrix was obtained. It is found by dividing the first value obtained in Table 10 by the square root of the sum of the squares of the values in that column.

The weight values (w) of the evaluation factors are determined. Among the evaluation factors, the w value of the cost factor was calculated as 0.31, the w value of the accessibility factor was calculated as 0.354, the w value of the social benefit and land features factors were calculated as 0.167. Then, Table 11 was created by multiplying the Standard Decision Matrix w value.

According to Table 11, it appears clearly that Accessibility is the most important criterion with coming right after Cost criterion. Social benefit and land features come then with close weights to each other (Table 12). This order is parallel to AHP results presented in Table 2.

In order to create the ideal solution set, the size of the weighted evaluation factors in the X matrix, that is, the column values is selected. Then, the values in the X matrix are first removed from the maximum value calculated in the fourth step and squared, and the square root of the sum of these values was found by calculating the ideal separation measure. The values in the X matrix are used to calculate the negative ideal separation measure.

In the last stage; ideal and negative discrimination measures are used to calculate the relative closeness of each decision point to the ideal solution. This criterion is the share of the negative ideal discrimination measure in the total discrimination measure. As for the relative closeness to the ideal solution, Tekirdağ has a greater relative closeness value 1.000 to the ideal solution compared to other options. Çerkezköy approached the ideal solution less than Tekirdağ and more than Marmara Ereğlisi. In addition, it took the second place with a value of 0.613. Marmara Ereğlisi presented the ideal solution as third level with a closeness value of 0.427. Havsa, preferred in the last place, was the last option in terms of closeness to the ideal solution.

Table 12. Weighted standard decision matrix

	Cost	Accessibility	Social benefit	Land features
Tekirdağ	0.219	0.247	0.113	0.093
Çerkezköy	0.158	0.179	0.100	0.093
M. Ereğlisi	0.134	0.151	0.067	0.093
Havsa	0.073	0.082	0.040	0.056

Table 13. Values of closeness to the ideal solution

Options	C value
Tekirdağ	1.000
Çerkezköy	0.613
M. Ereğlisi	0.427
Havsa	0.000

Tekirdağ is the option that has the best results in the study with both methods. Moreover, Havsa is the most disadvantaged location for both methods. The TOPSIS results presented in Table 13 are quite similar and shows consistency to AHP results. This result proves that our study was completed correctly with both techniques (Fig. 3).

4. Discussions and Conclusion

Thrace region has goals such as gaining more progress in opening up to the West and overcoming crises with its adaptation capacity. Yet the Region has several logistics issues. Despite its high potential, logistically chaotic region is observed, because of logistics supply and demand mismanagement (Thrace Development Agency, 2009; Thrace Development Agency, 2011; Thrace Development Agency, 2013; İBB, et al. 2009). Considering that the current industrial production will continue to increase, it is clearly seen that logistics sector in the region needs to be well organized. With the right planning strategies, it is possible to provide a sustainable logistics system in the region. It is in a critical position for both domestically distributed and inbound cargoes, as well as transit cargoes transferring abroad. Despite all types of transportation infrastructure, a low capacity performance is remained because of unbalanced road-based transportation system and the unplanned logistics factors. One of the

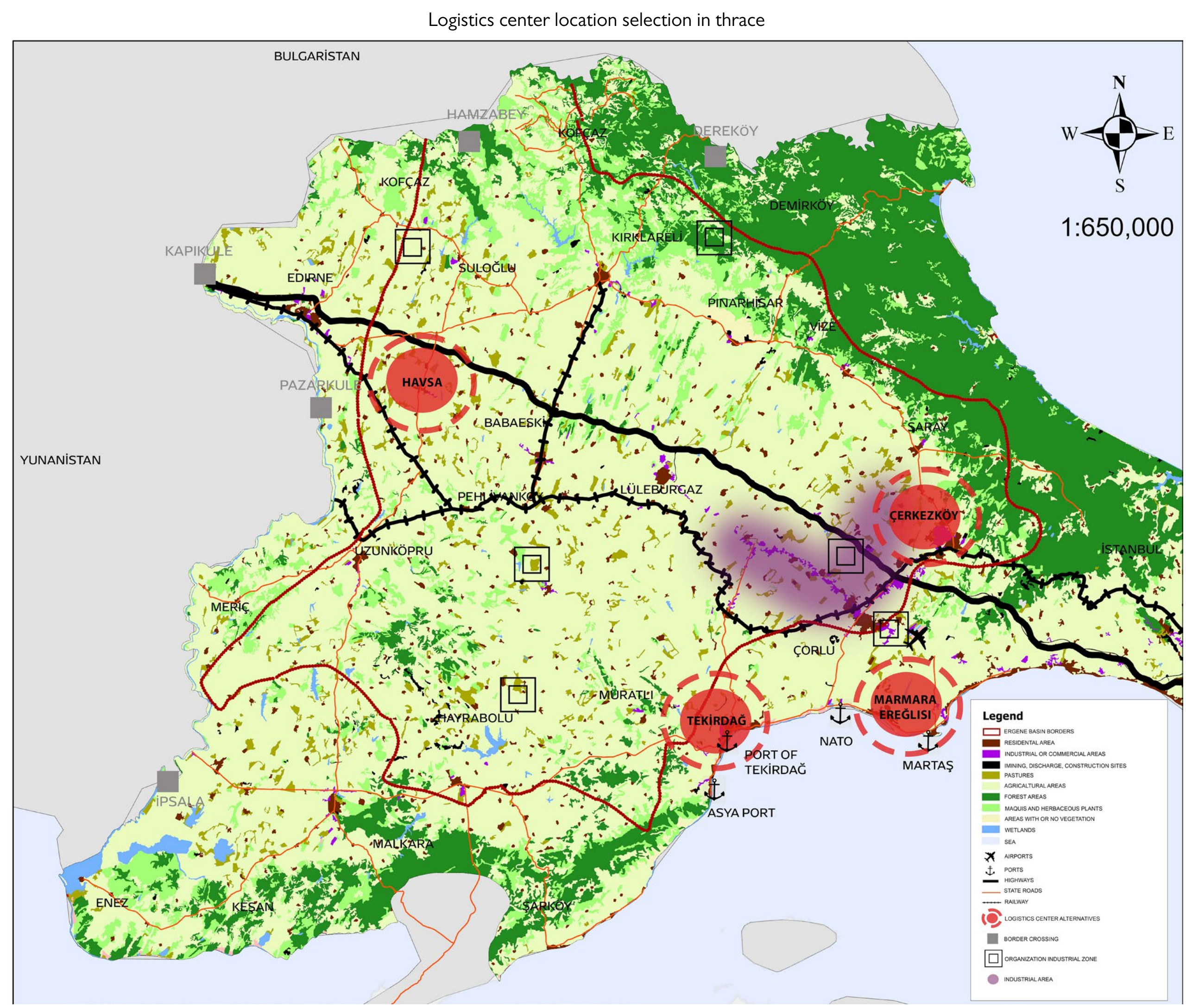

Figure 3. Logistics center location options in Thrace (Prepared by authors).

main reasons for the Region's logistics chaos is the absence of a logistics center. The logistics center that would improve the logistics organization; is thought that it can reverse the current negative conditions of the region. However locating logistics center in the right place is one of the most important issue. Therefore, this study aims to find the most suitable location for the logistics center in Thrace Region.

The structure of the study was prepared based on the literature review besides field study. Choosing the optimal logistics center location in the Thrace Region was determined as the objective function. The main criteria determined to achieve this aim are; (1) Cost, (2) Accessibility, (3) Land Features, (4)Social Benefit. Each of these main criteria is enriched with sub-criteria. After the preliminary studies of the method, multi-criteria decision-making techniques were applied by interviewing experts in the field. The most suitable place for logistics center location selection was questioned with AHP and TOPSIS methods. Appropriate location options, after preliminary field studies and literature reviews; Tekirdağ was determined as the optimal.

As the results of AHP and TOPSIS methods, the most significant finding is the similarity and consistency of the findings. Cost and accessibility criteria are the two more important criteria in choosing a logistics center's location than the rest. For a developing and middle-income country like Turkey, it can be considered natural that costs come to the fore. In our country, with infrastructure problems and very limited railway connections, the prominence of being accessible points to a result is consistent with costs. As the concepts of production and consumption are examined in recent economic conditions, it is seen that very few goods are consumed where they are produced. The high level of diversity in consumer demands, needs and preferences are not limited with production of geography. This fact makes accessibility major factor for logistics center location selection. However, accessibility and cost are factors both trigger and support each other. The location with high accessibility, logistics activities are carried out generally with less cost. The sub-criteria of accessibility is examination shows that accessibility to sea and railway is very important in terms of logistics center location selection. Since maritime and railway are the most suitable transportation systems in long-distance transportation. Therefore, the integration of these two transportation systems are very important, and this is one of the problem in Thrace. The relative importance of proximity to the airport is less than other criteria. The absence of an airport that is useful in terms of logistics activities has led to the low importance of the criterion of proximity to the airline in the selection of the logistics center location in the Thrace region. As a result; in the light of aforementioned criteria, it has seen that the most suitable place for the logistics center is Tekirdağ. The second most suitable option after Tekirdağ is Çerkezköy. Çerkezköy is advantageous in terms of accessibility, but its high costs have left Çerkezköy behind Tekirdağ. Marmara Ereğlisi and Havsa are the other options that come in order.

While comparing results of AHP and TOPSIS, findings are such consistent and similar that there becomes the –almost-same end point. Its widespread use in the literature is thought to occur because of this consistency. From this perspective; considering the convenience provided by the application of these two methods in logistics, it is estimated that the use of them will yield beneficial results for researchers.

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