İKTİSADİ İDARİ VE SİYASAL ARAŞTIRMALAR DERGİSİ
JOURNAL OF ECONOMICS BUSINESS AND POLITICAL RESEARCHES

e-ISSN: 2564-7466 | Cilt:8, Sayı: Özel Sayı
https://dergipark.org.tr/tr/pub/iktisad | Vol:8, No: Special Issue

Selection of Dry Port Locations Using PROMETHEE Approach: Case for Türkiye

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Kara Limanı Lokasyonlarının PROMETHEE Yöntemi ile Seçimi: Türkiye Örneği

Yunus KAYMAZ*
Ural Gökay ÇİÇEKLİ**

DOI: https://doi.org/10.25204/iktisad.1192459

Article Info

Paper Type: Research Paper

Received: 20.10.2022

Accepted: 17.07.2023

Abstract

The aim of this study is to determine the most suitable location for a possible dry port in the Aegean Region of Türkiye based on various criteria. The concept of dry port, which is highly discussed especially in foreign literature, and accordingly, dry port location selection is examined as a multi-criteria decision making (MCDM) problem that requires various evaluation criteria. In this context, the PROMETHEE method, which is one of the MCDM methods, is used for dry port selection. As a result of the analyses, it can be said that in an environment where port congestion is increasing, dry ports can decrease this congestion, in this context, Türkiye is in an advantageous position and considering the global crisis events such as the pandemic called Covid-19, such applications will contribute to the overall efforts to strengthen Türkiye's logistics infrastructure. In the study, 10 locations were evaluated based on a total of 13 criteria. Among these locations, the location with the highest score can be considered as the most suitable dry port area.

Keywords: *Dry port, location selection, PROMETHEE, multi-criteria decision-making, supply chain.*

Makale Bilgileri

Makale Türü: Araştırma Makalesi

Geliş Tarihi: 20.10.2022

Kabul Tarihi: 17.07.2023

Öz

Bu çalışmanın amacı Türkiye, Ege Bölgesi kapsamında kurulması olası bir kara limanı için çeşitli kriterler dahilinde en uygun konumun belirlenmesidir. Özellikle yabancı literatürde oldukça tartışılan kara limanı kavramı ve buna bağlı olarak kara limanı lokasyon seçimi, çeşitli değerlendirme kriterleri gerektiren ÇKKV (çok kriterli karar verme) problemi olarak incelenmektedir. Bu kapsamda çalışmada, kara limanı seçimi için ÇKKV yöntemlerinden biri olan PROMETHEE yöntemi kullanılmıştır. Analizler sonucunda, liman sıkışıklıklarının arttığı bir ortamda kara limanlarının bu sıkışıklığı hafifletebileceği, bu bağlamda, Türkiye'nin avantajlı bir konumda olduğu ve Covid-19 olarak adlandırılan pandemi gibi küresel kriz olayları göz önünde bulundurulduğunda, bu tür uygulamaların Türkiye'nin lojistik altyapısının güçlendirilmesine yönelik toplam çabalara katkıda bulunacağı söylenebilmektedir. Çalışmada 10 lokasyon, toplam 13 kriter baz alınarak değerlendirilmiştir. Bu lokasyonlar arasında en yüksek puanı alan lokasyon en uygun kara limanı alanı olarak değerlendirilebilecektir.

Anahtar Kelimeler: *Kara limanı, lokasyon seçimi, PROMETHEE, çok kriterli karar verme, tedarik zinciri.*

Atıf/ to Cite (APA): Kaymaz, Y., and Çiçekli, U. G. (2023). Selection of dry port locations using PROMETHEE approach: Case for Türkiye. *Journal of Economics Business and Political Researches, 8*(Special Issue), 21-38. https://doi.org/10.25204/iktisad.1192459

*ORCİD Assist Prof., Iskenderun Technical University, Faculty of Business and Management Sciences, Logistics Management Department, yunus.kaymaz@iste.edu.tr
**ORCİD Assoc. Prof., Ege University, Faculty of Economics and Administrative Sciences, Business Administration Department, gokay.cicekli@ege.edu.tr

1. Introduction

The volume and types of cargo transported by maritime can vary depending on the global demand for goods, trade routes and agreements, and the capacity of ships. Jaržemskis and Vasiliauskas (2007) argued that to meet the market demand, the capacity of the seaport area should be increased as European Commission (2000) report stated that between 2000-2010 years, the hinterland transport would be doubled. Likewise, Roso (2007) emphasized the importance of inland intermodal terminals and containerization in maritime transport. Hence, Roso (2008) highlighted that such containerization eventually led to bottlenecks and congestions for port operations and gave examples of dry ports to ease such burdens. Khaslavskaya and Roso (2019) stated that the cargo volumes transported by maritime account for 80% of volume and 70% of value, and it takes a crucial portion of the whole cargo volume worldwide. Due to the increasing trade volume of cargo transportation also shows upward trends. It can be assumed that ports are significant trade nodes, and hinterland operations are affected by congestion.

Developing economies should consider providing a well-developed transport infrastructure for the transportation network to compete in the global market. Eliminating the disruptions of the supply chains and maintaining its sustainability pose great importance for providing high service quality and customer satisfaction. From a macro perspective, it can be concluded that the effectiveness and efficiency of the transportation infrastructure affect the development of the countries' economies. Ng and Gujar (2009) argued the dry port concept in India, a developing economy, and provided the conditions of the competitive structure of the dry port industry. Likewise, Ng and Tongzon (2010) stated that dry ports catalyze regional economic development. The further development of dry ports and the improvements in their operations should significantly improve the global competitiveness of Indian products. Indochina's seaport capacity will be supported through hinterland transportation hubs by introducing a feasible dry port system. (Do et al., 2011). By analyzing the dry port industry in India, dry ports contribute to economic development by easing public investments, introducing foreign direct investments and related technologies, and enhancing competition (Haralambides and Gujar, 2011). Ng and Çetin (2012) argued that the characteristics of dry ports in Northern India differ from the Western dry port examples and they stated that dry port locations are clustered around the industrial regions such as developing economies such as India and differ from the developed economies' dry ports' clustering structures.

Dry ports provide some advantages as such terminals propose intermodal nodes to support the regional economy. Dooms et al. (2013) underlined that intermodal trade is crucial to the economy. It reduces overload on the roads, enables environmentally friendly transportation, and is more reliable, efficient, and safe. However, considering the road modality, seaports face various problems. One of them is the lack of space at maritime terminals, long dwell times, and the increasing congestion in their access routes to inland connections (Ambrosino and Sciomachen, 2014). Hanaoka and Regmi (2011) argued that dry ports are nodes in the transport network and are developed to support seaport operations and the sustainable development of international intermodal transport networks. In their studies, Pekkaya and Bucak (2018) determined and evaluated the port locations by using PROMETHEE and concluded that PROMETHEE method is an advantageous method for this type of ranking-selecting evaluation.

Considering the literature related to location selection, many studies are trying to decide on various location decision problems. Görçün and Küçükönder (2021) introduced a novel approach that used an integrated approach consisting of the CRITIC (Criteria Importance Through Intercriteria Correlation) technique and the EDAS (Evaluation based on Distance from Average Solution) to evaluate the selection of RO-RO ports in Black Sea region. Mohan and Naseer (2022) used Analytic Hierarchy Process (AHP) in deciding locations by using Delphi survey for the experts. According to the results, they analyzed five main criteria as proximity, environmental, economic, site specific, and social. Raad et al. (2022) proposed a three-stage method where the decision-making criteria are weighed, potential sites are identified, and those alternatives are evaluated, respectively, using an

integrated MCDM (Multi-Criteria Decision Making)-GIS methodology made up of fuzzy SWARA GIS-based site selection with fuzzy functions and an enhanced version of fuzzy MULTIMOORA. However, as the dry port is a relatively new topic for Türkiye case, there are limited studies both on the dry port topic and their location selection decisions. Henceforth, this study was organized so that a literature review has been conducted on dry ports considering the location selection criteria and factors influencing the location of dry ports. For the methodology part, an MCDM method, PROMETHEE, has been applied to evaluate the possible locations in the context of the Türkiye case.

The originality of the study comes from various parts comparing to the studies in literature. Firstly, as Türkiye differentiates itself by its geopolitical advantage, logistical infrastructure and their efficient use become critical. On this occasion, different policies should be considered and evaluated by policy makers and professionals as well. Henceforth, although there are national studies considering dry port concept, they mostly contributed to the literature, considering international studies, there are various MCDM approaches for analyzing location analysis. Thus, this study contributes not only academic literature but also tried to complete the gap of location analysis of dry port concept in Türkiye context. This study offers some possible locations in Aegean region, which is a region that the density of marine transportation and road transportation are high.

The selection problem is often handled with MCDM methods because it involves a complex decision process with multiple, conflicting, and often subjective criteria. MCDM methods allow decision-makers to consider multiple criteria when selecting a dry port, such as the distance to the seaport, the cost of transportation and handling, the availability of storage and handling facilities, and the level of security. These methods also allow for considering subjective criteria, such as the level of government support or the level of service provided by the dry port. MCDM methods allow for handling the dry port problem in a comprehensive, systematic, and transparent way, considering multiple criteria, thus providing a robust decision-making process. In addition, they allow for the incorporation of different stakeholders' preferences and provide a way to weigh the relative importance of the different criteria.

For the application of the study, 10 locations were evaluated for the possible dry port location areas while considering the 13 criteria. Location 7 has the highest value comparing to the other locations.

2. Literature Review

Dry ports are inland terminals connected to seaports through transportation infrastructure (such as rail and road) and provide facilities for handling and storing cargo.

The earlier studies on dry ports can be found in the United Nations manuscript on dry ports. Beresford and Dubey (1990) defined the dry port as a terminal for import and export cargoes considering the hinterland networks of ports, and various concepts have been used, such as dry ports, inland freight villages, and inland ports, that such a difference in terminology emerged from the different functionality, shapes, and network position of these structures. According to Juhel (1999), a dry port is crucial in optimizing logistics activities to ensure cargo transportation efficiency. Leveque and Roso (2002) defined the dry port term as an intermodal terminal that directly connects to a seaport with high-capacity transport modes, where customers can leave or pick up their products as if directly to a port. Woxenius et al. (2004) underlined those services like storage, consolidation, storage of empty containers, maintenance and repair of containers, and customs clearance should be available at full-service dry ports. Another definition for a dry port state that it is a port situated in the hinterland providing service to an industrial region connected with one or several ports by rail and/or road transport and offers value-added services between the dry port and the transmarine destinations (Jaržemskis and Vasiliauskas, 2007). According to Roso (2008), the idea behind the concept of a dry port is achieving the shift of flows from road to rail resulting in the reduction of road transports to/from the seaport once a dry port is implemented in the transport system as well as maintaining the

quality of the access to a dry port. The quality of the road-rail interface affects the dry port's performance. The Economic and Social Commission for Asia and the Pacific (ESCAP) (2008) introduced the concept of dry ports as activities such as handling and storage of general and bulk cargoes by using means of transportation.

Henttu and Hilmola (2011) define the dry port concept as an inland intermodal terminal with additional value-added services connected by rail to at least a seaport, which provides that dry ports have the capability to achieve freight movement in a maximum amount through railway from the port. Sağlam et al. (2015) provided some characteristics for dry ports as they connected directly to one or more seaports, handling of intermodal activities, provided value-added services, and provided the primary operations of a port, such as storage, consolidation, and transportation of freights.

By considering all the definitions according to the dry port concept, there are various classifications stated in the literature. Leitner and Harrison (2001) also provided the earlier classifications of dry ports as inland ports, trade and transportation ports, feeder ports, and air cargo ports.

Woxenius et al. (2004) classified dry ports as distant, mid-range, and close dry ports, which can be seen in Figure 1;

- Close dry ports: The type of dry port serves as a consolidation point for freights from road to shippers through a railway. In Figure 1, the dry port labelled as A reflects the close dry port.
- Mid-range dry ports: provide a consolidation point and are consequently situated within a distance from the port generally covered by road transport. In Figure 1, the dry port labelled as B reflects the close dry port.
- Distant dry ports: the freight movement through rail is feasible considering the distance and size of the freight. In Figure 1, the dry port labelled as C reflects the close dry port.

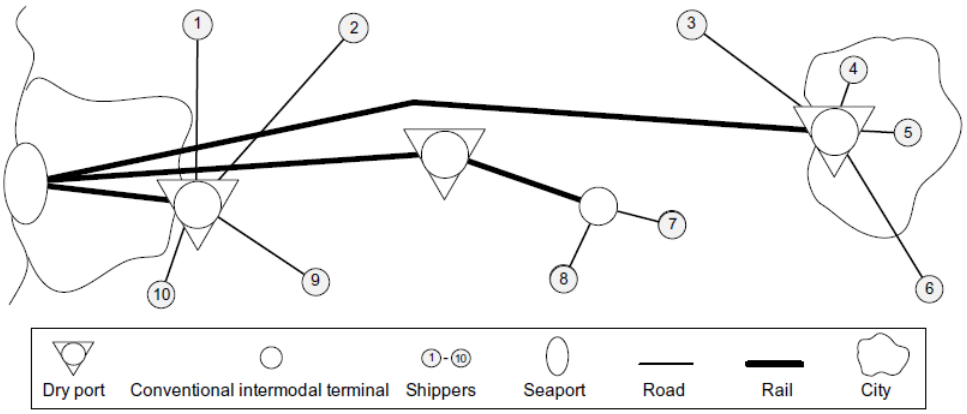


Figure 1. Visualization of Close, Medium-Range, and Distant Dry Ports
Source: Roso et al., 2009.

In addition to the economic, environmental, and managerial studies within the scope of the issues discussed on dry ports, publications related to the location selection of dry ports are also paid attention to in the literature. Thus, Chang et al. (2015) pointed out that as well as integer programming and linear programming, various MCDM methods such as AHP (analytical hierarchy process), F-AHP (fuzzy analytical hierarchy process), DEA (data envelopment analysis) have been used to determine the possible locations for dry ports. Using three MCDM techniques, the authors examined the selection criteria for dry ports within the context of the Chittagong port's hinterland. The proximity of the dry port to the seaport as well as the accessibility of the dry port to exporters and importers have been determined to be significantly relevant for the selection of the dry port location in the Fuzzy AHP analysis (Chowdhury and Haque Munim, 2022). Bentaleb et al. (2016) proposed a multi and mono-criteria methods in order to find an optimal dry port location. The PROMETHEE method is based on pairwise comparisons, considering the evaluation factors of the points to be determined, and

the most distinctive difference from other MCDM methods is that besides the weights of the evaluation criteria indicating the level of connection between each other, each evaluation criterion considers the relationship between each other (Asoğlu and Eren, 2018). This method is easier to use and more effective compared to the other methods, and thus, it has been chosen for this study. Another reason is that there is a separate preference function and superiority approach for each of the selection criteria (Çiçekli et al. 2018).

3. PROMETHEE Method

PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) is a family of multi-criteria decision-making methods that are commonly used to analyze and rank alternatives based on a set of criteria. Brans et al. (1986) developed the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), a method for multi-criteria decision-making. PROMETHEE is particularly useful in situations where there are multiple, conflicting, and often subjective criteria that need to be considered. The method is based on the concept of outranking and uses pairwise comparisons to rank alternatives.

One of the main advantages of PROMETHEE is its ability to handle both quantitative and qualitative criteria. It also allows for incorporating different stakeholders' preferences and provides a way to weigh the relative importance of the different criteria. The method also allows for the consideration of criteria with different measurement scales and different levels of importance.

PROMETHEE has been widely used in various fields such as logistics, transportation, energy, environment, and healthcare.

PROMETHEE is implemented in five steps, as shown in Figure 2.

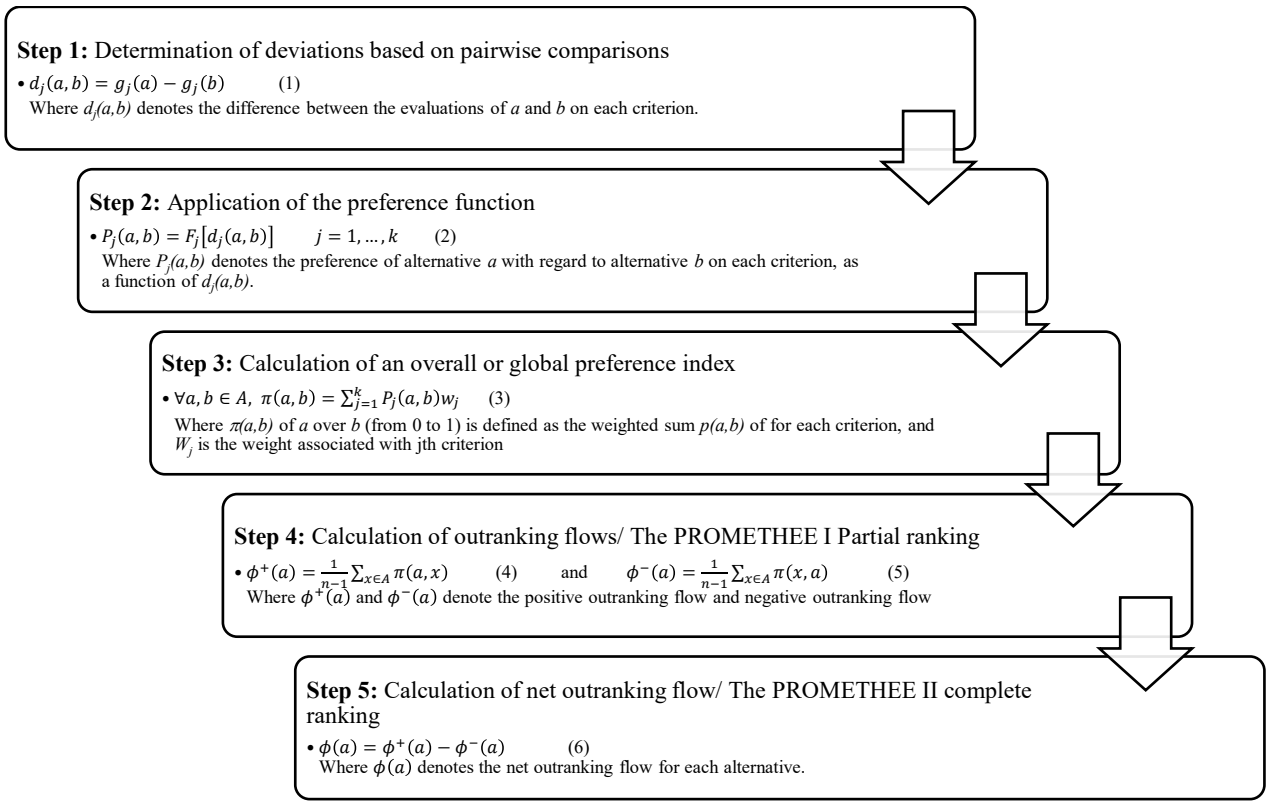


Figure 2. Stepwise procedure for PROMETHEE II
Source: Behzadian et al., 2010.

Behzadian et al. (2010) stated that this method outranks the related alternatives among conflicting criteria. While PROMETHEE I involve partial ranking, PROMETHEE II involves full ranking, and then the method decides the necessary decision points. Brans and Mareschal (2005) highlighted six functions in the PROMETHEE method. Figure 3 indicates the related functions.

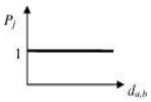
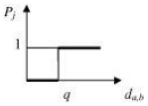
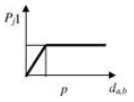
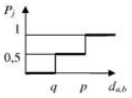
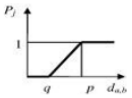
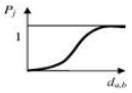
Function Type	Function Graph	Function	Explanation
Type 1: Regular Criterion		$P_j(a,b) = \begin{cases} 0; & d_{a,b} \le 0 \\ 1; & d_{a,b} > 0 \end{cases}$	When there is no preference for the decision maker for the evaluation criterion, this function type is used.
Type 2: U-Shape Criterion		$P_j(a,b) = \begin{cases} 0; & d_{a,b} \le q \\ 1; & d_{a,b} > q \end{cases}$	This function type should be used in cases where the decision maker wants to prefer decision points with values above the value determined by the relevant evaluation criteria.
Type 3: V-Shape Criterion		$P_j(a,b) = \begin{cases} \frac{d_{a,b}}{p}; & 0 < d_{a,b} \le p \\ 1; & d_{a,b} > p \end{cases}$	This function should be used when the decision maker wants to prefer decision points with above-average values for an evaluation criterion without ignoring the values below the average.
Type 4: Level Criterion		$P_j(a,b) = \begin{cases} 0; & 0 < d_{a,b} \le q \\ 0{,}5; & q < d_{a,b} \le p \\ 1; & d_{a,b} > p \end{cases}$	This function should be used when the decision maker determines his/her preference for an evaluation criterion as a certain range.
Type 5: Linear Criterion		$P_j(a,b) = \begin{cases} 0; & d_{a,b} \le q \\ \frac{d_{a,b}-q}{p-q}; & q < d_{a,b} \le p \\ 1; & d_{a,b} > p \end{cases}$	This function should be used when the decision maker wants to choose decision points with values above the mean for an evaluation criterion.
Type 6: Gauss Criterion		$P_j(a,b) = \left\{ {}^{e^x}/_{1+e^x} \right.$	This function should be used if the decision maker's preference will be determined by the deviation of the relevant evaluation criteria values from the mean.

Figure 3. Preference Functions for the PROMETHEE method
Source: Brans et al., 1986; Çiçekli et al., 2018.

PROMETHEE is a widely used MCDM method that is particularly useful in situations where there are multiple, conflicting, and often subjective criteria that need to be considered. Its ability to handle both quantitative and qualitative criteria, incorporate different stakeholders' preferences, and provide a way to weigh the relative importance of the different criteria are among the reasons it is commonly used in literature.

4. Factors Influencing the Location Selection of Dry Ports

Determining the criteria is critical for the selection of best location is crucial. On this occasion, an extensive literature review has been conducted for dry port selection to extract the suitable criteria. According to the ESCAP (2008), various criteria should be considered during a decision on a dry port location, and further, they proposed various key attributes as in Table 1:

Table 1. Key Attributes for A Dry Port

Key Attributes	Coverage
Geographical	linked to a sea or airport inland – located away from traditional land, air, and coastal borders
Transport logistics	high capacity transport link(s) more than one transport mode intermodal transfers
Warehouse logistics	temporary storage or warehousing consolidation and deconsolidation
International port	international trade involved customs inspection other services found in an international sea or airport
Value added logistics services	freight forwarding information systems other value-added services

Source: ESCAP, 2008.

According to Hanaoka and Regmi (2011), proximity to ports; links to other modes of transport; development, operation, and shipping costs; the potential to promote mode shifting; environmental concerns; the potential to attract production and distribution facilities; and some economic incentives for regional economic development are factors that affect the location of dry ports. Table 2 provides the evaluation criteria and the methods used.

Table 2. Criteria Considered in the Selection of Dry Port Locations

Author(s)	Evaluation Criteria	Methods Used
Wang and Wei (2008)	• Weather conditions • Geological conditions • Hydrological conditions • Terrain conditions • Labor conditions • Characteristics of goods • Level service • Customer conditions • Traffic • State of public facilities • Information infrastructure • Transport costs • The local labor wage level • Use of land resources • Environment protection	Analytical network process
Wei et al. (2010)	• Traffic • Information infrastructure • State of public facilities • Transport costs • The environment protection • Local labor wage level • Labor conditions • The distribution and quantity of goods • Customer conditions	Fuzzy-Analytical network process
Henttu and Hilmola. (2011)	• The location of city and its attractiveness (Ability to serve top 50 city in Finland) • Preparedness for necessary infrastructure • Accessibility to railway • The efficient use of coastal areas of cities • The availability of ports in cities to intermodal system • Population	Linear integer programming

Table 2 (Cont.). Criteria Considered in the Selection of Dry Port Locations

Rahimi et al. (2008)	• Adequate demand for intermodal transportation • The local supply for transportation services • Successful public relations management • Contribution of public/private sector	Single facility location model
Tamosaityte and Haat (2012)	• Infrastructure • Proximity to suppliers and customers • Tax and political advantages • Serving value added services	Semi-structured interviews
Awad- Núñez et al. (2014)	• Environmental protection • Noise on natural environment • Noise on urban areas • Hydrology • Land price • Geography • Accessibility to transportation modes • Accessibility to services • Weather • Orography • Geology • Distance to other logistics platforms	Multi-criteria decision-making
Ng and Noteboom (2016)	1-Criteria relevant to dry port users • Reduction of Transportation cost • Reduction of Transportation time • Accessibility to road infrastructure • Accessibility to railway infrastructure • Accessibility to waterway infrastructure • Range of services • Proximity to the production base • Proximity to other logistics platform 2- Criteria relevant to dry port service providers • Demand for dry port services • Investing and operating cost • Room for expansion • Investment and operational climate • Inter-project spillover effect 3- Criteria relevant to the community • Complementary with other inland transport and seaport planning • Contribution to land use reorganization • Maximizing value added services and return to government • Employment generation • Minimizing transportation pollution • Dry port related pollution • Noise • Minimizing visual intrusion • Minimizing road congestion	Multi-criteria decision-making
Komchornrit (2017)	• Seaport • Airport • Highway • Industrial area • Local market • Regional market • Cross-border market	Multi-criteria decision making

Source: Adapted from Çiçekli et al., 2016.

4.1. The PROMETHEE Approach in Multi-Criteria Decision-Making for the Selection of Dry Port Locations

To determine and weight the criteria set, a working group consisting of 3 people working at the managerial level at the port and five academicians working at the dry port was formed. Within the scope of the study, the criteria set in different studies in Table 2 were examined. Among these studies, the working group decided that the criteria set in the Awad-Núñez (2014) study is the most appropriate set of criteria for the selection of land ports in Türkiye. However, since the measurements of the geological criteria could not be made, it was decided to exclude it. The factors and explanations are presented in Table 3 below. These criteria were defined by identifying the elements observed in previous studies in Table 2.

Table 3. Selection criteria for dry port locations

no.	Factor name	Observations
1	Noise on environment	Noise level measured in dB on the natural environment
2	Distance to urban areas	Binary variable automatically discarded protected areas
3	Hydrology	Presence of vulnerable areas such as rivers, streams or lakes
4	Land price	Measurement of investment to make
5	Municipality	Considering the size of the municipality, the future development of urban centers and centers nearby and the demographic and economic potential
6	Accessibility to the rail network	Accessibility to freight and passenger transport networks
7	Accessibility to high-capacity roads	Accessibility to high-capacity motorway networks
8	Accessibility to airports	Accessibility to air cargo terminals
9	Accessibility to seaport	Connection with one or more Seaports
10	Accessibility to supplies and services	Accessibility to communication networks and the electrical grid and any other necessary utilities such as water, sanitation, etc.
11	Weather	The climates appropriateness for activities in the greatest number of days per year.
12	Orography	The orography is used to understand the topographic relief of the area on which the facility is located. This factor is commonly used to plan infrastructures.
13	Distance to other logistics platforms	Overlap between hinterlands and the agglomeration of industries

Source: Adapted from Awad-Núñez et al., 2014:45.

Considering the expert consensus and a comprehensive literature review in the related area, various criteria and PROMETHEE functions used for criteria were defined. Therefore, this study aimed to determine the most suitable location considering the criteria derived from expert decisions and literature. Figure 3 depicts the function type used in the specific criteria, the 13 criteria used to evaluate possible locations and the criteria weights. The possible locations used in this study can be seen in the Figure 4. Considering the related possible locations, each location in Figure 4 determined according to the land size and distance to the ports. The distance criteria derived from Crainic et al. (2015) that the authors indicated the distant dry port is located at a long distance from the interested seaport(s), higher than 500 km. Midrange dry ports are predicated on the presence of extra railway connections towards normal inland intermodal terminals and are situated within a distance from the seaport(s) that is/are typically covered by road transport (from 50 to 500 km). With the close dry port arrangement, the seaport's degree of congestion is significantly reduced because the dry port is only a short distance (less than 50 km) away. In this context, ten possible location consideration also reinforced through expert decisions and the final possible location can be seen as in Figure 4.

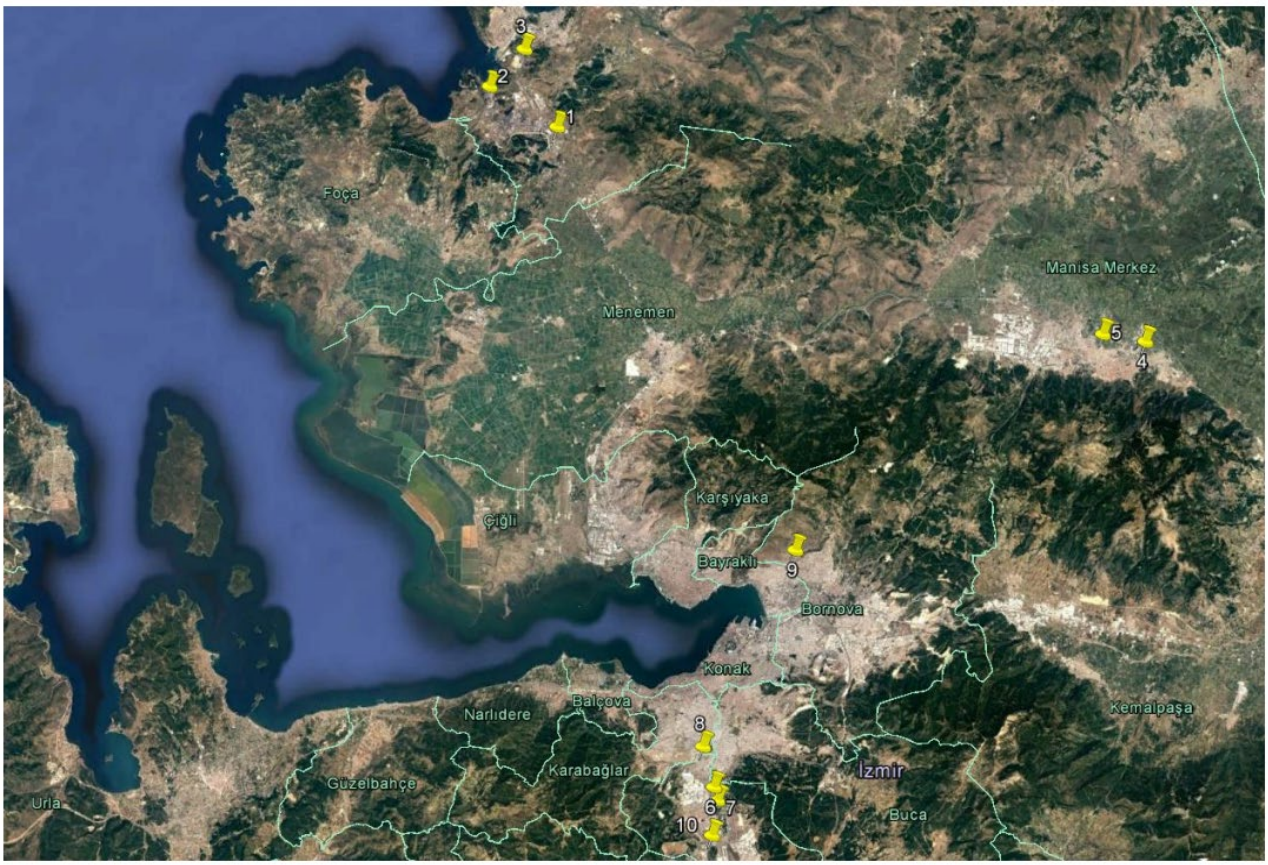


Figure 4. Possible Locations Used in the Selection of Dry Port Locations

As shown in Table 4, in the left hand of the table, the preferences column includes the criterion value, which is used as minimum or maximum for the evaluation, weight, and preference functions mentioned in Figure 3. Min/max value indicates the preference of criterion which uses the minimum or maximum value. For example, as municipality criterion considers the maximum value due to the economic considerations, land price criterion considers the minimum land prices. Weight preference concludes the weights for all the criteria separately while some of the criterion has more weights compared to the others. Preference function corresponds the function types for the PROMETHEE method. Indifference and preference rows state the difference thresholds values of each criterion.

Table 4. Thresholds and Functions Used in Criteria

Scenario1	**Noise on Env.**	**Distance to Urban Area**	**Hydrology**	**Land Price**	**Municipality**	**Rail**	**Road**
Min/Max	Max	Max	Max	Min	Max	Min	Min
Weight	0.01	0.03	0.06	0.03	0.02	0.05	0.06
Preference Fn.	V-Shape	V-Shape	Gaussian	V-Shape	Level	Linear	V-Shape
Thresholds	Absolute	Absolute	Absolute	Absolute	Absolute	Absolute	Absolute
Q: Indifference	n/a	n/a	n/a	n/a	33.33	1	n/a
P: Preference	3	3	n/a	150	66.66	5	2
Scenario1	**Airport**	**Seaport**	**Infrastructure**	**Weather**	**Orography**	**Other LP**	
Min/Max	Min	Min	Max	Max	Min	Max	
Weight	0.06	0.14	0.16	0.02	0.12	0.14	
Preference Fn.	Linear	Linear	V-Shape	Gaussian	Linear	V-Shape	
Thresholds	Absolute	Absolute	Absolute	Absolute	Absolute	Absolute	
Q: Indifference	5	5	n/a	n/a	4	n/a	
P: Preference	30	30	100	n/a	15	100	

Source: Created by authors.

The noise on the environment criteria threshold here is 3 km. A V-Shape function is used to select a dry port location. It is expected and preferred that the alternative site for a possible dry port location is going to take more points after the threshold limit of 3 km. which is also the preference threshold value. The possible dry port location is going to take more points if the related location is far from the preservative natural areas.

The distance to urban areas factor threshold is also 3 km. that a V-Shape function is used in the selection of dry port location. It is expected and preferred that the alternative site for a possible dry port location is going to take more points after the threshold limit of 3 km. Therefore, the preference threshold (p) for the function was determined as 3 km for this criterion.

Hydrology criterion is another factor that influences dry port location selection criteria. This criterion includes vulnerable areas such as rivers, streams, or lakes. The hydrology criterion uses the sixth type (Gaussian Shape), in which the highest point is 100 and the lowest point is 0. Therefore, it is expected that the possible locations will get a higher value considering the distance to the hydrology areas for this criterion.

Another factor influencing the selection of dry port locations is the land price criterion which uses a function of land price value, cement price. A third type function (V-Shape) was used in this criterion. The threshold value is 150, which indicates that above the value, the possible locations got 0 points, and a lower value below the threshold value of 150 is expected for this criterion.

Considering the size of the municipality, the future development of urban centers and centers nearby, and the demographic and economic potential will have an impact on the location decision of dry ports. The fourth type (Level) function was used for municipality criterion due that a gradual function structure was needed.

The transportation modes included in the selection of dry ports are rail, road, sea, and air transport. Rodrigue and Noteboom (2012) pointed out that geographical characteristics and regional access capacities play an essential role in establishing dry ports and shaping their development, besides railway networks that are also crucial regarding the utility and productivity of dry ports. They also indicated that every domestic market would require a different transportation system; thus, there will not be only one dry-port strategy. Similarly, Çağlıyan, et al. (2013) emphasized that the transportation of raw materials has become very important with mass production and the increase in the number of orders for raw materials with each passing day. They added that railway transportation has come to the forefront in distributing the raw materials arriving at ports across the inlands, although maritime transport remains essential. With the latest developments in the economy and technology, as well as the increase in the number of regions having a high load potential and which are close or connected to organized industrial sites, railway networks have gained significance in loading, and discharging operations carried out in the port hinterland (Turkish State Railways, 2014). The fifth type (Linear) function was used for the rail transportation criterion, with a preference value of 5 km. and the indifference was 1 km. In this criterion, the minimum value is expected, and there is a linear structure with a value between 1-5 km. In the context of transportation modes in Türkiye, Karadayı (2012:26) highlights that road transportation mode has the most advantage compared with the other transportation modes. However, Woxenius et al. (2004) state that road transportation mode still dominates traffic mode and involves adverse emissions, noise, and accidents. Thus, the road criterion uses a third type (V-Shape) function below 2 km. the possible locations got higher points after 2 km. possible locations got fewer values gradually.

Although air transport mode constitutes a small percentage of million tons (%0.6), the availability of air cargo transportation increases the competitiveness of the logistics service providers. The lack of sites and the congestion in terminal services can be listed among the main problems recently encountered at ports. Direct railway connection to seaports makes transportation to dry ports possible. So, further developing hinterland networks under the high-volume development conditions

of dry ports and inland terminals is crucial. Therefore, the fifth type (linear) function was used with a threshold of 30 km.

Infrastructural considerations are also an essential pillar for such facilities that, without proper investigations of related infrastructure elements, will decrease the efficiency and the dry ports' information capability. Here, accessing various communications mediums and the availability of infrastructure elements such as sewage, natural gas lines, electrical circuits, etc., might be considered vital. In this context, Awad-Núñez et al. (2014) highlighted that accessing supplies and services such as sanitation and other related utilities might affect the selection criteria. For this criterion, a V-Shape function was used, that a maximum value is 100 and the minimum value that a possible location can get is 0.

Climate conditions are also another criticism that affects transportation activities. Henttu and Hilmola (2011:3) stated that these two relate to each other. This study determines the climate conditions by considering the weather conditions of cities and counties for selected points.

Orography confronts the topographic characteristics of the land. Here, the slope and curl characteristics of the land determine the investment decision (Awad-Núñez et al., 2014:314). The geology criterion includes various characteristics of the soil. Here, soil term is a technical term that includes various elements such as the excavability of the soil, the pressure of the soil, etc.

Other logistics platforms referred to in calculating the points for this criterion, the distance between selected points and the industrial areas and logistics platforms were taken into consideration. The distances were calculated with statistical methods and classified as very close range, close range, medium range, distant range, and very distant range. Getting close to the industrial areas creates more demand potential and an advantage; however, closing to the logistics platform creates a disadvantage by distributing the logistics traffic.

The alternative location evaluation matrix can be seen in Table 5, which includes the ten possible locations for dry port locations and the related criteria.

Table 5. Evaluation Matrix Concerning the Alternative Locations

Scenario1	Noise on Env.	Distance to Urban Area	Hydrology	Land Price	Municipality	Rail	Road
Location 1	7.26	0.47	66.47	128.2	45.54	10.8	0.12
Location 2	5.62	1.62	60	103.01	45.54	7.4	4.5
Location 3	2.27	3.42	51.33	146.16	45.54	3.7	0.85
Location 4	0.14	1.55	60	133.37	67.1	1.3	0.6
Location 5	0.42	2.07	63.93	149.64	67.1	4	1.26
Location 6	0.57	1.68	80.43	106.53	8.32	2.1	1.37
Location 7	0.47	1.73	87.57	128.11	8.32	1.6	0.97
Location 8	0.16	3.15	60.04	128.8	8.32	4.4	0
Location 9	1.15	0.78	59.42	349.27	50	7	4.2
Location 10	0.11	1	88.36	167.51	8.32	5.6	1.25
Scenario1	**Airport**	**Seaport**	**Infrastructure**	**Weather**	**Orography**	**Other LP**	
Location 1	65.8	8.76	66.5	54.01	5.6	40.83	
Location 2	72.5	3.75	70.5	54.01	14.4	33.33	
Location 3	73	1.37	90	54.01	4.05	40.83	
Location 4	59.2	41.8	82	87.43	5.95	37.47	
Location 5	57	39.6	100	87.43	4.7	50.81	
Location 6	5.8	14.82	82	51.57	12.25	57.47	
Location 7	5.2	15.71	92	51.57	6.6	64.99	
Location 8	7.9	12.3	82	51.57	16.65	64.97	
Location 9	31.8	6.52	68	49.62	30.95	80	
Location 10	4.6	23	92	51.57	9.45	92.51	

Source: Created by authors.

The PROMETHEE II results can be seen in Table 6; considering the Phi values, the best alternative is Location 7.

Table 6. Ranking Results According to the PROMETHEE II Results

Rank	Action	Phi	Phi+	Phi-
1	**Location 7**	**0.2103**	**0.2639**	**0.0536**
2	Location 10	0.1415	0.2534	0.1119
3	Location 6	0.1218	0.2221	0.1003
4	Location 8	0.0459	0.1889	0.1430
5	Location 3	0.0279	0.1963	0.1684
6	Location 1	-0.0364	0.1662	0.2026
7	Location 5	-0.0590	0.1764	0.2354
8	Location 2	-0.1237	0.1250	0.2487
9	Location 4	-0.1340	0.1324	0.2664
10	Location 9	-0.1943	0.1531	0.3474

Source: Created by authors.

Figure 5 highlights the related levels at which locations are affected through determined criteria, positively or negatively. The criteria at the top advantageously influence the location, whereas the criteria at the bottom affect it in a disadvantageous way. According to the ranking results derived by PROMETHEE II, according to the rainbow table output, the advantageous and disadvantageous criteria for each location can be seen. For example, Location 7 has disadvantageous criteria such as the municipality, weather, noise in the environment, etc. In Figure 5, the nomenclature is as; Hyd: Hydrology, Air: Airport, Rai: Rail, Oro: Orography, Inf: Infrastructure, Olp: Other LP, Roa: Road, Mun: Municipality, Wea: Weather.

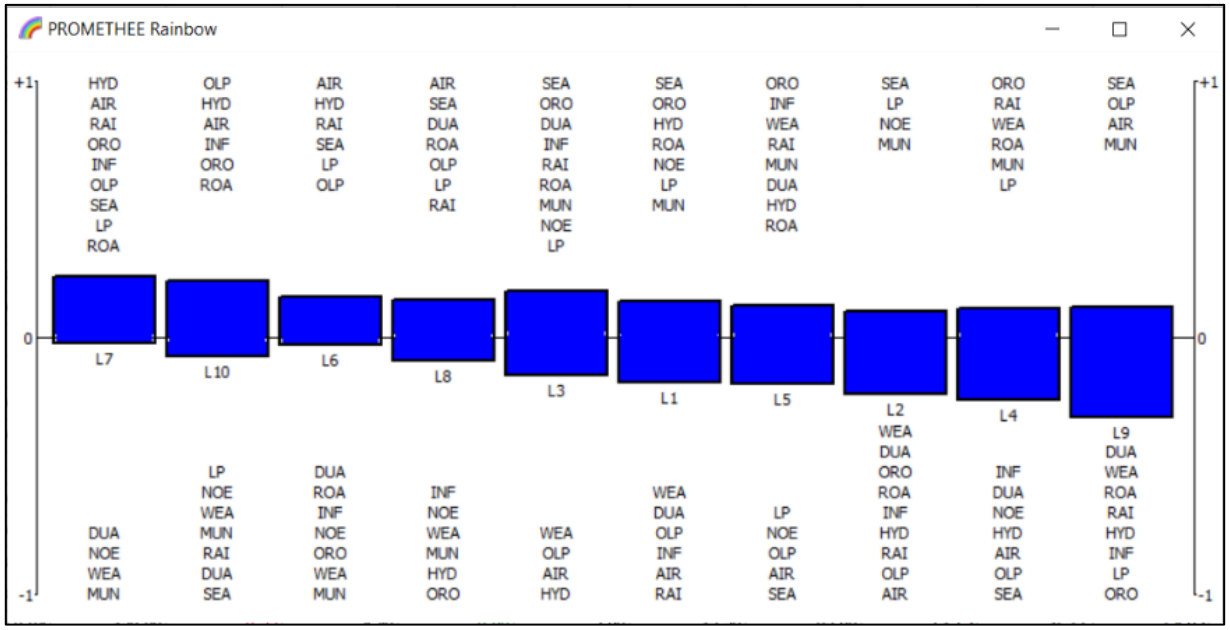


Figure 5. PROMETHEE Rainbow Results for Each Location Considering Positive and Negative Criteria.

Source: Created by authors.

According to the network graph (Figure 6), it can be interpreted that Location 7 has a clear advantage over Location 6 and Location 10. As Location 9 has the lowest score among all others, it has been on the farthest side of the diagram.

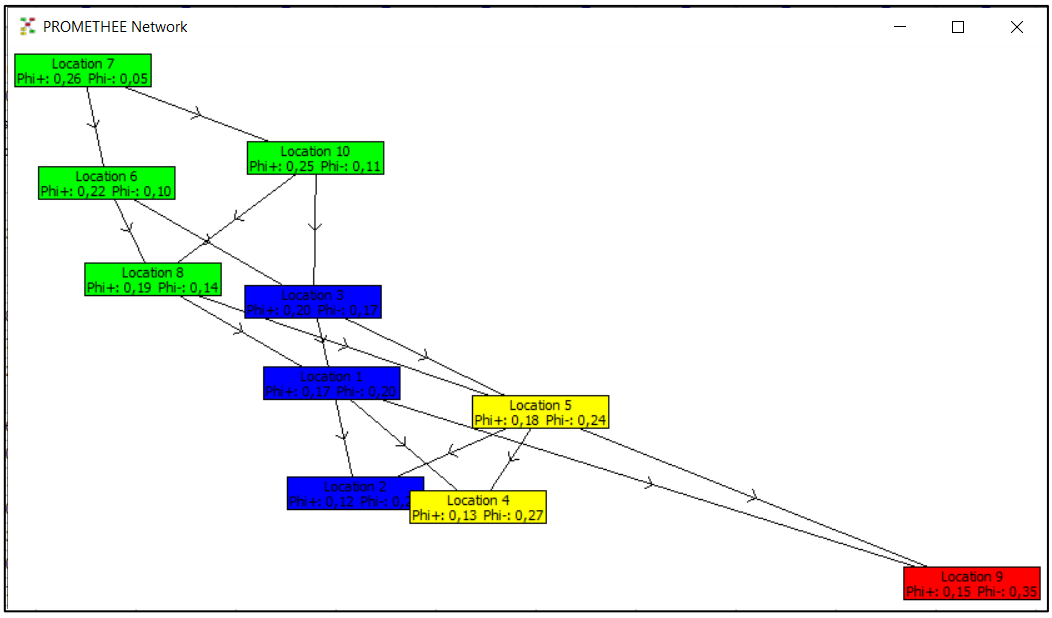


Figure 6. The Network Obtained by the Alternatives from the Criteria (PROMETHEE Network)

Source: Created by authors.

The last graphs (Figure 7 and Figure 8) introduced how each location has got points from each criterion. As can be seen, Location 7 has the most criteria above 0, and Location 9 has the most criteria below 0, which relates the findings with the second table.

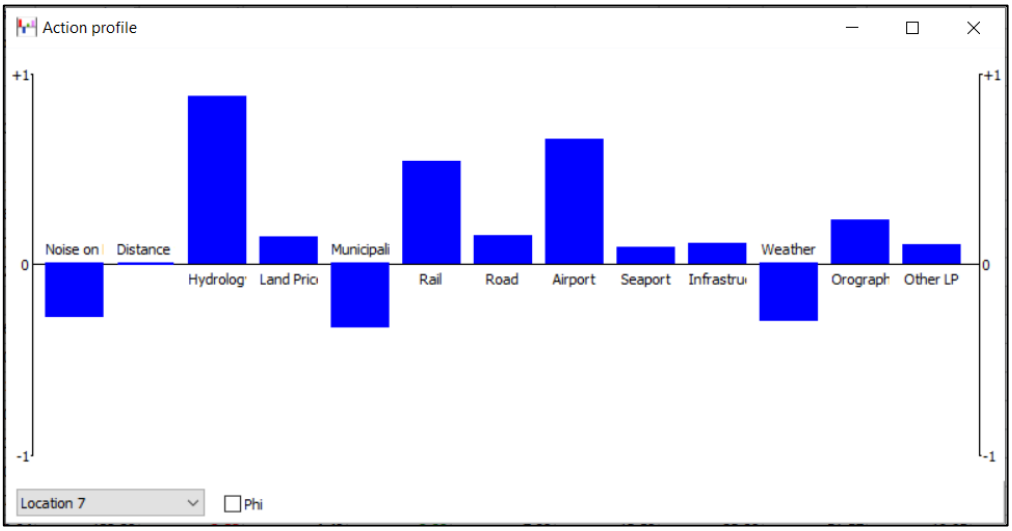


Figure 7. The Individual Location Point for Location 7 from PROMETHEE Action Profile.

Source: Created by authors.

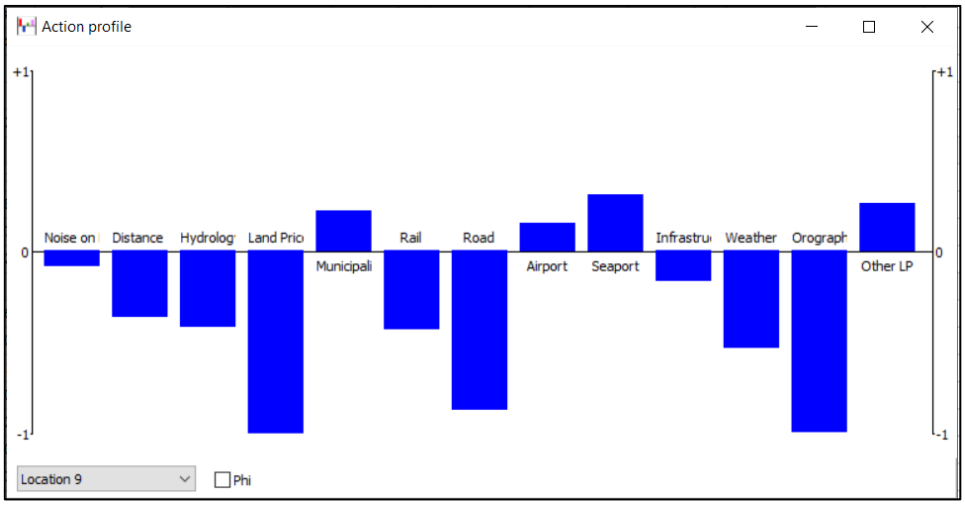


Figure 8. The Individual Location Points for Location 9 from PROMETHEE Action Profile
Source: Created by authors.

5. Conclusion

The increase in trade volume, especially with containerization, has caused the busiest ports around the world to be more crowded and, at the same time, operationally challenging. At this point, various expansions can be made to ease port operations, especially at certain points. Situations where expansions cannot be made for existing ports, are encountered more frequently. In this case, we come across the concept of dry port, which is a concept that has been put forward to use in port hinterland areas to accelerate port operations and increase efficiency. Although the concept of a dry port goes beyond the features of loading and unloading, it can have different roles in the process.

The dry port concept is not new in literature, and it is a concept that draws attention, especially in terms of its use and functionality. Although the definition of the concept of the dry port is made in different ways, it is emphasized by the authors that it is especially beneficial for the hinterland of the port. When viewed within the scope of Türkiye, the concept of a dry port appears as a relatively new concept. In this sense, differences of opinion can be seen in terms of both usage and concept. The fact that there are very limited studies on dry port location selection, especially within the scope of Türkiye, this study differentiates itself from other studies. This study contributes for both literature and practitioners. It contributes to the literature that there are very few studies about the selection of dry port locations. In such an environment that containerization increases the port congestion and its hinterland consecutively, efforts such as dry port terminals will ease that congestion. With this context, while Türkiye has an advantageous position and considering global crisis events such as pandemics so called Covid-19, the applications such effort will contribute to the total efforts for elevating the logistical infrastructure of Türkiye.

In the study, 10 locations were evaluated based on 13 criteria in total. Among these locations, Location 7 received the highest score and was determined as the most suitable location for the establishment of a dry port. Considering the decision-makers and managerial implications, this study, which can contribute to Türkiye's logistics strategy, will contribute to the managers in public institutions, especially for Türkiye, which is trying to achieve the strategy of being a logistics base in terms of location.

Although there are studies considering port locations by using MCDM methods, this study differentiates itself by using PROMETHEE approach. This study used PROMETHEE approach for the ranking of the alternatives. Yet, it has some drawbacks in generating weights for criteria in selection process. Henceforth, it is possible to use other MCDM methods such as Analytic Hierarchy Process (AHP), measuring attractiveness by a categorical based evaluation technique which is

MACBETH approach, Confirmatory Factor Analysis (CFA) may be used to create an alternative determination for the selection process of dry port locations.

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