

# A Set of Criteria for Logistics Center Development: A Fuzzy Analytic Hierarchy Process

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## Abstract

This research aimed to determine and prioritize a set of criteria for the development of logistics centers. Both qualitative and quantitative data collection methods were used to achieve the research aim. Content analysis and semistructured interview techniques were used as the qualitative research methods. Semistructured interviews were conducted with 14 experts, including seven logistics center managers and seven logistics company managers who have worked in a logistics center. The qualitative research revealed eight main criteria and their subcriteria, including location, infrastructure, activities and services, ownership and management, market conditions, regulations, benefits, and horizontal collaborations. The fuzzy analytic hierarchy process was conducted with 18 professionals/experts from different groups of logistics center stakeholders to prioritize the set of criteria. The results were interpreted based on the findings. Among the eight selected criteria, "location" (22%) was the most important criterion, followed by "market conditions" (20%).

**Keywords:** Logistics center concept, Logistics center development, Criteria set, Fuzzy analytic hierarchy process

## 1. Introduction

Logistics centers act as a node in the supply chain, connecting suppliers and customers; therefore, the logistics center concept has evolved in tandem with supply chain management, third-party logistics, intermodality, and sustainable transport concepts. As the supply chain becomes more complex, continual development of value-added, time-based logistics services is required to meet customer demands. The main facilitators of intermodal transport are logistics centers, which bring together the logistics operators offering various transport modes and services to provide synergic solutions. Environmental concerns also play an important role in the development of logistics centers. An important goal of logistics center development is switching to more environmentally friendly transport modes, such as railways and inland waterways rather than roads.

Logistics centers first appeared in the United States of America about 40 years ago, and as the demand for efficient sustainable logistics systems increased, they spread all over the world [1]. Successfully developed logistics centers improve transport infrastructures and logistics market conditions, reduce costs, and increase logistics system quality. In addition, public authorities and private actors can collaborate more effectively to attract and facilitate international trade and investments in a particular region [2]. Logistics centers also help to improve the environmental performance of logistics systems in a region by reducing the number of lorries on the roads, which decreases traffic congestion, accidents, road maintenance costs, and pollution [3]. They are also important nodes that can increase the value-added services in the logistics value chain, thereby increasing supply chain competitiveness. Logistics centers can have different roles, including specializing in the demands of certain products and markets in a global logistics



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network [4]. European Union (EU) transport policies have resulted in the formation of many logistics centers to enhance intermodality and interoperability, alleviate urban traffic congestion, increase transport efficiency, encourage innovation, and decrease transportation costs [5].

Logistics is a relatively new industry in Turkey that has progressed in recent years. Turkey is becoming a bridge between East and West in terms of international trade and logistics. Many authorities claim that Turkey will be a regional logistics base. Many international companies have already been drawn to its logistics sector because of its rapid growth [6]. Since the early 2000s, both the public and private sectors in Turkey have established logistics centers. Since then, nine public logistics centers have been completed out of 21 projects, and three private logistics centers have begun operations [7].

Despite the common use of the term “logistics center” in Turkey and other parts of the world, the term itself, concept definition, and features differ in the literature and in practice because logistics centers continue to evolve and expand. Thus, few keywords were selected to conduct a literature search for related papers. The keywords “logistics centre,” “logistics center,” “dry port,” “freight village,” and “inland port” were searched in Web of Science and Google Scholar from 1970 to 2018. The studies found mainly focused on the logistics center concept, location selection, transport chains, dry port evaluation and development, intermodality, handling operations, and value-added services. However, no research has been conducted to suggest a set of criteria that includes all aspects of logistics center development. Therefore, the main focus of this research was on determining and ranking a set of criteria for logistics center development.

This paper first analyzes the concept of logistics centers in the literature to identify some criteria for logistics center development. Second, section 3 describes the research methodology, and section 4 presents the findings of semistructured interviews with managers of logistics centers and managers of logistics companies located in logistics centers in order to provide an improved understanding of the current situation and expectations in Turkey. Thereafter, the fuzzy analytic hierarchy process (AHP) is used to prioritize the criteria set and compare the perspectives of different stakeholders. Section 5 discusses the results, and finally, section 6 states our conclusions and recommended topics for future research.

## 2. Literature on Logistics Center Concept

Although logistics centers first appeared nearly 40 years ago in the United States before they spread to EU countries, the term “logistics center” is often confusing. Rimiené and

Grundey [1] evaluated the number and scope of logistics center definitions and concluded that a logistics center can be a freight village, transport node, or distribution center. Notteboom and Rodrigue [8] labeled the inland facilities in the hinterland networks of ports as “inland nodes.” These nodes have been referred to as dry ports, inland terminals, inland ports, inland hubs, inland logistics centers, and inland freight villages. According to Roso [3], the basic idea behind the concept of dry ports is that they are directly connected to ports by rail in order to increase the capacity and productivity of the ports. As international trade grows, transportation facilities also grow, particularly container traffic and port facilities. The increase in container shipping highlights the importance of logistics centers in ports and encourages their use [9]. Logistics centers with direct rail connections to ports are called dry ports. These dry ports are vital for efficient intermodal transport and efficient access from and to seaports [10,11].

Logistics centers are a unique type of transport node. A logistics center can be referred to as a freight village, logistics node, or distribution center [1]. Some authors refer to a logistics center as a broad concept that encompasses all companies that engage in transportation and logistics activities [12]. Other authors refer it to as a functional equivalent of freight villages [13]. Studies have shown that both the terms and concepts vary. The logistics center concept is frequently combined with facilities, such as container yards, distribution centers, distriparks, dry ports, freight villages, inland container depots, inland terminals, intermodal terminals, freight terminals, transport nodes, and warehouses [1].

When we analyze the definitions of inland logistics facilities associated with the logistics center concept, we realized that these facilities can provide every aspect, from simple logistics services to advanced logistics services. In terms of regional aspects, these facilities range from local to regional to national to international; some of these centers provide international shipping services, while others provide urban logistics operations (local distribution). Many warehouses or terminals are also called logistics centers by their owners [14]. These facilities also range in geographical coverage, volume, capacity, and services [1,13]. Although there are several useful definitions of logistics centers, establishing a general definition is difficult. Therefore, different definitions that emphasize the functional characteristics are commonly used rather than a universal definition [12].

Table 1 summarizes key points in the literature that are used for differentiating between different types of facilities and identifying the functional characteristics of the terms associated with the logistics center concept.

The terms “logistics center” and “logistics village” are mainly used in Turkey, and the facilities mainly share the same characteristics as other facilities in the world. We prefer to use the term “logistic center” in this paper because of the features of existing formations in Turkey and its common use.

Unlike the definition, the objectives and purposes of logistic centers appear to have a consensus. The objectives of logistics centers according to different authors are summarized as follows:

- To enhance intermodal transport, regional economic activities, land use, and local commodity distribution [15];
- To serve a variety of purposes, such as cargo transshipment, production synchronization, and business and trade facilitation [16];

- To strengthen the logistics capability of a country and transform it into a more attractive competitive market [16];
- To support the creation of seamlessly integrated transport networks [2];
- To enhance the market attractiveness and competitiveness of logistics companies [2];
- To achieve a sustainable competitive advantage for transport and logistics companies [17];
- To create synergies and collaboration between transport and logistics companies [18]; and
- To improve the economic and productive performance of transport and logistics companies [18].

**Table 1.** Comparison of the characteristics of the terms associated with the logistics center concept [1,13]

Size	Term	Key Points and Activities
XS	Warehouse	<ul style="list-style-type: none"> <li>• Storage of goods</li> <li>• Usually belongs to only a single company</li> </ul>
S	Distribution Centre	<ul style="list-style-type: none"> <li>• Warehousing</li> <li>• Shipping and receiving</li> <li>• Cross-docking</li> <li>• Production flow rather than storage</li> <li>• Large warehouses or clusters of warehouses</li> </ul>
	Container Yard	<ul style="list-style-type: none"> <li>• Temporary storage of containers</li> <li>• Cleaning and repairing of containers</li> </ul>
M	Inland Container Depot	<ul style="list-style-type: none"> <li>• Located in the hinterland of a gateway port</li> <li>• Container handling and temporary storage</li> <li>• Container flow rather than storage</li> <li>• Basic customs clearance</li> <li>• Inspections</li> </ul>
	Intermodal Terminal	<ul style="list-style-type: none"> <li>• Transshipment of goods between rail, road, and other transport modes</li> <li>• Consolidation of intermodal freight</li> </ul>
L	Inland Port/Dry Port	<ul style="list-style-type: none"> <li>• Located in the hinterland of a gateway port and directly connected to a seaport by rail</li> <li>• Provides all the services that seaports provide except ship loading/unloading</li> <li>• Aims to mitigate the congestion at main port terminals</li> <li>• Handles all types of cargo</li> <li>• Offers full customs-related services</li> </ul>
	Logistics Center	<ul style="list-style-type: none"> <li>• All logistics activities are carried out by various operators</li> <li>• Handles all types of cargo</li> <li>• Includes warehouses, distribution centers, storage areas, offices, and truck services</li> </ul>
XL	Freight Village	<ul style="list-style-type: none"> <li>• Synonymous with logistics centers but differs in scale</li> <li>• Offers a broader range of services than logistics centers, such as banks, restaurants, repair services, cleaning services, and education facilities</li> <li>• A centralized management and ownership structure</li> </ul>
XXL	Mainport Terminal	<ul style="list-style-type: none"> <li>• Generates numerous activities both inside the facility and within its periphery</li> <li>• Handles large volumes of freight</li> <li>• Includes major seaports and airports with worldwide connections</li> <li>• High trade and passenger flows</li> </ul>

### 3. Methodology

In this research, content analysis of the literature and semistructured interview techniques were used as qualitative research methods, while the fuzzy AHP method was used as a quantitative research method. The semistructured interview method was used to provide a better understanding of the current situation and expectations in Turkey. It mainly consisted of face-to-face and open-ended interviews with logistic companies located in logistics centers and the management of logistics centers. Simultaneously, field observations were conducted by visiting logistics centers. The primary purpose of the literature review, interviews, and field observations was to provide an improved understanding of the research field and to collect the data required for the fuzzy AHP method. Subsequently, the fuzzy AHP technique was used as a quantitative method to analyze the data collected using the qualitative method. Figure 1 shows the scheduled process.

#### 3.1. Content Analysis of the Literature and Interviews

To conduct a literature review, the keywords “logistics centre,” “logistics center,” “dry port,” “freight village,” “inland port,” and “logistics village” were searched in the Web of Science and Google Scholar from 1970 to 2018. The most cited articles were selected for content analysis. The majority of the articles found in the literature using the keywords “logistics centre” and “logistics center” focused on the concept of the logistics center and location selection.

Location selection was also one of the most investigated topics in the articles found based on the keyword “dry port,” followed by transport chains, dry port evaluation, and dry port development. The articles that were discovered based on the keyword “freight village” also mainly focused on intermodality, while articles found with the keyword “inland port” focused on handling operations and value-added services. Furthermore, studies on logistics centers in Turkey also mainly focused on location selection.

Content analysis was employed to analyze the data collected from the literature. It was carried out within the framework of the selected articles. The most commonly used features in the literature related to the development of logistics centers, dry ports, freight villages, inland ports, and logistics villages were defined as criteria, while statements explaining them were defined as subcriteria. The overall findings from the content analysis of the literature were conducted as a preliminary step before the semistructured interviews and fuzzy AHP were conducted. Areas to be interviewed were selected based on the findings from the content analysis of the literature.

Interviews were conducted with both private sector and state logistics centers. Among the private sector logistic centers, we selected the first one to start operating because all the others were either too small, in the project phase, or under construction. Among the Turkish State Railways (TCDD) logistics centers, four were selected because they

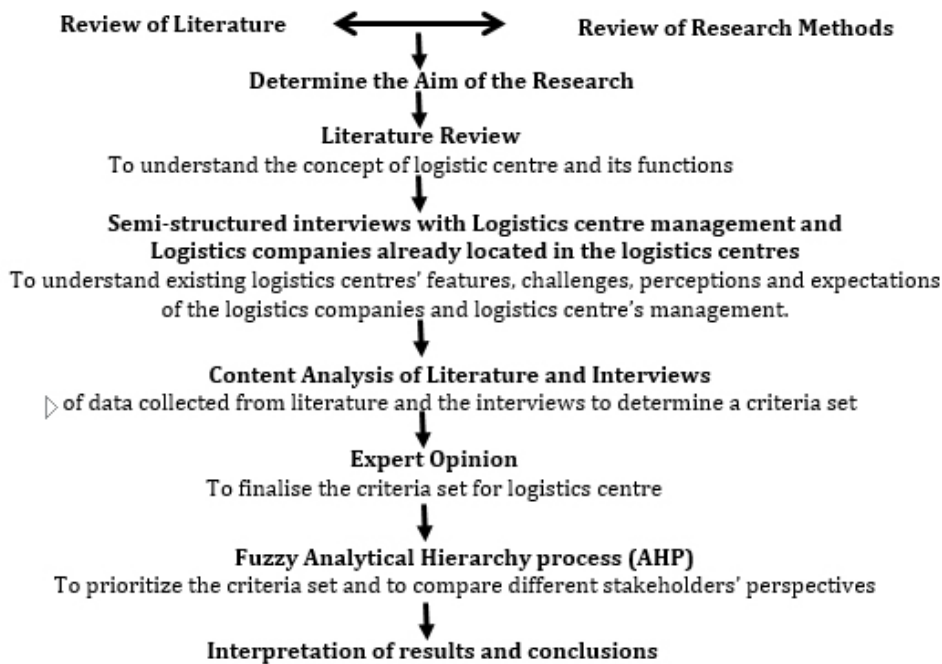


Figure 1. Research process

AHP: Analytic hierarchy process

are the longest-running TCDD logistics centers. In total, five logistics centers were selected, as shown in Table 2.

The Ankara Logistics Center is a private sector logistics center. It is also Turkey's first logistic center, which started operations in early 2011. Logistics companies in Ankara collaborated and formed Ankara Group Carriers Logistics Investments and Akaryakıt Tic. Inc. to launch the Ankara Logistics Center in 2004. The facility has an area of 700,000 m<sup>2</sup>, with a closed area of 198,000 m<sup>2</sup>. In the center, There are 5 blocks of rentable warehouses and bounded warehouses with a total area of 60 thousand m<sup>2</sup>. The facility is designed to serve 400 enterprises, with a total workforce of 4,000 people. During the visit to the Ankara Logistics Center in June 2017, multinational logistics company managers and logistics center managers (presidents, vice presidents, and directors) were interviewed, and a site tour was conducted. A face-to-face semistructured interview method was used. The semistructured interview technique is more flexible than the structured interview technique. In the semistructured interview technique, the researchers prepare the interview protocol in advance, which contains questions that they intend to ask. Conversely, the researchers can influence the flow of the interview with different side questions or subquestions, allowing the interviewees to open and elaborate their responses, depending on the flow of the interview. The researchers may not ask these questions if the person has already answered them during the interview [19]. A specific set of questions was prepared for this purpose and asked each interviewee in the same style and order. The interview questions consisted of open-ended questions. The data were recorded using a recording device rather than by taking notes. All interviews were held from June 13, 2017, to June 15, 2017. On average, each interview lasted 45-60 min on the interview recorder. The recorded data were decrypted, and the answers were analyzed in the direction of the research aim.

State logistics centers are called "freight villages" in Turkey. TCDD planned to build 21 freight villages of different sizes in several locations in Turkey. Nine of these logistics centers began operations by the end of 2019, five are still under construction, and the rest are still in the study, project, or tender phase [20]. Out of nine logistics centers

that are currently in operation, six TCDD logistics centers (Samsun Gelemen, Istanbul-Halkalı, İzmit-Köseköy, Uşak, Denizli-Kaklık, and Eskişehir-Hasanbey) were chosen for the interviews because they are the longest-running TCDD logistics centers; three of them have been in operation since 2010 and the others since 2014. The managers of the logistics centers were contacted by phone, and the interview questions were sent via email. One of the managers provided written answers by email, while the others were interviewed over the phone. After all, four of them were interviewed in total, and all interviews were held between June and August of 2017.

### 3.2. Fuzzy AHP Method

The fuzzy AHP method was used in this study to rank the criteria by importance. Scholars have criticized the traditional AHP because it does not consider the uncertainty associated with translating human judgment into numbers using natural language; the ranking of the AHP method is rather indefinite, and subjective judgments by perception, evaluation, improvement, and selection based on the preference of decision makers have a significant impact on the AHP results [21]. Although the pairwise formulation of the AHP consists of absolute numbers, the choices of decision makers are not always certain [21]. To overcome this problem, fuzzy logic is used in conjunction with the AHP to obtain detailed decisions of decision makers [21]. Chang's (1996) extent analysis method was used for the fuzzy AHP in this study. Many fuzzy AHP methods have been proposed by numerous authors, but Chang's approach is considered to be simpler than other fuzzy AHP approaches [22]. Chang (1996) proposed a new fuzzy AHP approach that uses triangular fuzzy numbers and the extended analysis method for comparisons. Triangular fuzzy numbers are a special variant of fuzzy numbers that are defined by three real numbers. They are expressed as  $(l, m, u)$ . The parameters  $l$ ,  $m$ , and  $u$  indicate the smallest possible value, the most likely value, and the greatest possible value, respectively. Figure 2 shows a representation of the triangular fuzzy number  $\tilde{M}$  [22]. Sun [23] developed a model integrating the fuzzy AHP and fuzzy Topsis methods, and he defined fundamental fuzzy AHP as follows:

**Table 2.** Interview sampling groups

Interview sampling groups	Number of Interviewees logistics center managers	Number of interviewees logistics company managers
Private sector logistics center (1)	3	7
State (TCDD) logistics centers (4)	4	-
Total	7	7

TCDD: Turkish state railways

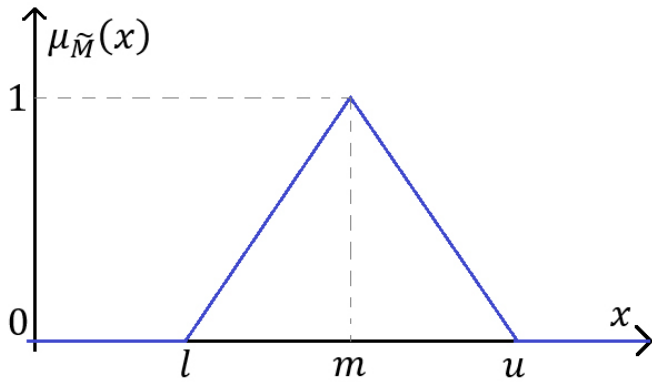


Figure 2. Triangular fuzzy number  $\tilde{M}$

The membership function  $\mu_{\tilde{M}}(x): \mathbb{R} \rightarrow [0,1]$  of a fuzzy number  $\tilde{M}$  is defined by

$$\mu_{\tilde{M}}(x) = \begin{cases} \frac{x-l}{m-l}, & l \leq x \leq m \\ \frac{u-x}{u-m}, & m \leq x \leq u \\ 0, & \text{otherwise} \end{cases}$$

The operational laws of fuzzy numbers  $\tilde{M}_i = (l_i, m_i, u_i)$  and  $\tilde{M}_j = (l_j, m_j, u_j)$  are defined as follows [23]:

Addition of the fuzzy number  $\oplus$ :

$$\tilde{M}_i \oplus \tilde{M}_j = (l_i + l_j, m_i + m_j, u_i + u_j).$$

Multiplication of the fuzzy number  $\otimes$ :

$$\tilde{M}_i \otimes \tilde{M}_j = (l_i \cdot l_j, m_i \cdot m_j, u_i \cdot u_j).$$

Subtraction of the fuzzy number  $\ominus$ :

$$\tilde{M}_i \ominus \tilde{M}_j = (l_i - l_j, m_i - m_j, u_i - u_j).$$

Division of the fuzzy number  $\oslash$ :

$$\tilde{M}_i \oslash \tilde{M}_j = \left( \frac{l_i}{l_j}, \frac{m_i}{m_j}, \frac{u_i}{u_j} \right).$$

Reciprocal of a fuzzy number:

$$\tilde{M}_i^{-1} = \left( \frac{1}{u_i}, \frac{1}{m_i}, \frac{1}{l_i} \right).$$

The following sections briefly explain how the fuzzy AHP was conducted in this study.

**Step 1. Definitions:** Eight criteria and their subcriteria were determined by analyzing the qualitative research findings, and a questionnaire form was subsequently prepared for pairwise comparison matrices among all the criteria in the dimensions of the hierarchy system. The nine-level linguistic terms listed below (Table 3) was used for comparison.

**Step 2. Construct pairwise comparison matrices:** Comparison matrix linguistic terms were assigned to pairwise comparisons by determining which of the two

dimensions was more important, as seen in the matrix  $\tilde{A}$  below [23].

$$\tilde{A} = \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & \tilde{a}_{nn} \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{12} & \dots & 1 \end{bmatrix},$$

where

$$\tilde{a}_{ij} = \begin{cases} \tilde{1}, \tilde{2}, \dots, \tilde{8} \text{ or } \tilde{9} & , i \text{ is relatively important to } j \\ \tilde{1}, \tilde{2}^{-1}, \dots, \tilde{8}^{-1} \text{ or } \tilde{9}^{-1} & , j \text{ is relatively important to } i \\ 1 & , i = j \end{cases}$$

Table 3. Membership function of the linguistic scale [23]

Fuzzy number	Linguistic	Fuzzy number scale
~ 9	Perfect	(8,9,10)
~ 8	Absolute	(7,8,9)
~ 7	Very good	(6,7,8)
~ 6	Fairly good	(5,6,7)
~ 5	Good	(4,5,6)
~ 4	Preferable	(3,4,5)
~ 3	Not bad	(2,3,4)
~ 2	Weak advantage	(1,2,3)
~ 1	Equal	(1,1,1)

**Step 3. Calculating geometric means:** The geometric mean technique was used to define the fuzzy geometric mean and fuzzy weights of each criterion. The geometric mean technique for calculating weights  $w_i$  was extended to  $\tilde{A}$ . The geometric mean of each row was calculated using the fuzzy pairwise comparison matrix  $\tilde{A} = [a_{ij}]$  [24]:

$$\tilde{r}_i = \left( \prod_{j=1}^n \tilde{a}_{ij} \right)^{1/n} = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \dots \otimes \tilde{a}_{in})^{1/n},$$

and

$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \dots \oplus \tilde{r}_n)^{-1},$$

where  $\tilde{\alpha}_{in}$  is the fuzzy comparison value of the  $i$ th criterion to the  $n$ th criterion,  $\tilde{r}_i$  is the geometric mean of the fuzzy comparison value of the  $i$ th criterion to each criterion, and  $\tilde{w}_i$  is the fuzzy weight of the  $i$ th criterion, which can be indicated by a triangular fuzzy number, and  $\tilde{w}_i = (l_{\tilde{w}_i}, m_{\tilde{w}_i}, u_{\tilde{w}_i})$ . Here,  $l_{\tilde{w}_i}$ ,  $m_{\tilde{w}_i}$ , and  $u_{\tilde{w}_i}$  represent the lower, middle, and upper values of the fuzzy weight of the  $i$ th criterion, respectively.

**Step 4. Converting fuzzy numbers to non-fuzzy numbers:** A fuzzy number is the outcome of the fuzzy synthetic decision reached by each criterion. Therefore, a nonfuzzy ranking method for fuzzy numbers must be used for the comparison of each criterion. In other words, defuzzification is the process of determining the best non-fuzzy performance (BNP) value. The mean of maximum, center of area (COA), and  $\alpha$ -cut are common defuzzification methods for fuzzy number ranking. The COA method was used to determine the BNP value in this study because it is a simple and practical method that does not require the preferences of any evaluators. The BNP value of the fuzzy number  $r_i$  can be calculated using the following equation:

$$BNP_i = \frac{(u_{\tilde{w}_i} - l_{\tilde{w}_i}) + (m_{\tilde{w}_i} - l_{\tilde{w}_i})}{3} + l_{\tilde{w}_i}, i = 1, 2, \dots, n$$

The ranking of the criteria can then be done based on the derived BNP value for each criterion.

The AHP survey was conducted from April to November of 2018. The survey was sent to 20 experts but 18 responses were received, which were divided into four groups, as shown in Table 4. The individual tables show comparisons of the main criteria and subcriteria, as well as the total results and individual results for each respondent group.

**Table 4.** Fuzzy AHP survey sampling groups

Fuzzy AHP survey sampling groups	Number of corporation surveys sent	Number of respondents
Logistics center managers	5	5
Logistics service providers	6	5
Logistics service buyers	5	4
Institutions	4	4
Total	20	18
AHP: Analytic hierarchy process		

## 4. Research Findings

### 4.1. Qualitative Research Findings

After the literature analysis and interviews, two different sets of criteria with subcriteria (one from the literature

and one from the interviews) were obtained for logistics center development. To finalize the criteria set, the two different sets of criteria were gathered, and repetitions were removed from the list. The criteria and subcriteria sets were then presented to two expert academicians to obtain their opinions in order to assess sets credibility, applicability, and the extent to which they serve the research aim [25,26]. The appropriate arrangements were made in accordance with their recommendations. Finally, a set of criteria for logistic center development was determined, and the eight main criteria are explained below and displayed with their subcriteria in Table 5.

**Criterion A. Location:** This refers to the area where a logistics center is located. Logistics centers should be located in areas where services can be provided efficiently. The factors that influence the selection of the location of a logistics center are determined as subcriteria. For example, one of the logistics center managers clearly stated that “Logistics centers should be on the main roads without entering the city traffic. It should be equipped with railways, roads, and port connections, be environmentally friendly, and supply all kinds of logistics services.” In addition, the other said, “When choosing the location of a logistics center, the region should be taken into consideration, such as the proximity to the organized industrial zones, the diversity of industrial activities, urbanization and planning decisions, and regional industrial development plans.”

**Criterion B. Infrastructure:** This refers to the infrastructure that a logistics center should have. Essential infrastructure features for logistics centers are determined as the subcriteria. The interviewees stated that there must be organizations that regulate foreign trade, particularly customs. Ankara Logistics Center already has warehouses, bonded warehouses, banks, insurance companies, social facilities, restaurants, markets, car parks, vehicle repair facilities, filling stations, health and safety facilities, central fire detection, extinguishing systems, and 24-h security. All vehicles are recorded, and 112 emergency services are also available. One of the TCDD logistics center managers emphasized that it is necessary to have an advanced communication and information technology infrastructure.

**Criterion C. Activities and Services:** This refers to the activities and services provided by a logistics center. The activities and services that logistics centers have the most of, or should have, are defined as the subcriteria. The managers specifically emphasized that logistic centers improve the service standards of logistics companies by providing warehouse and bonded warehouse services and other value-added services that are available in the logistics centers, resulting in faster import-export processes.

**Table 5.** Criteria set for logistic center development

Main criteria	Subcriteria
A. Location	A1. Along the main routes
	A2. Proximity and/or connectivity to seaports, airport and rail terminal
	A3. Proximity and/or connectivity to organized industrial centres
B. Infrastructure	B1. Multimodality
	B2. Warehouses and Bonded Warehouses
	B3. Offices and social facilities
	B4. Vehicle and equipment repair facilities
	B5. Telecommunications and information services
	B6. Car parks
	B7. Open storage areas
	B8. Land's ability to expand
C. Activities and services	C1. Loading and unloading operations
	C2. Custom services
	C3. Filling stations
	C4. Accommodation, restaurants and cafes
	C5. Banks and insurance services
	C6. Value added services
	C7. Security
D. Ownership and man.	D1. Public-private partnership
	D2. Owned and managed by private companies
	D3. Owned and managed by a public authority
E. Market conditions	E1. Logistics service providers' proficiency
	E2. Existing and potential business activities
	E3. Labour competence
	E4. Existing and integration of other logistic centres
F. Regulations	F1. Logistics centres should be managed by General Directorate for Logistics established under the Ministry of Transport
	F2. Regional logistics development plan should be set
	F3. Incentive and financial assistance programs offered by the government
	F4. Simple and efficient administration procedure for operating logistics centres
	F5. Low and simple tax system
G. Benefits	G1. Encourage and increase the combined transport
	G2. Operating cost reduction
	G3. Increase service quality and responsiveness
	G4. Increase in value-added activities related to logistics
	G5. Having an important role in regional/national development
	G6. Being environmental
H. Collaborations	H1. Project cooperations
	H2. Market cooperations
	H3. Joint use of infrastructure, bonded warehouses, equipments, warehouses
	H4. Joint purchasing of vehicle, equipment, fuel etc.
	H5. Sharing information
	H6. Cooperation on combining partial loads

**Criterion D. Ownership and Management:** This refers to the ownership of the area and the equipment and management model that are used to manage operations. The ownership and management models are defined as subcriteria. One of the private sector logistics center managers recommended private sector management by saying, "I do not think it is right to establish and manage logistics centers by the public because when the public is involved, things slow down. The public should support logistics centers by providing necessary services." However, TCDD expropriates or constructs logistics centers on its land. The TCDD investment program includes logistics centers, and expenditures are funded by appropriations. Leases are made through tenders when the private sector wants to invest in these logistics centers.

**Criterion E. Market Conditions:** This refers to the characteristics of the market that a logistics center serves. The market conditions that should be included in logistics centers are defined as subcriteria. The interviewees pointed out that the region should be considered when choosing the location of a logistics center, including its proximity to the organized industrial zones, the diversity of industrial activities, urbanization and planning decisions, and regional industrial development plans.

**Criterion F. Regulations:** This refers to the rules that regulatory agencies use to control, direct, or manage logistics centers. The managers frequently stated, "Turkey has no legislation for structuring logistic centers. We want this legislation to be included in the national transportation and logistics action plan. The bases of logistics center structuring must be regulated by law, and related regulations should be made as soon as possible."

**Criterion G. Benefits:** This refers to the benefits that logistics centers provide to all of their stakeholders. The benefits that logistics centers provide the most are defined as subcriteria. All of the managers who took part in the interview first mentioned the benefits of reducing costs. For example, one of the interviewees explained, "The most important advantages for logistics companies are that logistics centers reduce the costs of logistics companies and so increase their competitiveness. In addition, they improve their service quality and rapidness. Being operated in the logistic center allows them to interact and raise each other's standards. At the same time, companies can act together for a common will." The other one said, "Logistic centers contribute to the commercial potential and economic development of the region in which they are established, thereby contributing to the development of combined transport by increasing competition among companies operating in this region. Companies located in logistics villages can benefit from the



**Table 6.** Comparison of the main criteria

Main criteria	Overall		Logistics centre managers		Logistics service providers		Logistics service buyers		Institutions	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
A. Location	0.218	1	0.237	1	0.115	4	0.367	1	0.191	2
B. Infrastructure	0.105	5	0.115	4	0.112	6	0.104	4	0.033	6
C. Activities and services	0.126	4	0.108	5	0.114	5	0.091	6	0.120	4
D. Ownership and management	0.057	8	0.080	6	0.049	8	0.066	7	0.031	7
E. Market conditions	0.202	2	0.211	2	0.258	1	0.174	2	0.191	2
F. Regulations	0.067	7	0.044	8	0.094	7	0.041	8	0.125	3
G. Benefits	0.168	3	0.171	3	0.182	2	0.100	5	0.249	1
H. Collaborations	0.101	6	0.073	7	0.121	3	0.107	3	0.102	5

following advantages: optimum vehicle planning (especially truck-to-truck), warehouses, a safe environment for all activities, single-sided management and planning, reduced transportation, industrial and personnel costs, a quality working environment, and extensive support services.”

**Criterion H. Collaborations:** This refers to the different types of collaborations between logistics companies. The most common types of collaborations between logistics companies are defined as subcriteria. According to the managers, the logistics companies that operate in logistics centers cooperate in the following areas:

- Joint projects: If a company cannot afford to carry out a project alone, two or more companies can collaborate to complete the project.
- Joint purchases: This includes purchasing of vehicles, equipment, fuel, training, and information systems.
- Joint use of infrastructure and services: This includes warehouses, bonded warehouses, equipment, repair and maintenance services, bank and insurance services, and value-added services.
- Market expansion: When there is a demand for a market that the company normally don't serve, instead of rejecting the customer, they cooperate with the companies that already serve that market. By this way they extend their market.
- Partial loads are also combined.

They stated that the most common type of collaboration is market expansion. They want to increase their collaboration level but do not know how to address the issue of trust.

#### 4.3. Findings from the Fuzzy AHP Analysis

A survey was sent to 20 experts that were divided into four groups: logistics center managers, logistics service providers, logistics service buyers, and institutions. There were 18 responses. The results of the fuzzy AHP calculations

are displayed in Table 6 and Table 7 below. The Tables 6 and 7 show comparisons of the main criteria and subcriteria, as well as the total results and individual results for each respondent group.

First, the results of the **comparison of the main Criteria**, which include different judgments of the four respondent groups, are shown in Table 6. According to the final rankings, “**location**” appears to be the most important criterion, followed by “**market conditions**,” with “**regulations**” and “**ownership and management**” receiving the lowest ranks. “**Infrastructure**,” “**activities and services**,” and “**ownership and management**” received moderate scores from the overall respondents. Second, the **subcriterion comparison** results are shown in Table 7.

## 5. Discussion

The results of this study revealed that there are eight main criteria that can be considered as a set of criteria for logistics center development, each with various subcriteria. These criteria directly affect the performance of logistics centers. To understand their priorities, a group of 18 experts from different stakeholder groups was asked to compare the main criteria and their subcriteria. Finally, the fuzzy AHP results are discussed below.

- Overall, the respondents and logistics service providers considered “**proximity and/or connectivity to seaports, airports, and rail terminals**” as the most important location subcriterion, with a significant weight of 60.5%. Intermodality is highly essential for attracting logistics service providers, which is currently a major challenge in the industry in Turkey. While logistics center managers and institutions are more concerned about logistics centers being close to load/existing and potential customers, logistics service buyers expect the logistics centers to be easily accessible.

**Table 7. Comparison of the Subcriteria**

Main criteria	Subcriteria	Overall		Logistics centre managers		Logistics service providers		Logistics service buyers		Institutions	
		Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
A. Location	A1. Along the main routes	0.377	2	0.124	2	0.260	2	0.529	1	0.108	3
	A2. Proximity and/or connectivity to seaports, airport and rail terminal	0.469	1	0.100	3	0.605	1	0.348	2	0.122	2
	A3. Proximity and/or connectivity to organized industrial centres	0.174	3	0.135	1	0.153	3	0.150	3	0.132	1
B. Infrastructure	B1. Multimodality	0.283	1	0.226	2	0.171	2	0.413	1	0.370	1
	B2. Warehouses and bonded warehouses	0.230	2	0.316	1	0.126	4	0.251	2	0.212	2
	B3. Offices and social facilities	0.056	6	0.039	7	0.064	7	0.047	6	0.060	6
	B4. Vehicle and equipment repair facilities	0.046	8	0.036	8	0.072	6	0.032	7	0.033	7
	B5. Telecommunications and information services	0.104	5	0.070	5	0.283	1	0.055	5	0.060	6
	B6. Car parks	0.055	7	0.063	6	0.063	8	0.028	8	0.062	5
	B7. Open storage areas	0.131	3	0.149	3	0.124	5	0.112	3	0.105	4
	B8. Land's ability to expand	0.130	4	0.129	4	0.138	3	0.093	4	0.127	3
C. Activities and services	C1. Loading and unloading operations	0.268	1	0.364	1	0.192	3	0.211	2	0.290	1
	C2. Customs services	0.255	2	0.287	2	0.147	4	0.404	1	0.291	2
	C3. Filling stations	0.041	7	0.037	6	0.063	7	0.027	7	0.028	7
	C4. Accommodation, restaurants and cafes	0.044	6	0.035	7	0.070	6	0.046	5	0.041	6
	C5. Banks and insurance services	0.061	5	0.040	5	0.073	5	0.044	6	0.058	5
	C6. Value added services	0.196	3	0.129	4	0.258	1	0.181	3	0.186	3
	C7. Security	0.170	4	0.142	3	0.234	2	0.129	4	0.135	4
D. Ownership and man.	D1. Public-private partnership	0.595	1	0.518	1	0.436	2	0.705	1	0.737	1
	D2. Owned and managed by private companies	0.323	2	0.384	2	0.453	1	0.241	2	0.215	2
	D3. Owned and managed by a public authority	0.105	3	0.117	3	0.131	3	0.092	3	0.072	3
E. Market conditions	E1. Logistics service providers' proficiency	0.322	2	0.331	2	0.374	1	0.367	2	0.214	2
	E2. Existing and potential business activities	0.441	1	0.394	1	0.333	2	0.442	1	0.521	1
	E3. Labour competence	0.114	4	0.119	4	0.166	3	0.088	4	0.108	4
	E4. Existing and integration of other logistic centres	0.142	3	0.178	3	0.145	4	0.125	3	0.175	3

Table 7. continued

Main criteria	Subcriterias	Overall		Logistics centre managers		Logistics service providers		Logistics service buyers		Institutions	
		Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
F. Regulations	F1. Logistics centres should be managed by General Directorate for Logistics established under the Ministry of Transport	0.053	5	0.055	5	0.054	5	0.045	5	0.035	5
	F2. Regional logistics development plan should be set	0.208	3	0.282	2	0.143	4	0.162	4	0.139	3
	F3. Incentive and financial assistance programs offered by the government	0.306	1	0.256	3	0.302	2	0.298	2	0.430	1
	F4. Simple and efficient administration procedure for operating logistics centres	0.184	4	0.142	4	0.222	3	0.188	3	0.106	4
	F5. Low and simple tax system	0.278	2	0.293	1	0.326	1	0.347	1	0.319	2
G. Benefits	G1. Encourage and increase the combined transport	0.128	4	0.134	5	0.104	6	0.148	3	0.116	4
	G2. Operating cost reduction	0.209	2	0.145	4	0.173	2	0.321	1	0.309	1
	G3. Increase service quality and responsiveness	0.218	1	0.183	2	0.172	3	0.302	2	0.223	2
	G4. Increase in value-added activities related to logistics	0.118	5	0.101	6	0.181	1	0.060	5	0.086	5
	G5. Increase cooperation between logistics companies	0.074	7	0.085	7	0.081	7	0.053	6	0.049	7
	G6. Having and important role in regional/national development	0.178	3	0.217	1	0.168	4	0.116	4	0.182	3
	G7. Being environmental	0.108	6	0.165	3	0.153	5	0.045	7	0.063	6
H. Collaborations	H1. Project cooperations	0.092	6	0.108	5	0.189	2	0.064	6	0.081	5
	H2. Market cooperations	0.236	2	0.183	2	0.263	1	0.204	2	0.288	2
	H3. Joint use of infrastructure, bonded warehouses, equipments, warehouses	0.187	3	0.160	4	0.151	5	0.178	3	0.119	3
	H4. Joint purchasing of vehicle, equipment, fuel etc.	0.122	4	0.174	3	0.099	6	0.090	4	0.066	6
	H5. Sharing information	0.117	5	0.081	6	0.162	4	0.075	5	0.118	4
	H6. Cooperation on combining partial loads	0.285	1	0.337	1	0.175	3	0.401	1	0.362	1

- **“Multimodality”** as an infrastructure subcriterion is a prerequisite for logistics centers because it received high rates from all the groups. **“Warehouses and bonded warehouses”** were ranked second, with problems in customs processes such as cost of customs and blockages in customs being one of the bottlenecks in Turkey’s logistics sector. Bonded warehouses in logistics centers, in particular, can be an effective strategy for reducing problems in the customs process. The least important for all the groups appeared to be **“vehicle and equipment repair facilities”** and **“car parks.”** Remarkably, the logistics service providers placed more importance on **“telecommunications and information services”** than the other groups. They strongly believe in the importance of technology, and the management of logistics centers should consider this belief.
- All the groups except logistics service providers believed that **“loading and unloading operations”** and **“customs services”** are the most important subcriteria, with very high weights. The logistics service providers considered **“value-added services”** and **“security”** as the most important in contrast to the other groups. However, all the groups agreed that **“accommodations, restaurants, and cafes”** and **“filling stations”** were the least important.
- **“Public-private partnership”** is the most preferred ownership and management model for logistics centers. The logistics services providers preferred **“owned and managed by private companies.”** All groups were against the public governance of logistics centers. Therefore, public support is required for financial and intermodal infrastructure investments during the establishment phase, but private sector management is preferred.
- Regarding the ranking of the market condition subcriterion, most of the respondents ranked **“existing and potential business activities”** as the most important, followed by **“logistics service providers’ proficiency.”** The **“existing and integration of other logistics centers”** and **“labor competence”** criteria were ranked as the least important. The preferences of the logistics service providers differed slightly from those of the other groups in that they ranked the **“logistics service providers’ proficiency”** first and ranked **“existing and potential business activities”** second. They also placed a higher value on **“labor competence”** than the other groups.
- All the groups mostly agreed on the prioritizing of the regulation subcriterion. The managers of the logistics centers governed by central management under the Ministry of Transport strongly objected as they expect the government to promote logistics centers by incentives, financial assistance, and a low and simple tax system. The most important criterion was **“incentive and financial assistance programs offered by the government.”**

Actually, three groups ranked **“low and simple tax system”** first, and its weight was slightly lower than that of “incentive and financial assistance programs offered by the government.”

- The most significant opinion differences between the groups were observed in the benefit subcriteria. The following points can be noted: overall, the results demonstrated that the most important benefit of logistics centers is **“increase service quality and responsiveness,”** followed by **“operating cost reduction,”** with total weights of 42% among seven subcriteria. **“Increase service quality and responsiveness”** and **“operating cost reduction”** were important for all groups, particularly for logistics service buyers, with a total weight of 62%. The least important benefit subcriteria were **“being environmental”** and **“increase collaborations between logistics companies.”** The logistic center managers believed that the most important benefit was **“having an important role in regional/national development,”** while the logistics service providers believed it was **“increase in value-added activities related to logistics,”** and finally, the logistics service buyers believed it was **“operating cost reduction.”** The largest difference was observed in the **“increase in value-added activities related to logistics,”** which was the most important benefit for the logistics service providers but ranked sixth for the logistics center managers and fifth for the other groups.
- According to the respondents, logistics centers reduce operating costs and increase service quality. The majority of the stakeholders believed that **“collaboration on combining partial loads”** was the most important collaboration type, while **“market collaborations”** was considered the second most important, with a total weight of 53%. **“Sharing information”** and **“project collaborations”** were the least important among the six subcriteria. Noticeably, three groups (logistics center managers, logistics service buyers, and instructions) had similar overall results, but the ranking of logistics service providers differed from that of others. Logistics service providers ranked **“market collaborations”** and **“project collaborations”** as the most important collaboration types, with a total weight of 45%. They ranked **“joint purchasing of vehicle, equipment, fuel, etc.”** as the least important. The logistics service buyers placed more importance on **“collaborations on combining partial loads,”** which they weighted at 40%.

## 6. Conclusions

This research aimed to determine and prioritize a set of criteria for the development of logistic centers in Turkey. Data were gathered using both qualitative and quantitative

methods. The qualitative research method revealed eight main criteria with their subcriteria. The fuzzy AHP was used for ranking and was conducted with 18 professionals/experts from four different groups of logistics center stakeholders: logistics service providers (5 experts), logistics center management (5 experts), logistics service buyers (4 experts), and institutions (4 experts).

Since the early 2000s, both the government and the private sector in Turkey have initiated logistics center projects, with some still in progress. State (TCDD) logistics centers are mainly responsible for the consolidation and deconsolidation of incoming and outgoing freights in the railways they serve. Thus, they should be considered as “intermodal terminals” rather than logistics centers. Intermodal terminals, as defined by the United Nations Economic and Social Council, connect at least two transport modes, which are usually road and rail, and they are less complex than logistics centers. When the TCDD logistics center plans a project, it considers the logistics potential of a region, the land-rail-air-maritime transportation possibilities, and the proximity to the OIZ and industrial areas. The first-stage railway investments are made in the logistics centers, and rail transport warehouses are formed. The lands of the logistic centers are either expropriated by TCDD or built on TCDD’s land. The TCDD investment program includes logistics centers, and expenditures are funded by appropriations. When the private sector wants to invest in these logistics centers, leasing transactions are made through tenders. There is no specific legislation on logistics centers, which the interviewees strongly criticized. However, there are different types of private sector logistics centers, and the first one to open was the Ankara Logistics Center, which can be classified as a logistics center with many features. The Ankara Logistics Center delivers most of the products produced in Ankara to their final destination. The center creates added value for shippers and logistics companies through the various actors (public institutions, customs units, association and union representatives, and universities) that are located in the center. However, intermodality, which is one of the most important infrastructure features, is missing. The Ankara Logistics Center does not yet have a railway connection.

In terms of quality and quantity, Turkey’s logistics center development lags behind that of the rest of the world. There are 240 logistic centers in the EU, and most of them are located along TEN-T. Most of these centers are located in central Europe, including Germany (35), Spain (33), France (26), and Italy (21). The largest logistics center in Germany has 600 ha (GVZ Leipzig), while the average size of logistics centers is 175 ha. The logistics centers in Germany are all

public-private partnerships and have railway connections. There are many logistics centers in Asia, from China to Dubai, and their distinguishing features are advanced intermodality, simple customs procedures, and intensive information technology usage. All logistics clusters in the United States of America are linked by intermodal infrastructure. The TCDD logistics center has a small scale (average of 50 ha) and functions more like an intermodal transfer terminal. In general, activities and services, such as customs clearance, closed warehouse areas, offices, and repair maintenance areas, are below expectations. The Ankara Logistics Center covers 70 ha and possesses the typical characteristics of a logistics center, including the ability to expand. The MOS Logistics Center in Manisa is 32 ha in size. It is in an organized industrial zone and has a rail connection to the port. However, in terms of activities and services, it functions more like an intermodal transfer terminal, similar to the TCDD logistics centers. Logistics companies, particularly small- and medium-sized ones, need to be educated about logistics centers and become aware of them. Institutions should put extra effort to make this awareness possible, and public authorities should provide tax favors and incentives to promote logistics centers. Otherwise, the logistics sector in Turkey will be unable to compete internationally, and intermodality and transit trade will remain unimproved.

This research has some limitations. Benchmarking logistics centers in Turkey and other parts of the world would be beneficial, but this is not possible because of financial and physical constraints. Instead, logistics center formations in different continents have been solely based on the literature, reports, and institutions. Another limitation is the formation of logistics centers, which is a relatively new development in Turkey. Thus, there are not many facilities that actually function as “logistics centers.” TCDD has nine logistics centers in operation, but they operate more like intermodal terminals.

Future research could examine if the determined and prioritized criteria set for logistics center development are fulfilled by advanced/successful logistics centers around the world.

### Authorship Contributions

Concept design: D. Çavuşoğlu, Y. Zorba, S. Esmer, Data Collection or Processing: D. Çavuşoğlu, Analysis or Interpretation: D. Çavuşoğlu, Y. Zorba, S. Esmer, Literature Review: D. Çavuşoğlu, Writing, Reviewing and Editing: D. Çavuşoğlu, Y. Zorba.

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