

AHP Application for Logistics Center Location Selection According to Criteria

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Abstract

Today, logistics is effective in every field and has an important share in the revival of both domestic and foreign trade. The rapid increase in competition in global trade has increased the importance of the logistics sector and, accordingly, logistics centers. With well-planned and high-performance logistics centers in our country, the contribution of the logistics sector to the economy will increase and it will be ensured that our country is a logistics base in international transport corridors. In this study, criteria were determined by conducting a comprehensive literature review for logistics center location. These criteria consist of seven main criteria, namely population, economy, cost, socio-economic status, infrastructure, geographical location and service, and twenty-seven sub-criteria belonging to these main criteria. The criteria were evaluated by benefiting from the opinions of experts in the field of logistics, and the order of importance of the main and sub-criteria determined for the logistics center location determination was found by AHP methods.

1. Introduction

With the systematic and efficient realization of logistics activities, time and cost will be gained in global trade, where competition is rapidly increasing [1]. In order to reduce the cost of logistics facilities and to ensure a better flow of materials, efficient/effective design of distribution centers is required [2]. The development of a logistics center network at the national and international level is a prerequisite for the transport and logistics chain [3].

The main purpose of logistics is to minimize the cost in the supply chain. While the rate of logistics cost is 20% in underdeveloped countries, this rate varies between 3% and 5% in industrialized countries [4]. In addition, a 5% improvement in logistics costs, including shipping, storage, management costs, and inventory costs, is considered equivalent to a 20% improvement in sales. According to a report published by the World Bank, while the ratio of logistics costs to GNP (Gross National Product) is around 10% in developed countries, this ratio is around 30% in developing countries [5]. This difference in rates shows that the cost will be greatly

reduced with a well-designed and developed logistics network.

Logistics centers with high performance also have high profits and can provide services both regionally and globally. The profit of logistics centers where both domestic and foreign investors can be used effectively is higher. For this reason, the location of logistics centers should be designed in such a way as to get the most efficiency both in the region and internationally. In order to achieve the desired success in this regard, it is necessary to know the characteristics of the regions such as income sources and employment rates, to evaluate the geographical location in the best way, and to plan the logistics center design for the future correctly. Therefore, factors such as the needed facilities and applicability are important in order to achieve high performance in the logistics center application [6].

In this study, the relevant studies for the logistics center location determination were examined in detail and new criteria were found by taking into account the opinions of experts in the field. The importance levels of these criteria, which were determined for the location of the logistics center,

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relative to each other were found by using the AHP technique by taking the opinions of experts in the field of logistics.

2. Method

In this study, criteria were determined in detail with a comprehensive literature review in line with the opinions of experts in the field of logistics. The knowledge, experience and opinions of nine experts in the field of logistics were taken advantage to rank the criteria determined for the location of the logistics center according to each other. These people consist of faculty members in the Industrial Engineering, Civil Engineering, Logistics, City and Regional Planning departments of universities, members of LODER (Logistics Association) and engineers working in the relevant department of TCDD (State Railways of the Republic of Turkey), which carries out the establishment of logistics centers in Turkey. After criterias determined, these criterias were ranked according to weights of importance using the AHP method for the most appropriate logistic center location selection.

2.1. Criteria Selection For The Logistics Center

Many studies have been examined to determine the logistics center location selection criteria. By

- ✓ Tourism Activities: It expresses the tourism activities in the province where the logistics center is planned to be established.
- ✓ Export and Import Ratio: It has been determined as the trade volume of the province where the logistics center is planned to be established, and it represents the sum of export and import amounts.
- ✓ Border Gates: It refers to the presence of active iron, sea, land, and air border gates in the province where a logistics center is planned to be established.
- 3. Cost Main Criterion: It has been evaluated as a cost parameter for the logistics center planned to be established and consists of the sub-criteria of “Expropriation Cost”, “Installation Cost”, and “Infrastructure Cost”. The explanations of these sub-criteria are explained below.
 - ✓ Expropriation Cost: It refers to the required cost for the expropriation of the location where the logistics center is planned to be established.
 - ✓ Installation Cost: It indicates the required cost for the establishment of the logistics center planned to be established.

evaluating these studies, seven main criteria and 27 sub-criteria have been established in line with the opinions of experts in the field. Table 1 shows the studies examined for the criteria determined for the logistics center location selection. These criteria are given below.

1. Population Main Criterion: It expresses the population amount in the province where the logistics center is planned to be established.

2. Economy Main Criterion: It expresses the economic activities of the province where the logistics centers are planned to be established. It consists of five sub-criteria: “Organized Industrial Zone”, “Agricultural Organized Industrial Zone”, “Tourism Activities”, “Export and Import Ratio”, and “Border Gates” covers the criterion. The definitions of these sub-criteria are given below.

- ✓ Organized Industrial Zone: It refers to the areas (hectares) of the existing organized industrial zones in the province where a logistics center is planned to be established.
- ✓ Agricultural Organized Industrial Zone: It refers to the areas (decares) of the agricultural organized industrial zones that were put into operation and in the project phase in the province where a logistics center is planned to be established.
- ✓ Infrastructure Cost: It expresses the infrastructure costs of required transportation connections such as highway and railway for the province of the logistics center is planned to be established.
- 4. Socio-Economic Status Main Criterion: It expresses the socio-economic status in the province where the logistics center planned to be established. It consists of six sub-criteria as “Employment Rate”, “Labor Force Participation Rate”, “Unemployment Rate”, “Educational Activities”, “Health Activities” and “Cultural Activities”. The explanations of these sub-criteria are explained below.
 - ✓ Employment Rate: It refers to the employment rate of the province where the logistics center is planned to be established.
 - ✓ Labor Force Participation Rate: It refers to the labor force participation rate of the province where the logistics center is planned to be established.
 - ✓ Unemployment Rate: It expresses the unemployment rate of the province where a logistics center is planned to be established.
 - ✓ Educational Activities: It refers to educational activities such as the number of

- students at universities in the province where a logistics center is planned to be established.
- ✓ Health Activities: It refers to the health activities of the province where the logistics center is planned to be established.
 - ✓ Cultural Activities: It refers to cultural activities such as fairs, symposiums and congresses in the province where a logistics center is planned to be established.
5. Infrastructure Main Criterion: It expresses the existence of transportation infrastructure such as airport, port, railway in the province where a logistics center is planned to be established. It consists of “Capacity”, “Equipment” and “Transfer Facilities” sub-criteria. The definitions of these sub-criteria are given below.
- ✓ Capacity: It refers to transportation systems network such as the road, railway, airports and ports which are available to set in the province where a logistics center is planned to be established.
 - ✓ Equipment: It expresses as the number of vehicles such as cargo planes, ships, trucks used in the freight transportation in the province and transportation network such as airports, railway and ports of that province where a logistics center is planned to be established.
 - ✓ Transfer Facilities: It has been evaluated as the existing railway station, port, airport and road connection used in freight transportation in the province where a logistic center is planned to be established.
6. Geographical Location Main Criterion: It refers to the location of the province where the logistics center is planned to be established. It consists of six sub-criteria as “Land Structure”, “Natural Events”, “Accessibility”, “Distance to Logistics Centers”, “Distance to Supplier” and “Distance to Market”. This sub-criteria are listed below.
- ✓ Land Structure: It is defined as the percentage expression of the mountainous or flat areas of the province where a logistics center is planned to be established.
 - ✓ Natural Events: It refers to natural disasters such as avalanches, landslides and floods of the province where a logistics center is planned to be established.
 - ✓ Accessibility: It refers to the calculation of the accessibility levels of road, airway, seaway and railway network of the province where a logistics center is planned to be established with considering all of them together [7].
- ✓ Distance to Logistics Centers: It expresses the distances between the province where the logistics center is planned to be established and the logistics center in other province.
 - ✓ Distance to Supplier: It indicates the distance between the province where a logistics center is planned to be established and the capital cities of the importing countries of this province.
 - ✓ Distance to Market: It indicates the distance between the province where a logistics center is planned to be established and the capitals of the countries that this province exports to.
7. Service Main Criteria: Four sub-criteria have been determined as “Delivery Time”, “Risks”, “Environmental Sensitivity” and “Reliability”. These sub-criteria are defined as follows.
- ✓ Delivery Time: It refers to the transportation time of the cargo carried between the export and import countries of the province where the logistics center is planned to be established. In this criterion, the type of used transportation and distance between provinces is important.
 - ✓ Risks: It is expressed as the climatic conditions of the province where the logistics center is planned to be established.
 - ✓ Environmental Sensitivity: It is defined as establishing a connection with the carbon emission values of the used transportation systems in the province where the logistics center is planned to be established.
 - ✓ Reliability: It refers to the socio-economic development ranking in Turkey in order to foresee a more effective use of the province where the logistics center is planned to be established in the future.

Table 1. Studies on logistics center location selection

Studies	Criteria						
	Population	Economy	Cost	Infrastructure	Geographical Location	Socia-Economy Status	Service
Xie, et al., [8].	✓		✓	✓			✓
Duyguvar, [9].	✓	✓	✓	✓	✓	✓	✓
Karagülle, [10].	✓			✓	✓	✓	✓
Reis, et al., [11].		✓		✓	✓		✓
Orjuela-Castro , et al., [12].		✓	✓				✓
Zhou, et al., [13].		✓					
Anatol'yevna, et al., [14].		✓		✓	✓		✓
Kıvrak, [15].		✓	✓				✓
Kutsal, [16].		✓		✓	✓		
Kabak, et al., [17].		✓		✓			
Elgün, et al., [18].		✓				✓	
Ors, et al., [19].		✓	✓				
Pérez, et al., [20].		✓		✓	✓		✓
Grine, et al., [21].		✓		✓	✓		✓
Khongkan, et al., [22].		✓		✓	✓	✓	
Alumur, et al., [23].		✓		✓	✓	✓	
Vilko, et al., [24].			✓	✓	✓		✓
Smilowitz, et al., [25].		✓	✓				

2.2. Determination of Criterion Weights with AHP

Many studies have been carried out in the field of logistics with the use of the AHP method. In smart city development, management, economy, livability, people, mobility, and environment criteria were evaluated using the AHP method for the logistics function [26]. In order to evaluate the logistics performance in the postal sector, the importance weights of reliability, delivery time, convenience, flexibility, cost, return on assets, relationship, and innovation criteria are listed using the AHP method [27]. The AHP method was used to determine the importance weights of cost, product, supply, and order criteria for logistics operations in distribution centers [28]. The criteria for supplier selection based on AHP were determined as cost, operational efficiency, service quality, and technology level [29]. The best reverse logistic provider was selected with quality, reverse logistics cost, shipping, and technical capability criteria by using the AHP method [30]. The economic, technical, social, and natural criteria for emergency logistics center location selection are listed by the AHP method [31]. The cities of Doboj, Banja Luka, and Samac were ranked for logistics center location selection using the AHP technique with the criteria of available surface, land price, geographical location, affiliation to the form of transport, macro and micro level, and approach ways accessibility transport [32].

2.2.1. Analytical Hierarchy Process

The criteria of different individuals for the same problem and the importance levels of these criteria differ [33]. While choosing among the alternatives, the decision maker should choose the most suitable one among the criteria and rank the alternatives according to their degrees. In this case, Analytical Hierarchy Process (AHP), one of the multi-criteria decision making methods, helps the decision maker [34]. AHP is developed by Thomas L. Saaty in 1971. AHP allows decision makers to model in a hierarchical structure that shows the relationship between complex problems, the main goal of the problem, criteria, sub-criteria and alternatives [35]. Ease of use in group decisions and the ability to handle inconsistency in judgments are the biggest advantages of AHP when compared to other multi-criteria methods [36]. The most important advantage of AHP is that it is a simple method [37]. The purpose of this study is to inform the reader about the use of AHP for logistics center location selection. The steps of the AHP method are given below. Steps of the AHP method [33]:

1. Hierarchical structure: In this step, the decision problem is structured hierarchically. The created hierarchical structure is the most important part of the decision-making process. At the top of this structure is the purpose of the question, the criteria are in the next section, and the alternatives are in the last section.

2. Pairwise comparison matrix: In this step, the comparison matrix of the criteria is created. This comparison matrices with $n \times n$ dimensions is a square matrix. Each criterion is compared one-to-one according to its importance values, and the importance scale in Table 2 is used for this comparison.

Table 2. Fundamental scale [38]

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very,very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
1.1-1.9	When activities are very close a decimal is added to 1 to show their difference as appropriate	A better alternative way to assigning the small decimals is to compare two close activities with other widely contrasting ones, favoring the larger one a little over the smaller one when using the 1-9 values.
Reciprocals of above	If activity i has one of the above nonzero numbers assigned to it when compared with activity j , then j has the reciprocal value when compared with i	A logical assumption
Measurements from ratio scales		When it is desired to use such numbers in physical applications. Alternatively, often one estimates the ratios of such magnitudes by using judgment

3. Normalization of relationship matrices: In this step, First, the sum of each matrix column divided by the values of the column elements.

$$B_i = \begin{bmatrix} b_{11} \\ b_{21} \\ \vdots \\ b_{n1} \end{bmatrix} \quad b_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}}$$

Then its importance values (W_i) for a criterion are determined by dividing it in one score levels and matrix size.

$$C = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{n1} & b_{n2} & \dots & b_{nn} \end{bmatrix} \quad w_i = \frac{\sum_{j=1}^n c_{ij}}{n}$$

After these calculations, the decision matrix is obtained. Finally, the percentage distribution at the decision points is obtained by multiplying the decision matrix by the W column vector. Decision

options can now be prioritized, starting with the highest overall score.

4. Consistency ratio: Since the comparisons are subjective, the consistency rate is calculated. If the calculated rate is below 10%, it is considered sufficient. A low consistency ratio indicates that the decision maker's decisions in pairwise comparisons are consistent, while a high consistency ratio shows that inconsistent.

2.2.2. Determination of Criterion Weights

The main and sub-criteria determined in this study were evaluated in line with the knowledge, experience, and opinions of experts in the field of logistics, and the importance levels of these criteria were listed according to the AHP technique with the help of Super Decision.

The results of the main criteria of "Population", "Economy", "Cost", "Socio-Economic Status", "Infrastructure", "Geographical Location", and "Service" are shown in Table 3 according to the AHP method.

Table 3. The ratios of importance weights of the main criteria

Criteria	Importance weights
Population	0,048124649
Economy	0,242694409
Cost	0,1090094
Socio-Economic Status	0,12460071
Infrastructure	0,186011467
Geographical Location	0,216640538
Service	0,072918826

The main criterion of "Economy" takes the first place in the order of importance weights of the main criteria. The main criteria of "Economy" are followed by "Geographical Location", "Infrastructure", "Socio-Economic Situation", "Cost", "Service", and "Population" main criteria.

The sub-criteria of "Economy", "Cost", "Socio-Economic Status", "Infrastructure", "Geographical Location" and "Service" main criteria were found by applying the AHP technique. The results of the sub-criteria of the "Economy" main criterion according to the AHP method are shown in Table 4.

Table 4. Importance weights of sub-criteria of the "Economy" main criteria

Criteria	Importance weights
Organized Industrial Zone	0,32057
Agricultural Organized Industrial Zone	0,187285
Tourism	0,111853
Export and Import Ratio	0,270581
Border Gates	0,109711

"Organized Industrial Zone" takes first place in the ranking of the importance weights of the sub-criteria of the "Economy" main criterion. "Organized Industrial Zone" is followed by the sub-criteria "Export and Import Ratio", "Agricultural Organized Industrial Zone", "Tourism", "Border Gates", respectively.

The results of the sub-criteria of the "Cost" main criterion according to the AHP method are shown in Table 5.

Table 5. Importance weights of sub-criteria of the "Cost" main criteria

Criteria	Importance weights
Expropriation Cost	0,340139
Installation Cost	0,235791
Infrastructure Cost	0,424069

"Infrastructure Cost" takes the first place in order the importance weights of the sub-criteria of the "Cost" main criterion. This is followed by the "Expropriation Cost" and "Installation Cost" sub-criteria, respectively.

The results of the sub-criteria of the main criterion of "Socio-Economic Status" according to the AHP method are shown in Table 6.

Table 6. Importance weights of sub-criteria of the "Socio-Economic Status" main criterion

Criteria	Importance weights
Employment Rate	0,238598
Labor Force Participation Rate	0,275392
Unemployment Rate	0,178447
Educational Activities	0,141643
Health Activities	0,090562
Cultural Activities	0,075359

In ordering the importance weights of the sub-criteria of the "Socio-Economic Status" main criterion, "Labor Force Participation Rate" has the highest importance weight ratio, and "Employment

Rate”, “Unemployment Rate”, “Educational Activities”, “Health Activities” and “Cultural Activities” follows this order respectively.

The results of the sub-criteria of the “Infrastructure” main criterion according to the AHP method are shown in Table 7.

Table 7. Importance weights of sub-criteria of the “Infrastructure” main criteria

Criteria	Importence weights
Capacity	0,426414
Equipment	0,235696
Transfer Facilities	0,337891

“Capacity” takes the first place in order the importance weights of the sub-criteria of the “Infrastructure” main criterion. The sub-criteria of “Transfer Facilities” and “Equipment” follow this ranking respectively.

The results of the sub-criteria of the “Geographical Location” main criterion according to the AHP method are shown in Table 8.

Table 8. Importance weights of sub-criteria of “Geographical Location” criteria

Criteria	Importence weights
Land Structure	0,108562
Natural Events	0,088571
Accessibility	0,309495
Distance to Logistics Centers	0,109472
Distance to Supplier	0,194161
Distance to Market	0,189738

In the ranking of the importance weights of the sub-criteria of the main criterion of “Geographical Location”, the sub-criterion of “Accessibility” takes the first place. This ordering is–followed by sub-criteria of the “Distance to Supplier”, “Distance to Market”, “Distance to Logistics Centers”, “Land Structure”, and “Natural Events” respectively.

The results of the sub-criteria of the “Service” main criterion according to the AHP method are shown in Table 9.

Table 9. Importance weights of sub-criteria of “Service” main criteria

Criteria	Importence weights
Delivery time	0,201005
Risks	0,268229
Environmental Sensitivity	0,264372
Reliability	0,266394

The “Risks” sub-criterion ranks first in the ranking of the importance weights of the sub-criteria of the “Service” main criterion. This ranking is followed by the sub-criteria of “Reliability”, “Environmental Sensitivity” and “Delivery Time”.

3. Conclusion and Suggestions

In this study for logistics center location selection, the order of importance of seven main criteria consisting of “Population”, “Economy”, “Cost”, “Socio-Economic Status”, “Infrastructure”, “Geographical Location”, and “Service” is ranked by taking the opinions of experts in the field using the AHP method. These criteria were evaluated separately according to the AHP technique by taking the opinions of experts in the field of logistics and their importance weights were found according to each other.

In this study conducted for the logistics center location selection, the most important criterion among the seven main criteria, namely “Population”, “Economy”, “Cost”, “Socio-Economic Status”, “Infrastructure”, “Geographical Location”, and “Service”, was found to be the “Economy” criterion. In this case, logistics centers should be established in these regions to easily realize the product flow in the regions where economic activities are carried out effectively. Among the main criteria, the population criterion was found to be the criterion with the least importance.

Organized industrial zones were found to have the highest importance in the order of importance of the sub-criteria of the “Economy” main criterion. The production sector has the biggest share of foreign trade in Turkey [39]. For this reason, establishing logistics centers in regions where industrial zones are denser will support the manufacturing sector and provide incentives for production in these regions.

In the sub-criteria of the “Cost” main criterion, the infrastructure cost has been took the first place. This result shows that infrastructure has an important share in terms of the functioning of logistics centers. While the logistics center institution requires more costs for a place with weak transportation infrastructure, the transportation of the products will be more systematic, economical, and easier with the establishing logistics center in a developed transportation network.

The labor force participation rate among the sub-criteria of the “Socio-Economic Status” main criterion has been evaluated as the most important criterion. Establishing logistics centers in places with the highest labor force participation rate will allow for an increase in employment.

When sub-criteria of the “Infrastructure” main criterion is evaluated, it has been concluded that capacity is the most important criteria among the sub-criteria of infrastructure criteria. The developed network structures of railway, sea, air, and road transportation systems and the high transportation potential will ensure that the product flow of logistics centers is easy.

The accessibility sub-criterion has been determined as the most important sub-criterion in the logistics center location selection among the “Geographical Location” main criterion. Using all of the transportation systems in a logistic center will provide the product transportation easier, faster, and more economical. The importance of distance to logistics centers and land structure criteria have been found very close to each other.

The risks sub-criterion is the most important criterion among “Service” main criterion. According to expert opinions, parameters that may constitute a risk such as climate change have been an important

place for the logistics center location. Reliability and environmental sensitivity criteria have been found close importance to the risk criteria, and delivery time has been found the least importance.

Our country’s transportation systems should have a more developed network structure and work systematically to be a logistic base in the region. Turkey should develop coordination between regions and establish connections both within the borders of the country and between the border countries to have a larger share in the logistic field. Also, customs should be facilitated, multimodal transportation should be supported, logistics activities should be rehabilitated, information flow should be accelerated by closely observed technology, modernization in transportation systems should be ensured and infrastructure deficiencies should be eliminated.

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