A Logistics Model Suggestion for A Logistics Center to Be Established: An Application in Aegean and Central Anatolia Region

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Highlights
• This paper focuses on selecting the optimum location for a logistics center to be established.
• An integrated logistics model is proposed for the efficient and useful logistics center.
• The results of the proposed logistics model are similar for the industrial and logistics sectors.

Article Info

Abstract

The fact that the transport costs directly affect the countries' economies all around the world and that the transport costs increase depending on the energy resources steered the countries into developing combined transport strategies that will decrease the transport costs. In this study, an assessment is made for the selection of locations of the logistics centers which will contribute to decreasing the transport costs, develop logistics sector strategies in Turkey, and thereby enable to identify the strategies for the fastest, safest, and the most economic transport utilizing integration of modes of transport with each other. Nonetheless, an integrated logistics model which includes freight capacity and selection of the optimum location is proposed for the efficient and useful logistics center. In this logistics model, a freight model, which is a criterion for optimal location selection, has been obtained by using regression analysis. According to this freight model, freight carrying capacity is determined for each alternative region. Optimum location selection has been made utilizing AHP (Analytic Hierarchy Process)-VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje) method. We aim to contribute to the literature by making systematically estimating variable carrying capacities and by being decisive in the logistics center location selection. The proposed logistics model has been applied for a logistics center to be established, and effective and valid results have been obtained.

1. INTRODUCTION

Transport and logistics are some of the biggest parameters affecting the countries' economies. Another major problem of transport, in addition to increasing energy and transport costs, is the elimination of the damages to the environment and nature. The development of the logistics sector is of great importance to reduce the transport costs, to reduce the foreign-source dependencies in the transport sector, and to enable the interaction between the transport sector and the energy resources. Also, packaging has been recognized as an important activity to reduce logistics costs. Besides, it contributes to improving the efficiency of the supply chain including the reduction of logistics costs, which are affected both directly and indirectly by packaging.

In the literature, all operational activities realized from the production point of a commercial product to the final consumption point are called supply chains. As for the logistics supply, it is defined as transporting such a product safely to the final destination. When we consider the logistics supply as a whole, be applied both in the field and in theory. It has been proven by the studies that the most significant reflection of the

logistics sector on the field is the strengthening of the transport activities. With the transformations in world trade, each country is re-evaluating its seaway, airline, rail, and road transportation understanding. This change of understanding reveals the need for a logistics center that operates on an international scale and where all transport types are integrated. There are two important factors in the emergence of logistics centers. The first of these is the negative consequences of the increasing trade volume and the resulting logistic dynamism in the city. The second is to bring together logistics service providers operating in many different fields to achieve a better performance level and in this way ensure customer satisfaction [1]. Also, The selection of location supported by the logistics model is made through assessing and strengthening the transport which is the most important ring of the supply chain. In this study, to use public resources more efficiently and to maximize the economic effects of investments for a logistics center to be established, the interactions of the actors behind the investments have been examined and a holistic evaluation has been made. In addition to this, it is aimed to conduct a study that will provide an insight into the national strategies and investments of Turkey. For this, an integrated logistics model, which includes freight transport volume and optimum location selection, has been proposed. This model consists of three stages: 1-For the logistics center to be established, a survey was conducted to determine alternative regions, to determine the criteria to be considered in location selection, and to obtain freight transport data. The current situation analysis has been presented (together with the survey study) in the pilot region which is identified as the Aegean and Central Anatolian regions. In this survey, company officials (expert team) operating in the logistics and industry sector were interviewed. 2-According to the data obtained from the survey and field study, a freight model has been obtained by using regression analysis. According to this freight model, freight carrying capacity is determined for each alternative region. The freight carrying capacity is separate for each type of freight (pallet, package, package, bulk, and other). The freight model has been taken into account as a criterion for optimum location selection. 3-Optimum location selection has been made utilizing the AHP-VIKOR method.

When we have examined the studies in the literature, we have found that the freight modeling study has not been done for optimum location selection. The most important difference of this study is that a freight model is created with regression analysis and this freight model is using as a criterion for location selection. In this way, we aim to contribute to the literature by making the freight model more reliable estimating variable carrying capacities and being a determinant in the logistics center location selection.

The article is organized as follows: Section 2 provides literature research; section 3 highlights the methods adopted in the proposed model. Finally, the results are discussed in section 4.

2. LITERATURE RESEARCH

In the literature, we have observed that there are many different freight models. Considering the importance of freight transport for a country's economic activities, these models are predominantly on a country scale. Considering the common ground of all these different models, it is acknowledged that freight models are based on the logistics model, which is generated to estimate the passenger demand and to decide on the location of a logistics center. In these studies, multi-criteria decision making, fuzzy decision making, and integrated approaches come into prominence. Canel and Khumawala [2] carried out a selection study among 8 potential facilities to seek a solution for the production facilities that were insufficient to meet the increasing demand of a chemistry company. They proposed a multi-criteria model for this selection. Yang and Lee [3] analyzed 3 potential studies on the selection of location for a facility by using AHP based on the 4 main location factors of the market, transport capacity, labor force, and community, each consists of 3 sub-factors. Vlachopoulou et al. [4] emphasized the importance of the selection of logistics locations in terms of marketing strategies and developed an application for the utilization of Geographical Information Systems (GIS) in this problem. Birsel and Cerit [5] reviewed the effect of the lanin orded factor in the problem of selection of establishment location of the logistics firms and dealt with the selection of storage location problem as a subheading. Jacyna-Golda and Izdebski [6] stated that the following factors should be used for logistics center location selection: Production capacity of suppliers, the volume of demand of buyers, logistics warehouse capacity, amount of raw materials, transportation cost, raw material transfer cost, fuel cost, local taxes, additional expenses, ongoing costs, labor cost, possibility and cost of purchasing additional land for expansion, distance from rail and road infrastructure. In the same study, they stated that

such a problem could be solved by TOPSIS, ELECTRE, Gray Theory methods, fuzzy logic, or Choquet integral method. Zhang et al. [7] made a research for the selection of locations for the facilities which may have the minimum cost and maximum demand/coverage areas and which may become unserviceable due to natural disasters or other events. Ghadge et al. [8] attempted to optimize, via the case study, the decision of single and double center distribution center location. Elevli [9] applied F-PROMETHEE for selecting one of the five logistics center locations in Samsun-Turkey while taking into account the position, property price, geographical characteristics, ownership, and property conditions as criteria. Rao et al. [10] utilized a fuzzy method with a linguistic 2-tuple model to solve various decision-making problems and select the location of logistics centers. Pham et al. [11] applied the fuzzy Delphi TOPSIS for selecting logistics center locations in Vietnam. Pramanik et al. [12] proposed a novel score function for logistics center location selection. Lotfi et al. [13] proposed a hybrid Fuzzy TOPSIS and resource-constrained Fuzzy Linear Programming (FLP) approach for wind farm location planning. Tabak et al. [14] utilized CRITIC-AHP-VIKOR for optimum location selection of the logistics centers needed to develop combined transport. Özmen and Aydoğan [15] used the linear EDAS-BWM method to solve the problem of logistics center location in Kayseri-Turkey. Pamucar and Bozanic [16] extended the MABAC method to the SVNN environment while addressing the problem of multi-mode logistics center location. Li and Liu [17] proposed a 2-dimensional linguistic similarity-degree-based clustering analysis method, the 2-dimensional linguistic partitioned Maclaurin symmetric mean (2DLPMSM) operator, and the 2-dimensional linguistic weighted partitioned Maclaurin symmetric mean (2DLWPMSM) operator constructing a multiattribute group decision-making solution framework for the logistics center location selection. Yazdani et al. [18] aimed in developing a two-stage decision-making model (DEA-FUCOM-CoCoSo) to find out the most preferred zone in the autonomous communities of Spain for the establishment of logistics centers.

In this study, we have proposed an integrated logistic model based on AHP-VIKOR. The originality of this logistics model is the determination of the optimal location by performing freight modeling with regression analysis for a logistics center. For this, the proposed logistics model is considered for a logistics center to be established. The summary of the literature studies is given in Table 1.

Table 1. *Literature review*

Authors	Year	Methodology	Applications
Canel and Khumawala	1996	Mixed integer programming	Production facility
Yang and Lee	1997	AHP	Facility location
Vlachopoulou et al.	2001	GIS-Decision support system	Logistics location
Birsel and Cerit	2009	Land factor	Logistics location
Zhang et al.	2012	Integer Programming model	Facility location
Elevli	2014	Fuzzy PROMETHEE	Logistics center locations
Rao et al.	2015	Fuzzy multi-attribute group decision making	Logistics center locations
Ghadge et al.	2016	Mixed integer programming	Facility location
Zacyna-Golda and Izdebski	2017	Genetic algorithm	Warehouses location problem
Pham et al	2017	Fuzzy Delphi TOPSIS	Logistics center locations
Pramanik et al.	2018	Multi-attribute group decision making	Logistics center locations
Lotfi et al.	2018	Fuzzy TOPSIS-Fuzzy linear programming	Wind farm location planning
Tabak et al.	2019	CRITIC-AHP-VIKOR	Logistics center locations
Pamucar and Bozanic	2019	SVNN-MABAC	Multimodal logistics center
Özmen and Aydoğan	2020	BWM–EDAS	Logistics center locations
Li and Liu	2020	2DL-multiattribute group decision-making	Logistics distribution center location
Yazdani et al.	2020	Rough set theory-DEA	Logistics center locations
This study		Regression analysis-AHP-VIKOR	Logistics center locations

3. AHP-VIKOR BASED LOGISTICS MODEL

Freight transport is one of the most important parameters for realizing transport planning in national and regional studies [19]. On an urban scale, in addition to the traffic originated from the individual transport demands, while the traffic originated from the freight demand creates an additional traffic freight on the inner-city road network, inter-city, inter-regional, or inter-country freight transport gain importance in terms of mainly organized industrial zones (OIZs), logistics centers, freight focuses and the connections thereof. In this case, the issues such as the capacities of freight centers, the transport connections thereof become prominent, particularly on a country basis, rather than the additional traffic freight that occurs in the road and/or railway section [20]. In this section, the proposed logistic model and its methodology have been explained. The stages of this logistics model are shown in Figure 1.

The proposed logistics model consists of 3 stages:

1. Obtaining data through field and survey studies and grouping zones according to specific characteristics. (Survey Study)
2. Freight modeling for each alternative zone using regression analysis. The freight carrying capacity is separate for each type of freight (pallet, package, package, bulk, and other). The freight model has been taken into account as a criterion for optimum location selection. (Freight Model)
3. Location selection for the logistics center with AHP-VIKOR integrated method. (Optimum Logistics Center Location)
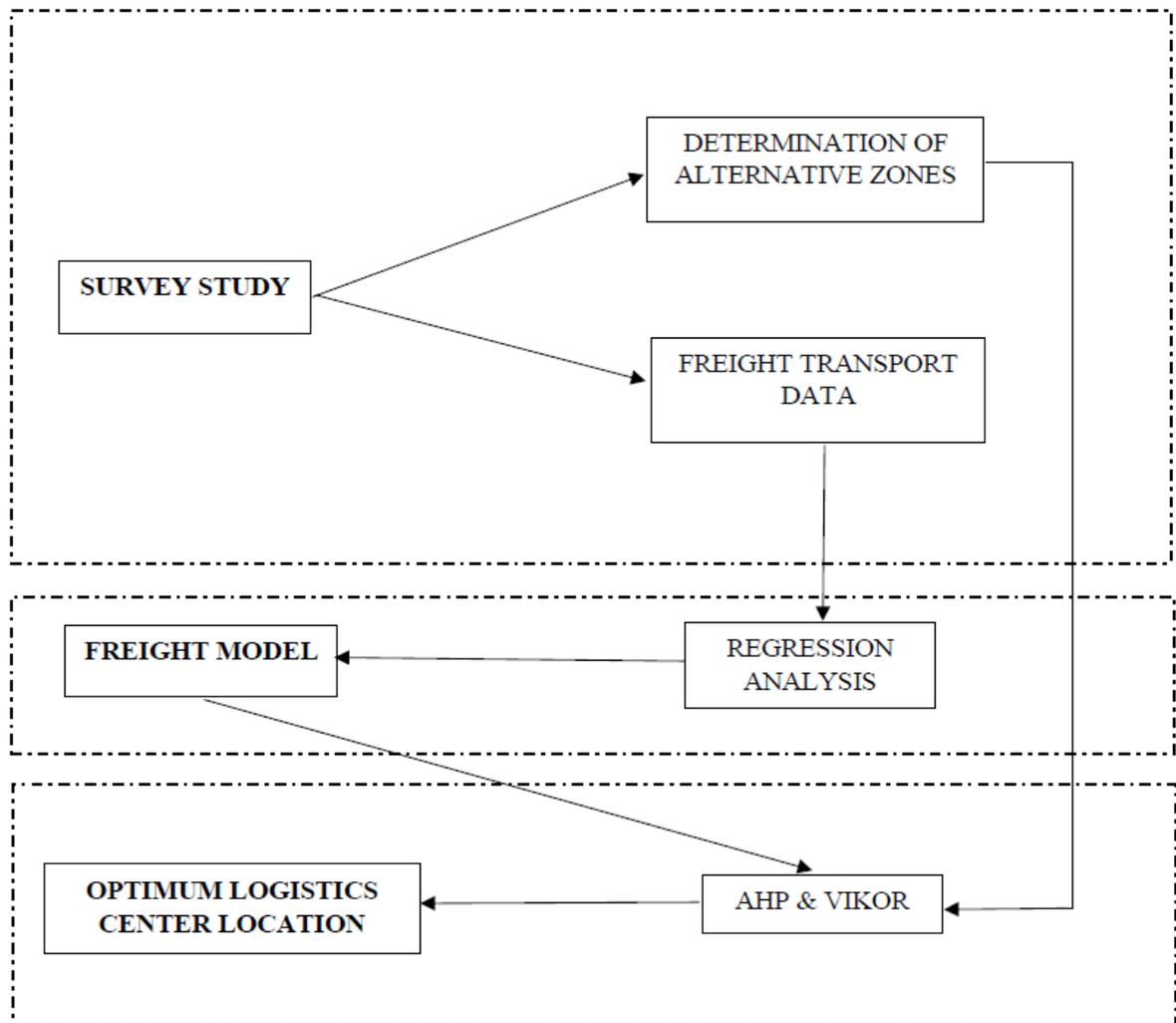
Figure 1. *The flow diagram of the proposed logistics model*

3.1. Survey Study

In the determination of the logistics model, the survey study and statistical analyses have been performed as the preliminary study. The field questionnaires were conducted with 663 companies in the industrial sector and 161 in the logistics sector in 8 provinces located in the Central Anatolia and Aegean regions. Compliance and evaluations related to data are given below: If there is an organized industrial zone (OIZ) in a province, it is assumed that the outgoing freight of that province is originated from that OIZ and the incoming freight is entering that OIZ. However, in provinces where there are multiple OIZs, it has concurred that the incoming and outgoing freight is only related to one of the OIZs. Accordingly, Ankara Anadolu OIZ for Ankara, Konya OIZ for Konya, and İzmir Atatürk OIZ for İzmir are the OIZs that consolidate the incoming/outgoing freight of their provinces.

For the shipments, the measurement unit of which is not tons, the average value of the tonnage shipments that are made to the same OIZ in the same freight type have been taken into consideration. As the units of the package, pallet, and stockpiling units are reported as cubic meters, the average of package and pallet type shipments have been used instead. A similar application is adopted for loadings that are entered as zero or left blank. It is agreed for the questionnaire data that the loadings, the loading province of which is unknown, are assumed to be coming from the province where the destination OIZ is located.

When the questionnaire data are analyzed, it is determined that a total of 14 different types of freight are handled in terms of the freight characteristics (details). Mainly, there are four different types of Cargo: Package, pallet, container, bulk (Without package or pallet and not in a container; freight is carried with an open-air or closed truck). There are also two different cases depending on whether the container is partially or fully loaded. The resulting 14 different types originate because the cargo contains more than one of the main types given, including the container loading level for the same transport. The number of shipments by the cargo types and their percentages in total is given in Table 2.

Table 2. *Number of shipments and their percentages in total*

Number	Cargo type	Number of shipment	%
1	Package	708	23,15
2	Package and pallet	302	9,88
3	Package, pallet and fully loaded container	13	0,43
4	Package, pallet and bulk	8	0,26
5	Package and fully loaded container	20	0,65
6	Package and bulk	23	0,75
7	Pallet	1140	37,28
8	Pallet and partially loaded container	7	0,23
9	Pallet and fully loaded container*	78	2,55
10	Pallet and bulk	21	0,69
11	Partially loaded container	41	1,34
12	Fully loaded container	378	12,36
13	Fully loaded container and bulk	4	0,13
14	Bulk	315	10,30
	Total	3058	100

As a result of this study, 12 alternative areas were established for the selection of logistics locations. In the survey study, the geometrical averages of the answers provided for the criteria evaluation are used as an input for the AHP method.

Determination of alternative zones

The zoning, which is the first stage in passenger or freight models, is to group the individuals or firms of similar characteristics among those who generate travel. Even if it is possible to establish the four-stage model in the unit scale of the questionnaire without grouping, as this approach requires detailed data, it is commonly referred to proceed with grouping. For grouping, different criteria such as socio-economic characteristics for individuals and economic characteristics for firms are used. The most commonly used criterion among all is the geographical grouping [21].

In the geographical grouping, the individuals are generally considered on a neighborhood basis and it is foreseen that the individuals living in the same neighborhood present similar social-economic characteristics to a certain degree. When we apply the same evaluation to the firms, it is apparent that OIZ and logistics centers are immensely suitable for that grouping. In this case, the study area is divided into pieces demonstrating similar characteristics. These pieces are generally named region or zone. In this study, these pieces are considered as on or multiple provinces. The resulting new sub-area is regarded as the areas that generate or attract freight. Then, for instance, the total freight going from the OIZs of a province to other provinces will be the freight generation of the area representing that province (Figure 2).

Figure 2. Representation of regions on the map of Turkey

In this study, the firms have been grouped by the OIZ scale. 12 OIZs located in the study area, which is overall Turkey, are presumed as areas generating or attracting freight transport. It is acknowledged that 8 provinces where these 12 OIZs are located do not have an additional freight generation or attraction and all freight generation and attraction is realized by OIZs in the province (Table 3).

Table 3. *Information on regions*

Number of regions	Name of regions	Provinces covered in the region
1	Afyonkarahisar OIZ	Afyonkarahisar
2	Ankara 1. OIZ	Ankara
3	Ankara Anadolu OIZ	Ankara
4	Ankara Başkent OIZ	Ankara
5	Denizli OIZ	Denizli
6	Eskişehir OIZ	Eskişehir
7	İzmir Atatürk OIZ	İzmir
8	İzmir Kemalpaşa OIZ	İzmir
9	Kayseri OIZ	Kayseri
10	Konya 1. OIZ	Konya
11	Konya OIZ	Konya
12	Manisa OIZ	Manisa

3.2. Freight (Generation/Attraction) Model

The objective of the freight (generation/attraction) model is to calculate the amounts of different types of freight going out and coming into a region by making mathematical connections used to make estimations according to different indicators. These mathematical connections can be assigned utilizing regression analysis. Regression analysis is a method used for identifying the relationship between one dependent variable and one or multiple independent variable/s that affect it [22]. The freight and transport values obtained in this section will be an input to the location selection problem.

In this chapter of the study, it is envisaged to use a total of four independent variables in the estimated freight attraction models. These are; the population of 2016 announced by the Turkish Statistical Institute (TÜİK) of the province where the OIZ attracting the freight is located, the total number of firms in the OIZ where the freight attracting firm is located, a dummy variable, representing the overseas shipments, with the value 1 if the shipment is going overseas and with the value 0 if the shipment is going domestic, and a dummy variable, representing the provincial shipments, with the value 1 if the shipment is being made within the province and with the value 0 if the shipment is not being made within the province. An invariable is not used in any of the estimated mathematical connections. An invariable is an important term in which all the effects that cannot be expressed by the independent variables are jointly represented. However, in models involving invariable, a production or attraction value will be calculated even if all the independent variables are zero. This may lead to erroneous results, especially in models similar to those used in the study, which includes demand analysis.

When selecting the variables to be used in the regression analysis, the independent variables should be lowly correlated and the variables are highly correlated. In the current data, it is seen that the second condition cannot be met at an adequate level. Not using the population variable is the most suitable solution to meet the first condition. Thus, two dummy variables representing the number of firms in the province where the OIZ is located and the overseas and inner-city shipments have been selected as independent variables.

The information on the data used in the regression analysis for different gnt freight types is presented in Table 4. In Table 4 below, the total number of overseas and inner-city loadings data for each of the five types of freights for which the regression analysis is carried out, the number of firms that are making these loadings, and the number of firms realizing the loadings and the amount of loading (tonnes). The table does not include the information on loadings that have both the inner-city and overseas characteristics at the same

time. All numbers and amounts given in the table are the values multiplied via the questionnaire multiplication coefficient.

Table 4. *Data of attraction model regression analysis*

Information		Freight type				
		Package	Package and pallet	Pallet	Bulk	Other
Number Of data	Total	291	138	335	136	185
	Inner-city	15	10	16	11	21
	Overseas	43	18	70	22	97
Number Of firms	Total	4326	1.873	6820	1870	3557
	Inner-city	583	157	747	323	771
	Overseas	761	178	2076	276	2.980
Loading (Ton)	Total	33934	14401	75984	24744	52463
	Inner-city	3397	1315	5994	3163	12163
	Overseas	7149	2729	22837	5398	45085

The coefficient values belonging to the regression equations estimated for each different freight type, the T-statistics of these coefficients, and the R^2 values of each model are presented in Table 5 by using the selected variables.

When we review Table 5, it is seen that R^2 values are not too high. In this case, the correlation between the independent variables that are previously mentioned and selected with a dependent variable affects. T-statistics indicate whether the predicted coefficients are statistically significant (whether they are equal to zero). It can be said that the coefficient estimates are significant at the selected level if the value is greater than 1,645 or less than -1,645, which are the critical values at 90% significance level. However, when the coefficients are compared, it is seen that the effect of the number of firms on the amount of the freight is mostly reflected in the pallet type among the freight types and that the increase in both the inner-city loading rate and the in overseas loading rates leads to an increase in the amount of most other types of loadings.

Table 5*. Attraction model regression equations*

Freight type	Independent variable	Coefficient value	T-Statistics	R^2
Package	Number of firms in OIZ	0,239	11,805	0,424
	Inner-city loading	124,746	3,094	
	Overseas loading	62,318	2,521	
Package and pallet	Number of firms in OIZ	0,196	9,462	0,505
	Inner-city loading	46,900	1,393	
	Overseas loading	82,419	3,239	
Pallet	Number of firms in OIZ	0,375	10,039	0,356
	Inner-city loading	188,426	2,451	
	Overseas loading	155,894	3,952	
Bulk	Number of firms in OIZ	0,266	7,829	0,421
	Inner-city loading	148,062	2,074	
	Overseas loading	83,363	1,583	
Other	Number of firms in OIZ	0,176	1,264	0,171
	Inner-city loading	313,088	1,715	
	Overseas loading	346,891	3,343	

The number of data that can be used for the production model is relatively low compared to the attraction model. Even if all shipping used in the questionnaire data originate from the same province as the OIZ, it can be used in the attraction model as it reaches an OIZ. However, the situation for the production data is different; when generating the production data, from the questionnaire data, only those which originate from a province where there is only one OIZ can be used. It is predicted that more independent variables can be used compared to the attraction model since all data will be used together in the production model. In addition to the population of the province where the firm is located, the total number of firms in the OIZ where he firms carry its business and the domestic and inner-city shipments, the percentages of those who work in agriculture and industrial sectors among all sectors as per TÜİK data and a dummy variable in case there are multiple OIZ in the province have been included in the evaluation as an indicator of the economic activities of a province.

Information regarding the data used in the regression analysis for the production model is given in Table 6. The number of data of total and overseas shipments, the number of firms that made these shipments, and the shipment amount (tonnes) are given in Table 6. All numbers and amounts given in the table are the values multiplied via questionnaire multiplication coefficient.

The coefficient values of the regression equation estimated by using the selected variables, the t-statistics of these coefficients, and the R^2 values of the model are presented in Table 7. When Table 7 is reviewed, it is seen that the R^2 value is not very high. As a result of this, it is clear that as in the attraction models, the low correlation between the dependent variable and the independent variables selected affects. Although the ratio of the employees working in the industry does not coincide with the T-statistics, this variable is used in the model.

Table 6. *Data of generation model regression analysis*

Information		Production data
Number of data	Total	264
	Overseas	40
Number of firms	Total	6.968
	Overseas	1.850
Loading (Ton)	Total	70.498
	Overseas	24.028

Table 7. *Generation model regression equation*

Independent variable	Coefficient value	T-Statistics*	R^2
The population of the province of OIZ	0,058	**3,596**	
Overseas loading	319,226	**3,879**	0,322
Industry employees in the province of OIZ (%)	1,871	1,051	

*T-statistics of the coefficient that are above 90% and meaningful are shown in bold.

By using the mathematical relations obtained as a result of multiplying the firm questionnaire data at the province scale using questionnaire multiplication rates, the generation/attraction calculations were concluded with the calculation of the model production and attraction values for overall areas obtained as a result of the grouping in this study. This calculation has been carried out for five freight types that are taken into account in the attraction model. The results given in Table 8 are the monthly average transport quantities and distances in the tonal unit of all regions considered in this study.

Table 8. *Average (Ave.) transport distances (km)*

Zone	Package			Package-pallet			Pallet			Bulk			Other		
	Tons-km	Tons	Ave. km	Ton-km	Ton	Ave. km	Tons-km	Tons	Ave. km	Tons-km	Ton	Ave. km	Tons-km	Ton	Ave. km
1	209.203	403	519	65.175	100	650	449.000	1.152	390	20.379	74	275	284.139	770	369
2	116.471	216	540	112.86	234	482	433.810	863	503	51.843	116	446	381.183	760	501
3	125.612	392	321	104.05	294	353	232.444	777	299	63.105	210	300	43.204	160	270
4	142.064	265	537	0	0	0	541.586	867	625	0	0	0	40.249	85	474
5	206.439	458	451	52.470	123	426	110.390	279	396	25.635	52	498	127.747	324	394
6	209.153	468	446	52.395	189	277	1.034.766	2.499	414	393.692	1.004	392	133.298	441	302
7	301.091	607	496	169.21	399	424	735.825	1.818	405	331.039	634	522	520.049	2.481	210
8	12.951	46	279	4.521	11	399	776.786	1.668	466	20.038	124	162	106.408	1.022	104
9	864.568	1.503	575	134.58	287	469	960.728	1.609	597	1.009.936	1.771	570	1.601.790	2.710	591
10	177.969	345	516	109.02	325	335	152.074	345	441	50.768	125	406	36	20	2
11	809.225	1.517	533	483.16	1.007	480	1.722.134	2.993	575	161.266	381	423	428.095	824	520
12	17.033	55	309	957	25	38	163.661	579	282	12.581	62	202	54.713	461	119

3.3. Selection of Location for the Logistics Center

Analytic Hierarchy Process (AHP) application

Analytic Hierarchy Process (AHP), developed by L. Thomas Saaty in 1965, is a MCDM technique widely used in the literature. AHP is a decision-making technique that measures the objective and subjective criteria by carrying out a double comparison and determines their relative order of importance (weight) by finding the priorities of these criteria for one another. AHP consists of 4 basic steps [23, 24]:

1.Decision making problem is identified: The criteria that are effective in the location selection of a logistics center to be established have been weighted. These criteria have been taken into consideration for both the logistics industry and the industrial sector. To score the alternatives, prioritization (weighting) of the criteria, which have been determined by the expert team, for each sector (logistics and industry) is made by the AHP method. The expert group consists of company officials operating in the logistics and industrial sector. The reason for selecting the AHP method in determining the weights of criteria to be considered in the optimal location selection for the logistics center to be established is that the criteria are independent. That is to say, the criteria do not affect each other as they are considered to be regional in freight transport The criteria and definitions determined by the expert team are as follows:
• Cost: Average cost for transport the freight from one region to another.
• Transport: Ratio of average transport weight to the transport distance. Transport density in distance. In Table 8, it is calculated for each type of freight by dividing the amount of transport by the transport distance and adding each one of them.
     Transport = (Package-ton + Package and pallet-ton + pallet-ton + bulk-ton + other) / (Package-ave. km +Package and pallet-ave. km + pallet-ave. km + bulk-ave. km + other-ave. km)
• Delivery time: Average delivery times of freights, in hours, from one region to another.
• Proximity to Center: Distance to the city center to which the alternative corridor is connected.
• Topology: Distance of the alternative corridor from the nearest train station.

2. A comparison factor matrix is created: The comparison factor (criteria) matrix is a n x n sized square matrix. Matrix components on the diagonal of this matrix take the value 1. Comparison of factors is made exactly and mutually according to their importance values. In comparing the factors one-to-one, 1-9 importance scale is used. In this study, the binary comparison matrix is obtained as follows: The survey participants (Company managers) were asked to compare each criterion according to 1-9 scale (1:Equally Important Preferred, 9: Extremely Important Preferred). Then, the binary comparison matrix is created by taking the geometric mean of the responses of the survey participants. The geometric mean is calculated using EXCEL software. An example binary comparison survey question is given in Table 9 and the binary comparison matrix in Table 10.

Table 9. An example binary comparison survey question

Criteria	Extremely important (9)	Very strongly important (7)	Strongly important (5)	Moderately important (3)	Equally important (1)	Moderately important (3)	Strongly important (5)	Very strongly important (7)	Extremely important (9)	Criteria
Cost										Transport
Cost										Delivery time
Cost										Proximity to center
Cost										Topology

Table 10. *The binary comparison matrix*

	Transport	Cost	Delivery time	Proximity to center	Topology
Transport	1	0,625	0,767	3,803	6,078
Cost	1,60	1	2,775	5,91	8,096
Delivery time	1,303	0,36	1	3,826	7,610
Proximity to center	0,263	0,169	0,261	1	3,309
Topology	0,164	0,123	0,131	0,302	1

4. Percentage distribution of factors are determined: The comparison matrix shows the importance levels of factors relative to each other in a certain logic. However, to determine the weight of these factors in all, in other words, percentage significance distributions, column vectors forming the comparison matrix are used and column B with n components is created. This vector is shown below:

$$B_i = \begin{bmatrix} b_{11} \\ b_{21} \\ . \\ . \\ . \\ b_{n1} \end{bmatrix}. \tag{1}$$

The formula 2 is used to calculate the B column vectors

$$b_{ij} = \frac{a_{ij}}{\sum\limits_{i=1}^{n} a_{ij}}. \tag{2}$$

When the steps described above are repeated within other evaluation factors, the B column vector as much as the number of factors is obtained. When n column vectors are combined in a matrix format, the C matrix shown below is created

$$C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{bmatrix}. \tag{3}$$

Using the C matrix, percentage importance distributions showing the importance values of the factors can be obtained. For this, as shown in formula 4, the arithmetic mean of the row components forming the C matrix is calculated and the weight value of each criterion is determined

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n} \ . \tag{4}$$

4. Consistency in factor comparisons is measured: A calculated consistency value of less than 0.10 indicates that the decision-making comparisons are consistent. In this study, the consistency rates of the factor comparisons were smaller than 0.1. The criteria weights are used to determine the S and R values in the VIKOR method. Weight values of the criteria for logistics and industry sectors are given in Table 11. In Figure 3, the graphical comparison of these criteria is given.
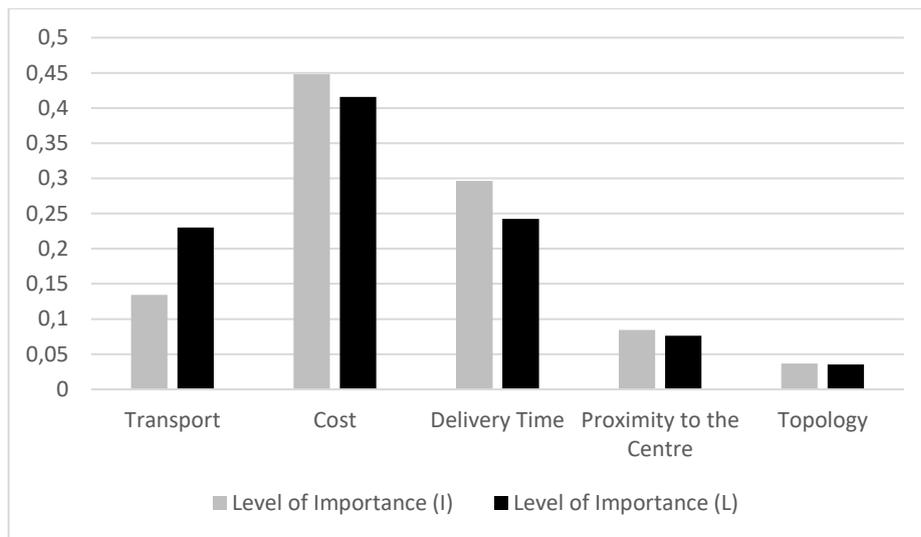
Figure 3*. Benchmark weights of industry (I) and logistics (L) sectors*

According to the results obtained from the AHP method, the most important criterion in the selection of logistics locations for both sectors is the cost. In other words, the cost is an important criterion for choosing a storage location. Therefore, the experts emphasize that establishing storage in places where the cost is low will be more useful in the management and operation of that storage. And this leads to the conclusion that the cost was not emphasized the warehouses previously established in Turkey (unplanned and unnecessary expenditure) and certain problems were arising from the costs. The other important criteria are, respectively, time and transport. In the selection of storage locations, time efficiency and transport conditions are important factors as well as the cost. Accessibility in distributing the goods in storage to the intended locations and making a delivery at the requested time provides an advantage to the firms.

When the levels of importance of the criteria are examined on a sectoral basis, it is seen that the cost and time criteria for the industry are more important than the logistics sector. Nonetheless, the transport conditions in the logistics sector are found to be more important than the transport conditions of the other sector. Other criteria are proximate to each other in both sectors.

In determining the alternative corridors, the levels of importance of the freight model criteria and Industry-Logistics criteria are set as equals by the expert team. *In other words, 50% of the Industrial-Logistics criteria weights gained by the AHP method is used as an input for the decision matrix in logistic location selection. In the meeting with company managers, it is concluded that the <u>Freight Model</u> criterion is very important and the criteria weight should be at least 50% in logistics location selection.*

- *Freight Model* criteria are total transported freight values (ton) of the generation/attraction model. (Table 8)

VIKOR Application

The VIKOR method, which was first suggested by Serafim Opricovic, was started to be used in solving multi-criteria decision-making problems together with the study carried out by Opricovic and Tzeng in 2004.

The method is based on identifying a consensual solution in the light of alternatives and within the scope of the evaluation criteria. This consensual solution comes out as the closest solution to the ideal solution. It is understood by the term solution that under certain conditions, the decision closest to the ideal solution is made by creating a multi-criteria ranking index for the alternatives. Assuming that each alternative is evaluated based on decision-making criteria, the consensus ranking is reached by comparing the proximity values to the ideal alternative. VIKOR method consists of 5 steps [25, 26]:
1. For all criteria, the best and worst values that the alternatives take are determined.
2. For each alternative, the benchmark weights are calculated using the average and worst scores values.
3. Calculate the maximum group benefit for each alternative or evaluation unit.
4. The obtained mean(Sj), worst (Rj) score, and maximum group benefit (Qj) values are sorted from small to large. Here, the alternative with the smallest group benefit value is the best.
5. Acceptable advantages and acceptable sets of stability are determined for decision-makers according to the order in Step 4.

The weight of the Freight model criterion, which is one of the criteria taken into consideration in the logistics location selection, is taken as 0.5. The total weight of the other 5 criteria determined by using the AHP method is 0.5 [27].

The decision matrix having 12 alternatives and 6 criteria which is addressed in selecting the location of optimal alternative corridor via the VIKOR method after the weighting of the criteria to evaluate the alternative regions is given in Table 11. VIKOR application is performed by following the steps suggested by [25] and EXCEL is used for the solution.

Table 11*. Decision matrix*

CRITERIA →	Cost($)	Transport (Amount/km)	Delivery time (hour)	Proximity to center (km)	Topology (km)	Freight model (Amount)
Criteria weights (I)	0,2240445	0,0670675	0,1481205	0,0423145	0,018453	0,5
Criteria weights (L)	0,20792	0,114998	0,121	0,038215	0,017751	0,5
Alternatives↓						
Afyonkarahisar OIZ	727467,288	1,13436223	34938,44	7,5	1,4	2499
Ankara 1. OIZ	1098289,568	0,8855178	52353,064	28,3	29,4	2189
Ankara Anadolu OIZ	804928,12	1,18794556	38094,072	41,4	51,7	1833
Ankara Başkent OIZ	938924,464	0,74388753	44805,688	42,7	53,9	1217
Denizli OIZ	688161,968	0,57090069	33003,76	29,8	17	1236
Eskişehir OIZ	945762,664	2,51283452	45583,472	9	2,9	4601
İzmir Atatürk OIZ	1551914,696	2,88721439	73784,88	21,2	28,2	5939
İzmir Kemalpaşa OIZ	1517507,904	2,03617021	72299,456	26,9	31,7	2871
Kayseri OIZ	1502693,96	2,81227695	72521,104	15,6	12,2	7880
Konya 1. OIZ	616528,264	0,68235294	29225,96	6,8	8,7	1160
Konya OIZ	1159337,992	2,65586725	55653,024	17,9	19,9	6722
Manisa OIZ	774011,784	1,24421053	37098,984	93,4	8,6	1182

After criterion analysis and decision, matrix is formed, the maximum group benefit values are presented in Table 12 in ascending order according to freight model and Industry(I)-Logistics(L) criteria weights as a result of AHP-VIKOR method process steps. The specified rank shows the priority rank of each alternative corridor. According to this, the best alternative corridor is Konya's 1. OIZ, which ranks first in both sectors.

Table 12. *Averages, worst scores and maximum zone benefit values of the zones*

Rank(I)	Alternatives↓	Qj(I)	Qj(L)	Rank(L)
1	Konya OIZ	0,042375845	0,018098858	1
2	Eskişehir OIZ	0,045132297	0,043866816	2
3	Ankara Başkent OIZ	0,068521213	0,110217577	4
4	Ankara 1. OIZ	0,06927666	0,079238652	3
5	Ankara Anadolu OIZ	0,139452237	0,167281473	5
6	Afyonkarahisar OIZ	0,232923711	0,268742983	7
7	Manisa OIZ	0,23420777	0,263191104	6
8	Denizli OIZ	0,289789873	0,337303692	8
9	Konya 1. OIZ	0,29866082	0,348311005	9
10	İzmir Atatürk OIZ	0,608938689	0,594756015	10
11	İzmir Kemalpaşa OIZ	0,829744327	0,837322911	11
12	Kayseri OIZ	1,00	1,00	12

In this study, alternative corridors (organized industrial zones (OIZ), logistics centers, freight centers, and the connections thereof) were identified by the expert team of the freight transport planning and a questionnaire has been conducted in the field of logistics in each region. As a result of the questionnaire, freight modeling was performed and a decision matrix was formed according to the data obtained from both the questionnaire and the freight modeling to determine the most appropriate logistics location. The VIKOR method, which is one of the Multi-Criteria Decision Making techniques, was used in determining the optimal alternative region. The reason why the VIKOR method is preferred is that the criteria possess the characteristic of proximity to the ideal. According to the results obtained from the VIKOR method, if it is decided to establish a new logistics center, the best options for the industrial sector would be Konya OIZ, Eskişehir OIZ, and Ankara Başkent OIZ, respectively; and for the logistics sector, Konya OIZ, Eskişehir OIZ and Ankara 1. OIZ, respectively. Transport cost, delivery time, and having a more advantageous location in freight transport density influenced these regions to be prioritized. The fact that the optimal corridors in both sectors are slightly different is because the criteria priority preference values of the participants in the two sectors are different.

4. RESULTS

In this study, intending to utilize the public resources more efficiently and to maximize the contribution of the effects of the investments to the economy and the region, the interactions of actors remained in the background of these studies were examined and a holistic evaluation was performed for a logistics center to be built. On the other hand, an integrated logistics model, which includes the freight model and the optimum selection of location, was suggested for an efficient and functional logistics center. In addition to the current situation analysis (the questionnaire) carried out in the pilot region which was identified as the Aegean and Central Anatolian regions, assessment of the selection of location supported by the logistics model of the logistics areas where the freight transport is intensely carried out was made. By using AHP-VİKOR methods, the selection of location was made via multi-criteria decision-making.

The proposed freight model can also be used in the shortcuts to the future. In the future, it is possible to perform freight projection forecasts utilizing knowing and/or estimating the value of variables used as inputs in the generation/attraction model which is the second phase of the model. On the other hand, the designed freight model has been input for the selection of logistics area. According to the results obtained from the AHP-VIKOR method, if it is decided to establish a new logistics center, the best options for the

industrial sector have been, respectively, Konya OIZ, Eskişehir OIZ, and Ankara Başkent OIZ; and for the logistics sector, respectively, Konya OIZ, Eskişehir OIZ and Ankara 1. OIZ. Transport cost, delivery time, and having a more advantageous location in freight transport density influenced these regions to be prioritized. The fact that the optimal corridors in both sectors are slightly different is because the criteria priority preference values of the participants in the two sectors are different.

In future studies, the optimum location selection can be made by using load modeling with fuzzy regression analysis for logistics centers where freight carrying amounts are uncertain.

ACKNOWLEDGEMENT

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

REFERENCES

[1]   Bediroğlu, Y., Yıldırım, V., "Lojistik Merkez Yer Seçimi İçin CBS & ÇÖKV Ara Yüzü Geliştirilmesi ve Ordu İli Pilot Bölge Çalışması", Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi, 9(1): 323-334, (2020).

[2]   Canel, C., Khumawala, B. M., "A mixed-integer programming approach for the international facilities location problem", International Journal of Operations & Production Management, 16(4): 49-68, (1996).

[3]   Yang, J., Lee, H., "An AHP decision model for facility location selection", Facilities, 15(9-10): 241-254, (1997).

[4]   Vlachopoulou, M., Silleos, G., Manthou, V., "Geographic Information Systems in Warehouse Site Selection Decisions", International Journal of Production Economics, 71(1-3): 205-212, (2001).

[5]   Birsel, A., Cerit, A.G., "Lojistik İşletmelerinin Kuruluş Yeri Seçiminde Arazi Faktörü", İzmir Ulaşım Sempozyumu, İzmir, Turkey, (2009).

[6]   Jacyna-Golda, I., Izdebski, M., "The Multi-criteria decision support in choosing the efficient location of warehouses in the logistic network", Procedia Engineering, (187): 635-640, (2017).

[7]   Zhang, M., Huang, J., Zhu, J. M., "Reliable facility location problem considering facility failure scenarios", Kybernetes, 41(10): 1440-1461, (2012).

[8]   Ghadge, A., Yang, Q., Caldwell, N., "Facility location for a closed-loop distribution network: a hybrid approach", International Journal of Retail & Distribution Management, 44(9): 884-902, (2016).

[9]   Elevli, B., "Logistics freight center locations decision by using fuzzy-PROMETHEE", Transport, 29(4): 412–418, (2014).

[10]   Rao, C., Goh, M., Zhao, Y., Zheng, J., "Location selection of city logistics centers under sustainability", Transportation Research Part D: Transport and Environment, (36): 29-44, (2015).

[11] Pham, T.Y., Ma, H.M., Yeo, G.T., "Application of fuzzy Delphi TOPSIS to lo- cate logistics centers in Vietnam: The logisticians' perspective", The Asian Journal of Shipping and Logistics, 33(4): 211-219, (2017).

[12] Pramanik, S., Dalapati, S., Roy, T.K., "Neutrosophic multi-attribute group decision-making strategy for logistics center location selection", Neutrosophic Operational Research, (3): 13-32, (2018).

[13] Lotfi, R., Mostafaeipour, A., Mardani, N., Mardani, S., "Investigation of wind farm location planning by considering budget constraints", International Journal of Sustainable Energy, 37(8): 799-817, (2018).

[14] Tabak, Ç., Yıldız, K., Yerlikaya, M.A., "Logistic location selection with CRITIC-AHP and VIKOR integrated approach", Data Science and Applications, 2(1): 21-25, (2019).

[15] Özmen, M., Aydoğan, E.K., "Robust multi-criteria decision-making methodology for real life logistics center location problem", Artificial Intelligence Review, 53(1): 725–751, (2020).

[16] Pamucar, D., Bozanic, D., "Selection of a location for the development of multimodal logistics center: Application of single-valued neutrosophic MABAC model", Operational Research in Engineering Sciences: Theory and Applications, 2(2): 55-71, (2019).

[17] Liu, P., Li, Y., "Multiattribute decision method for comprehensive logistics distribution center location selection based on 2-dimensional linguistic information", Information Sciences, (538): 209-244, (2020).

[18] Yazdani, M., Chatterjee, P., Pamucar, D., Chakraborty, S., "Development of an integrated decision making model for location selection of logistics centers in the Spanish autonomous communities", Expert Systems With Applications, (148): 113208, (2020).

[19] Cambridge Systematics, "Inc., Quick Response Freight Manual II", Federal Highway Administration, Publication No. FHWA-HOP-08-010, Washington, ABD, (2018).

[20] Hensher, D.A., Rose, J.M., Greene, W.H., Applied Choice Analysis: A Primer, Cambridge University Press, Cambridge, England, (2005).

[21] Ortuzar, J. D., Willumsen, L.G., Modelling Transport, 4th Edition, John Wiley and Sons Ltd., West Sussex, England, (2011).

[22] De Jong, G., Gunn, H.F., Walker, W., "National and international freight transport models: Overview and ideas for future development", Transport Reviews, 24(1): 103-124, (2004).

[23] Saaty, T. L., The Analytic Hierarchy Process, McGraw-Hill, New York, ABD, (1980).

[24] Yerlikaya, M.A., Arıkan, F., "Constructing the performance effectiveness order of SME supports programmes via Promethee and Oreste techniques", Journal of the Faculty of Engineering and Architecture of Gazi University, 31(4): 1007-1016, (2016).

[25] Opricovic, S., Tzeng, G.H., "Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS", European Journal of Operational Research, 156(2): 445–455, (2004).

[26] Tiwari, V., Jain, P.K, Tandon, P., "Product design concept evaluation using rough sets and VIKOR method", Advanced Engineering Informatics, 30(1): 16-25, (2016).

[27]   Tabak, Ç., "Türkiye'de Lojistik Faaliyet Alanlarının Yer Seçimi, Ulaştırma Modları ile Entegrasyonu ve Modellemesi", Doktora Tezi, Gazi Üniversitesi Fen Bilimleri Enstitüsü İnşaat Mühendisliği Ana Bilim Dalı, Ankara, (2018).