Determining Most Suitable Areas for Logistics Centers by Using GIS and S-MCDM

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Key words: geographic information systems (GIS), logistics centers, freight village, spatial-multi criteria decision making (S-MCDM)

SUMMARY

With the developing technology and trade volume, the concept of time becomes one of the most important concepts affecting the cost. For this reason, logistics and freight village concepts are important concepts to be considered in order to maintain order in trade and increase speed while reducing costs. In addition to literature surveys on this subject, action plans and strategic plans of public institutions were also examined. Accordingly, the logistics sector was identified as one of the priority sectors to work in Turkey. In this respect, the case study of the Investment Environment Improvement Project, which was prepared under the supervision of the Ministry of Environment and Urban Planning, was conducted on the logistics sector. The project aimed to determine the most suitable areas for sectoral facility investments. The results of the literature were examined in determining the factors affecting the location of the logistics centers. In the analysis phase of the project, the interface developed based on the integration of GIS and spatial MCDM techniques was used. In this study, AHP method was used as MCDM method. Through this interface, many GIS operations were implemented in a hierarchical sequence and cost surface maps were created. In addition, a workflow chart and methodology for site selection across the case study is presented.

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1. INTRODUCTION

With the impact of globalization and the increasingly competitive environment logistics has become one of the most important factors of trade (Martí et al., 2014). Logistics activities are of great importance in addressing transport, storage and packaging problems effectively and particularly to increase the competitiveness of companies and the country. The significant sources of sustainable competitive advantage have been supply chain management and logistics (Çakır, 2017).

Countries are reviewing their understanding of maritime, airline, rail and road transport in line with the transformations in world trade. The return of these changes in the understanding of trade can be seen on logistics centers, where all types of transport are integrated and operate on an international scale (Filik, 2011).

The goal of becoming a center in transportation, transportation and trade increases the need for logistics infrastructure. In order to take advantage of the advantages of Turkey's geographical position and to realize the objectives set out, a solid infrastructure needs to be established. Accordingly, the establishment of logistics centers on the intersection areas of the transportation networks in the regions that can be described as junction points comes to the fore as an important need.

A Logistics Center is a center in a defined area within which all activities relating to transport, logistics and the distribution of goods - both for national and international transit, are carried out by various operators on a commercial basis (URL-1). Most users use the same facilities and equipment around a transportation terminal. In this way, transportation costs are reduced and the reliability and healthy realization of the transportations are ensured.

In the view of such information, when the logistics centers in Turkey are examined, the lack of logistics centers throughout the Eastern Black Sea region is noticeable (Figure 1). There is a need to establish a Logistics Center to be used both in commercial activities with neighboring countries in the Black Sea region and in commercial activities within the country. In addition, the low amount of flat and wide area in the Black Sea region also necessitates the monitoring of the scientific and technical process in the "site selection for logistics center" operations in the region. In the site selection study conducted to meet this need, Ordu province located in the Central and Eastern Black Sea Region was chosen as the pilot study area (Figure 2).

Transportation investments such as the airport, the ring road connections, the highway project that will connect the Black Sea and the Mediterranean under construction, and the planned railway connection make the Ordu province logically feasible. In addition, the ports in the city will provide great advantages in terms of maritime trade.

Figure 1. Logistics Centers in Turkey (Ozceylan et al., 2016)

Figure 2. Pilot study area (Ordu Province in Turkey)

2. FACTORS AFFECTING LOCATION SELECTION OF LOGISTICS CENTERS

The results of national and international literature and application projects were examined in determining the factors affecting location selection of logistics centers.

(Kayikci, 2010) in her study, economic, environmental, etc. has used many factors. The most important of these are land use, transportation cost and time, accessibility, social balance, economic balance, import and export volume, hazardous materials, which can also be used in spatial location selection. In addition, in this study, Fuzzy-AHP method was used as the Multiple Criteria Decision Making (MCDM) method.

(Hong and Xiaohua, 2011) has conducted a study that minimizes transportation time by using environmental, economic and technical factors. In this study, time was used as a more important factor than cost for emergency centers. In addition, in this study, AHP method was used as the MCDM method.

(Jacyna-Golda and Izdebski, 2017) have stipulated that factors such as logistics warehouse capacity, transportation cost, fuel cost, raw material transfer cost, labor cost, distance to transportation infrastructures, local taxes should be used as basis for assessment. In the same study, it is stated that this type of MCDM problem can be solved by using TOPSIS, ELECTRE, Gray Theory methods, fuzzy logic or Choquet integral method.

(Roh et al., 2013) has predicted that the factors that should be used to determine regional logistics warehouse locations should be location, logistics, national stability, cost and cooperation. In addition, AHP method was used as a MCDM method in the study. The sub-factors used in the study are as follows;

- Location: Geographic location, distance to beneficiaries, disaster areas, opinion of suppliers, climate, proximity to other logistics warehouses, distance to disaster areas
- Logistics: Airport, port, road, logistics warehouses
- National Stability: Political stability, social stability, economic stability
- Cost: Labor, land, storage, replenishment, logistics
- Cooperation: Local governments, neighboring countries, logistics organizations.

(Zak and Weglinski, 2014) has used the following factors in his study: transport infrastructure, economic development, cost of investment, level of transport and logistics competition, investment attractiveness, transport and logistics attractiveness, social attractiveness, ease of use in environmental terms, trust and safety. In addition, ELECTRE method was used as the method of MCDM.

(Maharjan and Hanaoka, 2017) focused more on disasters and bad weather in their study and used these factors in their location analysis. Afterwards, they examined the results with sensitivity analysis. Factors used in the study in general terms; uncontrollable fires, storms, landslides, floods, extreme temperatures, epidemics, earthquakes and drought.

(Yildirim and Onder, 2014) stated in their study for Istanbul,Turkey that existing distribution centers did not meet the need. Land cost, proximity to industrial areas, proximity to the airport, proximity to ports, proximity to the railway network, proximity to highways are the factors used in the study. In the study, AHP method and PROMETHEE method were used as the MCDM method.

(Meidute, 2007) has made an economic evaluation of logistics centers. For this assessment, the total surface of the logistic storage areas, the total surface of the parking areas, the size of the administrative buildings, the surface of the railway, road terminal and transfer areas, the number and capacity of the loading and unloading equipment, the total length of the internal road and main road connection, the internal railway network and the main railway network, the total length of the connection, the total length of other technical infrastructures, land acquisition cost, total construction cost, equipment acquisition cost, etc. took into account the factors.

(Eryuruk et al., 2013) in their study for Istanbul, they used the necessary physical, spatial, infrastructure services, transportation, labor, fixed expense and capital factors. Also, AHP method was used as MCDM method in the study.

3. DATA USED IN PILOT REGIONAL STUDY

The factors used in the logistic area location selection in Ordu province, the geographical data sets and scales corresponding to these factors are shown in Table 1.

Table 1. Factors used in the study and geographical data sets

Factors	Geographic Data	Scale
Distance to the airport	Airport (point)	1/1000
Distance to highway	Highway (line)	1/25000
Distance to the port	Port (point)	1/1000
Distance to industrial zones	Industrial zone	1/1000
Slope	Topography	1/25000
Distance to streams	Hydrology	1/25000
Distance to lakes	Hydrology	1/25000
Natural gas infrastructure	Natural gas	1/5000
Soil structure	Soil	1/25000
Land use	Land cover	1/25000
Geological structure	Geology	1/25000
Highway projects	Highway (line)	1/25000

4. METHODOLOGY AND WORK FLOW PROCESSES

4.1. Analysis and calculations

In order to create the accumulated cost surface, analyzes were performed on the GIS using the appropriate S-MCDM parameters.
The data used in the study is divided into four different classes. In the first grade, there are data that come directly as raster. These data have subjected to reclassify operations according to

AHP scores and reclassified and made ready for use. There are point data to be interpolated in the second class. These data have interpolated by IDW, Kriging and similar methods. The resulting continuous surfaces have re-sampled according to standard Pixel-sized raster data and converted to raster data format. The third data class contains data to be converted directly to raster format. These data have converted to raster data format according to the values assigned to the attribute data in the relevant column. The fourth data type is the data that must be located at different distances to the domains and subject to different evaluations. These data have converted to polygon vector format while the line was in vector format with multiple ring buffer analysis, and then have converted to raster format over defined parameters. These data, collected in four different classes in raster format, have first converted into standard scales according to data score - weight distributions. All raster data have then multiplied (with AHP weight coefficients) and collected using the map algebra function to create an accumulated cost surface (Figure 3).

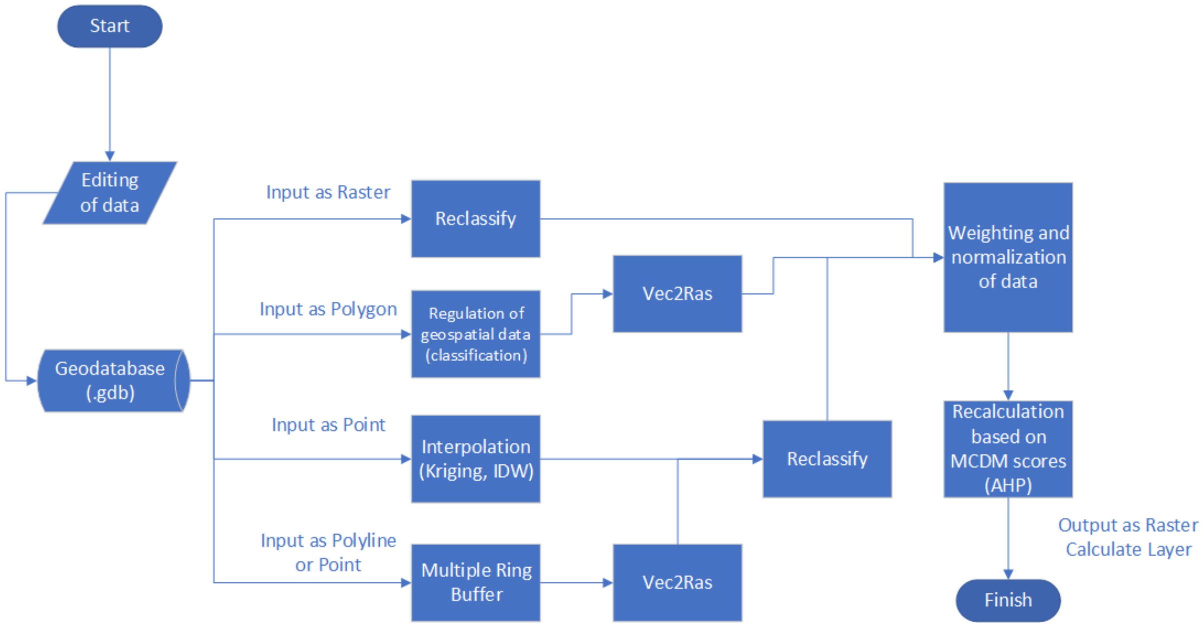


Figure 3. The process of transaction for site selection of logistics center

The processes have specified in the workflow diagram of the pilot zone application were carried out in a sequential manner and the logistics center location selection analysis has completed successfully. According to the approaches in projects and publications completed around the world, the geographical data sets (factors), their sub-factors and their scores were determined. Interviews were made with the experts on these data sets via the questionnaire and the final score table is presented below (Table 2). There are two different methods for sub-factor score valuation: giving high points to appropriate areas and low points to appropriate areas. In this study, the appropriate areas were given low scores on the cost surface. In other words, the areas with small pixel value in the intermediate layers and in the final cost surface map are the most suitable areas for logistics center location selection.

4.2. Calculation of Factor Weights

In Table 2 and Table 3, the calculation of the weights of the factors affecting the logistics area location selection was shown.

Table 2. The main factor matrix affecting logistics center location selection

	Contour	**Land Cover**	**Industrial Zone**	**Highway**	**Port**	**Airport**	**Stream**	**Lake**	**Mine**	**Soil Type**	**Geology**	**Natural Gas**
Contour	1.00	2.00	2.00	3.00	4.00	4.00	5.00	5.00	6.00	6.00	7.00	8.00
Land Cover	0.50	1.00	2.00	2.00	3.00	3.00	4.00	4.00	5.00	6.00	7.00	7.00
Industrial Zone	0.50	0.50	1.00	2.00	2.00	3.00	4.00	4.00	4.00	5.00	6.00	7.00
Highway	0.33	0.50	0.50	1.00	3.00	3.00	4.00	4.00	4.00	5.00	6.00	6.00
Port	0.25	0.33	0.50	0.33	1.00	1.00	2.00	2.00	3.00	4.00	4.00	5.00
Airport	0.25	0.33	0.33	0.33	1.00	1.00	2.00	2.00	3.00	4.00	4.00	5.00
Stream	0.20	0.25	0.25	0.25	0.50	0.50	1.00	1.00	1.00	2.00	3.00	4.00
Lake	0.20	0.25	0.25	0.25	0.50	0.50	1.00	1.00	2.00	2.00	3.00	4.00
Mine	0.17	0.20	0.25	0.25	0.33	0.33	1.00	0.50	1.00	3.00	4.00	4.00
Soil Type	0.17	0.17	0.20	0.20	0.25	0.25	0.50	0.50	0.33	1.00	4.00	5.00
Geology	0.14	0.14	0.17	0.17	0.25	0.25	0.33	0.33	0.25	0.25	1.00	4.00
Natural Gas	0.13	0.14	0.14	0.17	0.20	0.20	0.25	0.25	0.25	0.20	0.25	1.00
Weights	0.23	0.17	0.14	0.13	0.07	0.07	0.04	0.04	0.04	0.03	0.02	0.01

AHP Summary Report
Number of comparison: 66
Consistency rate: 5,3% (acceptable)

Table 3. Main factor weights as a result of AHP calculations

Factor	**Weight (Multiplication Factor)**	**Factor**	**Weight (Multiplication Factor)**
Contour	0,226	**Stream**	0,041
Land Cover	0,172	**Lake**	0,044
Industrial Zone	0,142	**Mine**	0,04
Highway	0,128	**Soil Type**	0,03
Port	0,72	**Geology**	0,02
Airport	0,71	**Natural Gas**	0,014

4.3. Calculation of Sub-Factor Weights

The calculation of sub-factor weights is shown in Table 4.

Table 4. Sub-factor weights

Factor	Sub-factor	Score	Factor	Sub-factor	Score
Slope (Degree)	0-5	1	Geology	Alluvion	3
	5-10	2		Conglomerate, sandstone	3
	10-16	3		Andesite, basalt, lava etc.	1
	16-22	4		Granitoid	7
	22-27	5		Argillaceous limestone	2
	27-32	6		Limestone	3
	32-38	7		Kackar granitoid	7
	38-49	8			
	49-100	9			
Land Use	Forest	6	Soil classification	I	8
	Pasture	1		II	7
	Shrubbery	1		III	6
	Agriculture	5		IV	5
	Dry farming	5		V	4
	City center	3		VI	3
	Marsh	7		VII	2
	Grassland	2		VIII	1
Distance to main road (m)	0-200	1	Natural gas	Exist	1
	200-400	3		Non-existent	10
	400-600	5			
	600-800	7			
	800-1000	9			
Distance to stream (m)	0-200	10	Port (m)	0-1000	2
	200-400	8		1000-2000	3
	400-600	7		2000-3000	5
	600-800	6		>3000	10
	800-1000	5			
	>1000	0			
Industrial facilities (m)	0-1000	0	Lake (diameter)	1000 m	10
	>1000	10		>1000 m	1
Mine sites (m)	0-1000	10	Airport (diameter)	3000 m	1
	>1000	0		>3000 m	10

5. ANALYSIS RESULTS

In the analysis phase of the study, the interface developed based on the integration of GIS and Spatial-Multi Criteria Decision Support Systems (S-MCDM) was used. Many GIS operations were implemented in a consecutive and hierarchical order through this interface and cost surface maps were created as a result (Figure 4, Figure 5a-5l). The "cost surface map" produced as a result of the analysis for the pilot region is shown below (Figure 4). In the first stage, 43 areas were determined on the cost surface map. Then, 5 of these 43 areas were evaluated as the most suitable areas for investment in terms of logistics centers. These areas were also examined in detail and it was decided that one of the 5 alternatives identified was the most suitable area.

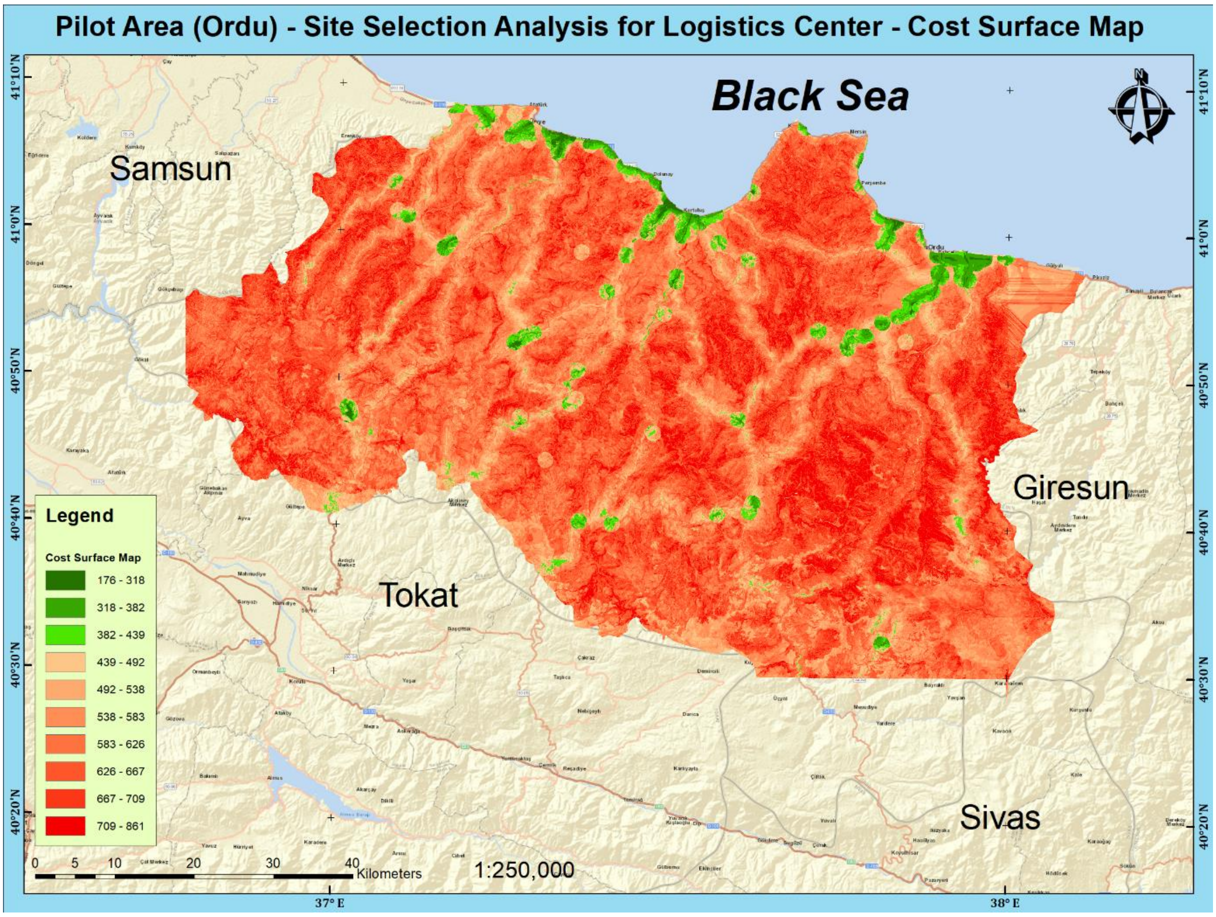
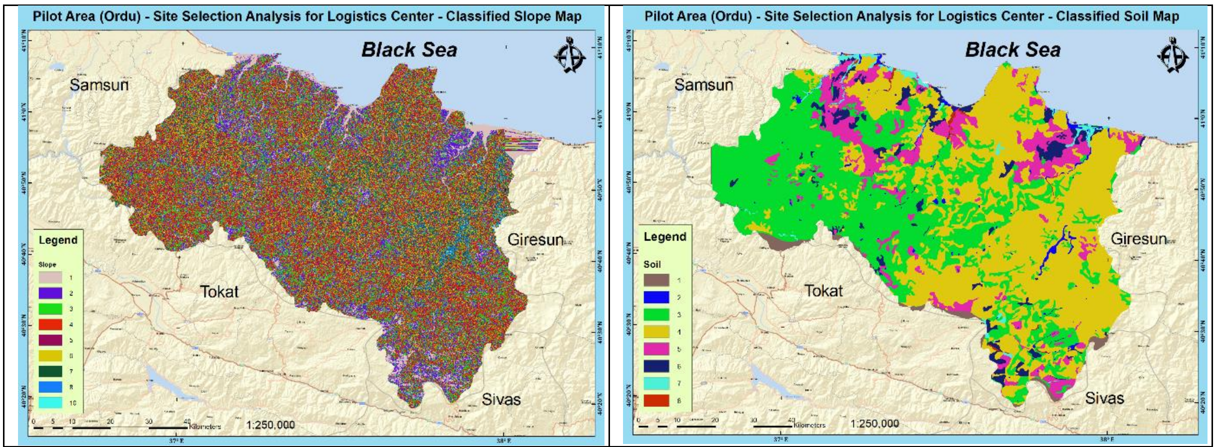
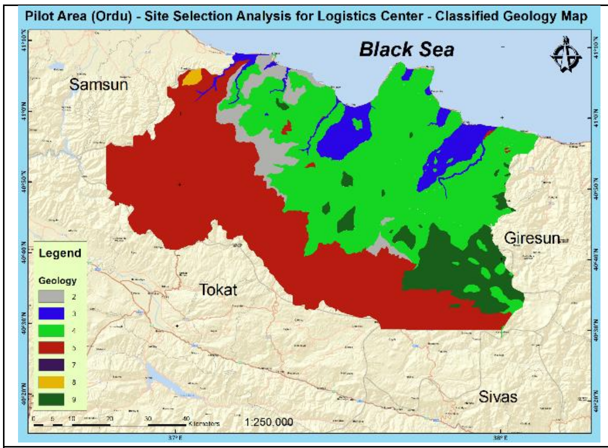


Figure 4. Accumulated cost surface map

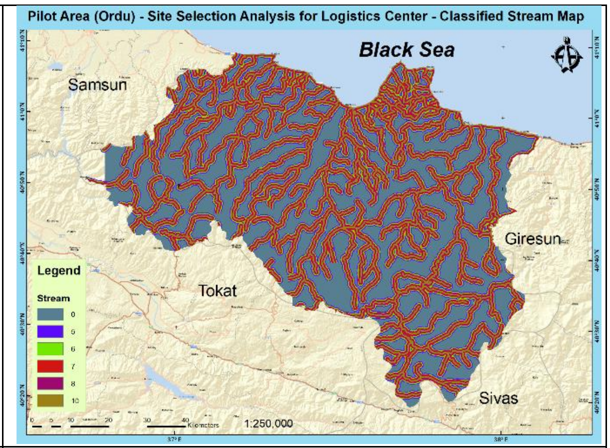
Scoring logic in analysis; it was constructed on the basis that the low scoring places are suitable for the logistics center and the high scoring places are not suitable for the logistics center due to their high cost.



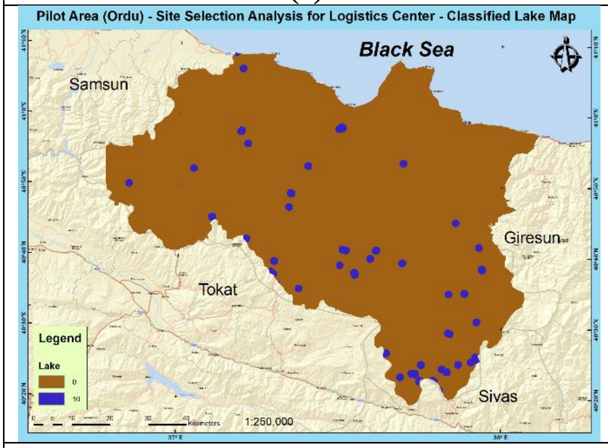
(a)	(b)


Pilot Area (Ordu) - Site Selection Analysis for Logistics Center - Classified Geology Map
Black Sea
Samsun
Giresun
Tokat
Sivas
Legend
Geology
1:250,000

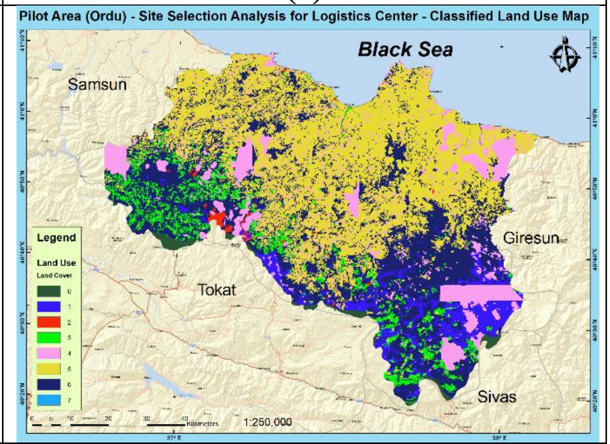
(c)


Pilot Area (Ordu) - Site Selection Analysis for Logistics Center - Classified Stream Map
Black Sea
Samsun
Giresun
Tokat
Sivas
Legend
Stream
1:250,000

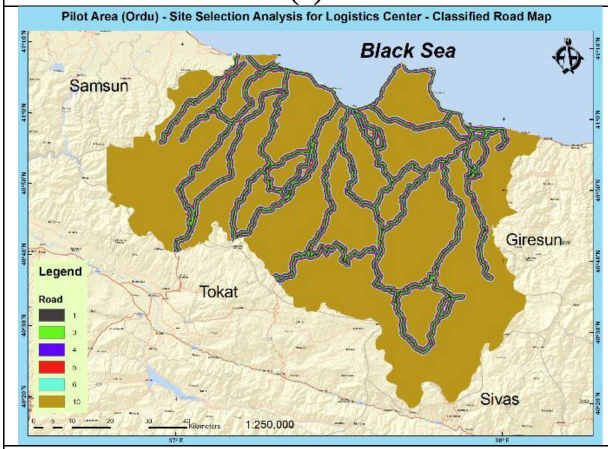
(d)


Pilot Area (Ordu) - Site Selection Analysis for Logistics Center - Classified Lake Map
Black Sea
Samsun
Giresun
Tokat
Sivas
Legend
Lake
1:250,000

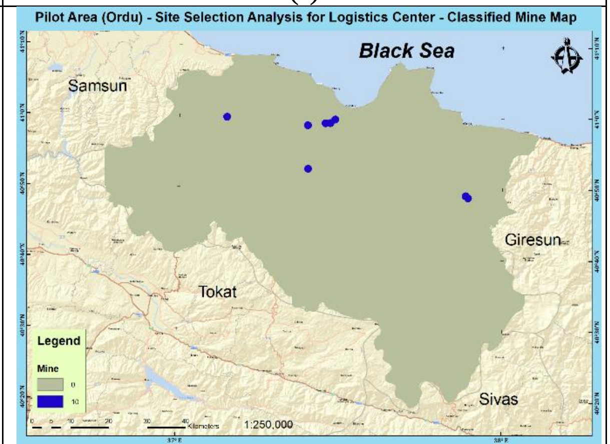
(e)


Pilot Area (Ordu) - Site Selection Analysis for Logistics Center - Classified Land Use Map
Black Sea
Samsun
Giresun
Tokat
Sivas
Legend
Land Use
Land Cover
1:250,000

(f)


Pilot Area (Ordu) - Site Selection Analysis for Logistics Center - Classified Road Map
Black Sea
Samsun
Giresun
Tokat
Sivas
Legend
Road
1:250,000

(g)


Pilot Area (Ordu) - Site Selection Analysis for Logistics Center - Classified Mine Map
Black Sea
Samsun
Giresun
Tokat
Sivas
Legend
Mine
1:250,000

(h)

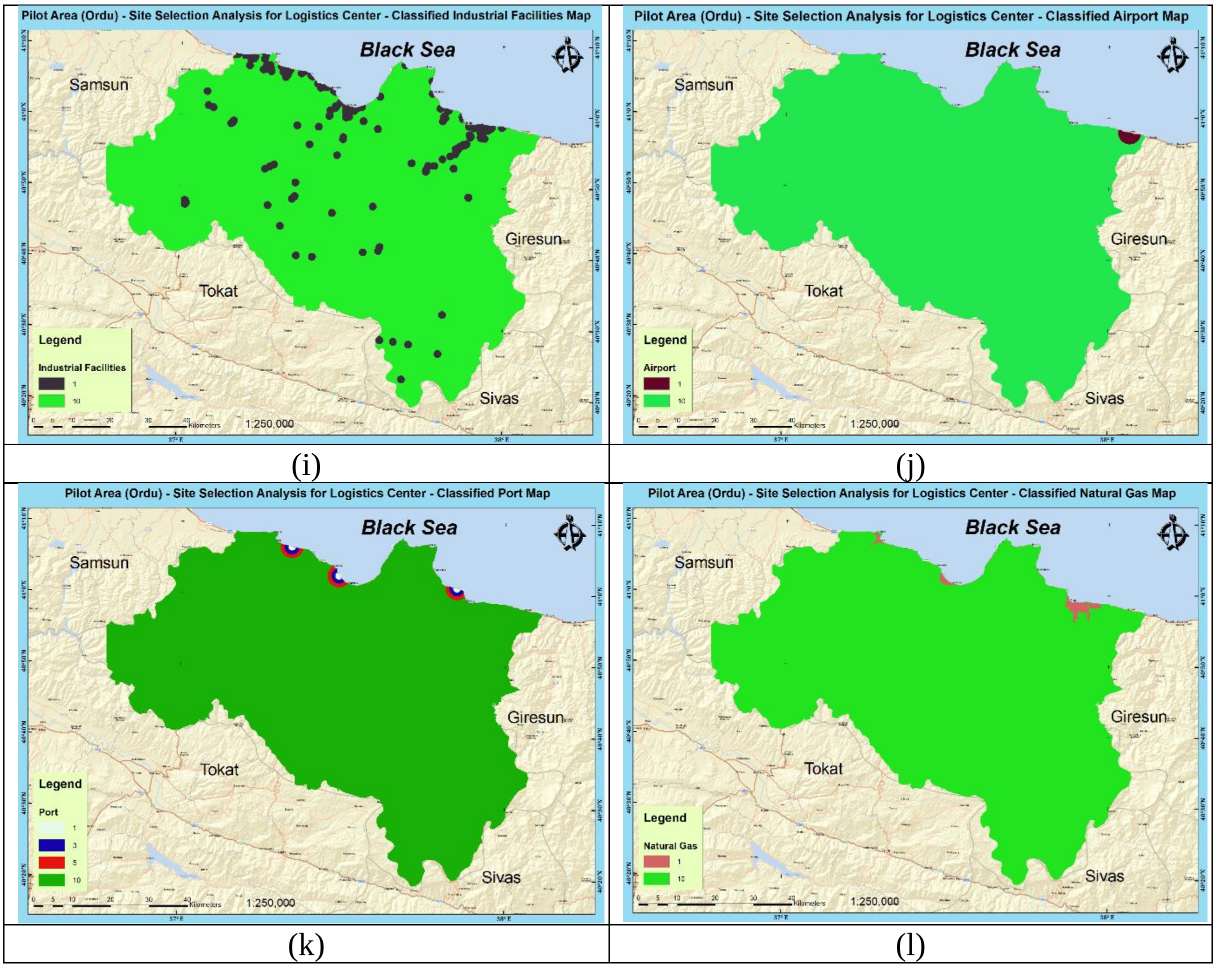


Figure 5. (a) Classified slope map; (b) Classified soil map; (c) Classified geology map; (d) Classified stream map; (e) Classified lake map; (f) Classified land use map; (g) Classified road network map; (h) Classified mine map; (i) Classified industrial facilities map; (j) Classified airport map; (k) Classified port map; (l) Classified natural gas infrastructure map

6. FINALIZATION AND DECISION MAKING PROCESS

After extensive S-MCDM analyzes, 43 different corridors have determined in the study area based on the raster-based result cost surface map for the logistics center location selection. The areal size of these 43 different corridors have determined were transformed into 5 alternative areas as a result of their statistical results on the cost surface map and finally their appearance on the satellite image (Figure 6-7).

Figure 6. 43 different corridors for site selection of logistics center

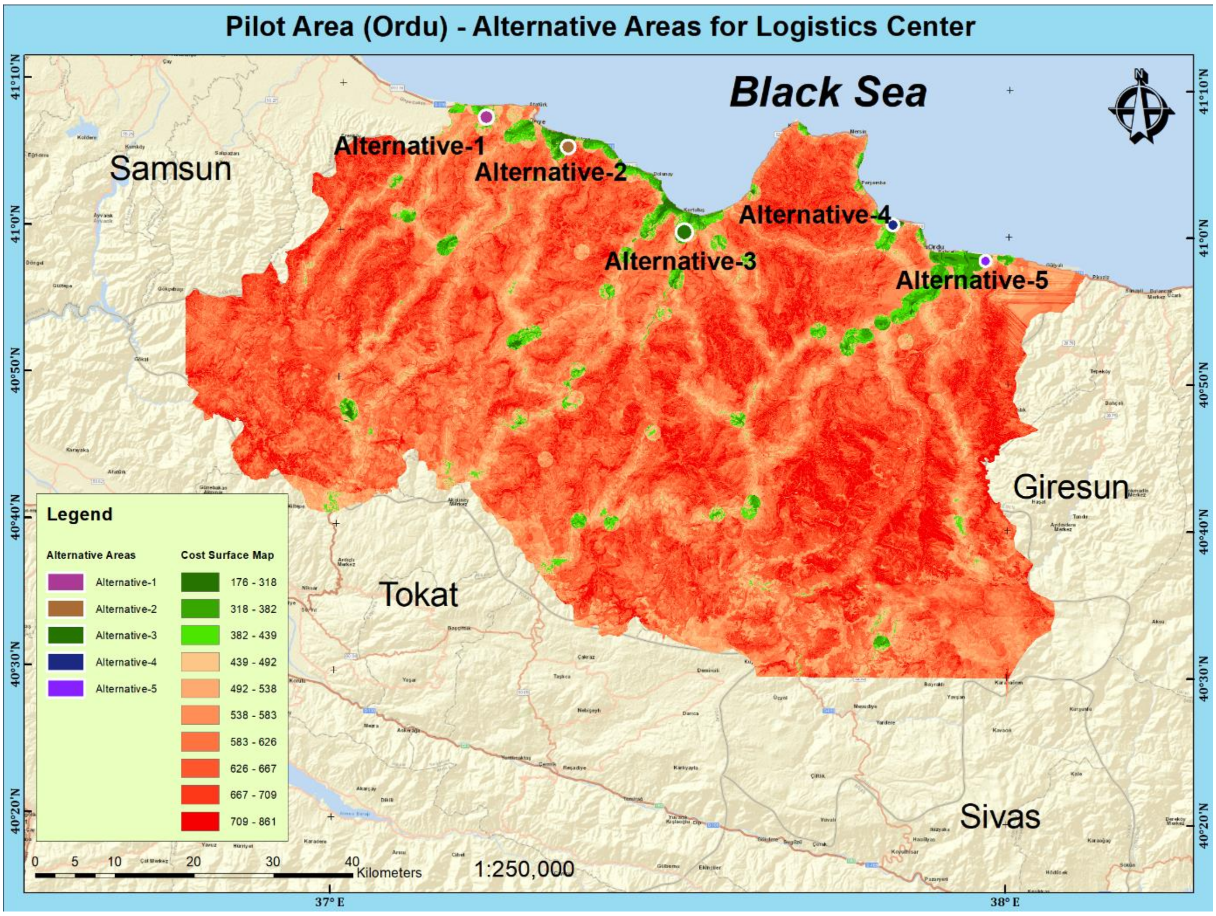


Figure 7. Alternative areas for logistics center

Table 5. Average scores obtained by alternative fields by layers

	Scores of alternative fields based on classified values												Results	
	Airport	*Geology*	*Port*	*Mine*	*Slope*	*Lake*	*Road*	*Land Use*	*Natural Gas*	*Industrial Facilities*	*Soil*	*Stream*	*Total*	*Cost Surface Map*
Alternative 1	10.00	3.28	10.00	0.00	1.39	0.00	3.21	4.77	10.00	1.00	6.80	5.48	55.93	375.06
Alternative 2	10.00	3.68	3.04	0.00	3.55	0.00	6.76	5.26	10.00	3.34	3.74	6.38	55.75	456.04
Alternative 3	10.00	3.12	10.00	0.00	1.92	0.00	3.75	4.46	10.00	1.00	5.64	7.33	57.22	392.49
Alternative 4	10.00	3.00	4.19	0.00	1.42	0.00	3.23	4.32	10.00	1.00	5.48	8.14	50.78	333.37
Alternative 5	10.00	3.37	10.00	0.00	1.39	0.00	1.91	4.34	3.53	1.00	5.69	4.02	45.25	332.74

The scores given in Table 5 shows the average scores obtained by the determined alternatives according to the layers. For example; the area which is named 'Alternative 1' obtained an average of 3.28 points from the layer named 'Geology'. The column titled 'Total' in the table shows the sum of the average scores obtained by the alternatives according to the layers. Similarly, the column titled 'Cost Surface Map' shows the average value obtained from the layer named 'Cost Surface Map' for alternative logistics centers. This value also gives the weighted sum of the average score values obtained by the alternatives given in the table for each layer.

According to the results obtained from Table 5, the eligibility rankings of the alternatives are given in Table 6 according to both the ‘Total’ and ‘Cost Surface Map’ columns. When the results are evaluated, Alternative-5 is considered to be the most suitable area within the pilot area for the logistics center.

Table 6. Suitability ranking of alternative areas

Sorting	Sort by 'Total' column	Sort by ‘Cost Surface Map’ column
1	Alternative 5	Alternative 5
2	Alternative 4	Alternative 4
3	Alternative 2	Alternative 1
4	Alternative 1	Alternative 3
5	Alternative 3	Alternative 2

ACKNOWLEDGEMENTS

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BIOGRAPHICAL NOTES

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