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Evaluating Current Logistics Facilities with Analytical Hyepapchy Process (AHP) and Geographical Information Systems (GIS)

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Abstract. Logistics facilities which have important position within logistics supply chain are established in order for the demanded goods to be supplied on time, with the minimum cost and in the shortest duration. Given the cost and time factors, the location of such facilities should be selected very carefully and effectively. Especially, a quick settlement in logistics manner is experienced depending on transportation network, work force, proximity to market and raw materials of the times following the industrialization period after establishing the Republic. Nowadays, with the development of transportation and the communication systems as well as technology transportation costs decreased and the facilities and possibilities transport from one place to another increased. For this reason, like the private sector the public institutions and organizations began to shrink, shut down or merge their facilities. This situation was brought to reconsider the existing facilities. The purpose of this study is to evaluate and analyze current six logistics facilities with Analytical Hierarchy Process (AHP) and Geographical Information Systems (GIS). Analyses results will contribute the decision of revising logistics facilities for which are planned to be restructured. Moreover, suggestions are presented for proper ones to continue operating, for improper ones to get closed or transferred to another place.
Keywords. Analytic Hierarchy Process, (AHP), Geographic Information Systems, (GIS), Facility Site Selection.
JEL. J61, L86, Q55.

1. Introduction

The Logistics facilities which have important position within logistics supply chain are established in order for the goods which are demanded by customers to be supplied on time, with the minimum cost and in the shortest duration. Logistics facilities should be selected very attentively and effectively as taking cost and time factors into account.

Since the facility site selection is a strategic and long term decision, establishing facilities and re-locating them is costly and requires extensive time. A wrong decision given by the first establishment of a logistics facility could be cause a huge economic and labor losses (Ağdaş, 2014).

In our country, a rapid restructuring in logistics has been accrued by the period of industrialization after establishing the Republic. Logistics facilities (factories, distribution centers, public facilities and so on) were established according to that

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time's nearness of transportation network, labor, market and row material. Logistics facilities had been established in many amounts and dispersedly since the fact that transportation networks were not advanced or nearly there was not any, work force insufficiency due to the fact that many citizens died during war times, and raw material scarcity.

Nowadays, development in transportation and communication systems with parallel to technological advancements allow to arrive one place to another quickly than before, and also transportation costs decreased. Increasement in demand points with increasement in educated work force, raw material sources and purchasing power brought forward critiques about sufficiency in current logistics facilities and their costs. Therefore, private sector, which generally focus on cost related issues, and public institutions and organizations which have intention to provide services for public, are downsized, closed their facilities, merging or relocated destinations. The current results brought forward the necessity to revise the current logistics facilities.

Depending on the literature, it can be seen that, facility site selection criteria are used to evaluate current facilities. There are numerous studies about facility site selection in the literature and recently, multi criteria decision making techniques which analysis qualitative and quantitative criteria together used frequently (Ağdaş, 2014).

Fuzzy Vikor, Fuzzy Topsis and Stochastic Multi-Criteria Acceptability Analysis (SMAA-2) from multiple criteria decision making methods are utilized since criteria are uncertain as both qualitative and quantitative specifications in logistics site selection for public institutions (Ağdaş, 2014), and also fuzzy linear programming method used for a public institution's site selection (Ballı, 2014). It is possible to vary facility site selection problems in terms of the criteria, methods and purposes (Owen & Daskin, 1998; Klose & Drexl, 2005; Boloori & Farahani, 2012; Kabak et al., 2012).

In this study, evaluation of current logistic facility as location is regarded as a facility site selection problem. Firstly, criteria are determined according to literature research and survey application. These criteria are weighted with AHP, and possible site locations are determined as analyzing the established criteria with GIS. A comparison is made between possible logistics facility locations and the current logistics facility locations, and then proper and improper facilities are determined, and necessary suggestions are presented.

It is aimed to evaluate the current logistics facilities as location with AHP and GIS, to determine the improper sites and to make suggestions for the most proper facility locations. It is therefore understood that GIS, which is commonly considered as data collection and storage tool, can also be utilized for different purposes.

2. Geographical Information Systems and Analytical Hyepapchy Process

GIS covers the processes of transferring all kinds of data related to earth as making connections with the location information to computer environment, and also the processes of storing, classifying, making mutual comparisons, analyzing, updating and visualizing as map, graphic and table as demanded. The most important qualification that distinguished GIS from other database systems is to enable users to make locational and un-locational analyses as storing all kinds of data related to earth in the locations where they are tied (Derviş et al, 2014). The data is symbolized as point, line and polygon features in GIS. Points are represented with a single coordinate pair, lines are with a coordinate series which has a starting and ending points (x,y), and polygon features are with a coordinate series which has same starting and ending points (x,y) (URL 1).

GIS is an important tool which is used in facility site selection problems with its ability to present locational and un-locational data together (Erbaş et al., 2014). Alternatives can be determined or prioritized among different alternatives as analyzing the established criteria with GIS.

It is important to select site as a location where companies can get most benefit out of it and which will cause the minimum environmental impacts after an unexpected accident while selecting a store house location. Therefore, using GIS is an indispensable truth for making site selection analysis using locational analyses (Erbaş et al., 2014). GIS is commonly used for logistics site selection problems (Costa et al., 2013).

AHP is a model which provides a perspective to managers on analyzing different location factors, evaluating alternative locations and determining the final site selection (Yang & Lee, 1997). Saaty showed the utilization areas of AHP as making applications and analyzed as classifying the criteria used in multiple criteria decision making methods into a hierarchical structure in a study conducted in 1990 (Saaty, 1990).

Using together GIS with MCDM method has currently become popular for facility site selection studies. As making analyses with GIS, alternatives are weighted with AHP for Istanbul fire station and proper locations are suggested (Doğramacı, 2009; Erden, 2011). GIS and AHP is used for determining the locations where there is landslide risk (Bhatt et al., 2013).

3. Implementation

Six logistics facilities which belong to public institutions which give services to 62 demand points in specific areas of Turkey (Marmara, Aegean, Mediterranean, Central and Western Black Sea and Central Anatolia regions) are evaluated as location using GIS and AHP, then proper locations are suggested for improper ones. Criteria which are used for facility site selection are determined with literature research study and these criteria are turned into survey by help of expert in this field then are applied to personnel who worked before or still work in logistics facilities which belong to public institutions. Criteria are developed by taking personnel suggestions.

Similar questions with the survey which were answered by 693 people and used with the thesis studies of Agdas and Bali in 2014, then similar results are obtained at a rate of nearly 90% (Ağdaş, 2014; Ballı, 2014).

Data analysis of the survey is made through SPSS 17.0 package program and reliability analysis is completed to measure the trustworthiness. Reliability analysis is made to measure the answers' consistency. The main analysis which is used is to find the Cronbach Alpha (α) value. α value which is found using SPSS program shows the survey reliability. If α>0.80, survey has high level of reliability. According to analysis result, α= 0.84 is obtained. The result shows that survey has high reliability. 55 people answered the survey which is consisted of 37 questions. 6 more criteria are suggested by the survey participants.

Factor analysis is made to reduce the amount of 43 criteria which are determined to use logistics facility evaluation and site selection after survey results and expert consultancy. At the same time, criteria are statistically analyzed in order to establish the data's weights and average, median and mod values are calculated. After statistical analysis results, 3 criteria are excluded since their contribution is limited comparing to other criteria contributions to survey, 12 criteria are excluded since repeated evaluation is not maintained; and since some criteria should be considered in logistics facility construction and design processes and some criteria do not create difference on evaluation process.

As a result, nine criteria which are determined by also taking expert consultancy to use in current logistics facility evaluation and site selection are shown in Table 1.

Table 1. *Criteria used in Logistics Facility Evaluation and Site Selection*

S.NU.	ANALYZED CRITERIA	EXPLANATION
C1	Proximity to demand points	Logistics facilities should be proximate demand points and the distance should be less than 400 km.
C2	Proximity to highway	Logistics facilities should be proximate highways (not including stabilized or other roads which are under village responsibility) and the distance should be less than 5 km.
C3	Proximity to railway/ station	The distance to railway is considered. The distance to railway should be less than 50 km.
C4	Proximity to Fuel distribution points	Materials like fuel, fuel for heating, engine, transmission oil etc. Are supplied by the fuel service facilities which companies get cooperation with. The distance of logistics facilities to such points should be less than 250 km.
C5	Proximity to Industry/ Organized Industry region	Logistics facilities should be proximate to industry regions in order to get supplied maintenance, repair and material needs and to get related services, and the distance to such points should be less than 50 km.
C6	Proximity to Airport	Airline transportation is demanded especially to meet emergent and small sized needs within a limited time duration and the distance should be less than 100 km.
C7	Distance to Borderline	Logistics facilities should be distant to border lines minimum 30 km. due to safety conditions.
C8	Distance to Possible Disaster Region	It is important to select site in such regions where natural disasters are experienced less than comparing to other regions and classified in less risky group as analyzing the Turkey disaster map.
C9	Proximity to City center	Distance to city/ county centers are considered. The distance of logistics facilities to city/ county centers should be less than 40 km.

3.1. Determining Criteria's Weight with AHP

Criteria comparision is made by executive managers, who worked or still working in public logistics facilities, with AHP.

1. Step: Building Hierarchical Structure: Problem's hierarchical structure is built in the first step.

2. Step: Making Paired Comparison: A matrix is created as comparing each criterion with each other in the second step. Opinions of 5 experts are utilized by making this comparison. 1-9 scale is used while making paired comparisons. Paired comparision matrix is shown in Table-2.

Table 2. *Paired Comparison matrix*

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1	1/3	1	3	3	3	1	1/3	3
C2	3	1	3	3	3	3	3	1	5
C3	1	1/3	1	3	3	1	3	1/3	3
C4	1/3	1/3	1/3	1	1	3	1/3	1/3	1
C5	1/3	1/3	1/3	1	1	1/3	1	1/3	1/3
C6	1/3	1/3	1	1/3	3	1	1/5	1/3	1/3
C7	1	1/3	1/3	3	1	5	1	1/3	1
C8	3	1	3	3	3	3	3	1	5
C9	1/3	1/5	1/3	1	3	3	1	1/5	1

3. Step: Finding Eigenvector: Eigenvector is calculated in the third step, which means obtained values as normalizing the geometric averages of criteria become criteria weights. All rows' geometric averages are calculated and shown in Table-3.

Table 3. *Criteria' Geometric Averages*

	C1	C2	C3	C4	C5	C6	C7	C8	C9	GEO.AVR
C1	1	1/3	1	3	3	3	1	1/3	3	1,08
C2	3	1	3	3	3	3	3	1	5	1.29
C3	1	1/3	1	3	3	1	3	1/3	3	1,08
C4	1/3	1/3	1/3	1	1	3	1/3	1/3	1	0,87
C5	1/3	1/3	1/3	1	1	1/3	1	1/3	1/3	0,83
C6	1/3	1/3	1	1/3	3	1	1/5	1/3	1/3	0,83
C7	1	1/3	1/3	3	1	5	1	1/3	1	0,98
C8	3	1	3	3	3	3	3	1	5	1,29
C9	1/3	1/5	1/3	1	3	3	1	1/5	1	0,89
∑GEO.AVR										9.14

Therefore, every criteria' eigenvector (weight) is calculated as each of the geometric average value in the table above is divided by the total geometric average value. WC1 = 1,08/9=0,116; WC2 = 1,29/9= 0,14; WC3 = 1,12/9= 0,12 … All criteria's eigenvector is calculated and shown in Table-4.

Table 4. *Criteria' Eigenvectors*

	C1	C2	C3	C4	C5	C6	C7	C8	C9	GEO.AVR	EIGENVECTOR(W)
C1	1	1/3	1	3	3	3	1	1/3	3	1,08	0,118
C2	3	1	3	3	3	3	3	1	5	1.29	0,141
C3	1	1/3	1	3	3	1	3	1/3	3	1,08	0,118
C4	1/3	1/3	1/3	1	1	3	1/3	1/3	1	0,87	0,095
C5	1/3	1/3	1/3	1	1	1/3	1	1/3	1/3	0,83	0,090
C6	1/3	1/3	1	1/3	3	1	1/5	1/3	1/3	0,83	0,090
C7	1	1/3	1/3	3	1	5	1	1/3	1	0,98	0,107
C8	3	1	3	3	3	3	3	1	5	1,29	0,141
C9	1/3	1/5	1/3	1	3	3	1	1/5	1	0,89	0,098
∑GEO.AVR										9.14	

4. Step: Reliability Analysis: Reliability analysis which enables to determine how reliable paired comparisons are is conducted to control the calculations made in this manner. Having less than 0.1 value after the calculations will claim that the calculations and comparisons are reliable.

In this process, the first thing is to find a vector as multiplying eigenvectors with paired comparison vectors. Then, each of the elements of the vector is divided by the element of the eigenvector in the same row and another vector is obtained. The last vector's elements are summed and divided by n amount of criteria. The obtained value is called as ƛmax. The calculations and obtained results in this step are shown in Table-5.

Table 5. *Reliability Analysis*

	C1	C2	C3	C4	C5	C6	C7	C8	C9	EIGENVECTOR(W)	A*W	A*W/Wi
C1	1	1/3	1/5	5	3	3	5	1/3	3	0,118	1,767	14,97
C2	3	1	3	3	3	3	3	1	5	0,141	1,932	13,72
C3	5	1/3	1	3	3	1	3	1/3	3	0,118	1,767	15,11
C4	1/5	1/3	1/3	1	1	3	1/5	1/3	1	0,095	0,474	4,98
C5	1/3	1/3	1/3	1	1	1/3	1/5	1/3	1/3	0,090	0,316	3,51
C6	1/3	1/3	1	1/3	3	1	1/5	1/3	1/3	0,090	0,522	5,80
C7	1/5	1/3	1/3	5	5	5	1	1/3	1	0,107	1,403	13,11
C8	3	1	3	3	3	3	3	1	5	0,141	1,932	13,72
C9	1/3	1/5	1/3	1	3	3	1	1/5	1	0,098	0,583	5,94
∑										9,14	14,003	90,86

$$\lambda_{\max} = 90,86/9 = 10,10$$

Reliability Indicator =(10,10-9)/8=0,137

Reliability Rate (RR)= Reliability Indicator /Random Indicator (RI) (RG=1,45 for n=9)

RR=0,137/1,45=0,094

RR (0,094)< 0.1 so that double sided comparisons are conducted in a reliable fashion.

3.2. Determining Possible Facility Sites with GIS

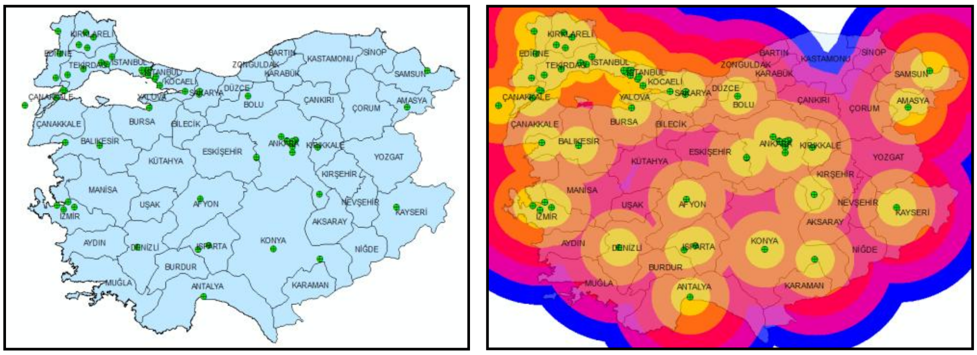
The data used in the implementation is prepared under ESRI Shapefile format. The data used in the analysis are shown in Table-6. The analysis depicted in Table-1 is made by using Spatial Analyst module of ArcGIS 10.2 software after preparing the data in GIS. Analyses are normalized in order to get the unit stability. Proximity to Demand Points analysis which is made for establishing the proximity to demand points is shown in Image-1.

Data normalization is conducted after making proximity analysis. Analysis normalization is carried out with the equation (1).

$$N = \left(\frac{X - V_{\min}}{V_{\max} - V_{\min}} \right) \quad (1)$$

Table 6. *Data used in the analysis*

S.NU.	Layer Name	Layer Type
1	Logistics Facilities	Point Layer
2	Highway	Line Layer
3	Railway	Line Layer
4	Fuel Distribution Points	Point Layer
5	Industry/ Organized Industry Region	Point Layer
6	Airports	Point Layer
7	Borders	Line Layer
8	Disaster Regions	Line Layer, Disaster Information
9	City Centers	Point Layer



(a) **(b)**

Figure 1: *Proximity to Demand Points (a-Demand Points; b-Proximity Analysis)*

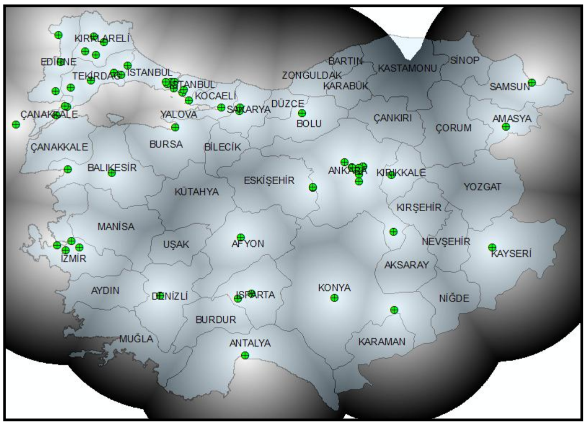
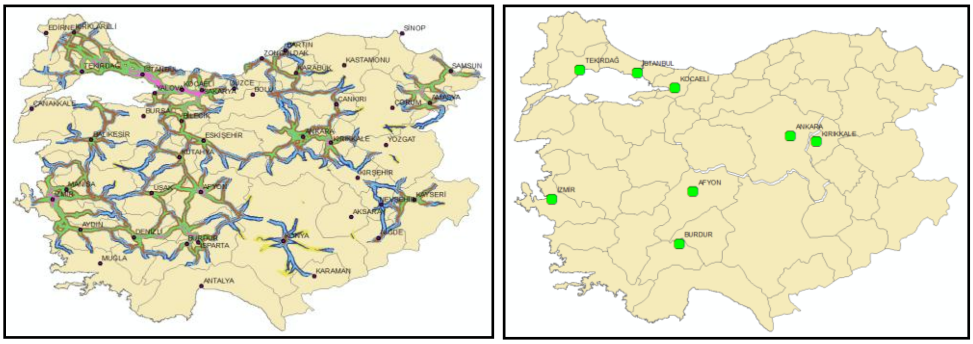


Figure 2. *Proximity to Demand Points Normalization*

The analyses made separately are combined with Spatial Analyst-Raster Calculator process, thus possible sites are determined as establishing a lowest limit by obtaining rational results for every possible site and with expert consultation so that the regions where located upper places of this lowest limit are considered as possible sites. Possible sites which are obtained through analyses are shown in Image 10-a and possible sites which are above of determined value by expert consultation are shown in Image 10-b. The regions which are in accordance with the demands are found as Tekirdağ, İstanbul, Kocaeli, Ankara, Kırıkkale, İzmir, Afyon and Burdur if analysis results are evaluated.



(a) (b)

Figure 3. *Possible Facility Sites Determined by GIS (a. Possible Sites Obtained through Raster Calculator; b. Possible Facility Sites which are above of the value determined by Expert Consultancy)*

Current logistics facilities are shown in Image 11. It is found out that the current logistics facilities located in Tekirdağ, İstanbul, Ankara and İzmir are proper and the ones in Gelibolu and Konya are not proper according to evaluations made throughout the study. The needs of demand points in Gelibolu can be met through Corlu, likewise the needs of demand points in Konya can be met through logistics points in Izmir and Ankara as improving the opportunities and abilities of logistics facilities whose site locations are found proper.

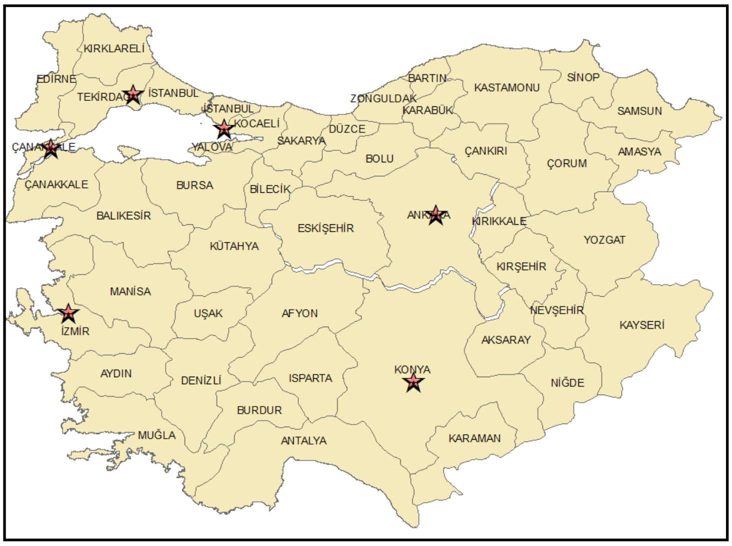


Figure 4. *Current Logistics Facilties*

4. Conclusion

Constant advancement in technology, communication and transportation from day to day make individuals, institutions and organizations to criticize the currently used systems and find cost efficient solutions. Therefore, many firms and organizations undergo re-construction. Systems are enforced to get rid of stabilization and have dynamic and modular structures. Private companies aim cost reduction while public institutions and organizations pretend to present services to those who need in effective manners.

In this study, 6 public logistics facilities (which serve 62 demand point and located to west regions in Turkey) locations propriety is analyzed. According to expert executive managers evaluations, the needs of demand points can be met through 4 logistics facilities. Evaluation is made using GIS and AHP methods and suggestions are offered about which two facilities may be closed.

GIS is a distinctive decision support tool, which helps on making decisions which turning back is hard for example facility site selection, with its distinguished qualifications like data can be updated, giving opportunity to make presentation as wanted versions, providing convenience to make locational and non locational analysis. AHP is one of the most commonly used Multi-Criteria Decision Making methods with its qualifications like building a hierarchical structure among criteria and prioritizing the alternatives.

The study is evaluated to be used with MCDM methods in evaluating various facilities of private sector and public institutions as locations, facility site selection, and vehicle rotation, determining alternative routes, analyzing various locational and non locational factors.

GIS can be used as a decision making tool (especially with its dynamic structure and its ability to provide analyzing and evaluation many criteria at the same time) for making various analysis, finding alternatives soutions to problems, facility site selection and supplier selection etc.

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