Volume XXII 2019
ISSUE no.2
MBNA Publishing House Constanta 2019

Scientific Bulletin of Naval Academy

SBNA PAPER • OPEN ACCESS

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To cite this article: E. Demirel, M. Şişlioğlu, Scientific Bulletin of Naval Academy, Vol. XXII 2019, pg.195-203.

Available online at www.anmb.ro

ISSN: 2392-8956; ISSN-L: 1454-864X

doi: 10.21279/1454-864X-19-I2-023

Mathematical Model for Logistics Base Selection Decision

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Abstract: Logistics bases are defined as a particular region, in which all activities related to transport, logistics and distribution of goods, at both national and international level, is carried out by various operators. In this context, the goal of this study to choose the best available port to be developed as a logistics base in Turkey. A mathematical model called Analytical Hierarchy Process (AHP) model is used as a tool to determine the best location for logistics base in Turkey.

After having a preliminary research for alternative locations, existing ports in Ambarlı/İstanbul, Samsun, Mersin and Aliağa/İzmir are designated as alternative bases. During this preliminary review, the existing facilities such as ports, transportation, infrastructure and their potential cargo capabilities to be handled are taken into consideration. In this model, total of five different sets of primary objectives/ choice criteria are defined. These are; current transportation capabilities and its connection with the hinterland, labor force to be employed in the base, current infrastructure capabilities, size of the area covered by the port, cargo potential to be handled in the base and number of the logistics companies in the region.

In order to achieve much more accurate result, second and third level sub-objectives are also assigned for each first level objective such as transportation, labor, infrastructure, and area.

To achieve a much more comprehensive picture, a sensitivity analysis for input parameters, such as transportation, is also applied. Further on this analysis, inputs (different preference values of transportation objectives) and outputs (port priority values) of this analysis are used to establish a Linear Regression Model for further predictions.

1. Introduction

Turkey as a country at the crossroads between east and west can also be considered an important player both as a transit country and as an origin and destination of freight. Turkey lies between Asia and Europe, serving as a bridge geographically, culturally and economically. Its location on two continents gives the country a major advantage in serving the markets of Europe, the Middle East and North Africa. Turkey's location in terms of having a strategic importance in connection with its proximity to important routes and centres requires some actions to improve its transport structure [1]. Increasing volumes of foreign trade have also accelerated this need and offered quite important opportunities to improve her economic growth. Therefore, establishment of logistics bases in Turkey is one of the preconditions for catching these opportunities.

Logistics bases are defined as a particular region, in which all activities related to transport, logistics and distribution of goods, at both national and international level. Transportation in logistics bases focus on intermodal and logistics activities. These bases are often selected from outside of the metropolitan areas, regions close to the connection points of different transport modes. Operators, who perform activities related to transport and logistics in these bases could be the owners or tenants of the buildings.

These bases are also supported by the rail link and can provide storage, handling, packaging, labelling, recycling, and they can even do production. Hong Kong, Antwerp, Rotterdam, Hamburg, Singapore, Dubai, Tokyo, Los Angeles, New York and Paris are among the most important logistics bases [2]. Sometimes the seaport area is nested with the airport. Even if it is not nested; they are interconnected by rail and road. Logistics bases are usually located in coastal area and include sea ports. If we take into consideration the amount of the investment required to establish a logistics base and its potential contributions to the national economy, it would be a strategic level decision to select the best suitable place for logistics bases.

2. Research method

2.1. Goal

A mathematical model is designed to conduct an analytical decision process. By examine the algorithm of “Expert Choice” computer program, similar approach is followed to establish our model. The goal, alternatives and decision criteria (objectives) are explained in the following parts of the study.

The goal of the model is to choose the best location (port) to establish a logistics base in Turkey.

The port selection criteria adopted by carriers are essential to successful performance of the liner shipping business in terms of capacity utilization and revenue management. Basic strategies are driven by the consideration of a number of factor, such as; Amount of cargo, Feeder network, Rapid cargo transhipment, Efficiency of port operations, Continuous operations, Port facilities, Intermodal network, IT support, Port competiveness [3][4] [5]

In order to offer a service involving more than purely sea transport, the vessel operator has to become involved; Port handling facilities, Inland transport, container yards, facilities for custom clearance away from the port, packing and unpacking depots [6]

In the light of the above mentioned criteria a preliminary research for alternative locations in Turkey has been conducted. As a result of this preliminary research, existing ports in Ambarlı/İstanbul, Samsun, Mersin and Aliağa/İzmir are designated as alternative candidate bases as depicted in Figure 1. During this preliminary review, the existing facilities such as ports, transportation, infrastructure and their potential cargo capabilities are taken into consideration.

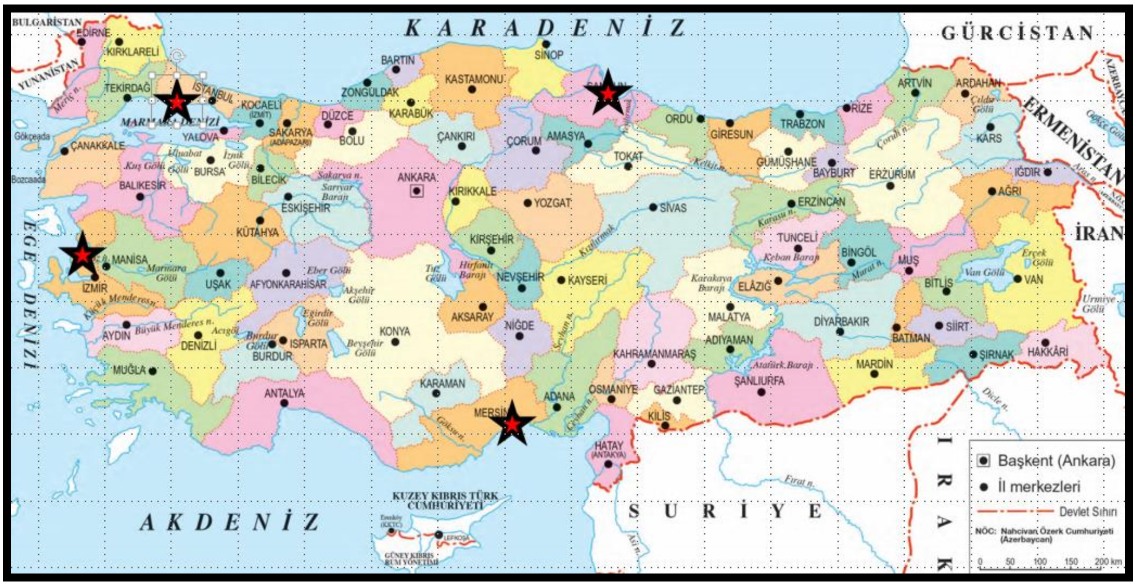

Figure 1. Geographical Position of Candidate Ports.

2.2. Decision criteria (Objectives)

As a second step, to be able to establish a mathematical model, total of five different sets of objectives are defined. These are:

- Current transportation capabilities and its connection with the hinterland,
- Labour force to be employed in the base,
- Current infrastructure capabilities,
- Size of the area covered by the port,
- Cargo potential to be handled in the base and number of the logistics companies in the region.

2.3. Sub-Objectives

In order to achieve much more accurate result, second and third level sub-objectives are also assigned for each first level objective. These are:

2.3.1. Transportation

- Road transportation

    *Proximity to motorways,

    *Accessibility to motorways,

    *Traffic density.

- Sea transportation

    *Port facilities such as number of terminals, dock dimensions, lifting capability,

    *Accessibility to open seas,

    *Water depth in port and approaching waters which limits the size of the ship.

- Railways

    *Proximity to railways,

    *Accessibility to railways.

- Air transportations

    *Proximity to airports,

    *Airport capacity such as number of runway, air traffic control and loading facilities.

2.3.2. Labour

-Availability of qualified labour force to be employed in the base,

-Average cost of labour,

-Housing capabilities (number of available house for rent, prices) for accommodation of workers.

-Availability of social and medical facilities such as hospitals, schools, shopping and entertainment centres.

2.3.3. Infrastructure

-Warehouses to be used as depot for transit items as well as assembly line for semi-manufactured items,

-Parking area for transportation vehicles such as trucks and cars,

-Container storage capacity,

-Custom facilities, number of custom officers/teams,

-Internal and external security arrangements, firefighting capacity,

-Telecommunication and information capabilities.

2.3.4. Area

-Total size of the port,

-Availability of area for future enlargement of the base,

-Unit cost of neighbouring area for future enlargement.

2.3.5. Cargo potential to be handled in the base and the number of logistics companies in the region

-Total quantity of production in facilities within 300 kilometres of the port,

-Total quantity of import items to be used as an input in facilities within 300 kilometres of the port,

-Total quantity of items to be stored or processed in the base,

-Number of companies in logistics business such as shipping, transportation, storage and insurance companies, brokers in the surrounding region.

2.4. Judgments/ Pairwise comparisons

After having established the framework of the mathematical model, judgments/pairwise comparisons are made for objectives and alternative ports. The numerical representations of these judgments, based on the real world information, are listed in forms of tables presented in the following section. The values, which are scaled between 0 and 9, indicate that the row element (objective or alternative) is preferred to column element (objective or alternative) proportionally with this number. In other words, the higher the value means that the higher the row element is preferred to row element or vice versa.

2.5. Matrix multiplications

As a final step, in order to achieve solution to our model, specially designed Visual Basic programs are used for essential calculations which are mostly matrix multiplications [7]. Algorithms similar to Expert Choice program are followed in designing the programs. To achieve a much more comprehensive picture a sensitivity analysis is also applied via another Visual Basic program. As an example, sensitivity analysis for “transportation objective” is explained in the following section. Further on this analysis, inputs (different preference values of transportation objectives) and outputs (port priority values) of this analysis are used to establish a Linear Regression Model. With this mathematical formula, it will be possible to find port priority values without using computer program or making lengthy mathematical matrix calculations for any given transportation preference value.

3. Execution of the model

3.1. Comparison of first level objectives

The next step in the modelling process is to make judgment/pairwise comparisons to derive priorities (preferences) with respect to goal which is “to choose the best port for logistics base “and for the alternative ports with respect to each objectives including second and third level objectives. Total of 47 tables which include judgment values are used.

As an example, judgment/pairwise comparison values of first level objectives with respect to goal is depicted in Table 1 below.

	TRANSP.	LABOUR	INFRASTR.	AREA	CARGO	OUTPUT
TRANSP.	1	7	3	5	2	***.429***
LABOUR	1/7	1	1/4	1/3	1/5	***.046***
INFRASTR.	1/3	4	1	3	1/2	***.171***
AREA	1/5	3	1/3	1	1/4	***.086***
CARGO	½	5	2	4	1	***.267***

Table 1. Comparison of First Level Objectives With Respect to (WRT) Goal

After running the computer program with these values as input, we obtain the relative priorities of each objective which are presented in the far right column labelled as “output” in the table. According to results, transportation objective has the highest priority (0.429) among objectives. These values are between 0 and 1.0. The higher the value means that the more preferred objective with respect to goal.

In a similar way, for each specific objective (including second and third level objectives), comparisons of alternative ports with respect to that specific objective is made. As an example, judgments about relative preference of alternative ports namely Ambarlı, Samsun, Mersin and Aliağa are made with respect to third level objective "port capabilities" in Table 2, second level objective "sea transportation" in Table 3 and first level objective "transportation" in Table 4. The results of each comparison are displayed under the columns titled "output".

	AMBARLI	SAMSUN	MERSİN	ALİAĞA	OUTPUT
AMBARLI	1	3	1/2	4	***.322***
SAMSUN	1/3	1	1/4	1/2	***.093***
MERSİN	2	4	1	3	***.448***
ALİAĞA	1/4	2	1/3	1	***.137***

Table 2. Port Preference WRT Third Level Objective Port Capabilities

	PORT	ACCES.	DEPTH	OUTPUT
AMBARLI	.322	.161	.139	***.257***
SAMSUN	.093	.096	.479	***.154***
MERSİN	.448	.466	.068	***.393***
ALİAĞA	.137	.277	.314	***.196***

Table 3. Port Preference WRT Second Level Objective Sea Transportation

	ROAD	SEA	RAILWAY	AIR	OUTPUT
AMBARLI	.465	.257	.157	.526	***.362***
SAMSUN	.132	.154	.281	.223	***.167***
MERSİN	.258	.393	466	.083	***.315***
ALİAĞA	.145	.196	.096	.168	***.156***

Table 4. Port Preference WRT First Level Objective Transportation

In this case, the final preference of ports with respect to "transportation "objectives (displayed in the output column of Table 4) are as follows

Ambarlı=0.362 Samsun=0.167 Mersin=0.315 Aliağa=0.156

In calculations, bottom-up approach is used. The results (outputs) of third level objective matrix calculations are used as an input for second level objective matrix calculations. The bottom-up approach is preferred, due to the fact that the insights we gain about the trade-off among the alternative ports will help in making judgments about the importance of that objective.

3.2. Final synthesis of the model

After all judgments in the model have been made and priorities have been calculated, a final synthesis is performed. The priorities for the alternative ports with respect to each first level objectives are listed in Table 5.

	TRANSP.	LABOUR	INFRAS..	AREA	CARGO	OUTPUT
AMBARLI	.362	.363	.183	.066	.555	***.357***
SAMSUN	.167	.155	.273	.198	.059	***.159***
MERSİN	.315	.283	.338	.209	.171	***.269***
ALİAĞA	.156	.199	.206	.527	.215	***.215***

Table 5. Port Priorities WRT First Level Objectives

As it was mentioned before, the values in "transportation" column are transferred from the output of Table 4 (transportation table). For final synthesis of the model, the values in Table 5 and output of Table -1 which are the relative priorities of the first level objectives with respect to goal are multiplied. The result of the matrix multiplication displayed in the output column of Table 5 shows the priorities of alternative ports to be chosen as a logistics base. These are:

Ambarlı=0.357 Samsun=0.159 Mersin=0.269 Aliağa=0.215

Based on these priority values, Ambarlı port in İstanbul with the highest value of 0.357 will be chosen as a best port to be developed and invested as a logistics base. The geographical location of Ambarlı port is shown in Figure 2 and 3.

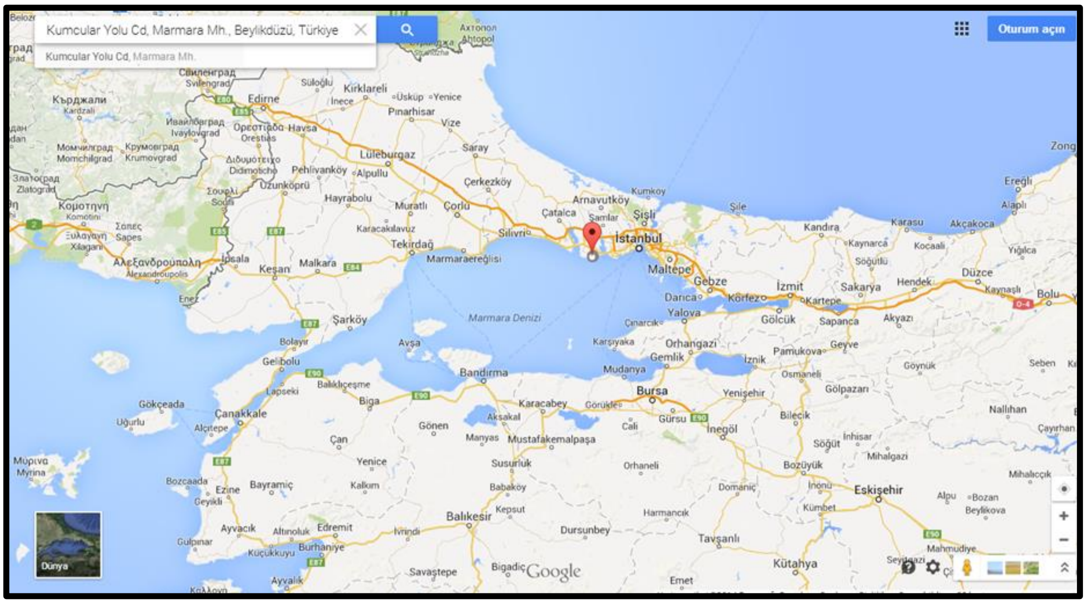

Figure 2. Geographical Position of Ambarlı Port [8]

Figure 3. Port of Ambarlı (MARPORT) [8].

4. Mathematical analysis of results

4.1. Sensitivity analysis

In order to understand the effect of the objectives on alternative port priority values, a sensitivity analysis is conducted with Visual Basic program. While the coefficient of the “transportation” objective (as an example) is increased by 0.10 point in each step, the other objectives (labour, infrastructure, area and cargo) are held proportionally constant. Total of 10 different transportation coefficients, starting from 0.0 up to 1.0 are used. For each coefficient, different port priority values are obtained. The results of the analysis is displayed in Table 6 (for Ambarlı and Samsun ports).

TRANSPORTATION COEFFICIENTS	PORT PRIORITY VALUES	
	AMBARLI	SAMSUN
0.000	0.3542	0.1555
0.100	0.3550	0.1563
0.200	0.3558	0.1571
0.300	0.3566	0.1579
0.400	0.3574	0.1587
0.500	0.3582	0.1595
0.600	0.3590	0.1603
0.700	0.3598	0.1611
0.800	0.3606	0.1619
0.900	0.3614	0.1627
1.000	0.3622	0.1635

Table 6. The Results of Sensitivity Analysis

4.2. Regression analysis

As a follow on analysis, output of sensitivity analysis is used in modelling a linear regression model. The purpose of this is to be able to calculate the port priority values for any given objective value without using a computer program or complex matrix multiplications. SPSS 17 statistics package [9] is used in the analysis.

In the model, total of 20 “transportation” values are defined as independent variable and port priority values are assigned as dependent variable. The graphical representation of the linear relation between variables which is designed for Ambarlı Port is shown in Figure 4.

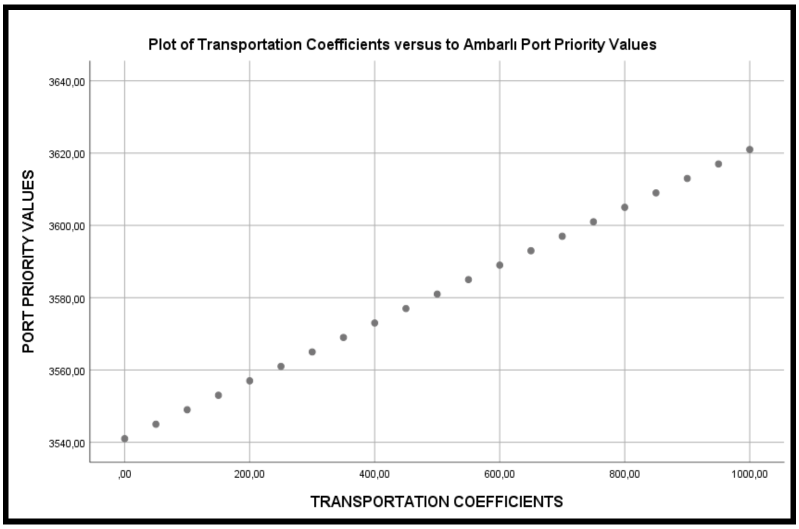

Figure 4. Plot of Transportation Values versus to Ambarlı Port

The output of the linear regression analysis is depicted in Table 7.

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	**.354**	**.000**		**2.215E10**	**.000**
	TRANPORT	**.008**	**.000**	**1.000**	**2.925E8**	**.000**

a. Dependent Variable: AMBARLI

Table 7. Result of Regression Analysis

The regression equation to be used for Ambarlı port priority values for given transportation coefficient is as follows.

Ambarlı Priority = 0.354 + 0.008 * Transportation Coefficient

5. Future analysis

As a continuation of this study, the following topics can be examined to reach more comprehensive results.

- Instead of using single person assessment, it would be much more realistic and objective approach to use the assessments of a group of experts. Another way of doing this type of analysis is to use nominal group techniques.
- Cost dimension might be added to analysis in order to achieve cost effective solutions and to be able to give priority on allocation of investment budget.
- The number and echelon levels of objectives can be increased to cover all aspects of logistics bases. In this respect, additional decision criteria such as multimodal transportation capabilities, possible international demand for the base, and government support policy for the region might be taken into consideration.

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