Determination of Dry Port Location within the Hinterland of Kocaeli Ports by Applying AHP

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ABSTRACT
It is considered that a dry port connected with Kocaeli container terminals would enable quicker and effective transportation through both production and consumption centers within the hinterland of Kocaeli ports. An "Analytic Hierarchy Process (AHP)" have been conducted to determine the most appropriate location for these terminals. The possible locations have been determined related to some certain qualities in coordination with two different public institutions. The criteria that would affect the selection of dry port location were determined by taking the expert opinions from the relevant sectors. These criteria were graded by a survey method which includes the opinions of 85 experts from 11 sectors. The "Convenience for transportation within the hinterland" among these criteria, has been determined as the highest priority criterion. Kosekoy location, at a distance of 20-50 km from Kocaeli ports, has been determined as the most suitable dry port location by applying AHP.

1. INTRODUCTION
The increase of containerized traffic has led to the development of dry ports within the hinterlands of seaports all over the world [1]. Determining the most appropriate location for a dry port is a delicate process that requires careful consideration of many criteria [2]. A dry port must have a large enough land area and connection to a high capacity transportation network that will easily connect it to the ports, to the production centers and to the consumption centers. Especially the railway connection is preferable due to enabling mass transportation [3]. The size of a dry port may differ related to the needs, but the current examples in the world indicate that ideal dry port should have a uniform land area with more than 10 hectares, at a location available to expand for future needs.

Possible locations in East Marmara Region were designated in a working group meeting at "East Marmara Development Agency". Thereafter the feasibility of rail connection to these locations was discussed in another working group meeting held at First Regional Directorate of "Turkish Republic State Railways (TCDD)". At the end of the studies, five locations (see Figure-1) were determined as candidates (decision points) for dry port location.

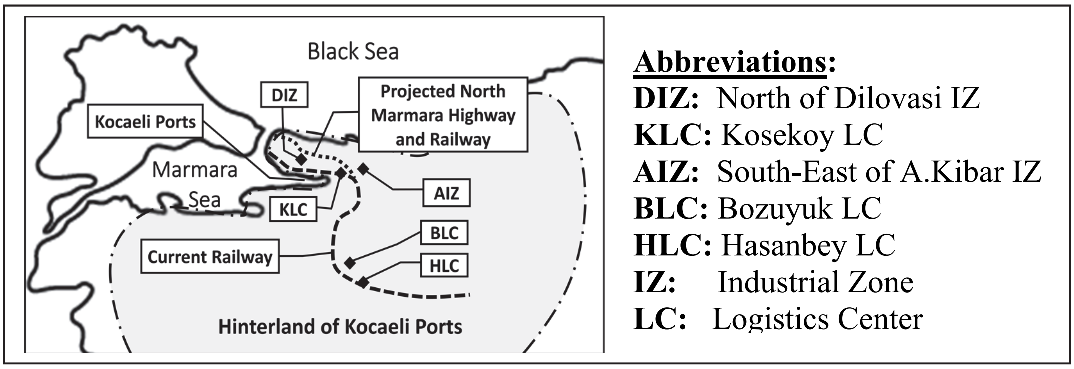


Figure-1: Hinterland of Kocaeli ports and the alternative locations for a dry port (Described by the Authors).

A simple AHP model has been developed to determine the most appropriate location among these five candidates. AHP is a methodology for relative measurement [4] through pairwise comparisons [5]. It is a mathematical tool to select the best from a number of alternatives evaluated regarding to a number of criteria [6]. Since its appearance in 1980 AHP has been used all over the world [7] widely in decision-making processes, including transportation and determination of location [8]. As an example, Ka [9] applied AHP method to find the best location among seven sites, using the criteria of transportation, economic and trade levels, infrastructure, environment and cost.

2. DETERMINING THE CRITERIA OF AHP AND GRADING THEM

After reviewing the literature and taking the opinions of the experts, it was decided that seven criteria would be taken as a basis in the AHP study. The criteria were graded by a survey method which includes the opinions of 85 experts from 11 sectors (see Table-1).

Table-1: Sectors of the Participators and Total Number of Participators (Described by the Authors).

Nu.	Related Intuitions/Sectors of the Participators	Nu. of Participators	Percentage (%)
1	Researcher/Scholar	15	17,65
2	Port	14	16,47
3	Transportation	25	29,41
4	Logistics Center/Logistics Facility	3	3,53
5	Railway Infrastructure/Rail Freight	8	9,41
6	Municipality	2	2,35
7	Industry	3	3,53
8	Investment Specialist/Investment Planning	3	3,53
9	Ministry of Environment and Urbanization	2	2,35
10	Ministry of Transport and Infrastructure	7	8,24
11	Ministry of Customs and Trade	3	3,53
Total		85	100

The result of the survey demonstrates that the weights of the criteria are conspicuously very approximate values to each other. However, the "Convenience for transportation within the hinterland" has been designated as the highest priority criterion among the seven criteria. The weights of the criteria, which are effective in determining the most appropriate location at a later stage of the AHP, are exhibited in Table-2.

Table-2: Result of the survey for grading the criteria related to their priority (Described by the Authors).

Nu.	Abbr.	Criteria	Rating %
1	TRA	Convenience for transportation within the hinterland	16,62
2	POR	Proximity to the port	14,81
3	IND	Proximity to the industry	14,49
4	COS	Cost of investment	14,07
5	CEN	Centrality in the transport network	13,95
6	ENV	Environmental effect on urban areas	13,90
7	EST	Process of establishing a dry port	12,16

3. SURVEYING THE DECISION POINTS RELATED TO THE CRITERIA

Among the candidate locations, DIZ is an empty state land area very close to the projected North Marmara Highway and Railway; AIZ is also an empty but private land area, very close to both current and projected highways and railways. Other three candidates are projects of TCDD to serve as logistics centers. KLC and HLC are in service with limited capabilities, KLC waits for a modernization plan on expanded area, and BLC is still on construction.

From the point of railway transportation: KLC and HLC are located on the main railway line, whereas BLC is planned to connect to the main railway. On the other side, DIZ and AIZ do not have any connection to the main railway but the projected North Marmara railway line will pass close to these locations. The new railway line is planned to be connected to the current railway at a point around KLC. As for the point of highway transportation, KLC, AIZ, and BLC are more advantageous than other candidates since they provide very easy access to highways. HLC requires 10 km road way within the city to reach the highways. DIZ is predicted to have easy access to the new highway in the future.

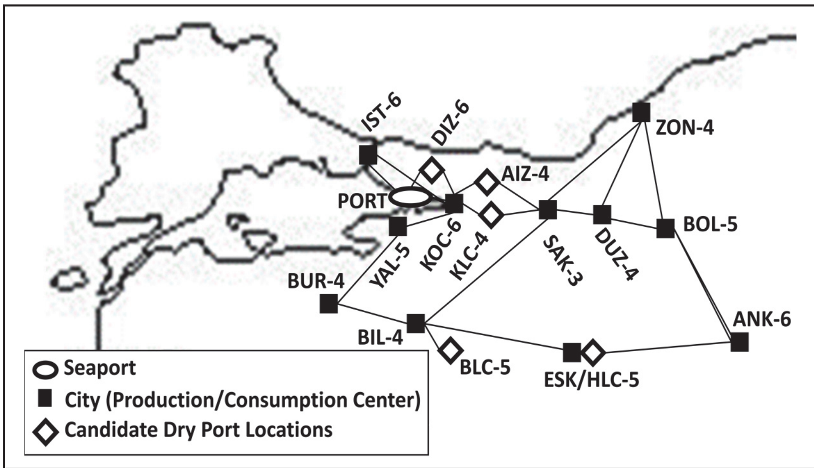
From the point of proximity to Kocaeli ports (five container terminals): DIZ is the closest one with distances 16 through 43 km, followed by KLC with 17 through 48 km, AIZ at 22 through 56 km, BLC at 188 through 221 km and HLC at 233 through 266 km. Although DIZ is the closest candidate, due to the geographical constraints, rail transportation to the ports is not an economic way. In order to transfer the goods by train from DIZ, it will require to alter the route to the opposite direction at the intersection point of the two railways (see Figure-1).

There are 327 Organized Industrial Zones (OIZs) totally in Turkey [10]. A total of 121 OIZs, equivalent to 37% of Turkey's total, are located within the hinterland of Kocaeli ports. From the point of proximity to industry, ranking the candidates with the number of OIZs that are located as closest to these candidates is as follows: (1) BLC (42 OIZs; 35%), (2) KLC and AIZ together (40 OIZs; 33%), (3) HLC (31 OIZs; 25%), and (4) DIZ (8 OIZs; 7%).

All alternatives have different conditions and different capabilities as of the moment. Necessary investment stages and expense items can be sorted as (1) Cost for land acquisition, (2) Cost for the construction of infrastructure facilities, (3) Cost for procurement of operating equipment, and (4) Cost for connection of the transport system.

If either DIZ or AIZ is selected, the dry port will be built from the ground up, all cost items will be required. In terms of land acquisition, AIZ will be more costly since it is a privately

owned land. On the other side, DIZ will cost more in terms of the transport system's connection since there is no road or railway passing over there yet. KLC and HLC mainly require investment for operating equipment, but BLC requires additional investments for infrastructure and for junctions to main railways and to the OIZs at the proximity.
For an assessment in terms of centrality position, it is necessary to determine the hinterland of the Kocaeli ports. The cities and the candidate dry port locations together within the hinterland constitute the transportation network as seen in Figure-2.



Abbr. of Cities:
ANK: Ankara
BIL: Bilecik
BOL: Bolu
BUR: Bursa
DUZ: Duzce
ESK: Eskişehir
IST: Istanbul
KOC: Kocaeli
SAK: Sakarya
ZON: Zonguldak
YAL: Yalova

Figure-2: Nodes with Konig numbers within the core hinterland of Kocaeli ports (Described by the Authors).

It is assumed that origins and destinations in a network are vertices while the road and rail linking them are edges. The Konig numbers in Figure-2 represent the total number of edges which must be traveled along in order to reach each of the vertices from the most distant location [11]. KLC and AIZ, getting the lowest Konig number within this network, are regarded as the best sites for constructing a dry port, from the viewpoint of centrality.
From the point of environmental effect, a dry port is expected to lessen the negative effects (harmful gas emission, health problems, noise, traffic congestion, etc.) caused by road transportation in the port city and also in the vicinity. All candidates are expected to support the environmental purposes at a high level but for DIZ and BLC at the highest level since having a very limited residential area around them.
From the point of the process of establishing dry port, it will take a long time to establish a dry port on the locations of DIZ and AIZ. DIZ, of which the altitudes vary from 280 to 350 meters, would have even a longer process due to the additional efforts to flatten the land. The process of BLC would also be longer than KLC and HLC due to the continuing constructions.

4. APPLYING AHP

The objective of the AHP model in this paper is "Determination of the most appropriate dry port location within the hinterland of Kocaeli ports". The structure of the decision hierarchy is seen in Figure-3 (explanation of the abbreviations are as in Figure-1 and Table-2).

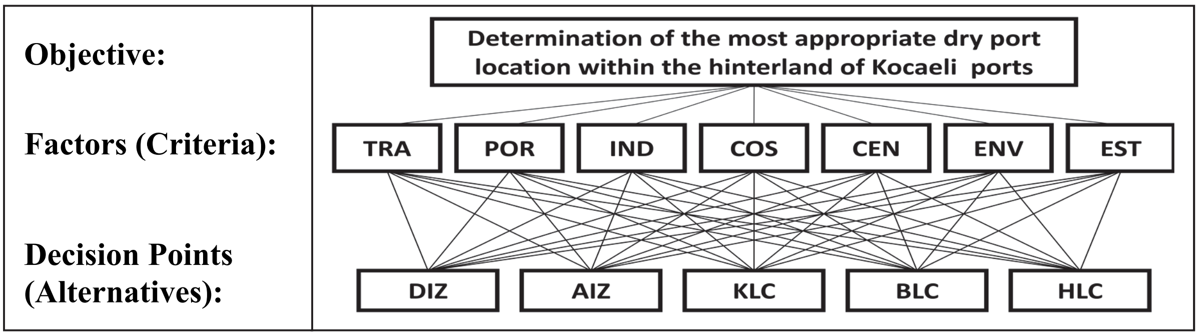


Figure-3: The structure of the decision hierarchy (Described by the Authors).

The pairwise comparison matrices are constituted for each factor (criterion) to compare the alternatives mutually. The scales of relative importance and definitions are seen in Table-3.

Table-3: Scales of relative importance to be used in the pairwise comparison (Source: [5]).

Scale	Definition of Scale	Scale	Definition of Scale
1	Equal importance	6	Strong plus importance over another
2	Weak/slight importance over another	7	Very strong importance over another
3	Moderate importance over another	8	Very strong to extreme importance over another
4	Moderate plus imp. over another		
5	Strong/essential imp. over another	9	Extreme importance over another

Pairwise comparison matrices for each criterion (CRT.) are seen in Table-4.

Table-4: Pairwise comparison matrices (Described by the Authors).

CRT.	Pairwise Comparison Matrices (Pn)						Explanation about the comparison
TRA	P1	DIZ	AIZ	KLC	BLC	HLC	Very strong importance of KLC over HLC; strong importance of KLC over DIZ and BLC; moderate importance of KLC over AIZ; strong importance of AIZ over HLC; moderate importance of AIZ over DIZ and BLC; moderate importance of DIZ and BLC over HLC.
	DIZ	1	1/3	1/5	1	3	
	AIZ	3	1	1/3	3	5	
	KLC	5	3	1	5	7	
	BLC	1	1/3	1/5	1	3	
	HLC	1/3	1/5	1/7	1/3	1	
POR	P2	DIZ	AIZ	KLC	BLC	HLC	Very strong importance of DIZ, AIZ, and KLC over HLC; strong importance of DIZ, AIZ, and KLC over BLC; moderate importance of BLC over HLC.
	DIZ	1	1	1	5	7	
	AIZ	1	1	1	5	7	
	KLC	1	1	1	5	7	
	BLC	1/5	1/5	1/5	1	3	
	HLC	1/7	1/7	1/7	1/3	1	
IND	P3	DIZ	AIZ	KLC	BLC	HLC	Very strong importance of BLC over DIZ; strong importance of BLC over HLC; strong importance of AIZ and KLC over DIZ; moderate importance of BLC over AIZ and KLC; moderate importance of AIZ and KLC over HLC.
	DIZ	1	1/5	1/5	1/7	1/3	
	AIZ	5	1	1	1/3	3	
	KLC	5	1	1	1/3	3	
	BLC	7	3	3	1	5	
	HLC	3	1/3	1/3	1/5	1	
COS	P4	DIZ	AIZ	KLC	BLC	HLC	Extreme importance of KLC over DIZ and AIZ; strong to very strong importance of HLC over DIZ and AIZ; strong importance of KLC over BLC; moderate to strong importance of BLC over DIZ and AIZ; moderate importance of KLC over HLC; equal to moderate importance of HLC over BLC.
	DIZ	1	1	1/9	1/4	1/6	
	AIZ	1	1	1/9	1/4	1/6	
	KLC	9	9	1	5	3	
	BLC	4	4	1/5	1	1/2	
	HLC	6	6	1/3	2	1	
CEN	P5	DIZ	AIZ	KLC	BLC	HLC	Strong importance of AIZ and KLC over DIZ; Moderate importance of AIZ and KLC over BLC and HLC; Moderate importance of BLC and HLC over DIZ.
	DIZ	1	1/5	1/5	1/3	1/3	
	AIZ	5	1	1	3	3	
	KLC	5	1	1	3	3	
	BLC	3	1/3	1/3	1	1	
	HLC	3	1/3	1/3	1	1	
ENV	P6	DIZ	AIZ	KLC	BLC	HLC	Strong importance of DIZ and BLC over AIZ and KLC; moderate importance of DIZ and BLC over HLC; moderate importance of HLC over AIZ and KLC.
	DIZ	1	5	5	1	3	
	AIZ	1/5	1	1	1/5	1/3	
	KLC	1/5	1	1	1/5	1/3	
	BLC	1	5	5	1	3	
	HLC	1/3	3	3	1/3	1	
EST	P7	DIZ	AIZ	KLC	BLC	HLC	Extreme imp. of KLC over DIZ; extreme to very strong imp. of KLC over AIZ; strong to very strong imp. of HLC over DIZ; strong imp. of KLC over BLC, and HLC over AIZ; moderate to strong imp. of BLC over DIZ; moderate imp. of KLC over HLC, and BLC over AIZ; equal to moderate imp. of KLC over HLC.
	DIZ	1	1/2	1/9	1/4	1/6	
	AIZ	2	1	1/8	1/3	1/5	
	KLC	9	8	1	5	3	
	BLC	4	3	1/5	1	1/2	
	HLC	6	5	1/3	2	1	

In the following step, the sum of each column of each P matrix is calculated. Each matrix element is divided by this column sum. This operation is performed for each column. The resulting matrix is the normalized matrix (N). The average of the row elements of matrix N is calculated. These averages form the final vector (F) indicating the weights of the decision points (alternatives). The weights of the decision points are combined to create the decision matrix (D) by using the F vectors. The weights of the criteria, which were obtained through the survey (see Table-2), constitute vector (W). The resultant matrix (R) is obtained by multiplying matrix "D" with vector "W" as seen in Table-5.

Table-5: Obtaining the resultant matrix (Described by the Authors).

	Alt.	F1	F2	F3	F4	F5	F6	F7	
Matrix D (Decision Matrix)	DIZ	0,1053	0,2967	0,0436	0,0445	0,0557	0,3579	0,0400	
	AIZ	0,2454	0,2967	0,2017	0,0445	0,3424	0,0646	0,0597	
	KLC	0,4971	0,2967	0,2017	0,5271	0,3424	0,0646	0,5261	
	BLC	0,1053	0,0721	0,4641	0,1432	0,1298	0,3579	0,1371	
	HLC	0,0469	0,0377	0,0888	0,2407	0,1298	0,1549	0,2371	
X (Multiply)									
Vector W (Weight of the criteria)		w1	w2	w3	w4	w5	w6	w7	
		0,1662	0,1481	0,1449	0,1407	0,1395	0,1390	0,1216	
= (Equal to)									
	Alt.	r1	r2	r3	r4	r5	r6	r7	Sum
Matrix R (Resultant weights of the decision points)	DIZ	0,0175	0,0439	0,0063	0,0063	0,0078	0,0498	0,0049	0,1364
	AIZ	0,0408	0,0439	0,0292	0,0063	0,0478	0,0090	0,0073	0,1842
	KLC	0,0826	0,0439	0,0292	0,0742	0,0478	0,0090	0,0640	0,3507
	BLC	0,0175	0,0107	0,0673	0,0201	0,0181	0,0498	0,0167	0,2001
	HLC	0,0078	0,0056	0,0129	0,0339	0,0181	0,0215	0,0288	0,1286
	Sum	0,1662	0,1481	0,1449	0,1407	0,1395	0,1390	0,1216	1,0000

The values in the column "Sum" gives the resultant weights of the alternative dry port locations. The KLC with the highest rate (35,07%) is seen as the best alternative dry port location, followed by BLC with a rate of 20,01%. The consistency ratios for each comparison matrices were calculated less than 0.1 implying that comparisons were reasonably consistent. The results of the AHP solution and sensitivity analysis are seen on Table-6. Case-1 indicates the original weights of the criteria and the original results of solution. In Case-2, the rate of "ENV" criterion, and in Case-3 the rate of "IND" criterion are increased individually, and in Case-4, the rates of both "IND" and "ENV" criteria are increased together, and all other criteria are decreased at an equal rate in cases 2 through 4. The sensitivity analysis exhibits that minimum 30% change in only one criterion and a total of 25,5% change in two criteria would require to change the selected alternative (BLC would take over the first rank from KLC). Actually, such high changes in the weight of the criteria appear to be quite far from the actual situation.

Table-6: The results of the AHP solution and sensitivity analyses (Described by the Authors).

Cases	Weights of the Criteria in %							Ratings of the Decision Points in %				
	TRA	**POR**	**IND**	**COS**	**CEN**	**ENV**	**EST**	**KLC**	**BLC**	**AIZ**	**DIZ**	**HLC**
Case-1	**16,62**	14,81	14,49	14,07	13,95	13,90	12,16	**35,07**	20,01	18,42	13,64	12,86
Case-2	11,52	9,81	9,49	9,07	8,95	**44,00**	7,16	25,01	**25,52**	14,39	21,48	13,61
Case-3	11,32	9,51	**46,29**	8,77	8,65	8,60	6,86	29,54	**29,76**	19,25	10,26	11,19
Case-4	11,50	9,69	**27,00**	8,95	8,83	**27,00**	7,03	27,22	**27,50**	16,73	16,10	12,45

5. CONCLUSION

Considering that a dry port would support the container terminals in Kocaeli Gulf, a total of five locations were identified as the candidates of a dry port in the hinterland of Kocaeli ports.

These candidates have been assessed in relation with seven criteria to determine the best site by applying an AHP model. Determining the criteria of the model is an important stage which guides the whole process until the end. So, it is advisable to determine the factors (criteria) by gathering the opinions of the experts from relevant sectors. Weighting the factors is also a critical step, which might affect the result. Instead of one's opinion, it would lead to more factual results, getting the opinions of a large experts group to prioritize the factors.

In this study, the pairwise comparisons have been made according to the assessment of the authors themselves. But the critical point is that those assessments depend on the detailed research about the candidate locations in relation to the criteria of the AHP. At the end of this AHP, the KLC has markedly placed the top rank. KLC has got the top weights related to five criteria, whereas BLC has got that of two criteria. The sensitivity analysis, a step within the AHP, has shown that any of these two criteria should have an extremely high increase to be able to affect the result. The decision will be made based on the results and sensitivity analysis of this AHP. Sensitivity analysis is considered as a useful and important mechanism in supporting the decision-maker in order to show to which extent a change in the weight of a criterion can affect the result. This study has exhibited that AHP is a clear methodology, an effective and reliable decision making tool, applicable for any kind of problem requiring a decision. It is believed that AHP will be used in various fields for decision-making issues. And, it is assessed that the criteria of the method applied in this study can be taken as a sample for studies with similar purposes in different regions of the world.

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