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Evaluating Potential Freight Villages in Istanbul Using Multi Criteria Decision Making Techniques

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Abstract Evaluating freight villages and selecting one of them are complicated tasks due to the fact that various criteria or objectives must be considered in the decision making process. Also in many real world cases the criteria are not equally important for the logistic managers and government authorities. In this study, we proposed a freight village analysis model considering both Analytic Hierarchy Process (AHP) and PROMETHEE (preference ranking organization method for enrichment of evaluations) method. Subjective and objective opinions of logistic managers/experts turn into quantitative form with AHP. PROMETHEE technique is used for calculating the freight villages' ratings. Apparently, freight village location selection is a multi-criteria problem that includes both quantitative and qualitative factors. It is necessary to make trade-off between these tangible and intangible factors while considering a suitable location. Accessibility, transport infrastructure, the value of freight villages (maritime connections, rail connections, road connections, and airport connections), distance from city center and total surface area are some of the key success factors of freight villages. The aim of this paper is to determine the appropriate freight village candidate providing the most satisfaction for the criteria identified in the supply chain management.

Keywords Freight Villages, Logistic Management, Analytic Hierarchy Process, PROMETHEE, Multi Criteria Decision Making

1. Introduction

Globalization and today's competitive environment forces companies to reduce costs. The basic condition for increasing the competition and continuity in domestic and global markets is to control costs. Locations depots have a great effect on operating cost and price. The evaluation of a logistic village location among alternative locations is a multi-criteria decision-making problem including both quantitative and qualitative criteria. All the factors should be taken into consideration because of the fact that the decisions for location selection compel a government to work under same conditions for time. If official decision makers and authorities select the wrong logistic village location, it may not have adequate access to firms, workers, vehicles, agents, and so on.

The general process for making location decisions usually is composed of the following steps[1]:

1. Decide on the criteria that will be used to evaluate location alternatives.
2. Determine the criteria that are important.
3. Develop suitable location alternatives.
4. Evaluate the alternatives and make a decision.

The aim of this paper is to identify the appropriate location providing profitability and productivity for the logistic sector. In this paper, distance and proximity data calculated via googlemaps[2]. "Opportunities for possible site expansion" and "Cost of land" data was taken from http://www.igd.com.tr/ and "ekonomi.haber7.com"[3],[4]. All data is used to illustrate the logistic village evaluation procedure. We proposed a logistic village evaluation analysis using AHP and PROMETHEE methodologies. Subjective and objective opinions of experts turn into quantitative form with Analytic Hierarchy Process. AHP is applied to determine the relative weights of the evaluation criteria. In this study, Bamyaci's weights of criteria were utilized[5]. PROMETHEE technique is used for calculating the locations' ratings.

This paper is arranged into five sections. The second section provides an overview of existing methods and studies. The third section shows the structure of the problem in Turkey. The next section describes the proposed approach and gives information about AHP and PRMOMETHEE methodologies. In section five, an empirical study is illustrated in İstanbul candidate logistic villages. Results of the study are presented in section six. Finally, concluding remarks and discussions follow.

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2. Literature Review

Several approaches have been proposed in the literature for solving the logistic/distribution center problems. Some of these methods and applications are mentioned below.

Janic and Reggiani illustrates the application of three Multiple-Criteria Decision-Making (MCDM) methods (Simple Additive Weighting, Technique for Order Preference by Similarity to the Ideal Solution and Analytic Hierarchy Process) to the problem of the selection of a new hub airport for a hypothetical European Union (EU) airline[6].

Jaržemskis's research focuses on logistics center concept and benefits for users. In this paper author presents intermodal benefit, forwarders impact, IT solutions, new transport flows due to synergy, better supply chain management, additional services, cost sharing, economies of scale, quality of the services, know-how, joint marketing impact, and benefit for growth of third-party logistics services[7].

In the paper of Ballis and Mavrotas three alternative designs of the freight village layout are compared using the PROMETHEE method. The multicriteria framework consists of selecting the most meaningful criteria of evaluation and the required decision parameters. Results of their analysis reveal the preference order of the alternative designs[8].

Lindholm and Behrends contribute to lay the groundwork for designing strategies to overcome the challenges involved in sustainable urban freight transport. Potentials and shortcomings in urban freight transport planning are presented and the results show that freight transport is increasingly important for regional competitiveness while freight traffic is a growing threat for urban sustainability[9].

Cerreno et al.[10] emphasizes in determining the feasibility of Freight Villages for the NYMTC region. They investigated the NYMTC's three goals (congestion mitigation, rational and efficient land use, and economic development) regarding location selection of Freight Villages[10].

Yanga et al.[11] investigates distribution centers location problem under fuzzy environment via chance-constrained programming model. They integrate tabu search algorithm, genetic algorithm and fuzzy simulation algorithm to seek the approximate best solution of the model[11].

Awasthi, Chauhan and Goyal[12] present a multi-criteria decision making approach for location planning for urban distribution centers under uncertainty. Their model starts with identification of potential locations, selection of evaluation criteria, than use of fuzzy theory to quantify criteria values under uncertainty and application of fuzzy TOPSIS to evaluate and select the best location for implementing an urban distribution center[12].

Li, Liu and Chen[13] present a comprehensive methodology for the selection of logistic center location. Their proposed methodology consists of two parts: Axiomatic Fuzzy Set clustering method for effectively evaluate logistics center location, and TOPSIS method for selection. Their case includes fifteen regional logistics center cities and thirteen criteria[13].

Taniguchi et al.[14] describe a mathematical model developed for determining the optimal size and location of public logistics terminals using queuing theory and nonlinear programming techniques for finding the best solution. They applied their model to an actual road network in the Kyoto-Osaka area in Japan[14].

Sirikijpanichkul and Ferreira[15] proposed a model to solve the conflicts in intermodal freight hub location decisions based upon the multi-objective evaluation techniques with other supporting established modules including land use allocation and transport network models; financial viability; hub user cost; and environmental and traffic impact modules[15].

3. Structure of the Freight Village Location Selection Problem

Target of the government and logistic sector with the new investments, is find the optimum locations of the logistic villages. Capacity of current distribution centers cannot meet the customers/firms' demand, for this reason all logistic sector actors' management are planning building a new logistic villages in order to meet growing demand. The experts determined six freight village location alternatives for the new distribution centers including Silivri, Hadimkoy, Halkali, Pendik, Gebze and Tuzla. Criteria taken in to account for freight village selection are as follows:

1. Opportunities for possible site expansion
2. Cost of land
3. Proximity to industrial zone
4. Proximity to airport
5. Proximity to harbor
6. Proximity to railroad system
7. Proximity to highway system

4. Proposed Methodology

AHP is an effective decision making method especially when subjectivity exists and it is very suitable to solve problems where the decision criteria can be organized in a hierarchical way into sub-criteria. The findings of previous studies about factors influencing experts' choice of location of logistic villages were first identified by literature review. Experts expressed or defined a ranking for the attributes in terms of importance/weights. Each experts is asked to fill ''checked mark'' in the 9-point scale evaluation table. The AHP allows group decision making.

AHP based weights were taken from Bamyaci's research[5]. The questionnaires are answered by 42 experts (11 academicians, 13 public official logistic experts, 7 experts in customer firms, 11 experts of logistic firms). Experts are asked to compare the criteria at a given level on a pair-wise basis to identify their relative precedence.

4.1. Using AHP to Analyze Priorities

Table 1. The fundamental scale of pair-wise comparison for AHP

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities have equal contribute to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another.
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong on demonstrated importance	An activity is favored very strongly over another
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically

Table 2. Average RI values

n	1	2	3	4	5	6	7	8	9	10
Random Consistency Index (RI)	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1,49

AHP was developed in the 1970s by Thomas Saaty is a multi-criteria decision making (MCDM) methodology. It has been used extensively for analyzing complex decisions. The approach can be used to help decision-makers for prioritizing alternatives and determining the optimal alternative using pair-wise comparison judgments[16],[17]. Weighting the criteria by multiple experts avoids the bias decision making and provides impartiality[18].

The AHP is a selection process that consists of following steps[19],[20],[21]:

1. Define the problem and determine the criteria. Factors and related sub factors must be correlated[22]
2. Structure the decision hierarchy taking into account the goal of the decision.
3. Construct a set of all judgments in a square comparison matrix in which the set of elements is compared with itself (size nxn) by using the fundamental scale of pair-wise comparison shown in Table 1. Assign the reciprocal value in the corresponding position in the matrix. Total number of comparison is n.(n-1)/2[22].
4. Use overall or global priorities obtained from weighted values for weighting process. For synthesis of priorities obtain the principal right eigenvector and largest eigenvalue.

Matrix A=(aij) is said to be consistent if aij.ajk=aik and its principal eigenvalue (λmax) is equal to n.

The general eigenvalue formulation is:

$$Aw = \begin{bmatrix} 1 & \mathrm{w}_1/\mathrm{w}_2 & . & \mathrm{w}_1/\mathrm{w}_n \\ \mathrm{w}_2/\mathrm{w}_1 & 1 & . & \mathrm{w}_2/\mathrm{w}_n \\ . & . & . & . \\ \mathrm{w}_n/\mathrm{w}_1 & \mathrm{w}_n/\mathrm{w}_2 & . & 1 \end{bmatrix} \begin{bmatrix} w_1 \\ . \\ . \\ w_n \end{bmatrix} = nw \quad (1)$$

$$a_{ij} = w_i / w_j, \qquad i, j = 1, 2, \ldots .n \quad (2)$$

$$Aw = \lambda_{\max} w \quad (3)$$

For measure consistency index (CI) adopt the value:

$$CI = (\lambda_{\max} - n) / (n - 1) \quad (4)$$

Accept the estimate of w if the consistency ratio (CR) of CI that random matrix is significant small. If CR value is too high, then it means that experts' answers are not consistent [19]. When CR value is less than 0.10, consistency of the comparisons is appropriate[22]. The CR is obtained by comparing the CI with an average random consistency index (RI).

$$CR = \frac{CI}{RI} \quad (5)$$

The following gives the average RI:

Briefly, maximized eigenvalue, CI and CR are found to obtain the weights of each criterion [22].

4.2. Using Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) to Rank the Alternatives

Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) method is developed by Brans (1982)[23] and further extended by Brans and Vincke (1985)[24]. It was partly designed as a reaction to the complete aggregation American Multi Attribute Utility Theory (MAUT) methods[25].

PROMETHEE family of outranking methods are intended to provide a complete ranking of a finite set of feasible alternatives from the best to the worst. The methods of PROMETHEE have successfully been applied in many fields and used in decision-making problems.

Behzadian et al. (2010)[26] have presented a comprehensive literature review in the current research on PROMETHEE methodologies and applications. They classified the PROMETHEE applications into Environment Management, Hydrology and Water Management, Business and Financial Management, Chemistry, Logistics and Transportation, Manufacturing and Assembly, Energy Management, Social, and Other Topics[27]. Three main

PROMETHEE tools can be used to analyse the evaluation problem[28]:

1. PROMETHEE I for partial ranking
2. PROMETHEE II for complete ranking and
3. the GAIA plane for graphical representation

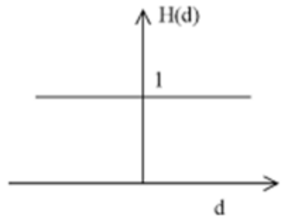
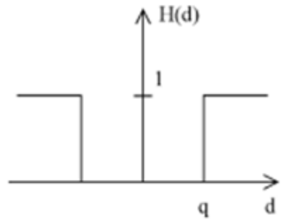
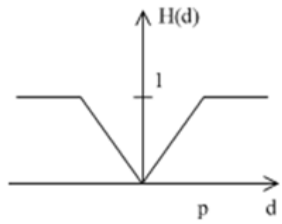
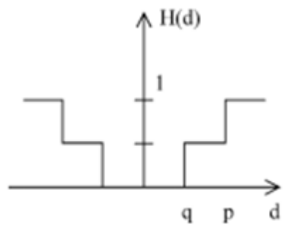
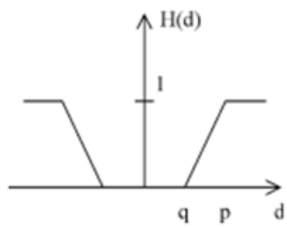
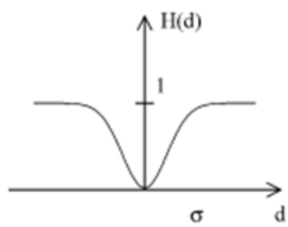
Generalized criterion type	Preference function ($H(d)$)
Type I: Usual criterion $H(d) = \begin{cases} 0 & d = 0 \\ 1 & \lvert d \rvert > 0 \end{cases}$	
Type II: U-shape criterion $H(d) = \begin{cases} 0 & \lvert d \rvert \le q \\ 1 & \lvert d \rvert > q \end{cases}$	
Type III: V-shape criterion $H(d) = \begin{cases} \frac{\lvert d \rvert}{p} & \lvert d \rvert \le p \\ 1 & \lvert d \rvert > p \end{cases}$	
Type IV: Level criterion $H(d) = \begin{cases} 0 & \lvert d \rvert \le q \\ \frac{1}{2} & q < \lvert d \rvert \le p \\ 1 & \lvert d \rvert > p \end{cases}$	
Type V: V-shape criterion with indifference criterion $H(d) = \begin{cases} 0 & \lvert d \rvert \le q \\ \frac{\lvert d \rvert - q}{p - q} & q < \lvert d \rvert \le p \\ 1 & \lvert d \rvert > p \end{cases}$	
Type VI: Gaussian criterion $H(d) = 1 - \exp(-d^2/2\sigma^2)$	

Figure 1. PROMETHEE General Preference Functions[32]

PROMETHEE requires two additional types of information, namely[29]:

- Information on the relative importance (i.e. the weights) of the criteria considered.
- Information on the decision-maker's preference function, which decision maker uses when comparing the contribution of the alternatives in terms of each separate criterion.

There are six basic preference functions suggested by Brans, Vincke, and Mareschal (1986)[30] and shown on Figure 1. Six different preference function cover almost all the possible criteria[31]

1. Usual criterion,
2. U-shape criterion,
3. V-shape criterion,
4. level criterion,
5. V-shape criterion and
6. Gaussian criterion.

For each criterion,

- the value of an indifference threshold, q;
- the value of a strict preference threshold, p;
- and the value of an intermediate value between p and q, s, has to be fixed.

Stepwise procedure for PROMETHEE II shown on Fig 2.

The PROMETHEE is implemented in four steps. The first step of method is determination of deviations based on pair-wise comparisons. It is followed by using a relevant preference function for each criterion in Step 2., calculating overall preference index in Step 3. and calculating positive and negative outranking flows for each alternative and partial ranking in Step 4. The procedure completes with the calculation of net outranking flow for each alternative and complete ranking[26].

Step 1. Determination of deviations based on pair-wise comparisons

$$d_j(a,b) = g_j(a) - g_j(b) \qquad (1)$$

Where $d_j(a,b)$ denotes the difference between the evaluations of a and b on each criterion.

Step 2: Application of the preference function

$$P_j(a,b) = F_j[d_j(a,b)] \qquad j=1,\ldots,k \qquad (2)$$

Where $P_j(a,b)$ denotes the preference of alternative a with regard to alternative b on each criterion, as a function of $d_j(a,b)$.

Step 3: Calculation of an overall or global preference index

$$\forall a,b \in A, \qquad \pi(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j \qquad (3)$$

Where $\pi(a,b)$ of a over b (from 0 to 1) is defined as the weighted sum $p(a,b)$ of for each criterion, and w_j is the weight associated with jth criterion.

Step 4: Calculation of outranking flows/ The PROMETHEE I partial ranking

$$\phi^+(a) = \frac{1}{n-1}\sum_{x \in A} \pi(a,x) \qquad (4) \qquad \text{and} \qquad \phi^-(a) = \frac{1}{n-1}\sum_{x \in A} \pi(x,a) \qquad (5)$$

Where $\phi^+(a)$ and $\phi^-(a)$ denote the positive outranking flow and negative outranking flow for each alternative, respectively.

Step 5: Calculation of net outranking flow/ The PROMETHEE II complete ranking

$$\phi(a) = \phi^+(a) - \phi^-(a) \qquad (6)$$

Where $\phi(a)$ denotes the net outranking flow for each alternative.

Figure 2. Stepwise procedure for PROMETHEE II[26]

4.3. Combining AHP and VIKOR to Determine the Rank of Alternatives

In analyzing the data, Analytical Hierarchy Process (AHP) and PROMETHEE methodologies are used for the outranking of logistic village destination alternatives. Figure 3 shows the steps of the proposed method.

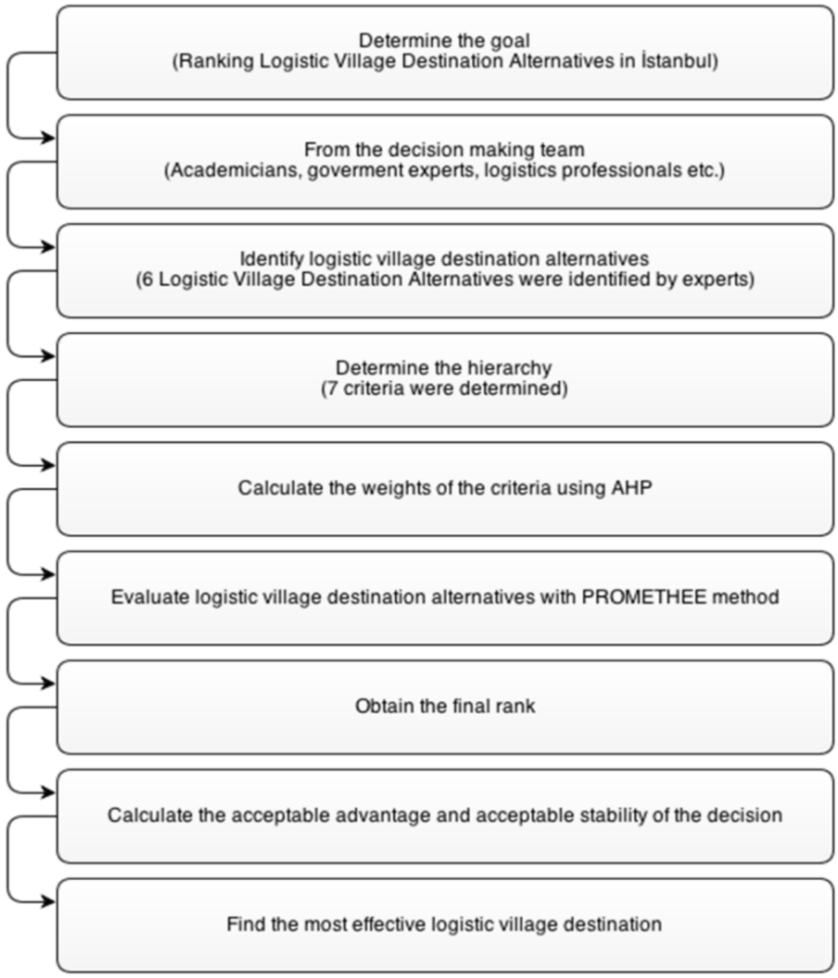


Figure 3. Steps of proposed method

4.4. Solving Case Problem

To apply proposed method a real world logistic village location evaluation problem was solved. In this logistic village location evaluation problem there are 7 criteria and 6 candidate location including Silivri, Hadimkoy, Halkali, Pendik, Gebze and Tuzla. The hierarchical structure to select the best logistic village location is shown in Figure 4. In order to identify weights of the criteria previous academic research done by Bamyacı (2008) was used.

Criteria to be considered in the evaluation of logistic village location are determined by literature review. It was very hard to evaluate some of qualitative criteria. Therefore in this research just quantitative criteria were investigated.7 important criteria to be used for logistic village location evaluation are established. These 7 criteria are as follows: “Opportunities for possible site expansion” (C1), “Cost of land” (C2), “Proximity to industrial zone” (C3), “Proximity to airport” (C4), “Proximity to harbor” (C5), “Proximity to railroad system” (C6) and “Proximity to highway system” (C7).

As a result, only these 7 criteria were used in evaluation and decision hierarchy is established accordingly. Decision hierarchy structured with the determined alternative logistic village locations and criteria is provided in Figure 4. There are three levels in the decision hierarchy structured for logistic village location evaluation problem. The overall goal of the decision process is ‘‘ranking logistic village destination alternatives in Istanbul” in the first level of the hierarchy. The criteria are on the second level and alternative locations are on the third level of the hierarchy.

After forming the decision hierarchy for the problem, the weights of the criteria to be used in evaluation process are calculated by using AHP method. In this phase, the experts in the expert team are given the task of forming individual pairwise comparison matrix by using the Saaty’s 1-9 scale.

Geometric means of experts’ choice values are calculated to form the pairwise comparison matrix on which there is an agreement (Table 3). The results obtained from the calculations based on the pairwise comparison matrix provided, are presented in Table 3.

The “C7: Proximity to highway system” (0.190) and “C2: Cost of land (0.180) are determined as the two most important criteria in the logistic village location selection process by using AHP. Consistency ratios of the experts’ pairwise comparison matrixes are all less than 0.1. So the weights are shown to be consistent and they are used in the selection process. The most important criterion is “C7: Proximity to highway system” (0.190) and the least important criterion is “C4: Proximity to airport” (0.040).

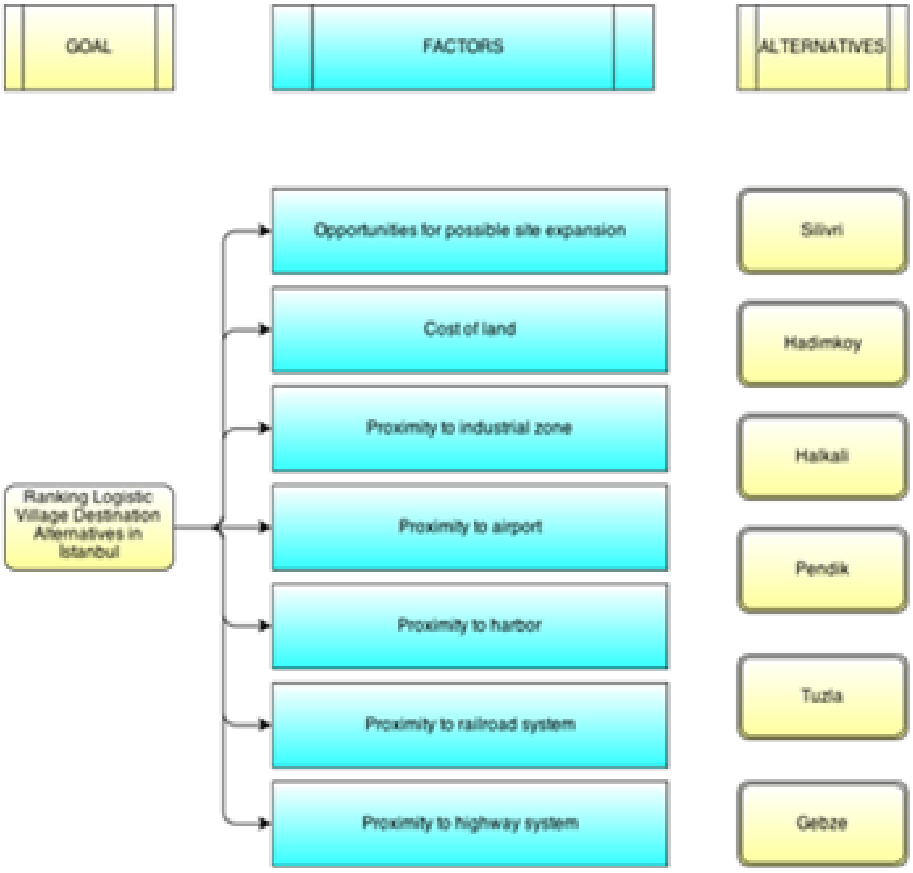


Figure 4. Hierarchical Structure for Logistic Village Evaluation

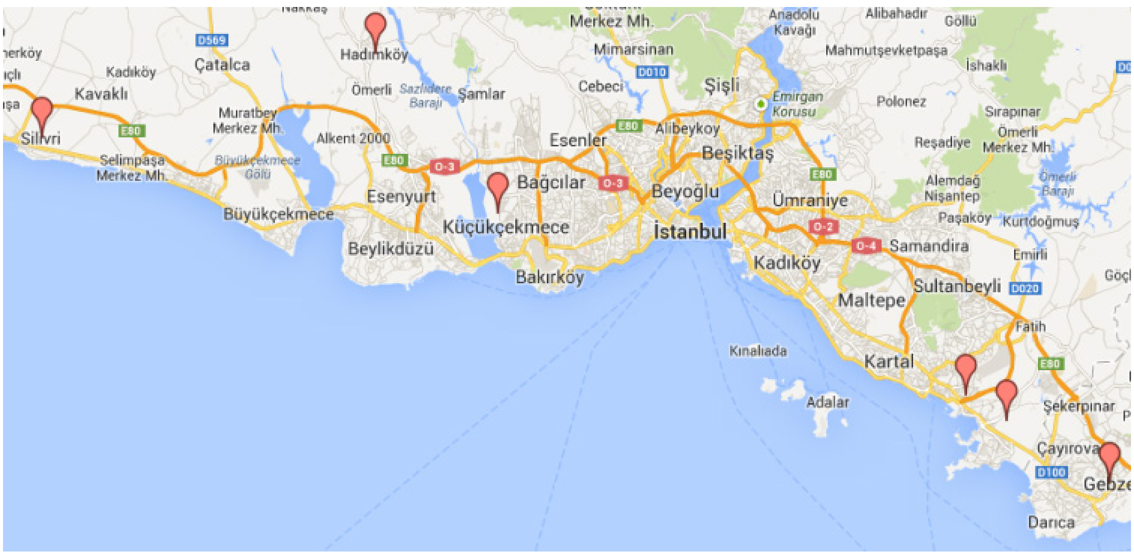


Figure 5. Location alternatives of the problem

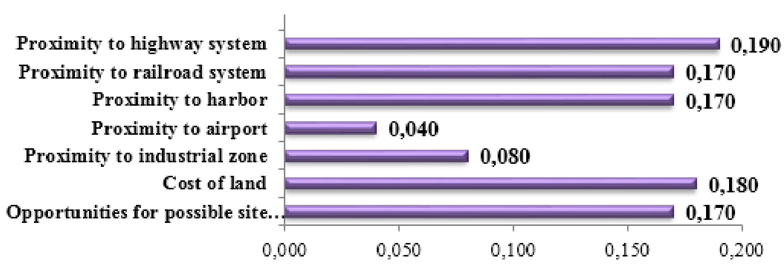


Figure 6. Overall resulting weights of criteria obtained with AHP

Table 3. Weights obtained using AHP

Ranking Logistic Village Destination Alternatives in Istanbul

Criteria	Weights
Opportunities for possible site expansion	0.17
Cost of land	0.18
Proximity to industrial zone	0.08
Proximity to airport	0.04
Proximity to harbor	0.17
Proximity to railroad system	0.17
Proximity to highway system	0.19

Finally, PROMETHEE method is applied to rank the alternative locations. The priority weights of alternative locations with respect to criteria, calculated by AHP and shown in Table 3, can be used as input of PROMETHEE (Table 4). The preference parameters of all criterion are shown in Table 5.

Table 4. Input values of the PROMETHEE analysis

Alternatives	C1	C2	C3	C4	C5	C6	C7
Silivri	5960	3,5	37,6	63,5	48,9	88,8	7,2
Hadimkoy	345	5	20,7	36,7	23,6	62,1	10,8
Halkali	3100	6,5	7,9	13,9	20,2	43,7	5
Pendik	100	8,5	7,7	13,4	5	36,4	16,1
Tuzla	100	6	4,3	17,6	7,9	38,1	16,3
Gebze	100	6	8,8	28,5	19	46,5	15,1

Table 5. The preference parameters of all criterion

	C1	C2	C3	C4	C5	C6	C7
Min/Max	*max*	*max*	*max*	*max*	*max*	*max*	*max*
Weight	0,17	0,18	0,08	0,04	0,17	0,17	0,19
Preference Func.	*Usual*	*Usual*	*Usual*	*Usual*	*Usual*	*Usual*	*Usual*

The candidate locations have advantages and disadvantages. These are shown in Table 6.

Table 6. Features of Candidate Locations

Alternatives	Advantages	Disadvantages
Silivri	Opportunities for possible site expansion	Proximity to airport
Hadimkoy	Cost of land	Proximity to railroad system
Halkali	Proximity to highway system	Proximity to harbor
Gebze	-	Opportunities for possible site expansion
Tuzla	Proximity to industrial zone	Opportunities for possible site expansion
Pendik	Proximity to harbor	Cost of land

Table 7. Statistics for destination alternatives

	C1	C2	C3	C4	C5	C6	C7
Minimum	100	3,5	4,3	13,4	5	36,4	5
Maximum	5960	8,5	37,6	63,5	48,9	88,8	16,3
Average	1617,5	5,92	14,5	28,93	20,77	52,6	11,75
Standard Dev.	2220,46	1,51	11,54	17,56	14,24	18,21	4,43

Table 8. Flowtable for destination alternatives

Alternatives	C1	C2	C3	C4	C5	C6	C7
Silivri	1,00	-1,00	1,00	1,00	1,00	1,00	-0,60
Hadimkoy	0,20	-0,60	0,60	0,60	0,60	0,60	-0,20
Halkali	0,60	0,60	-0,20	-0,60	0,20	-0,20	-1,00
Gebze	-0,60	0,00	0,20	0,20	-0,20	0,20	0,20
Tuzla	-0,60	0,00	-1,00	-0,20	-0,60	-0,60	1,00
Pendik	-0,60	1,00	-0,60	-1,00	-1,00	-1,00	0,60

Table 9. Calculation of Phi for criteria

Alternatives	Phi	Phi+	Phi-
Silivri	0,336	0,668	0,332
Hadimkoy	0,164	0,582	0,418
Halkali	-0,020	0,490	0,510
Gebze	-0,040	0,428	0,468
Tuzla	-0,204	0,346	0,550
Pendik	-0,236	0,348	0,584

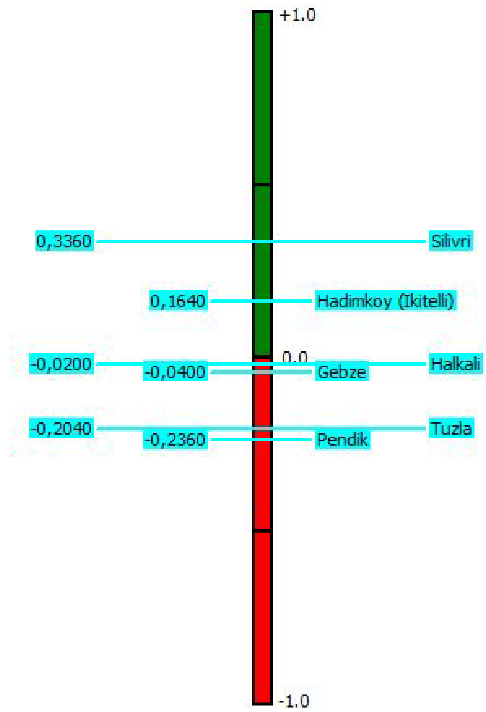


Figure 7. Optimal Phi values obtained with PROMETHEE

Depends on the optimal phi values, the ranking of the first three alternatives from top to bottom order are Silivri, Hadimkoy and Halkali (Table 10). Proposed model results show that Silivri is the best alternative with 0,336 Phi value. Depends on the analysis the least suitable logistic village is Pendik.

Table 10. PROMETHEE II Complete rankings

Freight Villages	Optimal Phi	Rank
Silivri	0,336	1
Hadimkoy	0,164	2
Halkali	-0,020	3
Gebze	-0,040	4
Tuzla	-0,204	5
Pendik	-0,236	6

5. Conclusions and Suggestions

Logistic village location decisions are very important part in any countries' overall strategic plan. This paper presents a multi-criteria decision model for evaluating alternatives of logistic village destinations. For this purpose, a two-step methodology is introduced, in which the AHP determines importance level of criteria via expertise of decision making team members. Then, PROMETHEE method applies AHP' weights as input weights. Finally, logistic village location problem was solved by using proposed method to show applicability and performance of the proposed methodology. Proposed model results show that Silivri is the best alternative with 0,336 Phi value. Depends on the analysis the least suitable logistic village is Pendik. By the compromise ranking method, the compromise solution is determined which would be most acceptable to the decision makers because it provides a maximum ‘‘group utility’’ for the ‘‘majority’’, and a minimum of individual regret for the ‘‘opponents’’. In next studies analytic network process (ANP) may be used to structure network and identify dependence among criteria. Extensions of the other MCDM techniques can be applied for decision making under fuzzy environment. The proposed methodology can also be applied to any other selection problem involving multiple and conflicting criteria. Selection of the logistic village location can also be done using other MCDM techniques for comparing the results.

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