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FUZZY AHP-PROMETHEE METHODOLOGY TO SELECT BUS GARAGE LOCATION: A CASE STUDY FOR A FIRM IN THE URBAN PASSENGER TRANSPORT SECTOR IN ISTANBUL

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ABSTRACT
Urban passenger transportation demand is increasing by the population and land use growth. This situation causes to the increase in the number of busses and in parallel with bus garages. In the bus garages, the maintenance, repair, fulfillment and warehouse operations are done so the location and layout are important. In this study we will look into garage location selection problem. The main objective in the garage location selection problem is to minimize the lost dead kilometers that busses travel. Therefore, the garages should be closer to the city centers or the area that they serve to. They should also have the appropriate capacity and should be positioned relevant that they will not disturb the urban inhabitant.
In this study, the garage location selection problem for a firm in urban passenger transport sector in Istanbul will be studied. When the problem is investigated, it will be noticed that there are lots of criteria that must be taken into account to minimize the dead kilometers. Hence firstly, the criteria will be determined and then the problem will be solved using multi criteria decision making techniques.
Keywords: Urban passenger transport, Garage location selection, Multi criteria decision making techniques

1. INTRODUCTION

When the decision making literature is considered, it is seen that many techniques are combined for a numerous application areas. Tabari et.al.(2008), uses fuzzy AHP to select the optimal location that satisfies the decision maker. Özcan et.al.(2011) have compared AHP, TOPSIS, ELECTRE and Grey Theory decision making techniques and they have applied these methodologies on the warehouse location selection problem. Önüt and Soner (2008) are applied a fuzzy TOPSIS based methodology to solve the solid waste transshipment site selection problem in Istanbul, Turkey and they calculated the criteria weights by using the AHP. Awasti et.al. (2011), proposed an approach that involves identification of potential locations, selection of evaluation criteria, 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. Kayikci (2010) is explored the applicability of the way for the development of a conceptual model based on a combination of the fuzzy-analytical hierarchy process (AHP) and artificial neural networks (ANN) methods in the process of decision-making in order to select the most appropriate location. Kuo (2010) is used the fuzzy DEMATEL to arrange a suitable structure between criteria, and the analytic hierarchy/ network process (AHP/ANP) to construct weights of all criteria to select the optimal international distribution center location selection. Dağdeviren and Erarslan (2008) has used PROMETHEE to select the most appropriate supplier. Tuzkaya (2009) has developed a decision making methodology to chose the environmentally convenient transportation mode with respect to the determined evaluation criteria in Marmara Region of Turkey. Even though Fuzzy-AHP and PROMETHEE techniques are combined for solving the decision making problems of the different areas, this study is novel due to the applying them for an urban garage location selection.

2. SOLUTION APPROACH

2.1 Fuzzy AHP

In this study, Chang (1996) extent analysis method is preferred, since the steps of this approach are relatively easier than the other fuzzy-AHP approaches and similar to the crisp AHP.

2.2 PROMETHEE

The explanation and mathematically calculation steps of the PROMETHEE are summarized below. Let i represents the alternatives (i=1,2,…,m and $i \in A$), j represents the set of criteria (j=1,2,…,n and $j \in C$) and $g_j(i)$ is the value of criterion j of alternative i. After the $g_j(i)$ values are determined in the first step, preference function $F_j(i, i') = g_j(i) - g_j(i)' = x_j$, which is the preference degree of alternative i in comparison to i' in terms of criterion j, is defined with one of the six different generalized shapes given with Eq. 1-6. The names of generalized criteria functions are usual criterion, quasi criterion, criterion with linear preference, level criterion, criterion with linear preference and indifference area and Gaussian criterion. q and p are the indifference and strict preference thresholds of a specific criterion, respectively [8].

$$p(x) = \begin{cases} 0, & x \le 0 \\ 1 & x > 0 \end{cases} \tag{1}$$

$$p(x) = \begin{cases} 0, & x \le q \\ y, & q < x < p \\ 1, & x \ge p \end{cases} \tag{4}$$

$$p(x) = \begin{cases} 0, & x \le q \\ 1 & x > q \end{cases} \tag{2}$$

$$p(x) = \begin{cases} 0, & x \le q \\ (x-q)/(p-q), & q < x < p \\ 1, & x \ge p \end{cases} \tag{5}$$

$$p(x) = \begin{cases} 0, & x \le q \\ x/p, & q < x < p \\ 1, & x \ge p \end{cases} \tag{3}$$

$$p(x) = \begin{cases} 0, & x \le q \\ 1-e^{-x^2/2z^2}, & q < x < p \\ 1, & x \ge p \end{cases} \tag{6}$$

Then, the aggregated preference functions are calculated for each alternative pair using the preference functions obtained in the previous step. The next step is calculating the preference index $\pi(i,i')$ with Eq 7 which is a weighted average of preference functions $P(x_j)$ for all the criteria. Here, w_j is the weight assigned to criterion j and it is obtained from the fuzzy-AHP evaluations.

$$\mu(i,i') = \frac{\sum_{j=1}^{n} w_j P(x_j)}{\sum_{j=1}^{n} w_j} \tag{7}$$

Sum of the π (i,i') is used as a measure of the strength of the alternative $i \in A$ and is named as leaving flow. Thus, leaving flow yields a measure of the outranking character of i as given in Eq. (8).

$$\phi^{+}(i) = \frac{1}{m-1}\sum_{i'=1}^{m} \pi(i,i') \qquad i' \ne i, \qquad \forall i \in A \tag{8}$$

Another measure for the weakness of the alternative $i \in A$ is entering flow. This is the outranking character of alternative i as given in Eq. (9).

$$\phi^{-}(i) = \frac{1}{m-1}\sum_{i'=1}^{m} \pi(i',i) \qquad i' \ne i, \qquad \forall i \in A \tag{9}$$

CONTENTS AUTHORS

By the above calculations, required results are obtained for PROMETHEE-I and PROMETHEE-II. The PROMETHEE-I partially preorders the alternatives by comparing the leaving and entering flows and determines the weak preferences and incomparability of alternatives. When one of the Eqs. 10-12 are provided, alternative *i* is superior to *i'* .

$$\phi^+(i) > \phi^+(i') \text{ and } \phi^-(i) < \phi^-(i') \quad (10)$$

$$\phi^+(i) > \phi^+(i') \text{ and } \phi^-(i) = \phi^-(i') \quad (11)$$

$$\phi^+(i) = \phi^+(i') \text{ and } \phi^-(i) < \phi^-(i') \quad (12)$$

If the Eq. 13 is realized, alternative *i* and *i'* have the same preferences.

$$\phi^+(i) = \phi^+(i') \text{ and } \phi^-(i) = \phi^-(i') \quad (13)$$

At least, alternative *i* and *i'* are incomparable, when one of the Eqs 14-15 is provided.

$$\phi^+(i) > \phi^+(i') \text{ and } \phi^-(i) > \phi^-(i') \quad (14)$$

$$\phi^+(i) < \phi^+(i') \text{ and } \phi^-(i) < \phi^-(i') \quad (15)$$

Even the partial preorders derived by PROMETHEEI contain realistic information, complete preorders are requested generally. This is yielded by calculating the net flows as the difference of leaving and entering flows which is called as PROMETHEE-II given in Eq. 16:

$$\phi^{net}(i) = \phi^+(i) - \phi^-(i)$$
(16)

2.3 Model Structure

In our study we propose a decision making model to select the most appropriate garage location selection. We firstly determine the sub-criteria weights by using Fuzzy AHP and then we use PROMETHEE I and II in our model.

3 CASE STUDY

There are six main criteria and sixteen sub-criteria in our model and they are as follows:

1. *Cost:* Investment cost (C1), Spare parts transportation cost (C2), Vehicle transport cost (C3)
2. *Infrastructure:* Telecommunication systems (C4), Municipality services (C5), Technological infrastructure (C6)
3. *Accessibility:* Service zone proximity (C7), Proximity to suppliers (C8)
4. *Social and economic structure:* Population structure (C9), Urbanization of the region (C10), Neighborhood response (C11), Behavior of the passengers (C12)
5. *Macro factors:* Government policy (C13), Reconstruction and building plans (C14)
6. *Environmental factors*: Effects on the open land (C15), Convenience of the land(C16)

Table 1. The weights of sub-criteria

Cost			Infrastructure			Accessibility		Social and economic structure				Macro factors		Environmental factors	
C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**
0,37	0,37	0,37	0,02	0,02	0,02	0,44	0,44	0	0	0	0	0	0	0,18	0,18
0,84	0	0,16	0,36	0,64	0	1	0	0,04	0,55	0,41	0	1	0	0	1
0,31	0	0,06	0,01	0,01	0	0,44	0	0	0	0	0	0	0	0	0,18

After we have determined the weights of sub-criteria by fuzzy AHP, we applied PROMETHEE to make the last decision.
The data that we have used and the values for each alternatives are as in the tables below (Table 2-3):

Table 2: The data used in PROMETHEE

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
Weights	0,31	0	0,06	0,01	0,01	0	0,44	0	0	0	0	0	0	0	0	0,18
Preference Function Type	V Shape	V Shape	V Shape	V Shape	V Shape	V Shape	V Shape	V Shape	V Shape	V Shape	V Shape	V Shape	V Shape	V Shape	V Shape	V Shape
Max/Min	min	min	min	max	max	max	max	max	max	max	max	max	max	max	min	min
Indifference (Q)	0	0	0	3	3	3	3	3	3	3	3	3	3	3	0	0
Preference (P)	-4	-4	-3	0	0	0	0	0	0	0	0	0	0	0	-3	-3

Table 3: The obtained values of criteria for each alternatives

Sub-criteria	Beylikdüzü	Arnavutköy	Silivri
C1	9	4	6
C2	4	6	9
C3	5	7	9
C4	7	4	5
C5	7	4	4
C6	6	4	6
C7	8	6	5
C8	7	6	4
C9	8	6	6
C10	9	5	8
C11	7	9	8
C12	8	8	8
C13	6	8	9
C14	7	9	4
C15	9	5	6
C16	9	5	6

By PROMETHEE I the results could not be evaluated so as second step we applied PROMETHEE II.

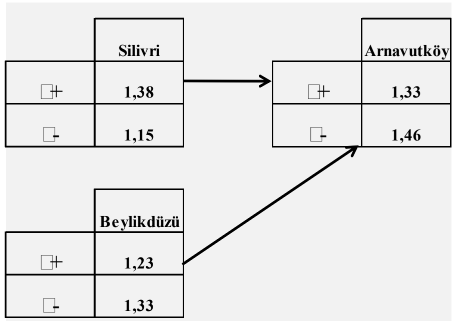

Figure 1. Partial ranking of PROMETHEE I

Table 5: The results of PROMETHEE II

	Beylikdüzü	Arnavutköy	Silivri
+	1,23	1,33	1,38
-	1,33	1,46	1,15
FARK	-0,10	-0,13	0,23

4 CONSLUSION

In garage location selection problem, there are lots of criteria that must be taken into account. In our methodology, we firstly determined our criteria and alternatives, then by fuzzy AHP we found the weights of all sub-criteria. After that we used these weights in the PROMETHEE. In our study, Beylikdüzü, Arnavutköy and Silivri are the alternatives and after the calculations, it is shown a new garage must be built in Silivri. In future studies, different multi criteria decision making techniques can be used for this selection problem or this methodology can be used for another selection problem.

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