# The Cruise Port Place Selection Problem with Extended VIKOR and ANP Methodologies under Fuzzy Environment

Nihan ÇETİN DEMİREL, and G.Nilay YÜCENUR

*Abstract*—**In this paper, a decision making problem is considered and fuzzy analytic network process (ANP) and extended fuzzy VIKOR methodologies have been proposed to deal with the cruise port place selection problem in Istanbul. In this paper, we proposed a model for selection of the most suitable place by using analytical network process and VIKOR method under fuzzy environment due to linguistic terms. The implementation of the system is demonstrated by a problem having four stages of hierarchy which contains four criteria and thirteen sub-criteria. The study compares the fuzzy analytic network process and VIKOR method results.**

**Index Terms—Multi-criteria decision making problem, Fuzzy ANP, extended VIKOR method, cruise port**

## I. Introduction

CRUISE tourism is one of the fastest growing sectors of global tourism. Cruise tourism is the quintessential ‘‘footloose’’ industry. Cruise ships are constantly being moved between markets from one year to the next and even within a given calendar year thus making individual cruise markets highly contestable [1].

The harbor transformation and redevelopment activities are mostly seen in industrially advanced countries, such as the US, Canada, some of the European countries, Japan and Australia. However, as their economies grow rapidly, the newly industrializing countries are also affected by this worldwide phenomenon. As a middle-income developing country, the Republic of Turkey has also begun to face a similar phenomenon in some of its harbors. Among them, Karaköy Harbor, one of the inner city harbors in the Istanbul harbor system, has been undergoing a transformation since the mid-1980s. This change might have important consequences for the harbor itself as well as for Istanbul city [2].

The selection of the cruise port place is a very important and complex problem. The decision makers have to consider all criteria which have significant effects on the economy, environment, human life, and society. In this paper, ANP and extended VIKOR methodologies are used under fuzzy environment and the results are compared. The implementation of the system is demonstrated by a problem having four stages of hierarchy which contains four criteria and thirteen sub-criteria.

Multi-criteria decision making involves determining the optimal alternative among multiple, conflicting, and interactive criteria [3, 4]. The ANP is fundamentally a way to measure intangible factors by using pair wise comparisons with judgments that represent the dominance of one element over another with respect to a property that they share [5]. Analytic network process (ANP) is a new tool for multi-criteria decision making but can also be applied in academic research to prioritize factors or criteria. It enhances the function of analytic hierarchy process (AHP) to develop a complete model that can incorporate interdependent relationships between elements from different levels or within levels, which are assumed to be uncorrelated in AHP [6]. On the other hand, the VIKOR method was developed to solve multi-criteria decision making problems with conflicting and non-commensurable (different units) criteria, assuming that compromising is acceptable for conflict resolution, the decision maker wants a solution that is the closest to the ideal, and the alternatives are evaluated according to all established criteria. This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria, and on proposing compromise solution (one or more) [7]. In the literature, Liou et al. (2010) used a modified VIKOR method for improving the domestic airlines service quality and Chang and Hsu (2009) used VIKOR method for prioritizing land-use restraint strategies in the Tseng-Wen reservoir watershed [8, 9]. Sayadi et al. (2009) used extension VIKOR method for the solution of the decision making problem with interval numbers [10].

Zadeh (1965) introduced the fuzzy set theory to deal with the uncertainty due to imprecision and vagueness. A major contribution of fuzzy set theory is its capability of representing vague data. The theory also allows mathematical operators and programming apply to the fuzzy domain [11].

The remainder of this paper is organized as follows. Section 2 briefly introduces sea tourism commerce and cruise tours. Section 3 goes over description of the proposed model and selection criteria of the problem. Section 4 and Section 5 contain applications of fuzzy ANP method and extended fuzzy VIKOR method in a suitable cruise port place selection, respectively. Some conclusion remarks are made in Section 6.

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## II. SEA AND CRUISE TOURISM

Tourism has been accepted as an alternative economic development strategy by many governments in developing countries. Turkey as a developing country is not exceptional in this case. After experiencing three military coups caused by social unrest and serious economic crises, Turkey adopted tourism not only as an alternative economic growth strategy, but also as a tool for social change to political strategy to create a favorable image in the eyes of European people [12].

Water has been an attraction in establishing and developing cities all around the world. The significance of water was reinforced with the industrial revolution. With increasing trading activities, harbors became important properties for cities. However, today, across the world industrial activities and trade are in dramatic change. As a reflection of these changes, industrial activities relocated either to suburbs or to another country, leaving inner city economic activities in decline. Additionally, the technological developments in transportation, shipbuilding and handling, such as container transportation and super capacity vessels resulted in outmoded facilities. All these developments have changed the comparative advantages of many harbors. As a result, harbors all around the world have been undergoing changes as an effect of the postindustrial era with most emphasis of market-led policies and initiatives [2].

Cruise tourism has certain features [12]:

- Be located some distance away from potential visitors
- Be seen as a potential destination area
- Have reasonable accessibility to a potential market
- Have some minimum level of economic and social infrastructure that can support tourism development
- Be large enough to contain more than just one community.

In Turkey, in Istanbul there is one active cruise port in Karaköy. Karaköy Harbor area is located at the European side of Istanbul, where the historical core of the city surrounds it. The main functions of the surrounding area are finance, wholesale and retail trade, small workshops, office and residential use. Along with the harbor, the Mimar Sinan University campus is also an important education and fine arts institution in the area. With the becoming of the cruise tourism popular, Karaköy is not enough to accompany of all cruises overall the world. That is why the new port place is very big problem in Istanbul. This paper tries to find a new solution of this problem.

## III. SELECTION CRITERIA FOR CRUISE PORT PLACE

The problem has a hierarchy with four levels, and the different decision criteria, sub-criteria and the decision alternatives, will be further discussed. In hierarchy, the overall objective is placed at level 1, criteria at level 2, attributes at level 3, and the decision alternatives at level 4. The main objective here is the selection of the most suitable cruise port place in Istanbul. The criteria which are considered here in selection of the city are strategic, technical, economic and social conditions.

These criteria can be decomposed into various other attributes. The main four criteria and numbers of sub-criteria relevant to selection are described below. The criteria are denoted by $C_i$, sub-criteria by $SC_j$, and alternative places by $AP_k$ (where, $i, k = 1, 2, 3, 4, 5$ *and* $j = 1, 2, \ldots, 28$). The hierarchy of the selection criteria, sub-criteria and decision alternatives can be seen in Figure 1. The criteria, and attributes identified and analyzed in this paper can be seen in the literature and the government's researches.

*Strategic conditions ($C_1$):* The factors affecting strategic conditions criteria can be stated as follows: nearliness of the touristic places ($SC_1$), nearliness of the tourism market ($SC_2$) and expansion possibility ($SC_3$).

*Technical conditions ($C_2$):* The factors which affect the technical conditions can be stated as follows: meteorological characteristics ($SC_4$), water depth ($SC_5$), dock convenience ($SC_6$), wave effects ($SC_7$) and status of coast line ($SC_8$).

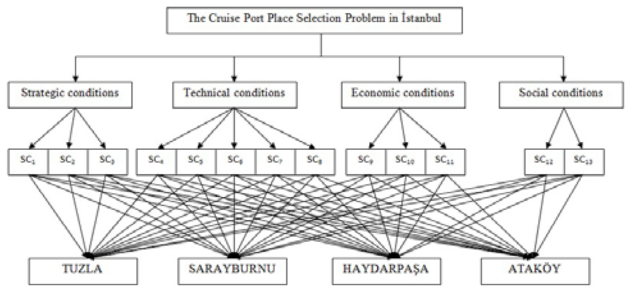


Fig. 1. The hierarchy of the selection problem.

*Economic conditions ($C_3$):* The economic conditions criteria have the following attributes: investment cost ($SC_9$), operating cost ($SC_{10}$) and advertising cost ($SC_{11}$).

*Social conditions ($C_4$):* The factors affecting the social conditions can be stated as follows: means of transport ($SC_{12}$) and educational status ($SC_{13}$).

*Alternative cruise port places in Istanbul:* The above-mentioned criteria and sub-criteria help in deciding the cruise port place in Istanbul. In this paper, depending on the selection criteria and sub-criteria there are four different alternative places such as Haydarpaşa ($AP_1$), Tuzla ($AP_2$), Sarayburnu ($AP_3$) and Ataköy ($AP_4$).

## IV. APPLICATION OF THE FUZZY ANP IN THE CRUISE PORT PLACE SELECTION PROBLEM

Analytic network process (ANP) is a new tool for multi-criteria decision-making (MCDM) but can also be applied in academic research to prioritize factors or criteria and it is the generic form of AHP and allows for more complex interdependent relationships among elements [6].

The advantages of the ANP are that it is not only appropriate for both quantitative and qualitative data types, but it also can overcome the problem of interdependence and feedback among criteria. Although the ANP have been widely used in various applications, two main problems should be highlighted as follows. The first is the problem of comparison. In the ANP, the decision maker is asked to answer the question like "How much importance does a criterion have compared with respect to our interests or preferences?" However, sometimes the questions are hard even for the expert to answer the question above due to

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some questions are anti-intuitive. Furthermore, the key for the ANP is to determine the relationship structure among features in advance. The different structure results in the different priorities. However, it is usually hard for the decision maker to give the true relationship structure by considering many criteria [3]. The method of the ANP can be described as follows:

*Step 1:* The criteria and attributes are identified.

*Step 2:* Local weights of the criteria and attributes which take part in the second and third levels of ANP model same AHP model, provided in Figure 1, are calculated. Pair wise comparison matrices are analyzed by the Chang's extend analysis method and local weights are determined.

TABLE I
COMBINATION OF CRITERIA OF THE GOAL

| | Strategic Cond. | Technical Cond. | Economic Con. | Social Cond. | Alternative Priority Weight |
|---|---|---|---|---|---|
| Weight | 0.12 | 0.42 | 0.42 | 0.04 | |
| Alternative Strategies | | | | | |
| Haydarpaşa | 0.30 | 0.18 | 0.26 | 0.30 | 0.23 |
| Tuzla | 0.08 | 0.11 | 0.29 | 0.04 | 0.18 |
| Sarayburnu | 0.27 | 0.19 | 0.20 | 0.28 | 0.21 |
| Ataköy | 0.35 | 0.52 | 0.25 | 0.38 | **0.38** |

*Step 3:* In this step, interdependent weights of the factors are calculated and the dependencies among the factors are considered. The pair wise comparison matrices are formed for the factors. The weight vector for strategic conditions is calculated as $W_1 = (0.47, 0.47, 0.06)^T$, for technical conditions is calculated as $W_2 = (0.16, 0.81, 0.03)^T$, for economic conditions is calculated as $W_3 = (0.81, 0.16, 0.03)^T$ and for social conditions is calculated as $W_4 = (0.06, 0.47, 0.47)^T$.

*Step 4:* Using the computed relative importance weights, the dependence matrix of the criteria is formed. Interdependent weights of the criteria are computed by multiplying the dependence matrix of the criteria we obtained with the local weights of factors. The interdependent weights of the factors are calculated as follows:

$$\begin{bmatrix} strategicconditions \\ technicalconditions \\ economicconditions \\ socialconditions \end{bmatrix} = \begin{bmatrix} 1.00 & 0.16 & 0.81 & 0.06 \\ 0.47 & 1.00 & 0.16 & 0.47 \\ 0.47 & 0.81 & 1.00 & 0.47 \\ 0.06 & 0.03 & 0.03 & 0.01 \end{bmatrix} \times \begin{bmatrix} 0.12 \\ 0.42 \\ 0.42 \\ 0.04 \end{bmatrix} = \begin{bmatrix} 0.26 \\ 0.28 \\ 0.42 \\ 0.04 \end{bmatrix}$$

*Step 5:* Using interdependent weights of the criteria and local weights of the attributes, global weights for the attributes are calculated in this step. Global attributes weights are computed by multiplying local weight of the attributes with the interdependent weight of the criteria to which it belongs. The values are shown in Table II.

Finally, the overall priorities of the alternative places, reflecting the interrelationships within the criteria, are calculated. The hierarchical model given in Figure 1 was analyzed with the Fuzzy ANP. According to the ANP analysis, alternative cruise port places are ordered as Ataköy, Haydarpaşa, Tuzla and Sarayburnu.

TABLE II
COMPUTED GLOBAL WEIGHTS OF ATTRIBUTES

| Factors and local weights | | Local weights | Global weights |
|---|---|---|---|
| Strategic conditions | 0.26 | | |
| Nearliness of the touristic places | | 0.70 | 0.18 |
| Nearliness of the tourism market | | 0.15 | 0.04 |
| Expansion possibility | | 0.15 | 0.04 |
| Technical conditions | 0.28 | | |
| Meteorological characteristics | | 0.34 | 0.10 |
| Water depth | | 0.12 | 0.03 |
| Dock convenience | | 0.34 | 0.10 |
| Wave effects | | 0.08 | 0.02 |
| Status of coast line | | 0.12 | 0.03 |
| Economic conditions | 0.42 | | |
| Investment cost | | 0.82 | 0.34 |
| Operating cost | | 0.16 | 0.07 |
| Advertising cost | | 0.02 | 0.01 |
| Social conditions | 0.04 | | |
| Means of transport | | 0.83 | 0.03 |
| Educational status | | 0.17 | 0.01 |

$$\begin{bmatrix} Weight \\ vectors \\ for \\ attributes \end{bmatrix} \times \begin{bmatrix} Global \\ weight \\ of \\ attributes \end{bmatrix} = \begin{bmatrix} 0.22 \\ 0.21 \\ 0.21 \\ 0.36 \end{bmatrix}$$

## V. APPLICATION OF THE EXTENDED VIKOR METHOD UNDER FUZZY ENVIRONMENT IN THE MOST SUITABLE CITY SELECTION PROBLEM

Multi-criteria decision making problems are usually under uncertainty. One of these uncertain parameters is the decision maker (DM)'s degree of optimism, which has an important effect on the results. Fuzzy linguistic quantifiers are used to obtain the assessments of this parameter from DM and then, because of its uncertainty it is assumed to have stochastic nature [13].

VIKOR was developed by Opricovic (1998) and Opricovic and Tzeng (2002) with the Serbian name: VlseKriterijumska Optimizacija I Kompromisno Resenje, means multi-criteria optimization and compromise solution. The VIKOR method was developed for multi-criteria optimization of complex systems and this method focuses on ranking and selecting from a set of alternatives, and determines compromise solutions for a problem with conflicting criteria, which can help the decision makers to reach a final decision. Here, the compromise solution is a feasible solution which is the closest to the ideal, and a compromise means an agreement established by mutual concessions. It introduces the multi-criteria ranking index based on the particular measure of "closeness" to the ‘‘ideal" solution [14].

In this paper the problem is evaluated under fuzzy environment with fuzzy sets. The main steps of the algorithm are taken from Sanayei et al.'s (2010) study [14]:

*Step 1:* Identifying the objectives of the decision making process and define the problem scope.

*Step 2:* Arranging the decision making group and define and describe a finite set of relevant attributes.

*Step 3:* Identifying the appropriate linguistic variables: In this step, the appropriate linguistic variables for the importance weight of criteria, and the fuzzy rating for alternatives with regard to each sub-criterion these linguistic variables can be expressed in positive trapezoidal fuzzy numbers.

*Step 4:* Pull the decision makers' opinions to get the aggregated fuzzy weight of criteria, and aggregated fuzzy rating of alternatives and construct a fuzzy decision matrix: Let the fuzzy rating and importance weight of the $k$ th decision maker be $\tilde{x}_{ijk} = \left(x_{ijk1}, x_{ijk2}, x_{ijk3}, x_{ijk4}\right)$ and $\tilde{w}_{jk} = \left(w_{jk1}, w_{jk2}, w_{jk3}, w_{jk4}\right)$; $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$ respectively. Hence, the aggregated fuzzy ratings $\left(\tilde{x}_{ij}\right)$ of alternatives with respect to each criterion can be calculated as:

$$\tilde{x}_{ij} = \left(x_{ij1}, x_{ij2}, x_{ij3}, x_{ij4}\right), \tag{1}$$

where $x_{ij1} = \min_k \left\{x_{ijk1}\right\}$, $x_{ij2} = \frac{1}{K}\sum_{k=1}^{K} x_{ijk2}$, $x_{ij3} = \frac{1}{K}\sum_{k=1}^{K} x_{ijk3}$, $x_{ij4} = \max_k \left\{x_{ijk4}\right\}$

The aggregated fuzzy weights $\left(\tilde{w}_j\right)$ of each criterion can be calculated as:

$$\tilde{w}_j = \left(w_{j1}, w_{j2}, w_{j3}, w_{j4}\right), \tag{2}$$

where $w_{j1} = \min_k \left\{w_{jk1}\right\}$, $w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{jk2}$, $w_{j3} = \frac{1}{K}\sum_{k=1}^{K} w_{jk3}$, $w_{j4} = \max_k \left\{w_{jk4}\right\}$.

A suitable insurance firm selection problem can be concisely expressed in matrix format as follows:

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{12} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}, \quad \tilde{W} = \left[\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n\right],$$

where $\tilde{x}_{ij}$ the rating of alternative $A_i$ with respect to $C_j$, $\tilde{w}_j$ the importance weight of the $j$th criterion holds, $\tilde{x}_{ij} = \left(x_{ij1}, x_{ij2}, x_{ij3}, x_{ij4}\right)$ and $\tilde{w}_j = \left(w_{j1}, w_{j2}, w_{j3}, w_{j4}\right)$; $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$ are linguistic variables can be approximated by positive trapezoidal fuzzy numbers.

*Step 5:* Defuzzify the fuzzy decision matrix and fuzzy weight of each criterion into crisp values: This calculation is done by using center of area defuzzification method.

*Step 6:* Determine the best $f_j^*$ and the worst $f_j^-$ values of all criterion ratings, j = 1, 2, …, n

$$f_j^* = \max_i x_{ij} \tag{3}$$

$$f_j^- = \min_i x_{ij} \tag{4}$$

*Step 7:* Compute the values $S_i$ and $R_i$ by the relations

$$S_i = \sum_{j=1}^{n} w_j \left(f_j^* - f_{ij}\right) / \left(f_i^* - f_i^-\right) \tag{5}$$

$$R_i = \max_j w_j \left(f_j^* - f_{ij}\right) / \left(f_i^* - f_i^-\right) \tag{6}$$

*Step 8:* Compute the values $Q_i$ by the relations

$$Q_i = v\left(S_i - S^*\right) / \left(S^- - S^*\right) + \left(1 - v\right)\left(R_i - R^*\right) / \left(R^- - R^*\right) \tag{7}$$

where $S^* = \min_i S_i$, $S^- = \max_i S_i$, $R^* = \min_i R_i$, $R^- = \max_i R_i$ and $v$ is introduced as a weight for the strategy of maximum group utility, whereas $1-v$ is the weight of the individual regret.

*Step 9:* Rank the alternatives, sorting by the values $S$, $R$ and $Q$ in ascending order.

*Step 10:* Propose as a compromise solution the alternative $\left(A^{(1)}\right)$ which is the best ranked by the measure $Q$ (minimum) if the following two conditions are satisfied

- C1. Acceptable advantage:

$$Q\left(A^{(2)}\right) - Q\left(A^{(1)}\right) \geq DQ, \tag{8}$$

where $A^{(2)}$ is the alternative with second position in the ranking list by $Q$; $DQ = 1 / (J - 1)$.

- C2. Acceptable stability in decision making: The alternative $A^{(1)}$ must also be the best ranked by $S$ or/and $R$. This compromise solution is stable within a decision making process, which could be the strategy of maximum group utility (when $v > 0.5$ is needed), or "by consensus" $v \approx 0.5$, or "with veto" ($v < 0.5$). Here, $v$ is the weight of decision making strategy of maximum group utility.

  If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consist of:

Alternatives $A^{(1)}$ and $A^{(2)}$ if only the conditions C2 is not satisfied or Alternatives $A^{(1)}$, $A^{(2)}$, …, $A^{(M)}$ if the condition C1 is not satisfied; $A^{(M)}$ is determined by the relation $Q(A^{(M)}) - Q(A^{(1)}) < DQ$ for maximum $M$ (the positions of these alternatives are "in closeness").

As an application, the proposed model has been applied to select the cruise port place in Istanbul. The steps of the solution process can be defined as in follows:

Four alternative places (Haydarpaşa, Tuzla, Ataköy, Sarayburnu)

A committee of three decision makers, D1, D2 and D3, has been formed to select the most suitable place with the criteria.

The research model shown in Figure 1 is used.

Three decision makers use the linguistic weighting variables to assess the importance of the criteria. The importance weights of the criteria determined by these three decision makers are shown in Table III. Also the decision makers use the linguistic rating variables to evaluate the ratings of candidates with respect to each criterion. The ratings of the four place alternatives by the decision makers under the various criteria are shown in Table IV.

The linguistic evaluations shown in Tables III and Table IV are converted into trapezoidal fuzzy numbers. Then the aggregated weight of criteria and aggregated fuzzy rating of alternatives is calculated to construct the fuzzy decision matrix and determine the fuzzy weight of each criterion, as in Table V.

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TABLE III
IMPORTANCE WEIGHT OF CRITERIA FROM THREE DECISION MAKERS

| Criteria | Decision makers | | |
|---|---|---|---|
| | D1 | D2 | D3 |
| Strategic conditions | H | H | VH |
| Technical conditions | H | H | MH |
| Economic conditions | M | M | ML |
| Social conditions | ML | M | ML |

TABLE IV
RATINGS OF THE FOUR ALTERNATIVE PLACES BY THE DECISION MAKERS UNDER THE VARIOUS CRITERIA

| | Alternatives | Criteria | | | |
|---|---|---|---|---|---|
| | | Strategic cond. | Technical cond. | Economic cond. | Social cond. |
| D1 | Haydarpaşa | P | P | P | G |
| | Tuzla | G | MP | MP | P |
| | Sarayburnu | P | P | P | G |
| | Ataköy | VG | VG | VP | M |
| D2 | Haydarpaşa | P | P | MP | MG |
| | Tuzla | MG | M | M | P |
| | Sarayburnu | P | P | MP | MG |
| | Ataköy | G | G | P | M |
| D3 | Haydarpaşa | MP | MP | P | MG |
| | Tuzla | MG | MP | M | MP |
| | Sarayburnu | MP | MP | P | MG |
| | Ataköy | VG | VG | P | MP |

TABLE VI
CRISP VALUES FOR DECISION MATRIX AND WEIGHT OF EACH CRITERIA

| | Criteria | | | |
|---|---|---|---|---|
| | Strategic cond. | Technical cond. | Economic cond. | Social cond. |
| **Weight** | **0.88** | **0.73** | **0.43** | **0.40** |
| Haydarpaşa | 0.28 | 0.28 | 0.28 | 0.60 |
| Tuzla | 0.60 | 0.40 | 0.43 | 0.28 |
| Sarayburnu | 0.28 | 0.28 | 0.28 | 0.60 |
| Ataköy | 0.88 | 0.88 | 0.15 | 0.43 |

The crisp values for decision matrix and weight of each criterion are computed as shown in Table VI.

The best and the worst values of all criterion ratings are determined as follows:

| | | | |
|---|---|---|---|
| $f_1^* = 0.88$ | $f_2^* = 0.88$ | $f_3^* = 0.43$ | $f_4^* = 0.60$ |
| $f_1^- = 0.28$ | $f_2^- = 0.28$ | $f_3^- = 0.15$ | $f_4^- = 0.28$ |

The value of S, R and Q are calculated for all alternative places as Table VII.

TABLE VII
THE VALUES OF S, R AND Q FOR ALL ALTERNATIVE PLACES

| | Alternatives | | | |
|---|---|---|---|---|
| | Haydarpaşa | Tuzla | Sarayburnu | Ataköy |
| S | 1.84 | 1.39 | 1.84 | 0.64 |
| R | 0.88 | 0.58 | 0.88 | 0.43 |
| Q | 1.00 | 0.51 | 1.00 | 0.07 |

The ranking of the alternative firms by S, R and Q in decreasing order is shown in Table VIII.

TABLE VIII
THE RANKING OF THE ALTERNATIVE PLACES BY S, R AND Q IN DECREASING ORDER

| | Ranking alternatives | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| By S | **Ataköy** | Tuzla | Sarayburnu | Haydarpaşa |
| By R | **Ataköy** | Tuzla | Sarayburnu | Haydarpaşa |
| By Q | **Ataköy** | Tuzla | Sarayburnu | Haydarpaşa |

Due to the extended fuzzy VIKOR method, Ataköy is the most suitable place for a cruise port and the alternative places after Ataköy are Tuzla, Sarayburnu and Haydarpaşa according to Q value, respectively.

## VI. CONCLUSION

The analytic network process (ANP) is a simple mathematically based multi-criteria decision making tool to deal with unstructured and multi-attribute problems and it allows for more complex interrelationships among decision levels and attributes. On the other hand, the VIKOR method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. It determines a compromise solution that could be accepted by the decision makers. For these reasons, in this paper ANP and extended VIKOR approaches have been presented under the fuzzy environment to select the most suitable place for a cruise port in Istanbul. The results of different place alternatives produced fuzzy ANP and extended fuzzy VIKOR have been compared.

In conclusion, according to the final score both fuzzy ANP and extended fuzzy VIKOR analysis, Ataköy is the most suitable place for a new cruise port in Istanbul. On the basis of the numerical results, we can conclude that the proposed methods can soundly deal with the structural multi-criteria decision making problem with our criteria and sub-criteria.

TABLE V
AGGREGATED FUZZY WEIGHT OF CRITERIA AND AGGREGATED FUZZY RATING OF ALTERNATIVES

| | Criteria | | | |
|---|---|---|---|---|
| | Strategic conditions | Technical conditions | Economic conditions | Social conditions |
| **Weight** | **(0.70, 0.83, 0.87, 1.00)** | **(0.40, 0.57, 0.63, 0.80)** | **(0.20, 0.43, 0.47, 0.60)** | **(0.10, 0.27, 0.33, 0.50)** |
| Haydarpaşa | (0.10, 0.23, 0.27, 0.50) | (0.10, 0.23, 0.27, 0.50) | (0.10, 0.23, 0.27, 0.50) | (0.40, 0.57, 0.63, 0.80) |
| Tuzla | (0.40, 0.57, 0.63, 0.80) | (0.10, 0.27, 0.33, 0.50) | (0.20, 0.43, 0.47, 0.60) | (0.10, 0.23, 0.27, 0.50) |
| Sarayburnu | (0.10, 0.23, 0.27, 0.50) | (0.10, 0.23, 0.27, 0.50) | (0.10, 0.23, 0.27, 0.50) | (0.40, 0.55, 0.63, 0.80) |
| Ataköy | (0.70, 0.83, 0.87, 1.00) | (0.70, 0.83, 0.87, 1.00) | (0.00, 0.13, 0.17, 0.30) | (0.20, 0.43, 0.47, 0.60) |

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