Using Decision Making Method for Construction Project Management Selection Based VIKOR under Fuzzy Environment

Safar Fazli

Abstract—The nature of manager selection is a complex multi-criteria problem including both quantitative and qualitative factors which may be in conflict and may also be uncertain. The complexity and importance of the problem call for analytical methods rather than intuitive decisions. On the other hand many individual attributes considered for manager selection; such as personality, and leadership exhibit vagueness and imprecision, therefore fuzzy set theory appears as an important tool to provide a decision framework that incorporates imprecise judgments inherent in the manager selection process. In this paper, a multi criteria decision making model based on fuzzy sets theory and VIKOR method is proposed to deal with the construction project manager selection problems. Then a suitable management was elected for Karaj municipality construction projects through a practical experience, using the proposed model. The results indicate that most capable person could be elected via the framework of group decision making process, using this model.

Keywords—Manager Selection, Multi Criteria Decision Making, Linguistic Variable, Fuzzy VIKOR, Construction Project Management.

I. INTRODUCTION

In the wake of increasingly competitive world market the future survival of most companies, depends mostly on the dedication of their personnel to companies. Employee or personnel performances such as capability, knowledge, skill, and other abilities play an important role in the success of an organization. The main goal of organizations is to seek more powerful ways of ranking of a set employee or personnel who have been evaluated in terms of different competencies [6]. Personnel selection is the process of choosing individuals who match the qualifications required to perform a defined job in the best way. It determines the input quality of personnel and plays a decisive role in human resource management [5]. Management policies, processes, tools and structures play a critical role on how to exploit the opportunities and avoid the threats. Above all, people that apply management have the key role. Managers at every level (tactical, operational and strategic) are those who design, develop, lead the implementation and assess the policies, processes, tools and structures. Managers’ decisions determine the development and sustainability or the failure and collapse of an organization. Thus, it is an essential parameter for managers to have the necessary knowledge and skills in order to deal with the challenges of the contemporary business settings. Knowledge and skills as outputs of formal education, experience or personal characteristics comprise the basis for proper management behaviors. Improved management skills can be achieved through training and development programs inside an organization, as well as through experience in practice. Nevertheless, the initial and decisive step is the selective selection of those managers that possess at a minimum extent a number of contemporary management skills [10]. Since the purpose of this research is presenting a method for selection of a suitable construction project manager, we terminate discussion about manager selection on project manager selection.

Project management is applying knowledges, skills, tools and technologies in activities of project to satisfy and Outshine stakeholders of project's needs and expectations. Compliance and Outshining shareholder of project's needs and expectations certainly need a competitive balance between:

- Time, quality and cost
- Stakeholders with different needs and expectations
- Recognized and un recognized expectations

In recent years, the number of construction projects has been growing rapidly. Therefore, it is very important to find the right project managers for such projects. It has become a major task in project implementation. All stakeholders, consultants, and contractors are looking for a few good project managers available. They are indeed hard to find and even a search firm is hardly capable of finding the suitable staff even though the target candidate (a good project manager) can practically write his own pay. This paper presents the analysis of matching managers to construction projects.

The construction process is risky and its success largely depends on the choice of the right project manager. Project manager influence on construction process is shown in Figure 1.

Every building project differs in place, size, time, cost, etc. Zavadskas and his coworker have studied twelve articles that were related to construction project manager selection.
They have identified 20 factors as effective factors for construction project manager selection [19]:

1. Education level
2. Age
3. Insufficient time spent in family
4. Gender
5. Personal skills
6. Dependability
7. Experience (in similar projects)
8. Self views
9. Self relevant goals
10. Paperwork
11. Job stress
12. Pay
13. Problem specification, selection, analysis of alternatives
14. Conceptual and organizational skills
15. Project management skills
16. Business skills (markets)
17. Technical skills
18. Appropriate computer tools developed
19. Control
20. Quality

It must be noted that using the criteria could result in selecting a project manager for the wrong reasons. Collins states: "The process focuses on the premise that a successful project manager must master two primary skill sets: the project manager's technical skills and leadership skills.

Technical skills mentioned by Collins include the following items: integration management, scope management, time management, cost management, quality management, risk management and procurement management. Leadership skills include items like individual influence, integrity, strategic leadership, teamwork and collaboration, communication and tenacity. He concludes: "As these [project managers] continue to improve, they can become more proficient in the role and assume a broader spectrum of complex projects. Lorda and Brown define self-concept as a broad amalgam of knowledge, experience, self views and possible selves, self relevant goals that individuals see as self relevant or self descriptive".

Taking into account the above mentioned, the aim of this paper is to propose a new approach towards construction project managers’ selection problem. Highlighting the complexity of this problem, we consider its multi dimensions. Multi criteria decision making (MCDM) methods and fuzzy logic ideally cope with it, given that they incorporate many criteria at the same time, each of them assigned to different importance level. Also, fuzzy logic has the potential to reflect at a very satisfactory degree the vague – most of the times – preferences of the decision makers.

The rest of the paper is organized as follows: In the next section, comments on the recent literature are summarized as concerns the human resources selection problem. Given the limitations and deficiencies of the current approaches, Section 3 provides the basic concepts of fuzzy logic and VIKOR multi criteria decision support method, based on which a new approach is presented in Section 4, supporting the decision making on managers’ selection. In Section 5, a real-life application is demonstrated while conclusions and potential future steps are discussed in Section 6.

II. LITERATURE REVIEW

Tools and techniques from operational research and artificial intelligence fields have been used to cope with this specific decision problem. Fuzzy sets and numbers, expert systems, artificial neural networks and multi criteria decision analysis techniques lie among them.

In literature, there exist numerous studies conducted with the aim of performing personnel selection within the boundaries of objective criteria. Miller and Feinzig (1993) suggested the fuzzy sets theory for the personnel selection problem [12]. Liang and Wang developed an algorithm which also uses the fuzzy sets theory [11]. In this algorithm, subjective criteria, such as personality, leadership, and past experience, along with some objective criteria, such as general aptitude, and comprehension were made use of. Karsak modeled personnel selection process by using fuzzy multiple criteria programming and evaluated qualitative and quantitative factors together via membership functions in this model [8]. Gungor, Serhadioglu, and Kesen have developed a personnel selection system based on fuzzy analytic hierarchy process [6]. The result obtained by FAHP was compared with results produced by Yeager's weighted goals method. Huang, Chiu, Yeh and Chang proposed a bi-objective binary integer programming (BOBIP) model for personnel selection problem [7]. Celik, Kandakoglu and Er proposed fuzzy integrated multi-stages evaluation model (FIMEM) under multiple criteria in order to manage the academic personnel selection and development processes in Maritime Education and Training (MET) institutions [3].

Kelemenis and Askounis proposed a multi criterion method based on TOPSIS to solve CIO selection problems [9]. In this study, fundamental criteria were strategy formulation/strategic decision making, change management/ change adaptability, communication/interpersonal skill, leadership, risk/crisis
management, computer networks, software tools, databases, professional experience, educational background, emerging/new technologies. They incorporated also introduced a new concept based on the TOPSIS threshold, a critical characteristic of the main outranking methods and combined it with TOPSIS method. Recently Dursun and Karsak developed a fuzzy multi-criteria decision making (MCDM) algorithm using the principles of fusion of fuzzy information, 2-tuple linguistic representation model, and technique for order preference by similarity to ideal solution (TOPSIS) for industrial engineering selection problem [5]. Also Kelemenis, Ergazakis and Askounis proposed a multicriteria approach based on fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for group decision making [10].

III. VIKOR METHOD

Opricovic (1998), Opricovic and Tzeng (2002) developed VIKOR, the Serbian name: VlseKriterijuemska Optimizacija I Kompromisno Resenje, means multi-criteria optimization and compromise solution [15]. The VIKOR method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. Practical problems are often characterized by several non-commensurable and conflicting (competing) criteria, and there may be no solution satisfying all the criteria simultaneously. The compromise solution, whose foundation was established by Yu and Zeleny, is a feasible solution, which is the closest to the ideal, and here “compromise” means an agreement established by mutual concessions [18]. The VIKOR method determines the compromise ranking list and the compromise solution by introducing the multi criteria ranking index based on the particular measure of “closeness” to the “ideal” solution [16]. Assuming that each alternative is evaluated according to each criterion function, the compromise ranking could be performed by comparing the measure of closeness to the ideal alternative. The multi criteria measure for compromise ranking is developed from the Lp-metric used as an aggregating function in a compromise programming method [13]. The various m alternatives are denoted as A1, A2, ..., Am. For alternative Ai, the rating of the jth aspect is denoted by fjij, i.e. fjij = fij the value of jth criterion function for the alternative Ai; n is the number of criteria. Development of the VIKOR method started with the following form of Lp-metric [14]:

\[ L_p = \left( \sum_{j=1}^{n} w_j \left( f_{ij} - f_{ij}^* \right)^p \right)^{1/p} \]

1 ≤ p ≤ ∞ ; i = 1, 2, ..., m

Within the VIKOR method L1, (as Si in Eq. (2)) and L∞ (as Ri in Eq. (3)) are used to formulate ranking measure.

\[ S_i = \sum_{j=1}^{n} w_j \left( f_{ij}^* - f_{ij} \right) \left/ \left( f_{ij}^* - f_{ij}^* \right) \right. \]

\[ R_i = \max_j \left( w_j \left( f_{ij}^* - f_{ij}^* \right) \left/ \left( f_{ij}^* - f_{ij}^* \right) \right. \right) \]

The solution obtained by mini Si is with a maximum group utility (“majority” rule),and the solution obtained by mini Ri is with a minimum individual regret of the “opponent”. The compromise solution Fc is a feasible solution that is the “closest” to the ideal F*, and compromise means an agreement established by mutual concessions, as is illustrated by:

\[ \Delta f_1 = f_1^* - f_1^* \]

\[ \Delta f_2 = f_2^* - f_2^* \]

Also TOPSIS, another MCDM method, is based on aggregating function representing “closeness to ideal”. In TOPSIS the chosen alternative should have the “shortest distance” from the ideal solution and the “farthest distance” from the “negative-ideal”. The TOPSIS method introduces two reference points, but it does not consider the relative importance of the distances from these points. These two MCDM methods use different kinds of normalization to eliminate the units of the criterion functions, whereas the VIKOR method uses linear normalization, the TOPSIS method uses vector normalization. The normalized value in the VIKOR method does not depend on the evaluation unit of criterion function, whereas the normalized values by vector normalization in the TOPSIS method may depend on the evaluation unit [14].

IV. FUZZY APPROACH

Professor L.A. Zadeh developed the fuzzy set theory in 1965 while trying to solve problems of fuzzy phenomena existing in the real world, which refer to situations that are uncertain, about which the information is incomplete, or that behave in unpredictable ways. Fuzzy set theory is much better suited than traditional set theory to expressing set concepts in human language. Fuzzy set theory presents unspecific and fuzzy characteristics in relatively clear language, and it represents a field using a membership function that permits situations like “incompletely belong to” and “incompletely not belong to” [17]. The key concept behind this definition is that of “membership”: any object may be a member of a set “to some degree”; and a logical proposition may hold true”to some degree”. Each element in a set is associated with a value indicating to what degree the element is a member of the set. This value comes within the range [0, 1], where 0 and 1, respectively, indicate the minimum and maximum degree of membership, while all the intermediate values indicate degrees of “partial” membership [2].

V. PROPOSED APPROACH FOR PERSONNEL SELECTION BASED ON FUZZY VIKOR

A systematic approach to extend the VIKOR is proposed to solve the supplier selection problem under a fuzzy environment in this section. In this paper the importance weights of various criteria and the ratings of qualitative criteria are considered as linguistic variables. Because
linguistic assessments merely approximate the subjective judgment of decision makers, we can consider linear trapezoidal membership functions to be adequate for capturing the vagueness of these linguistic assessments.

In fact, supplier selection in supply chain system is a group multiple criteria decision making (GMCDM) problem, which may be described by means of the following sets [15]:

(1) A set of K decision makers called \( E = \{ D_1, D_2, \ldots, D_K \} \).

(2) A set of m candidates for specified job called \( A = \{ A_1, A_2, \ldots, A_m \} \).

(3) A set of n criteria, \( C = \{ C_1, C_2, \ldots, C_n \} \), with which candidates performances are measured;

(4) A set of performance ratings of \( A_i \), \( i = 1, 2, \ldots, m \), with respect to criteria \( C_j \), \( j = 1, 2, \ldots, n \); are linguistic variables can be approximated by positive triangular fuzzy numbers [15].

The main steps of the algorithms are:

5.1 Arrange the decision making group and define and describe a finite set of relevant attributes;

5.2 Identify the appropriate linguistic variables;

In this step we must define the appropriate linguistic variables for the importance weight of criteria, and the fuzzy rating for alternatives with regard to each criterion

5.3 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 weight of criteria, and aggregated fuzzy rating of the alternatives be:

\[ f_\tilde{j}(f_{ij1}, f_{ij2}, f_{ij3}) \] and \( \tilde{w}_{ij}=(\tilde{w}_{ij1}, \tilde{w}_{ij2}, \tilde{w}_{ij3}) \); \( i : 1, 2, \ldots, m; j : 1, 2, \ldots, n \); are linguistic variables can be approximated by positive triangular fuzzy numbers [15].

5.4 Defuzzify the fuzzy decision matrix and fuzzy weight of each criterion into crisp values: Let \( \Lambda = (a_1, a_2, a_3) \) is triangular fuzzy number then crisp value of it can be calculated as follow [4]:

\[ \text{defuzz}(\tilde{x}) = \frac{a_1 + 2a_2 + a_3}{4} \] (6)

5.5 Determine the best \( f_j^* \) and the worst \( f_j^- \) a values of all criterion ratings, \( j = 1, 2, \ldots, n \);

\[ f_j^* = \max_{i \in \Lambda} f_{ij}, \quad f_j^- = \min_{i \in \Lambda} f_{ij}; \quad \text{if the j-th function represents a benefit} \]

\[ f_j^* = \min_{i \in \Lambda} f_{ij}, \quad f_j^- = \max_{i \in \Lambda} f_{ij}; \quad \text{if the j-th function represents a cost}. \]

5.6 Compute the \( S_j \) and \( R_j \) values for i=1, 2, \ldots, m, which represent the average and the worst group scores for the alternative \( A_i \) respectively, with the relations

\[ S_j = \frac{1}{w_j} \sum_{i=1}^{m} (f_j^* - f_{ij}) / (f_j^* - f_j^-), \quad S_j \in [0,1] \]

\[ R_j = \max_{i \in \Lambda} \left[ \frac{w_{ij}}{f_j^* - f_j^-} \right], \quad R_j \in [0,1] \]

Here \( w_j = \sum_{i=1}^{m} w_{ij} \in [0,1], j = 1, \ldots, n \) are the relative importance weights of the criteria set by the DM.

The smaller values of \( S_j \) and \( R_j \) correspond to the better average and the worse group scores for the alternative \( A_i \) respectively [1].

5.7 Compute the values \( Q_i \) by the relation:

\[ Q_i = \frac{\nu(S_i - S^*) + (1-\nu)(R_i - R^*)}{S^* - S^*}, \]

(9)

Where \( S^* = \min S_j, \quad S^* = \max S_j, \quad R^* = \min R_j, \quad R^* = \max R_j \) and \( \nu \) is introduced as weight of the strategy of "the majority of criteria", here \( \nu=0.5 \).

5.8 Rank the alternatives, sorting by the values \( S, R \) and \( Q \) in decreasing order. The results are three ranking lists.

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

\( C_1 \). Acceptable advantage:

\[ Q(A^{(2)}) - Q(A^{(1)}) \geq DQ \]

Where \( A^{(2)} \) is the alternative with second position in the ranking list by \( Q \);
DQ = 1 / (m − 1)

C3: Acceptable stability in decision making:
The alternative A(i) 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=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 consists of:
- Alternatives A(1) and A(2) if only the condition 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:

\[ Q(A(m))_R < DQ \]

For maximum m (the positions of these alternatives are “in closeness”).

VI. APPLICATION OF PROPOSED MODEL FOR CONSTRUCTION PROJECT MANAGER SELECTION

Different projects require different skills and capabilities on the part of the project manager. All stakeholders, consultants, and contractors are looking for a few good project managers available. They are indeed hard to find and even a search firm is hardly capable of finding the suitable staff even though the target candidate (a good project manager) can practically write his own pay. This paper presents the analysis of matching managers to construction projects [2].

Karaj municipality wants to select a project manager for curb making of some part of the city.

The proposed model has been applied to a construction project manager process of Karaj municipality in the following steps:

Step 1: Different people were introduced to Karaj municipality for incumbency of project management, after Primal screening, three candidates remained that were introduced to council of city. Then a committee composed of four people from council of city was shaped to select the best project manager. According to scientific studies six criteria were selected as below:

C1: Personal skills, C2: Project management skills, C3: Business skills, C4: Technical skills, C5: Quality control skills C6: Experience (in similar projects)

Step 2: Four decision makers use the linguistic weighting variables shown in Table 1 to assess the importance of the criteria. The importance weights of the criteria determined by these three decision makers are shown in Table 2. The ratings of the three candidates by the decision makers under the various criteria are shown in Table 3.

TABLE I
IMPORTANCE WEIGHT OF CRITERIA FROM FOUR DECISION MAKERS

<table>
<thead>
<tr>
<th>decision makers</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>H</td>
<td>VH</td>
<td>VH</td>
<td>H</td>
</tr>
<tr>
<td>C2</td>
<td>M</td>
<td>VH</td>
<td>H</td>
<td>VH</td>
</tr>
<tr>
<td>C3</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>C4</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>C5</td>
<td>VH</td>
<td>H</td>
<td>VH</td>
<td>VH</td>
</tr>
</tbody>
</table>

TABLE II
RATINGS OF THE THREE CANDIDATES BY THE DECISION MAKERS UNDER THE VARIOUS CRITERIA

<table>
<thead>
<tr>
<th>criteria candidates</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>VG</td>
<td>G</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>C2</td>
<td>F</td>
<td>G</td>
<td>P</td>
<td>G</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C3</td>
<td>G</td>
<td>VG</td>
<td>F</td>
<td>G</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C4</td>
<td>G</td>
<td>VG</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>C5</td>
<td>F</td>
<td>G</td>
<td>G</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>C6</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

Step 3: The linguistic evaluations shown in Tables 1 and 2 are converted into triangular 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 Tables 3.

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

<table>
<thead>
<tr>
<th>criteria</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.51</td>
<td>0.85</td>
<td>0.75</td>
<td>0.51</td>
<td>0.85</td>
<td>0.51</td>
</tr>
<tr>
<td>A1</td>
<td>(0.6, 0.85, 1)</td>
<td>(0.5, 0.85, 1)</td>
<td>(0.3, 0.85, 1)</td>
<td>(0.5, 0.7, 0.8)</td>
<td>(0.3, 0.5, 0.7)</td>
<td>(0.3, 0.8, 1)</td>
</tr>
<tr>
<td>A2</td>
<td>(0.3, 0.65, 1)</td>
<td>(0.3, 0.65, 1)</td>
<td>(0.3, 0.65, 1)</td>
<td>(0.3, 0.65, 1)</td>
<td>(0.3, 0.65, 1)</td>
<td>(0.3, 0.65, 1)</td>
</tr>
</tbody>
</table>

Step4: The crisp values for decision matrix and weight of each criterion are computed as shown in Table 4.

TABLE IV
CRISP VALUES FOR DECISION MATRIX AND WEIGHT OF EACH CRITERION

<table>
<thead>
<tr>
<th>criteria</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.8</td>
<td>0.72</td>
<td>0.52</td>
<td>0.56</td>
<td>0.83</td>
<td>0.8</td>
</tr>
<tr>
<td>A1</td>
<td>0.67</td>
<td>0.54</td>
<td>0.61</td>
<td>0.67</td>
<td>0.65</td>
<td>0.7</td>
</tr>
<tr>
<td>A2</td>
<td>0.65</td>
<td>0.73</td>
<td>0.71</td>
<td>0.61</td>
<td>0.61</td>
<td>0.82</td>
</tr>
<tr>
<td>A3</td>
<td>0.71</td>
<td>0.71</td>
<td>0.82</td>
<td>0.5</td>
<td>0.69</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Step 5: The best and the worst values of all criterion ratings are determined as follows:

\[ f^+ = \max \{ 0.67, 0.65, 0.71 \} = 0.71, f^- = \min \{ 0.67, 0.65, 0.71 \} = 0.65, \]

\[ f^+ = \max \{ 0.54, 0.73, 0.71 \} = 0.73, f^- = \min \{ 0.54, 0.73, 0.71 \} = 0.54 \]
\[ f_1^* = \max \{0.61, 0.71, 0.82\} = 0.82, f_1 = \min \{0.61, 0.71, 0.82\} = 0.61 \]
\[ f_2^* = \max \{0.67, 0.61, 0.5\} = 0.67, f_2 = \min \{0.67, 0.61, 0.5\} = 0.5 \]
\[ f_3^* = \max \{0.65, 0.61, 0.69\} = 0.69, f_3 = \min \{0.65, 0.61, 0.69\} = 0.61 \]
\[ f_4^* = \max \{0.7, 0.82, 0.82\} = 0.82, f_4 = \min \{0.7, 0.82, 0.82\} = 0.7 \]

Steps 6: The values of S, R and Q are calculated for all candidates as Table 5

<table>
<thead>
<tr>
<th>TABLE V</th>
<th>THE VALUES OF S, R AND Q FOR ALL CANDIDATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>candidates</td>
<td>A_1</td>
</tr>
<tr>
<td>S</td>
<td>2.98</td>
</tr>
<tr>
<td>R</td>
<td>0.8</td>
</tr>
<tr>
<td>Q</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Step 7: The ranking of the candidates by S, R and Q in decreasing order is shown in Table 6.

<table>
<thead>
<tr>
<th>TABLE VI</th>
<th>THE RANKING OF THE CANDIDATES BY S, R AND Q IN DECREASING ORDER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranking candidates</td>
<td>1</td>
</tr>
<tr>
<td>By S</td>
<td>A_3</td>
</tr>
<tr>
<td>By R</td>
<td>A_3</td>
</tr>
<tr>
<td>By Q</td>
<td>A_2</td>
</tr>
</tbody>
</table>

Step 8: As we see in Table 6, the candidate A_3 is the best ranked by Q. Also the conditions C_1 and C_2 are satisfied
\[ (Q(A^{(2)})) - Q(A^{(1)}) = 0/81 - 0 = 0/81 \geq 1/3 - 1 = 1/2 \]
and A_3 is best ranked by R and S). So A_3 is the best choice.

VII. CONCLUSION AND SUGGESTIONS

In this paper an extension of the VIKOR, a recently introduced MCDM method, in fuzzy environment is proposed to deal with the both qualitative and quantitative criteria and select the suitable construction project manager effectively. It appears this method has some advantages which may be useful in dealing with construction project management selection problem. The proposed method is very flexible. Using this method not only enables us to determine the outranking order of candidates, but also assess and rate the candidates. These rating can be used in combination with mathematical programming and other methods to deal with construction project manager selection in multiple sourcing environments.

Also the proposed method for construction project manager selection in fuzzy environment provides a systematic approach which can be easily extend to deal with other management decision making problems. In the future research, similar studies can be conducted based on different multi-criteria decision-making techniques such as fuzzy PROMETHEE, fuzzy ELECTRE or fuzzy TOPSIS for comparative purposes.

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