**Supplier Selection for Construction Projects Through ‘TOPSIS’ and ‘VIKOR’ Multi-Criteria Decision Making Methods**

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Abstract--Materials constitute 60% in total cost of the project. Cement contributes for 10 to 15% of the total materials cost. Selecting a best supplier for supply of cement is very crucial for profit making and further achieving success of any construction project. In recent times, there has been a trend not to select a supplier who is having lowest bid offer. Multi-criteria approach is quite effective to select a best supplier. In this paper, seven criteria such as quality, cost, delivery time, technical capability, financial capability, commercial and managerial capability and trust are considered. Relative weights of criteria in the form of criteria weights are generated through Analytic Hierarchy Process (AHP). Then, Technique for order preference by similarity to ideal solution (TOPSIS) and Visekriterijumska Optimizacija I Kompromisno Resenje (VIKOR) methods are applied for best supplier selection. The results show that one of the suppliers is ranked first by both the methods. Being the highest ranked supplier by the TOPSIS method, it shows that this supplier is the best in terms of the ranking index. As the same supplier is highest ranked by VIKOR method, it shows that it is the closest to the ideal solution. Such innovative approach can bring profit maximization and quality enhancement of construction projects.

Keywords--Supplier selection; Multi criteria methods; Analytic Hierarchy Process; TOPSIS; VIKOR

I. INTRODUCTION

Material component is more than 60% of the total cost in any construction project. Construction companies have to follow strategies to get better quality material at most economical rate with shortest lead time. Hence, supplier plays a key role in achieving success of the project. Supplier selection is a crucial strategic decision which brings long term impact on company’s efficiency and profitability. The main objective of supplier selection process is to reduce purchase risk, maximize overall value to the purchaser and develop closeness and long-term relationships between buyers and suppliers [15]. Supplier selection depends upon several conflicting factors such as: Quality, cost, delivery time, technical capability, financial capability etc. Hence, it is a multi criteria decision making problem. More research is needed to suggest best supplier due to increasing complexity of projects, increasing expectations of owners, more competition and higher performance expectations. Several methods, such as Analytic Hierarchy Process [1], Analytic Network Process (ANP) [14], linear weighting methods [18] and total cost approach [12] have helped decision makers to deal with supplier selection problem. While selecting the supplier, his information is not always precisely studied and hence decision making could prove to be wrong. Most of the construction companies are selecting the supplier based on few criteria and that too without use of any scientific technique. Cement is one of the most important of all construction materials. It contributes for 10 to 15% of total material cost in any construction project [3]. Quality of the structure largely depends on quality of cement. Hence, best supplier selection for purchase of cement is the most crucial decision in any construction project. This paper uses three multi criteria decision making techniques such as: Analytic Hierarchy Process (AHP), Technique for order preference by similarity to ideal solution (TOPSIS) and Visekriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method for best supplier selection for purchase of cement in construction project.

II. LITERATURE REVIEW

In this paper AHP technique is integrated with ‘TOPSIS’ and ‘VIKOR’ methods for supplier selection in construction project for purchase of cement. In next section of “Methodology”, the TOPSIS and VIKOR methods are elaborately explained.

III. METHODOLOGY

In recent past, many researchers have used ‘TOPSIS’ and ‘VIKOR’ methods for decision making of supplier selection problem [21]. Use of these two methods can help for best supplier selection on the basis of different criteria while considering their relative importance. The TOPSIS method determines the solution by giving the shortest distance from the ideal solution and with the greatest distance from the negative-ideal solution, while not considering the relative importance of these distances. The VIKOR method determines ranking of the criteria based on the particular measure of “closeness” to the ideal solution [13]. The compromise solution is a feasible solution that is the “closest” to the ideal solution, and compromise means an agreement established by mutual concessions.

A. TOPSIS Method

Technique for order preference by similarity to ideal solution (TOPSIS) was first introduced by Hwang and Yoon [7] with an idea to offer an alternative for elimination and choice expressing the “ideal solution, and compromise means an agreement established by mutual concessions.

Step 1: Prepare a decision matrix as given below:

\[
D = \begin{bmatrix}
A_1 & X_{11} & X_{12} & \ldots & X_{1n} \\
A_2 & X_{21} & X_{22} & \ldots & X_{2n} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
A_n & X_{n1} & X_{n2} & \ldots & X_{nn}
\end{bmatrix}
\]

Here,

\(A_i = i^{th}\) alternative supplier

\(X_{ij} = \) Numerical evaluation outcome for \(i^{th}\) supplier with respect to \(j^{th}\) criterion

Step 2: Calculate the normalized decision matrix with following formula:

\[
r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x_{ij}^2}} \quad j = 1,2,\ldots,n \quad \text{and} \quad i = 1,2,\ldots,m
\]

where \(j\) = number of alternatives ; \(i\) = number of criteria; and \(x_{ij}\) = value of the \(j^{th}\) alternative for the \(i^{th}\) criterion.

Step 3: Construct the weighted normalized decision matrix by multiplying the normalized decision matrix with its associated weights which are derived by Analytic Hierarchy Process. The weighted normalized value \(v_{ij}\) is calculated as:

\[
v_{ij} = w_{ij} r_{ij}
\]

where \(w_{ij}\) = weight of the \(i^{th}\) criterion

Step 4: Determine the positive ideal solution and negative ideal solution.

\[
A^+ = \{v_{1i}^+, \ldots, v_{ni}^+\} = \{(\max_{j} x_{ij} | i \in I'), (\min_{j} x_{ij} | i \in I')\}
\]

\[
A^- = \{v_{1i}^-, \ldots, v_{ni}^-\} = \{(\min_{j} x_{ij} | i \in I'), (\max_{j} x_{ij} | i \in I')\}
\]

Step 5: Calculate the separation measure. The separation of each alternative from the positive ideal one is given by:

\[
S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{ij}^+)^2}
\]

where \(i = 1,2,3,\ldots,m\)

Similarly, the separation of each alternative from the negative ideal one is given by:

\[
S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{ij}^-)^2}
\]

Step 6: Calculate the relative closeness with the ideal solution. The relative closeness of \(A_i\) with respect to \(A^+\) is defined as:

\[
C_i^+ = S_i^- / (S_i^+ + S_i^-) \quad 0 \leq C_i^+ \leq 1
\]

where \(i = 1,2,3,\ldots,m\)

Larger the \(C_i^+\) value better is the performance of the alternatives. Rank the alternatives by the value of \(C_i^+\) in decreasing order. Propose the alternative that is the best ranked by the measure.

B. VIKOR Method

Všeobecněji úzkeho Optimizace I Kompromisnoro Resenje (VIKOR) method works on the basis of the particular measure of closeness to the positive ideal solution. It gives a compromise solution that is the ‘closest’ to the ideal solution, where compromise means an agreement established by mutual concessions [5]. VIKOR method has following four steps as given by Opricovic and Tzeng [13]:

Step 1: Determine the best and worst values, which are known as positive ideal and negative ideal solutions:

\[
f_i^* = \max_j f_{ij} \quad \text{and} \quad \hat{f_i} = \min_j f_{ij}
\]

and if \(i^{th}\) function represents cost, then, \(f_i^* = \min_j f_{ij}\) and \(\hat{f_i} = \max_j f_{ij}\)

where \(f_{ij}\) = value of the \(j^{th}\) alternative for the \(i^{th}\) criteria.

Step 2: Calculate the values of \(S_i\) and \(R_i\) by following equations:
\[ S_j = \sum_{i=1}^{n} w_i (f_i^* - f_j) / (f_i^* - f_i) \]  
\[ R_j = \max_i \left[ w_i (f_i^* - f_j) / (f_i^* - f_i) \right] \]

Here, \( S_j \) is the maximum group of utility of the majority of alternative \( j \); \( R_j \) is a minimum of individual regret of the opponent of alternative \( j \) and \( w_i \) is the weight of the criteria, which expresses the expert’s opinion regarding relative importance of the criteria.

Step 3: Calculate the following values:
\[ S' = \min S_j; S = \max S_j; R' = \min R_j; R = \max R_j \]
\[ Q = v(S' - S') / (S - S') + (1 - v)(R' - R') / (R - R) \]  

\( v \) is introduced as a weight for the strategy of maximum group utility, whereas \( 1 - v \) is weight of individual regret. The solution obtained by \( \min S_j \) is with a maximum group utility and the solution obtained by \( \min R_j \) is with a minimum individual regret of the opponent. The value of \( v \) is taken as 0.5 however it can be taken from 0 to 1.

Step 4: Rank the alternatives, sorting by the values of \( S, R \) and \( Q \) in decreasing order. The results are three ranking lists. Propose as a compromise solution the alternative \( A^{(1)} \) which is the best ranked by the measure \( Q \) (minimum).

If one of the above conditions is not satisfied, then a set of compromise solutions is proposed which is given as below:

3. Alternative \( A^{(1)} \) and \( A^{(2)} \) if only condition 2 is not satisfied, or Alternatives \( A^{(1)}, A^{(2)}, \ldots, A^{(m)} \) if the condition 1 is not satisfied. \( A^{(m)} \) is determined by the relation \( Q [A^{(m)}] - Q [A^{(1)}] < DQ \) for maximum \( n \); the positions of these alternatives are “in closeness”.

IV. CASE STUDY

Cement is the major building material which is required for every construction project. It consists almost 20% of total material cost of the project. There are various companies in the market which manufactures good quality cement. In this study, cement supplier selection problem is solved through ‘TOPSIS’ and ‘VIKOR’ method. ‘TOPSIS’ and ‘VIKOR’ methods were used along with Analytic Hierarchy Process (AHP) technique. AHP helps the evaluator to decide how well each supplier satisfies or scores for each criterion, while assigning weights on the basis of expert’s opinion.

This study has decided 7 different criteria for best supplier evaluation: Quality (CR 1), Cost (CR 2), Delivery time (CR 3), Technical capability (CR 4), Financial capability (CR 5), Managerial & Commercial capability (CR 6) and Trust (CR 7). Various alternative suppliers for selection as the best one were:

‘Kamal’ brand, Digvijay Cement Co. Ltd. (S1), ‘Ambuja’ brand, Ambuja Cements Ltd. (S2), ‘Ultratech’ brand, Ultratech Cement Ltd, Aditya Birla Group (S3), ‘J K Laxmi’ brand, J K Laxmi Cement Ltd, J K Group (S4) and ‘Hi-Bond’ brand, Hi Bond Cement (India) Pvt. Ltd., Kishan Group of Companies (S5). To determine relative importance of criteria, AHP technique was used. Steps of AHP are explained below:

1. Construct a pair wise comparison matrix for each criterion using a scale of 1 to 9 for their relative importance.
2. Use Eigenvector approach of AHP: For each of the column, divide each entry in column of \( A \) by the sum of the entries in column of \( i \). This will give new matrix called as normalized matrix in which the sum of the entries in each column is 1. Estimate \( W_i \) as the average of the entries in row \( i \) of the matrix.
3. Consistency check: Following steps are used to check the consistency of the decision maker’s opinion:
4. Calculate \( AW^T \) where \( A \) is the pair wise comparison matrix and superscript \( T \) denotes transpose.
5. Workout Eigen value \( \lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} i_{tb} \) entry in \( AW^T/ib \) entry in \( W^T \).
6. Calculate Consistency index (CI): \( CI = \frac{\lambda_{max} - n}{n - 1} \). The smaller the CI, lesser is the deviation from the consistency.
7. Compare CI with Random Consistency Index (RI). RI is taken as per value given following Table. If (CI/RI) < 0.10, the degree of consistency is acceptable. If (CI/RI) > 0.10, expert is inconsistent and results may not be correct. Table 1 shows Random Consistency Index (RI) for different values of \( n \).

<table>
<thead>
<tr>
<th>Table 1: Values of Random Index (RI)</th>
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</thead>
<tbody>
<tr>
<td>n</td>
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<tr>
<td>RJ</td>
</tr>
</tbody>
</table>

In this study responses of 12 purchase managers were taken. They were actively involved in purchase of construction materials in various construction organizations. Their responses were handled through AHP technique and weights were generated for each respondent. Weights of all respondents were aggregated through Geometric Mean Method (GMM) to get final aggregated weight for each criterion. Table 2 gives weights of each respondent and final aggregated weight with their Consistency Ratio (CR). It is to be noted that each respondent’s CR value is below 0.10.

After deriving criteria weights with AHP process, next step is to evaluate different suppliers based on above criteria. An experienced purchase manager was asked to evaluate them on 1 to 9 scales. 9 point scale for various criterions is as given below:

- For Quality (CR 1), Technical capability (CR 4), Financial capability (CR 5), Managerial & Commercial capability (CR 6) and Trust (CR 7): Very poor – 1, Between very poor and poor – 2, Poor – 3, Between poor & good – 4, Good – 5, Between good and very good – 6, Very good – 7, Between very good & extremely good – 8 and Extremely good – 9.
- For Cost (CR 2): Very low – 1, Between very low and low – 2, Low – 3, Between low & high – 4, High – 5, Between high
and very high – 6, Very high – 7, Between very high & extremely high – 8 and Extremely high – 9.


Based on feedbacks of an experienced purchase manager of a construction firm, each supplier was evaluated on 1 to 9 scales for performance under seven different criteria. Table 3 gives evaluation attributes for various suppliers of cement.

Next, the 'TOPSIS' and the 'VIKOR' methods are applied. From available criteria, Quality, Delivery time, Technical capability, Financial capability, Managerial & Commercial capability and Trust are beneficial attributes, so, higher values are desirable. Cost is non beneficial attribute and so lower value is desirable. Applying TOPSIS method, the normalized matrix and weighted normalized matrix as per Eqs. (1) and (2) are calculated. The ideal (A*) and negative-ideal (A-) solutions are calculated using Eqs. (3) and (4) and they are shown in Table 5. Table 6 shows the values of the separation measures (Sj) and the relative closeness to the ideal solution (Cj) with reference to the five suppliers calculated using Eqs. (5) to (7).

As Supplier 3 is having maximum value of Ci* (0.5498), he is the best supplier out of the available ones. With reference to VIKOR method, Table 7 shows the best fij and the worst fj values of all criterion functions. The values of Sj, Rj and Qj are obtained using Eqs. (8) to (10) respectively. Sample calculations of them are as given below.

The results obtained by ‘TOPSIS’ and ‘VIKOR’ methods are given in Table 8. Ranking of Suppliers by the TOPSIS method gives Supplier 3 as the best one. VIKOR method finds that Supplier 3 is closest to the ideal solution. By VIKOR method, Supplier 3 is also best ranked by VIKOR method. TOPSIS as well as VIKOR method has ranked Supplier 3 as the lowest one, whereas VIKOR has ranked 5th supplier as the lowest one.

V. CONCLUSION

Cement plays very crucial role in success of construction projects. It contributes around 15% of total material cost. Hence, proper supplier selection for Cement is vital for performance of projects. Most of the construction companies select the supplier which offers lowest rates of materials. This may affect the project performance in longer run. In this paper, multi-criteria decision making methods like AHP, TOPSIS and VIKOR are used for the selection of best supplier for supply of cement to construction companies. The novel approach adopted in this paper considers multi-criteria in supplier selection along with their relative importance. Results show that one of the suppliers is best by TOPSIS as well as VIKOR method. TOPSIS suggests best supplier according to ranking index and VIKOR method suggests best supplier who is closest to the ideal solution. Such innovative approach can bring profit maximization and quality enhancement of construction projects.

ACKNOWLEDGMENT

Authors are thankful to the participating purchase managers in giving their valuable feedbacks.

Table 2: Weights of different criteria by Respondents with Consistency Ratio (CR)

<table>
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</thead>
<tbody>
<tr>
<td>Quality (CR 1)</td>
<td>0.19</td>
<td>0.24</td>
<td>0.29</td>
<td>0.21</td>
<td>0.27</td>
<td>0.17</td>
<td>0.28</td>
<td>0.26</td>
<td>0.32</td>
<td>0.31</td>
<td>0.31</td>
<td>0.24</td>
<td>0.318</td>
</tr>
<tr>
<td>Cost (CR 2)</td>
<td>0.19</td>
<td>0.21</td>
<td>0.16</td>
<td>0.23</td>
<td>0.19</td>
<td>0.16</td>
<td>0.20</td>
<td>0.22</td>
<td>0.22</td>
<td>0.19</td>
<td>0.21</td>
<td>0.202</td>
<td>0.2083</td>
</tr>
<tr>
<td>Delivery Time (CR 3)</td>
<td>0.06</td>
<td>0.06</td>
<td>0.05</td>
<td>0.05</td>
<td>0.08</td>
<td>0.08</td>
<td>0.05</td>
<td>0.03</td>
<td>0.03</td>
<td>0.04</td>
<td>0.03</td>
<td>0.040</td>
<td>0.0585</td>
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<tr>
<td>Technical Capability (CR 4)</td>
<td>0.16</td>
<td>0.12</td>
<td>0.12</td>
<td>0.11</td>
<td>0.12</td>
<td>0.13</td>
<td>0.09</td>
<td>0.08</td>
<td>0.11</td>
<td>0.10</td>
<td>0.11</td>
<td>0.101</td>
<td>0.1170</td>
</tr>
<tr>
<td>Financial Capability (CR 5)</td>
<td>0.13</td>
<td>0.10</td>
<td>0.08</td>
<td>0.08</td>
<td>0.10</td>
<td>0.09</td>
<td>0.08</td>
<td>0.07</td>
<td>0.06</td>
<td>0.06</td>
<td>0.09</td>
<td>0.090</td>
<td>0.0904</td>
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<tr>
<td>Managerial &amp; Commercial Capability (CR 6)</td>
<td>0.05</td>
<td>0.08</td>
<td>0.06</td>
<td>0.08</td>
<td>0.07</td>
<td>0.06</td>
<td>0.04</td>
<td>0.04</td>
<td>0.05</td>
<td>0.08</td>
<td>0.05</td>
<td>0.064</td>
<td>0.0644</td>
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<tr>
<td>Trust (CR 7)</td>
<td>0.18</td>
<td>0.15</td>
<td>0.15</td>
<td>0.24</td>
<td>0.16</td>
<td>0.21</td>
<td>0.22</td>
<td>0.22</td>
<td>0.17</td>
<td>0.21</td>
<td>0.23</td>
<td>0.182</td>
<td>0.191</td>
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<tr>
<td>Consistency Ratio (CR)</td>
<td>0.100</td>
<td>0.068</td>
<td>0.061</td>
<td>0.02</td>
<td>0.08</td>
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<td>0.08</td>
<td>0.03</td>
<td>0.10</td>
<td>0.07</td>
<td>0.10</td>
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Table 3: Structure of decision matrix – Supplier with evaluation attributes

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<tr>
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<tbody>
<tr>
<td>Supplier 1</td>
<td>7</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>7</td>
<td>8</td>
<td>7</td>
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<tr>
<td>Supplier 2</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td>7</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Supplier 3</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>7</td>
<td>8</td>
<td>8</td>
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<tr>
<td>Supplier 4</td>
<td>5</td>
<td>4</td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Supplier 5</td>
<td>5</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>6</td>
</tr>
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</table>

Table 4: Weighted normalized matrix by TOPSIS method

<table>
<thead>
<tr>
<th>Supplier</th>
<th>CR 1</th>
<th>CR 2</th>
<th>CR 3</th>
<th>CR 4</th>
<th>CR 5</th>
<th>CR 6</th>
<th>CR 7</th>
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</thead>
<tbody>
<tr>
<td>S 1</td>
<td>0.8494</td>
<td>0.5686</td>
<td>0.2694</td>
<td>0.5132</td>
<td>0.3071</td>
<td>0.2420</td>
<td>0.6375</td>
</tr>
<tr>
<td>S 2</td>
<td>0.8494</td>
<td>0.7739</td>
<td>0.1630</td>
<td>0.5132</td>
<td>0.3071</td>
<td>0.2420</td>
<td>0.6375</td>
</tr>
<tr>
<td>S 3</td>
<td>1.4041</td>
<td>1.0109</td>
<td>0.1630</td>
<td>0.5132</td>
<td>0.3071</td>
<td>0.2420</td>
<td>0.8327</td>
</tr>
<tr>
<td>S 4</td>
<td>0.4334</td>
<td>0.2527</td>
<td>0.2694</td>
<td>0.3105</td>
<td>0.2256</td>
<td>0.1853</td>
<td>0.4684</td>
</tr>
<tr>
<td>S 5</td>
<td>0.4334</td>
<td>0.1422</td>
<td>0.1630</td>
<td>0.3105</td>
<td>0.1567</td>
<td>0.1853</td>
<td>0.4684</td>
</tr>
</tbody>
</table>

Table 5: Ideal (A*) and Negative-ideal (A¯) solutions – TOPSIS method

<table>
<thead>
<tr>
<th>Quality</th>
<th>Cost</th>
<th>Delivery Time</th>
<th>Technical Capability</th>
<th>Financial Capability</th>
<th>Managerial &amp; Commercial Capability</th>
<th>Trust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
</tr>
<tr>
<td>A*</td>
<td>1.4041</td>
<td>0.1422</td>
<td>0.2694</td>
<td>0.5132</td>
<td>0.3071</td>
<td>0.2420</td>
</tr>
<tr>
<td>A¯</td>
<td>0.4334</td>
<td>1.0109</td>
<td>0.1630</td>
<td>0.3105</td>
<td>0.1567</td>
<td>0.1853</td>
</tr>
</tbody>
</table>

Table 6: Separation measures ($S_i^*$ and $S_i^-$) and Relative closeness to Ideal Solution ($C_i^*$)

<table>
<thead>
<tr>
<th>Supplier</th>
<th>$S_i^*$</th>
<th>$S_i^-$</th>
<th>$C_i^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier 1</td>
<td>0.7264</td>
<td>0.3959</td>
<td>0.4780</td>
</tr>
<tr>
<td>Supplier 2</td>
<td>0.8696</td>
<td>0.5699</td>
<td>0.7687</td>
</tr>
<tr>
<td>Supplier 3</td>
<td>0.8752</td>
<td>1.0686</td>
<td>0.8687</td>
</tr>
<tr>
<td>Supplier 4</td>
<td>0.8752</td>
<td>1.0686</td>
<td>0.8687</td>
</tr>
<tr>
<td>Supplier 5</td>
<td>0.8752</td>
<td>1.0686</td>
<td>0.8687</td>
</tr>
</tbody>
</table>

$$S_i = 0.2623 \left(\frac{9 - 7}{9 - 5}\right) + 0.2083 \left(\frac{8 - 6}{8 - 3}\right) + 0.085 \left(\frac{9 - 9}{9 - 7}\right) + 0.1170 \left(\frac{9 - 9}{9 - 7}\right) + 0.0904 \left(\frac{7 - 7}{7 - 5}\right) + 0.0644 \left(\frac{8 - 8}{8 - 7}\right) + 0.1990 \left(\frac{8 - 8}{8 - 6}\right) = 0.3136$$

$$R_i = \max \left\{0.2623 \left(\frac{9 - 7}{9 - 5}\right), 0.2083 \left(\frac{8 - 6}{8 - 3}\right), 0.085 \left(\frac{9 - 9}{9 - 7}\right), 0.1170 \left(\frac{9 - 9}{9 - 7}\right), 0.0904 \left(\frac{7 - 7}{7 - 5}\right), 0.0644 \left(\frac{8 - 8}{8 - 7}\right), 0.1990 \left(\frac{8 - 8}{8 - 6}\right)\right\} = 0.3136$$

$$Q_i = 0.50 \left[\frac{0.3136 - 0.0585}{0.9990 - 0.0585}\right] + (1 - 0.5) \left[\frac{0.1315 - 0.0585}{0.2623 - 0.0585}\right] = 0.3135 \ (v \text{ is assumed as 0.50})$$
The values of $S$, $R$, and $Q$ are given in Table 7.

<table>
<thead>
<tr>
<th>Supplier</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
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<td>0.3030</td>
<td>0.0584</td>
<td>0.8538</td>
<td>0.0000</td>
</tr>
<tr>
<td>R</td>
<td>0.1312</td>
<td>0.1312</td>
<td>0.0584</td>
<td>0.2623</td>
<td>0.2640</td>
</tr>
<tr>
<td>Q</td>
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<td>0.3230</td>
<td>0.0000</td>
<td>0.9226</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Table 8: Results of TOPSIS and VIKOR methods

<table>
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<tr>
<th>Rank</th>
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<th>VIKOR METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$C_i^+$</td>
<td>$Q$</td>
</tr>
<tr>
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<tr>
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<td>Supplier 1</td>
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<tr>
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<tr>
<td>5</td>
<td>Supplier 2</td>
<td>0.396</td>
</tr>
</tbody>
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REFERENCES