An Efficient Approach for Service Selection Based on MCDM and QoS

1 Mohtam Khezrian, 2 Wan M. N. Wan Kadir, 3 Suhaimi Ibrahim

1,2,3 Universiti Teknologi Malaysia
1 m.khezrian@acm.org, 2 wnasir@utm.my, 3 suhaimiibrahim@utm.my

Abstract

Selection of Web services refers to a concept of choosing the appropriate Web services in order to perform services with higher performance. In this paper, we present an approach to solve Web service selection problems based on the Quality of Services (QoS). The proposed approach considers the power of decision makers as well as accounts for the preferences of service consumers to determine the weights of QoS. The present study is designed to determine the lack of using the power of decision makers in the process of service selection. Furthermore, we describe the capability and applicability of the VIKOR (VIsekriterijumsko Kompromisno Rangiranje) method as an alternative technique for assisting decision-making in Web service selection. Selection of the best service is illustrated using a case study, and the new approach is validated.

Keywords: Web Service Selection, Power of decision maker, QoS, VIKOR, MCDM

1. Introduction

Due to the development and growth of the Web, researchers have shown increased interest in Web services, which are among the most widely used groups in Service Oriented Computing (SOC) and service computing [1]. According to W3C, “A Web service is a software system designed to support interoperable machine-to-machine interaction over a network” [2]. Many organizations and companies develop applications which are accessible via the Internet [3]. Therefore, the capability of selecting correctly and combining inter-organizational and various services at runtime on the Web is a significant issue in the development of Web service applications [4].

From a recent research, the mechanism of Web services is separated into Discovery, Selection and Composition [5]. Web Service Discovery enables providers to publish service descriptions and profile information regarding businesses, services and other related details in repositories. However, there are instances in which we need to utilize non-functional properties and select the most appropriate service in order to cater for user requirements, apart from functional properties. Finally, Web Service Composition composes the selected services together within the time frame required. A set of services can be composed as a composite service to provide requisite functions [6].

As services are rising on converged network, how to select a service to meet user’s requirements has become a popular research area [7]. Web Service Selection appears when there is a set of discovered Web services which can fulfill user requirements, and one of these services should be selected to be returned to the service consumer [8]. It is essential that this selection is tailored to user preferences due to the fact that one user may require high quality whereas the other may require low prices [9]. Web Service Selection is one of the most significant discussions in SOC, which means to identify the best candidate services among a group of services with similar functions, but having different Quality of Service (QoS) [10]. QoS is important whereas quality metrics need to be accomplished through service stipulation. These metrics are measurable and include what service is being offered [11].

QoS-based service selection problems can be solved via methods such as Linear Programming [12], MCDM and Fuzzy logic [13]. However, in several studies [6, 11, 14-15], the hybrid methods were utilized to solve service selection problems. A majority of service selection techniques have been applied, and the characteristics of QoS-based service selection enable researchers to deal with service selection problems by Multi-Criteria Decision Making (MCDM). A number of approaches used the MCDM method for service selection. For instance TOPSIS [16], AHP [17], and PROMETHEE [18] were applied for service selection.

However, different MCDM methods often create different outcomes, especially when there are differences between alternative solutions are inherently close together for ranking a set of alternative decisions involving multiple criteria. Several researchers [6, 11, 14, 19] have suggested applying...
different MC DM methods concurrently to provide a more efficient tool in order to enhance the accuracy of the final decision. Therefore, there is a need to develop a more systematic and logical scientific procedure to help Web service designers to achieve the optimum Web design. VIKOR is one of the well-known MCDM methods, which is unavailable in the existing literature for service selection. This aspect is addressed in this paper, using an approach that demonstrates how QoS and VIKOR method can enhance the capability of Web Service Selection.

There is a research gap on service selection based upon the MCDM method, in which the power of decision makers is neglected. In the group decision maker each decision maker has a power to decide about the rates of alternatives; Section 3 discusses how our approach fulfills this research gap.

The remainder of this paper is structured as follows. [Section 2] outlines the related works of Web Service Selection based on MCDM, followed by a detailed description on the VIKOR method and its applicability in QoS-based service selection in [Section 3]. [Section4] illustrates the method using an arithmetic example, [Section 5] is about discussion, and [Section 6] presents the conclusions of paper.

2. Related Work

In this section, we investigate the criteria for Web Service Selection methods and relevant works, most of which are based on multi-criteria decision making methods.

A linear programming method was considered by [12], and they proposed an approach based on QoS and fuzzy linear programming in order to determine the dissimilarities between service alternatives and select the most appropriate service based on user preferences. In addition, since the approach is an optimal method, the results of the approach were unaffected by increasing the number of criteria in the decision matrix. This shows the scalability of the approach.

In [16], a general QoS-based service selection method is developed and they proposed a MCDM method which solves the problem based on TOPSIS. Particular attention was given on QoS awareness. The method was capable of declaring on-functional properties of Web services by means of importing the proposed QoS ontology into OWL-S model. The QoS values of a Web service were normalized whereas higher normalized values correspond to higher levels of service performance.

In [20], a service-ranking approach based on semantic descriptions of services for non-functional properties was proposed. They expressed how to attach non-functional properties to services and goals in WSMO. The proposed ranking mechanism uses logical rules in describing non-functional properties of services and evaluates them using a reasoning engine. Finally, a ranked list of services was constructed based on user preferences, considering the values calculated through the rules’ evaluation stage.

A fuzzy model was employed by [13] to solve services selection problems based on QoS. In the proposed method, the weights of QoS criteria could be analyzed from the evaluation of existing information. In this approach, customers were allowed to obtain a dynamic ranking of accessible services. Furthermore, a new method for making the right selection of QoS awareness was exploited to select the right service based on the customer preferences.

The work in [17], employed an approach, which focuses on how to solve service selection problems based on the AHP method. They collected the views of 30 professionals by means of the AHP method. Finally, the weight of each index was calculated at all levels based on the data collected from questionnaire survey. Although this approach is based on user preference, the approach lacks QoS.

An enhanced PROMETHEE was proposed by [18] in order to solve QoS-based service selection. They considered the relationship between QoS criteria and ANP was used to evaluate the weights of the criteria. There are two kinds of ranking, in which one is based on net outranking flows and the other is based on outranking flows which accounts for user requests. The overhead is high, and the performance and scalability are affected in such case.

3. Proposed Approach

The proposed approach is based on the QoS and VIKOR method. Our approach fulfills the research gap introduced in Section 1, by accounting for the power of decision makers. In the existing works for service selection based on MCDM [6, 11-14, 16-18, 21], it can be observed that the power of decision makers was neglected, in which multiple decision makers express the rate of alternatives. For example,
let us suppose that there are two decision makers evaluating the services, with the possibility that the one decision maker possesses higher expertise compared with the other. Hence, the former decision maker’s opinion is more significant compared with the latter, which should be taken into account during the assessment of services. Therefore, without consideration this important factor the power of decision makers will be ignored and simultaneously the accuracy of service selection method will be affected.

In this approach, we take into account a factor $E_2$ to determine the power of each decision maker. Firstly, the rates of alternatives are collected from expert decision makers. Secondly, these data are evaluated and converted into the required data using the proposed framework. The rates of alternatives are assessed with respect to the power of decision makers and the weights of criteria are calculated by means of the new method. Finally, the ranking of alternative services is carried out using the VIKOR method in order to select the appropriate service. In this paper, the user refers to the service consumer whereas expert decision maker refers to a person who is capable of evaluating the services. The process of the proposed framework for service selection is shown below.

![Flowchart of proposed framework for Service selection](image.png)

In decision making problems, the decision matrix and weight of each criterion should be prepared first. In service selection, there are a number of solutions available to gather these data such as trust and reputation, user preferences, group consensus, as well as estimating the weights of criteria.

In this approach, the important weights of criteria are gathered based on user preferences and the ratings of alternatives are created by collecting feedback from expert users who have utilized the service previously. The rating alternatives are gathered from expert decision makers and the important weights of criteria are expressed by users based on their preferences. We assume that there are $m$ alternatives $(A_1, A_2, ..., A_m)$ and $n$ criteria $(C_1, C_2, ..., C_n)$ with respect to $k$ users $(D_{1}, D_{2}, ..., D_{k})$. Based on these definitions, the decision matrix for each user is similar to the matrix in Eq. (1):
The $X_{ijt}$ element represents the perspective of user $d_k$ for rating of alternative $A_i$ with respect to criteria $C_j$ with $i=1,2,...,m$, $j=1,2,...,n$, and $t=1,2,...,k$. These elements are based on the viewpoint of a group of users, and thus they should be integrated together. Eq. (2) shows how these data, which may originate from various perspectives, can be converted into aggregated data:

$$f_{ij} = \sum_{t=1}^{k} (X'_{ijt} \times E_t)$$

Where $X'_{ijt}$ is the graded mean of $X_{ijt}$ with respect to $E_t$ is the power of the decision maker, $E_t$ indicates the level of expertise of the decision makers. The value of $E_t$ is between 0 to 1 and $\sum_{t=1}^{k} E_t = 1$. Following this, the data from the perspective of various users are converted into aggregated data. We apply the above formula so that the new decision matrix will be as follows:

$$d = \begin{bmatrix}
C_1 & C_2 & \ldots & C_n \\
A_1 & \begin{bmatrix} f_{11} & f_{12} & \ldots & f_{1n} \\
A_2 & \begin{bmatrix} f_{21} & f_{22} & \ldots & f_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
A_m & \begin{bmatrix} f_{m1} & f_{m2} & \ldots & f_{mn} \\
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}$$

(3)

### 3.1. A QoS-Aware Service Selection Approach Based on VIKOR

In this section, we focus on how to apply VIKOR for service selection. VIKOR is a method for multi-criteria optimization of complex systems. “It determines the compromise ranking-list, the compromise solution, and the weight stability intervals for preference stability of the compromise solution obtained with the initial (given) weights” [22].

The goal of this method is ranking and selecting from a set of alternatives in the presence of conflicting criteria. VIKOR addresses the multi-criteria ranking index based on the particular measure of “closeness” to the “ideal” solution [23].

VIKOR is a method which is suitable for problems having numerous alternatives [22], similar to service selection problems in which there is a great number of available services. In order to propose the method for service selection, we presume that there are $m$ alternative services ($A_1,A_2,A_3,\ldots,A_m$) with respect to $n$ QoS($C_1,C_2,C_3,\ldots,C_n$). From Eqs. (1-3), the steps of the VIKOR method for service selection are described as follows.

**Step 1.** Determine $f_{ij}$ and $f_{ij}^\prime$, which are the best and worst values of each criterion respectively, where $j=1,2,...,n$. In fact, these variables specify the maximum value and minimum value of each column in the decision matrix. The maximum and minimum refer to the highest and lowest for benefit criterion, and lowest and highest cost criterion, respectively.

**Step 2.** Since the scales for each criterion are not equivalent, the decision matrix should be normalized, as the dimensions “Performance” and “Price” are in different scales. The VIKOR method uses linear normalization for this purpose in order to ensure that the results are unaffected when the scales of the criteria are altered. The determination of $S_i$ and $R_i$ is formulated from Eq. (4).

$$S_i = \sum_{j=1}^{n} W_j \left( \frac{f_j^\prime - f_{ij}}{f_j^\prime - f_{ij}} \right) \quad \& \quad R_i = \max_j \left[ W_j \left( \frac{f_j^\prime - f_{ij}}{f_j^\prime - f_{ij}} \right) \right]$$

(4)

Where $f_{ij}$ ($i = 1,2,3,\ldots,m$ and $j = 1,2,3,\ldots,n$) $X_{ij}(i = 1,2,3,\ldots,m \text{ and } j = 1,2,3,\ldots,n)$ are the elements of the decision matrix (alternative $i$ respect to criterion $j$) and $W_j$ represents the important weights of criteria.
Step 3. Compute the index values. These index values are defined as:

\[
Q_i = \begin{cases} 
\frac{R_i - R^-}{R^+ - R^-} & \text{if } S^+ = S^- \\
\frac{S_i - S^-}{S^+ - S^-} & \text{if } R^+ = R^- \\
\frac{S_i - S^-}{S^+ - S^-} v + \frac{R_i - R^-}{R^+ - R^-} (1 - v) & \text{otherwise}
\end{cases}
\]

Where \( S^-, S^+, R^-, R^+ \) and \( R^+ \) can be defined as follows:

\[
S^- = \min S_i , \quad S^+ = \max S_i 
\]

and

\[
R^- = \min R_i , \quad R^+ = \max R_i 
\]

The value of \( v \) is introduced as a weight for the strategy of “the majority of criteria” (or “the maximum group utility”), whereas \( 1 - v \) is the weight of the individual regret. The value of \( v \) is in the range of 0-1 and these strategies can be compromised by \( v=0.5 \).

Step 4. The results are three ranking lists, by sorting the values S, R, and Q in descending order.

Step 5. Propose a compromise solution for alternative \( A^{(1)} \) which is best ranked by the measure Q (minimum) if the following two conditions are satisfied:

C1. Acceptable advantage:

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

Where \( A^{(2)} \) is the alternative, with second place in the ranking list, whereby Q and \( DQ \) are calculated from Eq. (9), and \( M \) is the number of alternative services.

\[
DQ = \frac{1}{M - 1}
\]

C2. Acceptable stability in decision making:

Alternative \( A^{(1)} \) should also be the best ranked by S and/or R.

A set of compromise solutions is proposed as follows, if one of the conditions is not satisfied:

Alternatives \( A^{(1)} \) and \( A^{(2)} \) if only C2 is not satisfied, or alternatives \( A^{(1)}, A^{(2)}, A^{(3)}, A^{(4)}, \ldots, A^{(M)} \) if C1 is not satisfied; \( A^{(M)} \) is determined using the relation in (12) for maximum \( M \).

\[
Q(A^{(M)}) - Q(A^{(1)}) < DQ
\]

The service which has minimum value of Q is the best alternative. The core ranking result is the compromise ranking list of alternative services, and the compromise solution with the “advantage rate”.

4. Case Study

In this section, an illustrative example [24] is used to demonstrate how the proposed approach can solve service selection problems. To validate the proposed approach, the results are compared with the outputs of the fuzzy TOPSIS approach, proposed in [6], under the same conditions.

Suppose that you would like to go to Paris from Kuala Lumpur on 23rd December. For this purpose, you need to book a flight as well as reserve a hotel. You express your requirements and preferences such as origin, destination, date and price. Following this, the system searches the appropriate services for flight booking and hotel reservation. Firstly, we demonstrate how to select the required service for flight booking and a similar process can be applied for hotel reservation.

After discovery, there are five alternative services generated with respect to four criteria, namely, Delay rate, Safety rate, Quality of flight and Price of ticket.

The proposed approach is implemented in a case study via flowchart described in Figure. 1. First, we collect the rates of alternatives from decision makers and weights of criteria from the service requester simultaneously. The powers of the decision makers are incorporated and the decision matrix is created. Finally, the VIKOR method is applied on the decision matrix.
Step 1. We gather the data from the viewpoints of three decision makers, and these data are shown separately in Table 1:

<table>
<thead>
<tr>
<th>QoS Alternative</th>
<th>Delay</th>
<th>Safety</th>
<th>Quality</th>
<th>Price $</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>7.5</td>
<td>6</td>
<td>7.5</td>
<td>430</td>
</tr>
<tr>
<td>A2</td>
<td>6.5</td>
<td>5</td>
<td>4</td>
<td>320</td>
</tr>
<tr>
<td>A3</td>
<td>1.5</td>
<td>8.5</td>
<td>7.5</td>
<td>350</td>
</tr>
<tr>
<td>A4</td>
<td>6</td>
<td>6.5</td>
<td>2.5</td>
<td>290</td>
</tr>
<tr>
<td>A5</td>
<td>4</td>
<td>6.5</td>
<td>6.5</td>
<td>300</td>
</tr>
<tr>
<td>$d_2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>6.5</td>
<td>5</td>
<td>6.5</td>
<td>405</td>
</tr>
<tr>
<td>A2</td>
<td>6</td>
<td>3.5</td>
<td>3.5</td>
<td>337</td>
</tr>
<tr>
<td>A3</td>
<td>6.5</td>
<td>3.5</td>
<td>2.5</td>
<td>340</td>
</tr>
<tr>
<td>A4</td>
<td>6.5</td>
<td>6</td>
<td>4</td>
<td>305</td>
</tr>
<tr>
<td>A5</td>
<td>3.5</td>
<td>6</td>
<td>6</td>
<td>290</td>
</tr>
<tr>
<td>$d_3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>6.5</td>
<td>5</td>
<td>7.5</td>
<td>410</td>
</tr>
<tr>
<td>A2</td>
<td>6.5</td>
<td>4</td>
<td>5</td>
<td>310</td>
</tr>
<tr>
<td>A3</td>
<td>3.5</td>
<td>8.5</td>
<td>8.5</td>
<td>339</td>
</tr>
<tr>
<td>A4</td>
<td>5</td>
<td>6.5</td>
<td>3.5</td>
<td>294</td>
</tr>
<tr>
<td>A5</td>
<td>5</td>
<td>6.5</td>
<td>7.5</td>
<td>310</td>
</tr>
</tbody>
</table>

Step 2. In order to acquire a unique table based on the above data, it is necessary to these data are integrated into a single table using Eq. (2), with reference to graded levels of decision makers. The graded levels are as follows:

\[ E_1 = 0.40, E_2 = 0.12, E_3 = 0.48 \]

The final decision matrix maker will be similar to Table 2:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Delay</th>
<th>Safety</th>
<th>Quality</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_1$</td>
<td>0.697</td>
<td>0.356</td>
<td>0.723</td>
<td>417.4</td>
</tr>
<tr>
<td>$W_2$</td>
<td>0.656</td>
<td>0.437</td>
<td>0.444</td>
<td>317.24</td>
</tr>
<tr>
<td>$W_3$</td>
<td>0.295</td>
<td>0.801</td>
<td>0.744</td>
<td>343.52</td>
</tr>
<tr>
<td>$W_4$</td>
<td>0.556</td>
<td>0.656</td>
<td>0.312</td>
<td>293.72</td>
</tr>
<tr>
<td>$W_5$</td>
<td>0.444</td>
<td>0.656</td>
<td>0.694</td>
<td>303.6</td>
</tr>
</tbody>
</table>

Step 3. The weights of criteria are collected from the service requester based on user.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>$W_1$</th>
<th>$W_2$</th>
<th>$W_3$</th>
<th>$W_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weights</td>
<td>0.16</td>
<td>0.38</td>
<td>0.26</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Step 4. We locate the best $f_j^+$ and worst $f_j^-$ values for each column, which are shown in Table 4:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>$W_1$</th>
<th>$W_2$</th>
<th>$W_3$</th>
<th>$W_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_j^+$</td>
<td>0.295</td>
<td>0.801</td>
<td>0.744</td>
<td>293.72</td>
</tr>
<tr>
<td>$f_j^-$</td>
<td>0.697</td>
<td>0.437</td>
<td>0.312</td>
<td>417.4</td>
</tr>
</tbody>
</table>
Step 5. Since there are several negative criteria and positive criteria, whereby the criteria are not within the same scale, we need to normalize the matrix by applying linear normalization formula in order to calculate $S_i$ and $R_i$. The normalized matrix is shown in Table 5:

Table 5. Normalized Decision Matrix

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Delay</th>
<th>Safety</th>
<th>Quality</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1$</td>
<td>1</td>
<td>0.728</td>
<td>0.021</td>
<td>1</td>
</tr>
<tr>
<td>$A_2$</td>
<td>0.898</td>
<td>1</td>
<td>0.694</td>
<td>0.19</td>
</tr>
<tr>
<td>$A_3$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.403</td>
</tr>
<tr>
<td>$A_4$</td>
<td>0.649</td>
<td>0.398</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$A_5$</td>
<td>0.371</td>
<td>0.398</td>
<td>0.116</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Based on the normalized matrix, the appropriate matrix used to compare $S_i$ and $R_i$ can be determined from Eq. (4). The values are listed in Figure 2.

Figure 2. Values of $S_i$ and $R_i$

Step 6. In this step, we calculate $S^-$, $S^+$, $R^-$, and $R^+$ in order to specify index values $Q_i$. These are the maximum and minimum values in $S_i$ and $R_i$, respectively, and are computed by Eq. (6) and Eq. (7):

$$S^- = 0.081, \quad S^+ = 0.742 \quad \text{And} \quad R^- = 0.081, \quad R^+ = 0.380$$

At this time, $Q_i$, which is the index value for ranking the alternatives can be accessible based on Eq. (5):

$$Q_i = \begin{bmatrix} A_1 & 0.752 \\ A_2 & 1 \\ A_3 & 0 \\ A_4 & 0.648 \\ A_5 & 0.250 \end{bmatrix}$$

Step 7. The three lists, $S_i$, $R_i$, and $Q_i$ are ranked in descending order:

Figure 3. Ranking of alternatives
Step 8. In this step, a compromise solution is determined by checking whether both conditions \((C_1, C_2)\) are satisfied. We apply both conditions for \(A_3\):

**C1 is satisfied:**

\[
0.250 - 0 \geq 0.25
\]

**Also, C2 is satisfied:** \(A_3\) dominates the best ranking in \(S_i\) and \(R_i\).

Therefore we can claim that alternative \(A_3\) is the best option with respect to QoS criteria. The final ranking list is obtained as follows:

\[A_3 > A_5 > A_1 \approx A_4 > A_2\]

5. Discussion

In this section we discuss how to validate our approach and then we prove that the result of our approach is accurate. We apply the method introduced in [6] in our case study, under exactly the same conditions. In this work, Fuzzy TOPSIS is applied for service selection problem. The basic principle of TOPSIS is to select alternatives with the shortest distance from the ideal solution and the longest distance from the negative-ideal solution. Moreover, this method uses vector normalization instead of linear normalization, which is used in the VIKOR method. The results of vector normalization may be dependent on the unit of criteria. The existing approach by [6] is applied in our case study:

Firstly, we prepare the Fuzzy decision matrix based on the proposed example in Section 4.1, as shown in Table 6.

**Table 6. Fuzzy Decision Matrix by TOPSIS**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Alternatives</th>
<th>Delay</th>
<th>Safety</th>
<th>Quality</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(A_1)</td>
<td>(0.5, 0.7, 0.9)</td>
<td>(0.3, 0.5, 0.7)</td>
<td>(0.5, 0.7, 0.9)</td>
<td>(390,410,430)</td>
</tr>
<tr>
<td></td>
<td>(A_2)</td>
<td>(0.5, 0.7, 0.9)</td>
<td>(0.3, 0.5, 0.7)</td>
<td>(0.3, 0.5, 0.7)</td>
<td>(300,320,340)</td>
</tr>
<tr>
<td></td>
<td>(A_3)</td>
<td>(0.1, 0.3, 0.5)</td>
<td>(0.5, 0.7, 0.9)</td>
<td>(0.5, 0.7, 0.9)</td>
<td>(520,340,360)</td>
</tr>
<tr>
<td></td>
<td>(A_4)</td>
<td>(0.3, 0.5, 0.7)</td>
<td>(0.5, 0.7, 0.9)</td>
<td>(0.1, 0.3, 0.5)</td>
<td>(270,295,310)</td>
</tr>
<tr>
<td></td>
<td>(A_5)</td>
<td>(0.3, 0.5, 0.7)</td>
<td>(0.5, 0.7, 0.9)</td>
<td>(0.5, 0.7, 0.9)</td>
<td>(290,300,310)</td>
</tr>
</tbody>
</table>

Based on the method of [6], the fuzzy numbers are converted into crisp numbers. Following this, we prepare the normalized decision matrix based on vector normalization proposed in the TOPSIS method, as shown in Table 7.

**Table 7. Normalized Decision Matrix by TOPSIS**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Alternatives</th>
<th>Delay</th>
<th>Safety</th>
<th>Quality</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(A_1)</td>
<td>0.572</td>
<td>0.401</td>
<td>0.562</td>
<td>0.549</td>
</tr>
<tr>
<td></td>
<td>(A_2)</td>
<td>0.529</td>
<td>0.314</td>
<td>0.325</td>
<td>0.426</td>
</tr>
<tr>
<td></td>
<td>(A_3)</td>
<td>0.2</td>
<td>0.521</td>
<td>0.487</td>
<td>0.454</td>
</tr>
<tr>
<td></td>
<td>(A_4)</td>
<td>0.484</td>
<td>0.484</td>
<td>0.261</td>
<td>0.392</td>
</tr>
<tr>
<td></td>
<td>(A_5)</td>
<td>0.343</td>
<td>0.484</td>
<td>0.522</td>
<td>0.397</td>
</tr>
</tbody>
</table>

In the third step, we specify the ideal \(A^*\) and negative ideal \(A^-\) solutions, which are tabulated in Table 8.

**Table 8. Ideal \(A^*\) and negative ideal \(A^-\) solutions**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>(W_1) Delay</th>
<th>(W_2) Safety</th>
<th>(W_3) Quality</th>
<th>(W_4) Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A^*)</td>
<td>0.038</td>
<td>0.223</td>
<td>0.135</td>
<td>0.081</td>
</tr>
<tr>
<td>(A^-)</td>
<td>0.092</td>
<td>0.119</td>
<td>0.068</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Finally, we define $C^*_j$, which is relative to the ideal solution and we rank the service alternatives with respect to $C^*_j$, as listed in Figure 4:

![Figure 4. $C^*_j$ and rank of alternatives](image)

Hence, the final ranking is determined as follows:

$$A3 > A5 > A1 > A4 > A2$$

In this approach, service alternative $A3$ is the best candidate and the majority of ranking alternatives are similar to our approach.

6. Conclusion

This paper presents an approach to solve service selection problems based on the QoS and VIKOR method. Most studies in the field have ignored the various levels of expertise of the decision makers. The present study determines the lack of using the power of decision makers in the process of service selection. The proposed approach accounts for the power of decision makers to determine more accurate rates of alternatives.

Furthermore, this research describes the capability and applicability of the VIKOR method as an alternative technique for assisting decision-making in Web Service Selection. In preparing the decision matrix, the new method is implemented to prepare the data with respect to the power of decision makers. Finally, the VIKOR method is implemented to solve the service selection problem in light of the proposed framework for Web Service Selection. Moreover, we discuss how to validate our approach and we prove that the result of our approach is accurate. We evaluate our approach by means of applying our approach and current approach on a certain case study. The experimental results reveal that the selection process is more accurate by considering the power factor.

7. Acknowledgments

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10. References


