QoS based Web Service Selection and Multi-Criteria Decision Making Methods

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Abstract

With the continuing proliferation of web services offering similar efficacies, around the globe, it has become a challenge for a user to select the best web service. In literature, this challenge is exhibited as a 0-1 knapsack problem of multiple dimensions and multiple choices, known as an NP-hard problem. Multi-Criteria Decision Making (MCDM) method is one of the ways which suits this problem and helps the users to select the best service based on his/her preferences. In this regard, this paper assists the researchers in two conducts: Firstly, to witness the performance of different MCDM methods for large number of alternatives and attributes. Secondly, to perceive the possible deviation in the ranking obtained from these methods. For carrying out the experimental evaluation, in this paper, five different well-known MCDM methods have been implemented and compared over two different scenarios of 50 as well as 100 web services, where their ranking is defined on an account of several Quality of Service (QoS) parameters. Additionally, a Spearman's Rank Correlation Coefficient has been calculated for different pairs of MCDM methods in order to provide a clear depiction of MCDM methods showing the least deviation in their ranking. The experimental results comfort web service users in conquering an appropriate decision on the selection of suitable service.

Keywords

AHP, COPRAS, SAW, Spearman's Rank Correlation Coefficient, TOPSIS, VIKOR.

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I. Introduction and Background

A web service is a self-describing software application which can be advertised, located and used over the Internet [5]. To initiate the provisioning of web service, a user must first identify the service that is desired. "How will I effectively select the web service that will meet my performance requirements?" [1]; the answer to this question, however, still remains a challenge faced by the user because of numerous services sharing similar functionalities in the web environment. The rise in the number of Web Services has been caused due to growing demands of increasing the flexibility of IT infrastructure in order to support rapidly evolving business needs [2]. The selection of web services is not only limited to meeting the users' needs, but also, non-functional information, including, reliability, response time, etc. [3].

A. Motivation

A Web Service can also be viewed as one of the encouraging technologies that could help business units to systematize their web operations on a large scale by automatic discovery and consumption of services [5]. In the Web Service Architecture [6], the Service Requester (client or user) may receive a pool of web services from the Service Provider (server) as per the initial query in "Service Discovery" stage. Subsequently, in "Service Selection" stage, the "best" web service, which satisfies all the constraints set by the original requester, is selected from the pool. This process of service filtration is carried out based on the degree of satisfaction to the users' non-functional requirements known as Quality of Service (QoS) parameters. For example, while booking flights or downloading music, there exists a number of available services sharing identical functionalities, however, they exhibit different QoS. A web service with remarkable QoS can deliver big competitive influence to service providers while bringing the social prosperity to service consumers. It has been acknowledged from the literature that due to intensive global competition, the experts recognize the decision on web service selection an important activity.

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B. Quality of Service (QoS) Parameters for Web Service Selection

The QoS based Web Service selection has gained the attention of many researchers in recent years, since maintaining the quality of their web services has become the topmost priority of each web service provider. In this paper, therefore, the activity of web service selection is carried out based on both functional as well as non-functional QoS parameters [4, 11]. QoS attributes are measured on a scale of 0 to 9. To facilitate the description, the set of QoS attributes is divided into two subsets: Benefit (Positive) attributes and Cost (Negative) attributes, as shown in Table I. The values of positive attributes need to be maximized, whereas the values of negative attributes need to be minimized. For the sake of simplicity, the values closer to 9 for benefit criteria and closer to 1 for cost criteria are considered good.

C. Multi-Criteria Decision Making (MCDM) Methods

In past many years, Multi-Criteria Decision Making (MCDM) methods have proven their effectiveness in addressing different complex real-world decision making problems. MCDM methods use knowledge from many fields, including economics, mathematics, behavioral decision theory, software engineering, computer technology and information systems [9]. In the context of this paper, the goal of MCDM methods is to find one web service from a pool of several web services such that the QoS is optimized and users' end-to-end QoS requirements are satisfied. In MCDM methods, each problem is stated in matrix design as:

$$\begin{array}{c|ccc} & C_1 & \cdots & C_n \\ \hline A_1 & x_{11} & \cdots & x_{1n} \\ \cdots & \cdots & \cdots & \cdots \\ A_m & x_{m1} & \cdots & x_{mn} \end{array}$$

where,

A_1, A_2, … A_m are possible 'm' alternatives or choices among which decision makers have to choose, C_1, C_2, ..C_n are possible 'n' criteria or attributes the basis of which the alternatives are ordered or selected,

x_{ij} is the rating of alternative A_i with respect to criterion C_j.

The general flowchart of MCDM method is shown in Fig 1. The sensitivity analysis is done to address the problems of uncertainty, imprecision, and inaccurate determination [10]. Various MCDM methods used for web service selection in the literature are briefly summarized in Table II, however Tables III and IV conveys overview and the advantages and disadvantages of various MCDMs used in this research concluded from literature by the authors. For a particular case, two or more MCDM methods often generate different rankings of web services.

D. Objectives of Present Research

The objectives of present study can be stated as follows:

- To address the problem of web service selection based on QoS.
- To study how service consumers are benefited by selecting the appropriate Web Service based on QoS using MCDM in literature.
- To implement and compare five different MCDM methods (AHP, TOPSIS, SAW, VIKOR and COPRAS) with two different large sets of web services (50 and 100) against 9 QoS attributes.

To evaluate the deviation in the rankings of different MCDM methods using Spearman's Rank Correlation Coefficient and to conclude which MCDM methods produce similar ranking.

E. Organization of Paper

The remainder of this paper is organized as follows: Section 2 throws light upon the dataset and several methods used for present study. Section 3 discusses the results from experimental evaluation. Finally, the conclusion and highlights on possible continuations of this work are addressed in Section 4.

II. Material and Methods

A. Dataset Used

The Quality of web service (QWS) dataset version 2.0 [12, 43] is chosen for the present study. This dataset includes a set of 2,507 web services and their QWS measurement which were conducted in 2007, using Web Service Broker (WSB) framework. Each row in the dataset represents a web service and its corresponding QWS measurements on nine different QoS parameters. In this paper, two different sets of 50 and 100 web services have been constructed by random sampling for the experimental study of various MCDM methods.

B. Various MCDM Methods

MCDM methods help in selecting the optimal one from a set of alternatives with respect to the predefined set of attributes. MCDM methods are continuously growing in the application areas of Business, Mathematics, Decision Sciences, Management and Accounting, Social Sciences, Medicine, Environmental Science, Economics, Econometrics and Finance, etc. [19]. In this paper, for QoS based web service selection, five different existing MCDM methods are taken into account: Simple Additive Weighting (SAW) [15], Analytic Hierarchy Process (AHP) [14], Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [9], VIšekriterijumsko KOmpromisno Rangiranje (VIKOR) [17] and COmplex PRoportional ASsessment (COPRAS) [18]. These methods are summarized in Tables III and IV. The general formal definition of MCDM is represented in (1):

$$mcdm_k\{f_k(A_{ij})\} \tag{1}$$

where,

$i=1,2,\ldots,I;\ k=1,2,..,K\ ;\ j=1,2,\ldots,J$

k is the set of different MCDM methods, i.e. k ={AHP=1, TOPSIS=2, COPRAS=3, VIKOR=4, SAW=5}

I is the number of alternatives

J is the number of criterion

f is the Aggregating function/method

A_{ij} is the decision matrix A obtained by taking criteria 'i' and alternative 'j' as row and column respectively

C. AHP (Analytical Hierarchy Process)

Suppose J represents the number of criterion and a_{jk} represents the importance of j^{th} criterion relative to k^{th} criterion in PC matrix. The AHP consists of following steps [14]:

i) Breaking down of a problem into a hierarchy of decision criteria and alternatives.

ii) Relative importance of each criterion is measured with respect to other criterion, which is known as Pairwise Comparison PC process. The consistency checks are also performed while the evaluations are made by the decision makers.

iii) Normalization of pairwise comparison matrix by using (2.1).

$$A_{jk} = \frac{a_{jk}}{\sum_{i=1}^{J} a_{ik}}$$

$$\text{where, } j=1,2\ldots.J;\ k=1,2,\ldots.J \tag{2.1}$$

iv) The Criteria Weight Vector is built with the help of (2.2).

$$W_j = \frac{\sum_{i=1}^{J} a_{ik}}{J}$$

$$\text{where } j=1,2,\ldots J \tag{2.2}$$

v) Obtaining the matrix S of scores of alternatives as shown in (2.3).

$$S = [s^1, s^2, \ldots..s^J] \tag{2.3}$$

vi) Using (2.4) to calculate the matrix of global scores V.

$$V = S.\ W \tag{2.4}$$

vii) Ranking of alternatives is done as per the decreasing order of global scores.

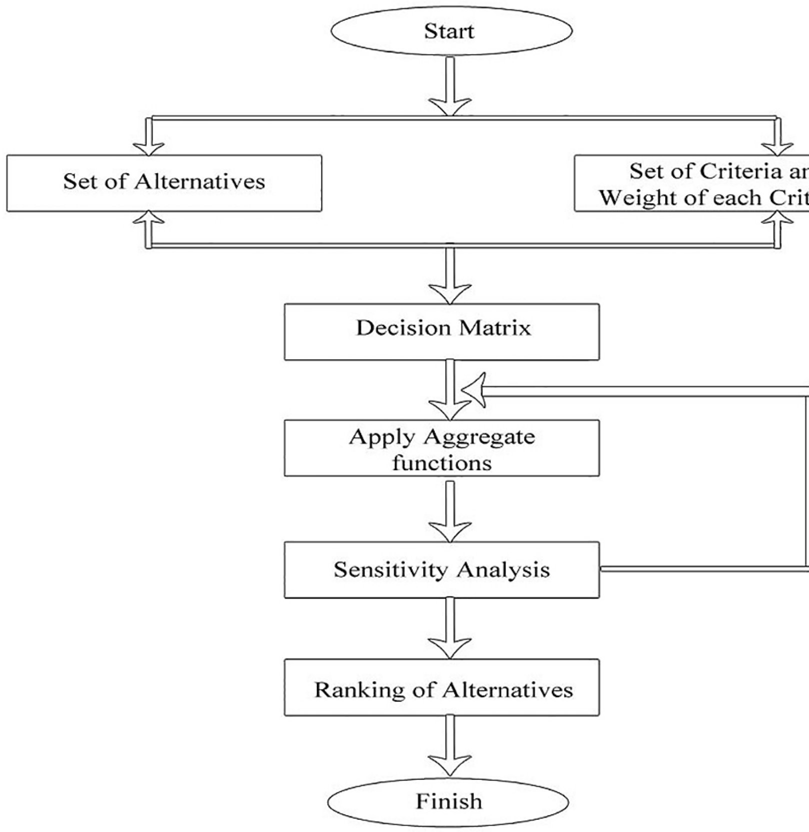


Fig. 1. General Flowchart of MCDM Method.

TABLE I. Various QoS Attributes Used for Web Service Selection [7-8, 27]

Attribute	Description	Expected Value	Units
Availability	Probability that the service is available. It is computed from historical data as: $\frac{\text{Amount of time the service is available}}{\text{Total time monitored}}$ Or $\frac{\text{Number of Successful Invocations}}{\text{Total Invocations}}$	Maximum	%
Throughput	Total number of invocations for a given period of time	Maximum	ips
Successability	It can be defined as: $\frac{\text{Number of Responses}}{\text{Number of Service Requests}}$	Maximum	%
Reliability	Probability that a request is correctly handled within the expected time. It is computed from historical data as: $\frac{\text{Number of Requests successfully responded}}{\text{Total number of requests}}$	Maximum	%
Compliance	The extent to which a WSDL (Web Services Definition Language) document is followed	Maximum	%
Best Practices	The extent to which a Web Service Interoperability industry consortium (WS-I) is followed	Maximum	%
Documentation	Measure of documentation (i.e. description tags) in WSDL	Maximum	%
Latency*	Time taken for the server to process a given request.	Minimum	ms
Response Time*	Time interval between when a user requests a service and when the user receives a response.	Minimum	ms

Note: * denotes Cost Attributes; % means Percentage for a particular attribute

TABLE II. Summary of MCDM Based Existing Related Researches

Reference No.	Authors	Year	Publisher	No. of Citations	No. of Criteria	MCDM	Target area
[34]	Shaikh et al.	2004	IEEE	10	3	AHP	E-business processes
[33]	Chemane et al.	2005	IEEE	3	4	AHP	Internet Access Technology
[30]	Colace et al.	2006	IEEE	40	5	AHP	E-learning
[26]	Zhuang et al.	2007	IEEE	8	NS	Fuzzy Multi-Attributive Group Decision-Making	Web Service Selection
[38]	Xiong et al.	2007	IEEE	53	6	Fuzzy MCDM	Web service selection
[29]	Godse et al.	2008	IEEE	23	5	AHP	Prioritizing Web Service Features
[16]	Tseng	2009	Elsevier	210	21	Grey theory, Fuzzy theory, DEMATEL	Customer Service Quality Expectation
[25]	Sun et al.	2009	Elsevier	140	12	Fuzzy TOPSIS	Shopping Websites
[40]	Pervaiz	2010	IEEE	35	4	AHP	Access Network Selection in WLAN
[41]	Yang et al.	2010	IEEE	0	4	CRML, TOPSIS	Cross-organizational service selection
[37]	Karim et al.	2011	IEEE	21	9	Enhanced PROMETHEE	Web Services
[39]	Garg et al.	2011	IEEE	193	6	AHP	Cloud Services Ranking
[36]	Luo et al.	2012	Elsevier	20	6	SAW	Wireless Network
[31]	Park et al.	2013	Springer	13	6	Pairwise comparison	Enterprise Resource Planning
[32]	Sun et al.	2013	IEEE	17	5	AHP	Consumer-centered Cloud services
[35]	Fakhfakh et al.	2013	Springer	4	3	MACBETH integrated with 2-additive Choquet integral	Degree of Service Orchestrations Measurement
[28]	Dragović et al.	2014	Taylor & Francis	14	5	AHP, Fuzzy Logic	Web services
[27]	Almulla et al.	2015	Elsevier	5	9	FDCRT, FSIRT	Real world web services
[21]	Lin et al.	2016	Elsevier	0	5	Hybrid of DEMATEL, PCA, ANP, VIKOR	Digital Music Services
[20]	Huang et al.	2016	Springer	0	6	DEMATEL, DANP	Social Networking sites
[22]	Sánchez-Lozano et al.	2016	Elsevier	5	10	Fuzzy AHP, Fuzzy TOPSIS	Geographical Information System
[23]	Gupta et al.	2016	Springer	0	6	Ordered Weighted Operators	Handling Outliers in Web Data
[24]	Rhimi et al.	2016	IEEE	0	NS	Fuzzy logic, TOPSIS	Skyline computation
[42]	Taibi et al.	2017	IMAI Software	0	4	Fuzzy AHP	Industrial Site Selection

Note: #Citations are taken up to November 2016, NS means Not Specified

DEMATEL: Decision MAking Trial and Evaluation Laboratory, ANP: Analytical Network Procedure, PCA: Principal Component Analysis, DANP: Decision MAking Trial and Evaluation Laboratory based Network Process, FSIRT: Fuzzy Interval-based Ranking Technique, FDCRT: Fuzzy Distance Correlation Ranking Technique, MACBETH: Measuring Attractiveness by a Categorical Based Evaluation TecHnique, SAW: Simple Additive Weighting, AHP: Analytic Hierarchy Process, TOPSIS: Technique for Order Preference by Similarity to Ideal solution, VIKOR: VIšekriterijumsko KOmpromisno Rangiranje

D. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

Suppose I represents the number of alternatives and J represents the number of criterion; x_{ij} is the value assigned to i^{th} alternative with respect to j^{th} criterion. The TOPSIS consists of following steps [9]:

i) Normalization of decision matrix using (3.1).

$$r_{ij} = \frac{x_{ij}}{[\,{}^{I}\sum_{k=1} (x_{kj})^2\,]^{1/2}}$$

where i=1,2…I, j=1,2,….J (3.1)

ii) Calculation of the weighted normalized decision matrix using (3.2).

$$v_{ij} = w_j \cdot r_{ij} \quad (3.2)$$

where W={w_1,w_2,…w_J}=relative weight about the criterion

iii) Determination of the positive ideal and negative ideal solutions which maximizes and minimizes the benefit criteria and cost criteria respectively using (3.3) and (3.4).

$$A^+ = \{v_1^+, v_2^+, \ldots\ldots v_J^+\}$$
$$= \{\max_j v_{ij} \mid j \in \text{set of Benefit Criteria},$$
$$\min_j, v_{ij} \mid j \in \text{set of Cost Criteria}\} \quad (3.3)$$

$$A^- = \{v_1^-, v_2^-, \ldots\ldots v_J^-\}$$
$$= \{\min_j v_{ij} \mid j \in \text{set of Benefit Criteria},$$
$$\max_j v_{ij} \mid j \in \text{set of Cost Criteria}\} \quad (3.4)$$

iv) Calculation of each alternative from positive ideal solution and negative ideal solution with the help of (3.5) and (3.6) respectively (Euclidean distance).

$${}^{+}D_i = [\,{}^{J}\sum_{j=1} (v_{ij} - v_j^+)^2\,]^{1/2}, \; i=1,2\ldots I \quad (3.5)$$

$${}^{-}D_i = [\,{}^{J}\sum_{j=1} (v_{ij} - v_j^-)^2\,]^{1/2}, \; i=1,2\ldots I \quad (3.6)$$

v) Calculation of the relative closeness of each alternative to the ideal solutions using (3.7).

$$RC_i = \frac{{}^{-}D_i}{{}^{+}D_i + {}^{-}D_i}$$

where i= 1,2,…I (3.7)

vi) Ranking of alternatives is done as per the increasing order of relative closeness. Higher the relative closeness to ideal solution is, better is the alternative.

E. COPRAS (COmplex PRoportional ASsessment)

Suppose I represents the number of alternatives and J represents the number of criterion; x_{ij} is the value assigned to i^{th} alternative with respect to j^{th} criterion; q_j represents the significance of j^{th} criterion. The steps of COPRAS are summarized as follows [18]:

i) Normalization of decision matrix using (4.1).

$$r_{ij} = \frac{x_{ij}}{{}^{I}\sum_{i=1} x_{ij}}$$

where i=1,2…I and j=1,2,….J (4.1)

ii) Calculation of Maximizing Criteria S_+ and Minimizing Criteria S_- using (4.2) and (4.3) respectively.

$$S_{+i} = {}^{J'}\sum_{j=1} r_{ij} \cdot q_j \quad (4.2)$$

where i=1,2,…I; j' is the number of benefit criterion

$$S\text{-}_i = {}^{J''}\sum_{j=1} r_{ij} \cdot q_j \quad (4.3)$$

where i=1,2,…I; j" is the number of cost criterion

iii) Relative weight of each alternative is obtained using 4.4.

$$Q_i = S_{+i} \; \frac{{}^{J}\sum_{i=1} S_{-i}}{S_{-i} \cdot {}^{J}\sum_{i=1} 1/S_{-i}}$$

where i=1,2,…I (4.4)

iv) Ranking of alternatives is done according to the ascending order of relative weight. Higher the relative weight of alternative is, higher is the priority of alternative.

F. VIKOR (VIšekriterijumsko KOmpromisno Rangiranje)

Suppose I represents the number of alternatives and J represents the number of criterion; f_{ji} is the value of j^{th} criterion for the i^{th} alternative The VIKOR involves the aforementioned steps [17]:

i) Determination of the best and the worst values of criterion using (5.1) and (5.2) respectively.

${}^{+}f_j = \max_i f_{ji}$ for benefit criterion

${}^{+}f_j = \min_i f_{ji}$ for cost criterion

where j =1,2,….J (5.1)

${}^{-}f_j = \min_i f_{ji}$ for benefit criterion

${}^{-}f_j = \max_i f_{ji}$ for cost criterion

where j =1,2,….J (5.2)

ii) Computation of the values S_j and R_j using (5.3) and (5.4) respectively.

$$S_i = {}^{I}\sum_{i=1} \frac{w_j ({}^{+}f_j - f_{ji})}{({}^{+}f_j - {}^{-}f_j)}$$

where j =1,2,….J (5.3)

$$R_i = \max_j [w_j ({}^{+}f_j - f_{ji}) / ({}^{+}f_j - {}^{-}f_j)]$$

where j =1,2,….J (5.4)

iii) Computation of Q_j using (5.5).

$$Q_i = v(S_i - S^+) / (S^- - S^+) + (1-v)(R_i - R^+) / (R^- - R^+) \quad (5.5)$$

where i =1,2,….I; and

$S^- = \max_i\{S_i\}$; $S^+ = \min_i\{S_i\}$; $R^- = \max_i\{R_i\}$; $R^+ = \min_i\{R_i\}$

iv) Three different Ranking of alternatives is done according to S, R and Q. Lower the value of Q is, better is the alternative.

v) The alternative A is considered as the compromised solution if the following two conditions are satisfied:

- *C1-Acceptable Advantage*: $Q(a^2)$- $Q(a^1) \geq DQ$, where a^2 and a^1 are the alternatives with ranking second and first respectively;

DQ=1/(Number of alternatives -1).

- *C2-Acceptable stability in decision making*: the alternative a^1 must also be best ranked by S and R.

vi) If any of the conditions is not true, then the set of compromised solutions are proposed consisting of

- If only C2 is not satisfied, then alternatives a^1 and a^2 are proposed.
- If only C1 is not satisfied, then alternatives a^1, a^2, …a^m are proposed; 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").

G. SAW (Simple Additive Weighting)

Suppose I represents the number of alternatives and J represents the number of criterion; x_{ij} is the value assigned to i^{th} alternative. The SAW method consists of the following steps [15]:

i) Normalization of decision matrix using (6.1) and (6.2) respectively for cost and benefit criterion.

$$V_{ij} = \frac{x_{ij}}{{}^{max}x_j} \tag{6.1}$$

$$V_{ij} = \frac{{}^{min}x_j}{x_{ij}} \tag{6.2}$$

ii) Calculation of weighted normalized values is done using (6.3).

$$v_{ij} = Vij \; . \; wj \tag{6.3}$$

where $W=\{w_1,w_2,…w_J\}$=relative weight about the criterion; j=1,2…J

iii) The sum S is calculated correspond to each alternative using (6.4).

$$S_i = {}^{J}\sum_{i=1} v_{ij}$$

where i=1,2….I (6.4)

iv) Ranking of alternatives is done according to the increasing order of S.

H. Spearman's Rank Correlation Coefficient

The Spearman's rank correlation coefficient method assists in finding the similarity between two sets of ranking obtained from two different 'k^{th}' and 'i^{th}' MCDM methods, using (7):

$$\rho_{ki} = 1 - \frac{6 \; {}^{n}\sum_{i=1} d_i^2}{n^3-n} \tag{7}$$

where, n is the number of web services, and d_i is the difference between the ranks of two MCDM methods. A larger absolute value indicates a good agreement between one MCDM method and other MCDM method [13].

III. Results and Discussions

For carrying out the experiments, two sets of web services are constructed out of present dataset: one set of 50 web services (Scenario 1) and other set of 100 web services (Scenario 2). Five different MCDM methods such as AHP, COPRAS, SAW, TOPSIS, and VIKOR

TABLE III. Brief Overview of Various MCDM Methods Used in Present Study

Method Name	Introduced By	Originating Year	Normalization Method	Distance Method	Aggregating Method
SAW	MacCrimmon	1968	Linear Normalization	NA	Additive Weights
AHP	Thomas Satty	1977	Linear Normalization	NA	Priority Vector
TOPSIS	Hwang and Yoon	1981	Vector Normalization	Euclidean	Closeness Coefficient
VIKOR	Serafim Opricovic	1990	Linear Normalization	Manhattan and Chebyshev	Distance from ideal solution
COPRAS	Zavadskas and Kaklauskas	1996	Linear Normalization	NA	Relative weight
Note: NA means Not Applicable					

TABLE IV. Comparison of Various MCDM Methods

Method Name	Advantages	Disadvantages
AHP	• Hierarchical structure of criteria. • Pairwise comparison gives better comparisons of criteria. • Gives option to evaluate quantitative and qualitative criteria and alternatives.	• If Hierarchical structure of criteria is not made properly user may get worst ranking. • In special cases (currencies exchange), it may not work. • Absolute zero doesn't exist.
TOPSIS	• Scalar value that accounts for both the best and worst alternatives simultaneously. • Sound logic that represents the thesaurus of human choice.	• Possess rank reversal problem. • Its use of Euclidian distance does not consider the correlation of attributes, difficult to weight and keep consistency of judgment.
COPRAS	• Degree of utility is the bases of ranking. • It doesn't require transformation of cost and benefit criteria.	It has complex aggregation procedure.
SAW	Simple to understand and implement.	Result not always real to situation.
VIKOR	It gives Ideal and compromised solution.	Complex to understand and implement.

are implemented in which the weights for different QoS attributes are calculated using AHP method in each scenario. The outline of experiments can be illustrated from Fig 2. The top five ranking of each method for each scenario is shown in Fig 3.

In order to check the consistency of user inputs to QoS attributes, the matrix analysis is usually done for AHP [14, 30], however, this effective technique of checking the evaluations made by the decision maker is used for each method while constructing the pairwise comparison matrices. The formula used for obtaining the Consistency Index is shown in (8).

$$CI = ((\lambda_{max} - n) / (n-1)) \tag{8}$$

where, n is the matrix size and λ_{max} is the eigen value.

Generally, the value CI = 0 is obtained by a perfectly consistent decision-maker, however, the smaller inconsistency may be tolerated. In particular, the inconsistencies are tolerable and reliable results have been expected from each method, if (9) holds true.

$$CI / RI < 0.1 \tag{9}$$

where, RI is Random Index, means the Consistency Index when matrix has entries which are completely random [30], and the ratio CI/RI is known as Consistency Ratio.

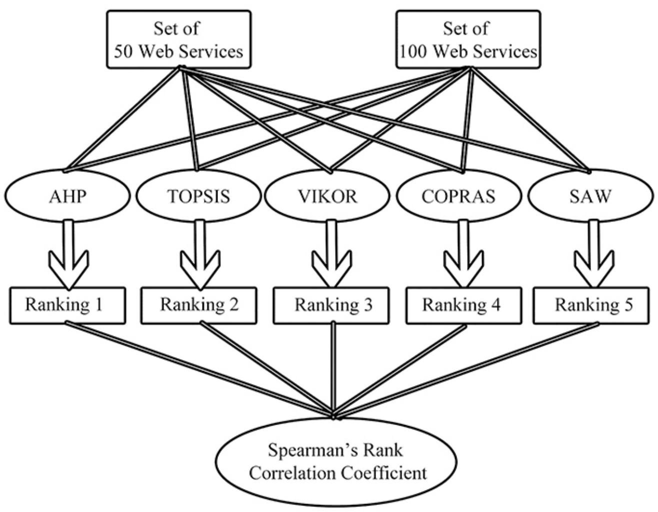


Fig. 2. Outline of Experimental Evaluation Process.

Scenario 1: 50 Web services and 5 MCDM methods (Table V)

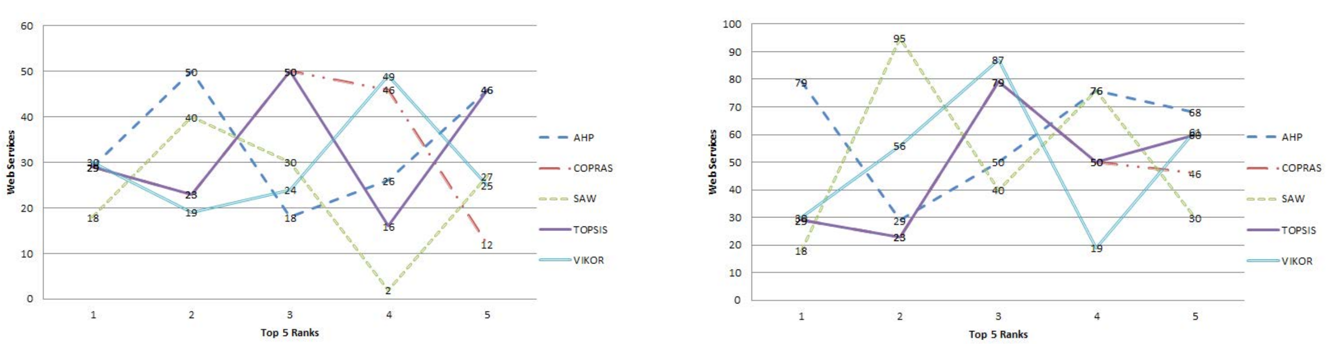
AHP method shows 29th, 50th and 18th numbered are the best three web services to be selected, whereas 21st, 6th and 38th numbered are the worst three to be selected. Moreover, COPRAS method produces 29th, 23rd and 50th as the best three web services and 38th, 7th and 27th as worst three web services. On the other hand, using SAW method, 18th, 40th and 30th numbered three best web services are obtained, whereas 21st, 38th and 6th are worst. Furthermore, TOPSIS method gives best three ranks to 29th, 23rd and 50th numbered web services, while worst three ranks to 7th, 6th and 38th. Also, 30th, 19th and 24th numbered are best three web services, while 32nd, 36th and 22nd are worst three web services chosen by VIKOR method.

Scenario 2: 100 Web Services and 5 MCDM methods (Table VI)

AHP method shows 79th, 29th and 50th numbered are the best three web services to be selected, whereas 38th, 96th and 50th numbered are the worst three web services to be selected. While, COPRAS method produces 29th, 23rd and 79th as best three web services and 64th, 77th and 27th as worst three web services. Similarly, using SAW method, 18th, 95th and 40th numbered three best web services are obtained, whereas 6th, 96th and 53rd are worst. On one hand, TOPSIS method gives best three ranks to 29th, 23rd and 79th numbered web services, on the flip side, worst three ranks to 96th, 38th and 53rd. Also, 30th, 56th and 87th numbered are best three web services, while 78th, 22nd and 73rd are worst three web services chosen by VIKOR method.

Clearly, in both the scenarios (1 and 2), rankings obtained from five different MCDM methods in the QoS based Web Service Selection problem yields divergent results. This difference in ranking can be seen due to either the use of different normalization techniques on decision matrix or the use of different aggregating methods in each MCDM method. Further, in order to evaluate the closeness of ranking, for both the scenarios, Spearman's rank correlation coefficients are calculated using (7).

The closeness of the correlation coefficient value (example, 0.9526), ranging between -1 to 1, in approximation to unity indicates complete dependency and reliability of either of the methods used. The dependency reduces with each unit reduction in the coefficient value. The negative sign indicates reverse trend existing between the two methods i.e. the rank value increasing in one method shall be declining under the second method in comparison. The inter-relationship between the MCDM methods is analyzed through correlation matrix using (7) as shown in Tables VII and VIII. It is found that AHP and TOPSIS show maximum Correlation value i.e. 0.9535 in Scenario 1 (Table VII) and 0.9526 in Scenario 2 (Table VIII), indicating the strongest correlation, as the values are generously high. Thus, it can be concluded that in this web service selection problem, AHP and TOPSIS can be used effectively for making similar types of decisions. All other combinations show positive correlation except COPRAS and VIKOR. These findings hold true for both scenarios of 50 as well as 100 web services.



(a) (b)

Fig. 3. Graphical Comparison of Top 5 Ranks obtained by each MCDM method for both scenarios: (a) 50 Web Services (b) 100 Web Services.

TABLE VII

Spearman's Rank Correlation Coefficients with Respect to Scenario 1

Methods	AHP	COPRAS	SAW	TOPSIS	VIKOR
AHP	-	0.7880	0.6379	**0.9535**	0.2949
COPRAS	0.7880	-	0.3290	0.8226	-0.0131
SAW	0.6379	0.3290	-	0.4982	0.3886
TOPSIS	**0.9535**	0.8226	0.4982	-	0.1602
VIKOR	0.2949	-0.0131	0.3886	0.1602	-

TABLE VIII

Spearman's Rank Correlation Coefficients with Respect to Scenario 2

Methods	AHP	COPRAS	SAW	TOPSIS	VIKOR
AHP	-	0.6872	0.7343	0.9526	0.3769
COPRAS	0.6872	-	0.3306	0.7391	-0.0432
SAW	0.7343	0.3306	-	0.6151	0.4748
TOPSIS	0.9526	0.7391	0.6151	-	0.7109
VIKOR	0.3769	-0.0432	0.4748	0.7109	-

IV. Conclusions and Future Scope

Nowadays, there is a need to distinguish increasing number of web services with similar functionalities, being made accessible across the Internet, using a set of QoS parameters. The QoS level displays abundant influence on degree of the web service usability as well as effectiveness, both of which further influences the service popularity. In this regard, the problem of web service selection based on QoS using MCDM method is addressed in this paper. Firstly, the rankings of web services are calculated using five different MCDM methods, including AHP, TOPSIS, VIKOR, SAW, and COPRAS. Secondly, since these rankings show divergent results, Spearman's rank correlation coefficient is used to compute the degree of similarity in the rankings of one MCDM method with other MCDM methods. The whole process is done for two larger sets of web services: 50 (Scenario 1) and 100 (Scenario 2). Maximum co-efficient correlation value is deduced for the combination of AHP and TOPSIS in both the scenarios. The experimental outcomes on different sets of web services using different MCDM methods reveal that AHP and TOPSIS methods show good agreement with each other. In future, the work can be extended using different correlation methods such as Pearson, Kendall or any other correlation method. The more focus can also be put on Rank Reversal problem of MCDM methods.

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