Cloud Service Evaluation and Selection based on User Preferences and Location

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Abstract
Nowadays an increasing number of cloud service vendors are offering their cloud computing services and resources to the users at competitive prices. Therefore, task of finding suitable cloud service vendor according to the users' business and operational requirements is becoming difficult day by day. This has led researchers to explore new ways and methods that help the users in selecting suitable cloud service vendor based on their needs and demands. Several cloud service evaluation and selection frameworks, methodologies and algorithms have been proposed over the past many years that have tried to simplify the task for the user to choose a suitable cloud service vendor. This paper focuses on a simple algorithm for evaluating and selecting cloud services which incorporates user preferences and user location / distance from the cloud server. To verify the proposed algorithm, simulations are conducted in MATLAB and comparative analysis of the results is performed with the results from another framework. The outcome of the comparative analysis shows that the results of the proposed algorithm are quite accurate.

Key words:
Cloud Service Selection, Multi-Criteria Decision-Making Techniques (MCDM), User Preferences

1. Introduction

Cloud computing is a computing paradigm that allows instant access to computing resources with minimum effort [1]. For this purpose, many cloud service providers have introduced cloud services that allow the users to access their cloud computing infrastructure and resources such as storage, processing power, etc. [2], [3]. Therefore, the users can now select a cloud service according to their business and operational requirements. Since, multiple criteria are used in evaluating and selecting of cloud services, hence the problem of finding a suitable cloud service may be categorized as a multi criteria decision-making (MCDM) problem [4]. Scientists have proposed numerous frameworks, techniques, algorithms, and methodologies that help users to select an appropriate cloud service as per their business and operational requirements. Many multiple criteria decision-making techniques are available that allow the users to select an appropriate cloud service as per their needs.

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Multiple criteria decision-making (MCDM) techniques deal with finding the best possible solution under complicated scenarios that may include multiple factors and conflicting goals [5]. MCDM techniques are used when many alternatives are available, and a decision has to be made in order to select best alternative or rank the alternatives based on multiple criteria for ease of selection. MCDM techniques have been widely used in cloud computing to evaluate and rank cloud services. In MCDM techniques, first, multiple QoS criteria are determined, and then these criteria are assigned priority and weightage according to user preferences based on some MCDM algorithm. Finally, they are ranked according to an MCDM algorithm [6].

This article presents a simple algorithm for cloud service evaluation and selection and the results are compared with the results from another framework. Our contributions to this paper are listed as follows:

1. Proposing a simple algorithm for evaluating and selecting cloud services which incorporates user preferences and the distance of the user from the cloud server.

Remaining article is summarized in the following manner. Section 2 discusses the related work carried out in the area of cloud service evaluation and selection. Section 3 describes the cloud services dataset used in the study to evaluate the cloud services. Section 4 discusses the proposed algorithm. Section 5 presents the Results and Discussion in which the two case studies are presented that show the accuracy of the proposed algorithm. Section 6 discusses the Conclusions.

2. Related Work

The following section discusses in detail the different MCDM related cloud service evaluation and selection techniques / mechanisms.
Kumar et al. [7] propose a computational framework that utilizes Fuzzy Analytical Hierarchy Process method (FAHP)

for assigning the criteria weights and TOPSIS method for ranking the different cloud services. User preferences on various nonfunctional QoS criteria are quantified using fuzzy numbers, a nine-point Likert scale is used to handle linguistic terms. The proposed methodology is compared with Analytical Hierarchy Process (AHP) and Improved TOPSIS using Sensitivity Analysis. The proposed approach is concluded to be stable and rarely sensitive to changes in criteria weights.

Hussain et al. [8] propose an MCDM based methodology for evaluating and selecting cloud selection that uses the Fuzzy Technique Best Worst Method (FTBWA) which is based on the non-linear model of Best Worst Method (BWM) technique. Further a consistency ratio method is presented that verifies the accuracy of the results of FTBWA technique, and an alternative ranking method is also proposed. Three algorithms are designed (and pseudocode is given) to program the FTBWA technique. The FTBWA technique is compared with Best Worst Method (BWM) technique and its extensions, eventually FTBWA has higher performance when considering consistency and has fewer constraints therefore it reduces implementation complexity. Also, FTBWA has higher performance when considering execution time, number of iterations and memory consumption.

Trabay et al. [9] suggest a model for calculating the trust of Cloud Services using four MCDM techniques namely 1. Analytical Hierarchy Process, 2. TOPSIS method, 3. Fuzzy variant of Analytical Hierarchy Process, and 4. Fuzzy variant of TOPSIS method. These four are utilized simultaneously in calculating the final trust score of cloud services. Cloud Analyst Application is used to perform the simulation of the cloud service providers. All four techniques (AHP, FAHP, TOPSIS and FTOPSIS) are applied on the QoS metrics data. After comparing each method with the other, FTOPSIS method is found to the most reliable method for calculating priorities as per the cloud service rankings. The results were analyzed based on complexity, data sensitivity and consistency, and FTOPSIS was found to be the most accurate method for all priorities.

Tiwari and Kumar [10] propose a framework that uses the Gaussian TOPSIS method (G-TOPSIS) for selecting cloud services. The proposed Gaussian method helps to resolve the rank reversal issue. The authors argue that the rank reversal issue encountered in the TOPSIS method is due to the normalization process and therefore the Gaussian TOPSIS method is proposed which resolves this issue. Sensitivity analysis for the proposed method is performed with the help of six different cases and it clearly shows that the proposed solution is quite robust. Also, the Performance analysis for the proposed solution is conducted and presented which compares the Gaussian TOPSIS with the original TOPSIS method and its other variants. From the results it is concluded that the Gaussian TOPSIS technique ranks the cloud services similarly like the normal TOPSIS method and is concluded to be quite reliable and accurate.

Nawaz and Janjua [11] propose a Quality-of-Service aware methodology that uses the Best-Worst Method (BWM) and weighted timeslot satisfaction values for selecting cloud services. A broker architecture is presented which evaluates the variations in Quality of Service over a time-period. Quality of service normalization data and the timeslot weight are used to calculate the quality-of-service variations and the satisfaction values against each criterion. Cloud service rankings are determined by the best worst method. The proposed approach is compared with Analytical Hierarchy Process (AHP) and it is concluded that Best Worst Method is better than Analytical Hierarchy method in terms of pair-wise computations. Also, consistency ratio comparisons of BMW and AHP are conducted, and BMW is found to be more reliable than AHP in calculating the precise objective weights. Therefore, it is concluded that the proposed approach based on weighted time slot satisfaction score is more reliable and suitable in selecting a cloud service.

Yang et al. [12] propose an algorithm that uses intuitionistic fuzzy numbers and Improved TOPSIS method for selection of cloud services. Using this algorithm, different QoS attributes are quantified using LIFN (lightweight intuitionistic fuzzy numbers). Weight co-efficient are assigned using a standard deviation method. Cloud services rankings are determined by the Improved TOPSIS method. A simulation experiment is conducted using MATLAB to prove the efficiency of the proposed algorithm. Two case studies are presented to support the proposed selection algorithm. The proposed algorithm is finally compared with another algorithm from a different study namely CSSAT. Simulations were run on both algorithms to rank different CSPs. It was concluded using simulations that, the time required for selecting cloud services using the proposed algorithm was less than the CSSAT method. Secondly, the computation overhead of the proposed algorithm was also less than that of CSSAT method.

Kumar et al. [13] propose a framework that uses the Best Worst Method (BWM) and TOPSIS method for selecting cloud services. Assigning of the criteria weights and prioritization of the quality-of-service metrics is done by the Best Worst Method. Cloud services rankings are determined by the TOPSIS method. For comparative analysis, the proposed ranking technique is compared with AHP and AHP-TOPSIS methods. Similar ranking results are obtained with proposed method and AHP-TOPSIS method, therefore the proposed ranking methodology performance is considered consistent with other methods.

Also, the BWM method is compared with the AHP method using the consistency ratio. Through experiments it is shown that BWM has better performance efficiency than the AHP method since the consistency ratio of BWM is better than AHP method.

Youssef [14] proposes a multicriteria decision making (MCDM) approach that selects cloud services based on Best Worst Method and TOPSIS method. It is contended that earlier studies using MCDM approaches are not feasible when the criteria are not easily quantifiable or time consuming when related preferences of criteria are used. Therefore, this study proposes an MCDM methodology that is feasible and efficient in view of the above constraints. Criteria weights are assigned using the BWM method. Cloud services rankings are determined by the TOPSIS method. The proposed approach is compared to AHP in terms of consistency and complexity. In terms of complexity, the proposed methodology requires less pairwise comparisons as compared to AHP therefore it is considered as computationally efficient. In terms of consistency, the proposed approach has a better consistency ratio when compared to AHP, therefore its more reliable and consistent.

Thasni and Kalaiarasan [15] have proposed a Cloud Service Selection algorithm that uses qualitative SMI metrics for selection of cloud services. Intuitionistic Fuzzy Logic is applied to quantify the qualitative attributes, assign them weights, and create a matrix. Cloud services ranks are determined by the TOPSIS method. A three-value linguistic rating scale is used to quantify the qualitative attributes according to the performance and importance of each criterion. For Performance: Poor, Fair, Good are used and for Importance Low, Medium, High are used respective ratings. No comparisons of the proposed approach are made with any other algorithm to show its efficiency, accuracy and reliability.

Jatoth et al. [16] propose a framework that uses an extended Grey TOPSIS (EGTOPSIS) algorithm for selection of cloud services. The proposed which extended Grey TOPSIS combines the Analytical Hierarchy Process method (AHP) and the Grey TOPSIS method. Criteria priorities and weights are assigned using the AHP method. Cloud services ranks are determined by the Grey TOPSIS method. The proposed Extended Grey TOPSIS approach deals with fuzziness and missing data. It also deals with the rank reversal issue. A case study is presented in which seven real world IAAS providers are evaluated. For comparative analysis the following experiments were conducted which include adequacy of the changes of alternatives, sensitivity analysis, modelling of uncertainty, computational complexity, and adequacy to the support decision-making.

Kumar et al. [17] recommend a framework that uses a combination of Analytical Hierarchy Process method (AHP) and TOPSIS method for selecting cloud services. Criteria priorities and weights are assigned using the AHP method. Cloud services ranks are determined by the TOPSIS method. A case study is presented where eleven cloud services are evaluated using five (5) QoS Criteria. The proposed approach is compared against AHP and Fuzzy AHP algorithms and the proposed approach shows similar results to some degree with other MCDM approaches. Sensitivity analysis of the proposed approach is carried out and it is established that the proposed approach is rarely sensitive to changes in criteria weights.

Nawaz et al. [18] propose a mechanism based on Markov Chains and Best Worst Method for selection of cloud services. It is argued that cloud service selection becomes a complex task when preferences are changed based on requirements and satisfaction levels of the experienced service. Markov Chains are employed to find the changes with-in the priorities of user preferences. Cloud services ranks are determined by the Best Worst Method. The proposed method is compared with Analytical Hierarchy Process (AHP) in terms of pairwise comparisons and convergence. From the results, it is shown that the recommended solution performs better than the AHP techniques which are quite frequently employed in selection of cloud service.

Sidhu and Singh [19] propose an evaluation framework that determines the trustworthiness of cloud services. An Improved TOPSIS method is proposed which determines the trust values based on the compliance values. The improved TOPSIS algorithm assigns the priorities and criteria weights using Analytical Hierarchy Process method (AHP). The proposed framework employs a Cloud Auditor that calculates trustworthiness of cloud services by examining the compliance between the offered services against the agreed service level agreement (SLA). Two case studies are presented to support the proposed Improved TOPSIS algorithm. A comparison of trust evaluation between both case studies is carried out. Also, the proposed approach is qualitatively compared against QoS monitoring and SLA validation methods since quantitative comparisons are not possible.

Rădulescu and Rădulescu [20] propose a cloud selection mechanism based on an extended TOPSIS method. An extended TOPSIS method is proposed by changing the parameter p in the Minkowski distance. A case study is presented for evaluation of ten Cloud Service Providers using the E-TOPSIS method. The criteria weights are calculated and assigned with the help of three methods namely 1. Coefficient variation weight method (CW), 2. Mean weight method (MW), and 3. Entropy weight method

(EW). The proposed E-TOPSIS solution is compared with the normal TOPSIS solution as well.

Upadhyay [21] proposes a framework that uses the TOPSIS method for selecting cloud services. To authenticate and support the framework, experiments are performed on three cloud services. The proposed framework supports quantitative and qualitative QoS metrics for cloud service evaluation. The results from the proposed framework are compared with results from other studies and found to be consistent and the proposed framework is concluded to be more effective, manageable, and simpler to use. The proposed framework is found to be efficient enough to consider numerous and extended quality of service attributes in selecting cloud services.

Rai and Kumar [22] propose Instance based model for selecting of cloud services. Two MCDM methods VIKOR and TOPSIS methods are used separately to perform the evaluation of the cloud services. It is argued that other methods involved in cloud selection take an absolute average over a period of time for all QoS criteria values and apply their proposed algorithm to it, whereas cloud service performance varies over a period of time and above approach is not suitable. More weightages must be given to the QoS criteria of the recent past to get more accurate results from the QoS metrics. Thus, the proposed method is employed on all daily instances of the QoS values, in this way, the overall result is calculated. Instance based calculation of metrics is proposed in this approach. Comparison of the results between VIKOR and TOPSIS methods is also carried out using the instance-based approach.

Tripathi et al. [23] propose a mechanism that uses the Analytical Network Process method (ANP) for selecting the cloud services. The ANP method handles the interactions between criteria's more effectively, therefore it is used in the ranking of cloud services. In the proposed method the different criteria are grouped into different clusters. Four different clusters are made, and different metrics are assigned to each cluster as follows. The sensitivity analysis of the proposed model is conducted, and the proposed method is found to be quite stable. Also, the proposed method is compared with the DEMATAL-ANP method, and it is concluded that when the number of providers is less then both methods take similar computation time but as the count of providers is increased then the recommended method has superior performance than the DEMATEL-ANP method.

Chauhan et al. [24] propose a redundant Infrastructure as a Service (IAAS) mechanism which uses MCDM methods for selecting cloud services. Using this approach, initially a cloud selection hierarchy is established, then the relative criteria are determined using Fuzzy AHP method. Next the pairwise comparison matrix is determined, and relative importance of criteria's is calculated. The three MCDM methods used to evaluate and compare the proposed approach are Weighted Sum Mean (WSM), Revised Analytic Hierarchy Process (RAHP) and the original Analytical Hierarchy Process (RAHP). All three approaches show similar somewhat rankings consistency. Therefore, it is concluded that the proposed model can be utilized in selection of other cloud models such as well. Also, it is concluded from the results that the proposed model can be used by organizations to evaluate and select potential CSPs that fulfil their long-term needs.

3. Cloud QoS Dataset

Before discussing the proposed algorithm, we will discuss the dataset based on which our algorithm will evaluate and select the cloud service.

The cloud services QoS dataset for the proposed algorithm has been taken from the study [13]. This dataset is part of the QWS data set [25] which is quite widely used for cloud and web services. The dataset consists of Quality-of-Service data of eleven cloud services CSA1, CSA2 …. CSA11 for five (5) different QoS parameters namely response time c1, reliability c2, throughout c3, best practices c4 and cost c5. The dataset is shown below in fig. 1.

Cloud Service	Response Time (C1)	Reliability (C2)	Throughput (C3)	Best Practices (C4)	Cost (C5)
CSA1	62.27	65.88	56.9	91	0.13
CSA2	122.05	119.03	101.1	131.01	0.41
CSA3	78.09	24.03	41.03	81.07	0.13
CSA4	6.18	79.05	111.15	83.88	0.12
CSA5	80.29	68	79.03	60.79	0.22
CSA6	43.05	70.19	62.99	62.89	0.23
CSA7	59.12	32.12	69.05	77.95	1.06
CSA8	36.85	35.85	103.04	133.17	1.55
CSA9	41.84	60.13	175.1	96.86	0.21
CSA10	4.88	134.01	81.91	84.14	0.12
CSA11	5.89	48	84.06	80.13	0.06

Fig. 1 Original Dataset from study [13]

For our study we have modified the above dataset by adding the distance and location column. The locations of the cloud services are assumed. The distances (in km) are measured from Karachi since in this study we have assumed our users to be from Karachi. The modified dataset is shown below fig. 2.

Cloud Service	Response Time (C1)	Reliability (C2)	Throughput (C3)	Best Practices (C4)	Cost (C5)	Distance (km)	City
CSA1	62.27	65.88	56.9	91	0.13	6935.43	Tokyo
CSA2	122.05	119.03	101.1	131.01	0.41	4861.5	Beijing
CSA3	78.09	24.03	41.03	81.07	0.13	5337.3	Shanghai
CSA4	6.18	79.05	111.15	83.88	0.12	890.15	Mumbai
CSA5	80.29	68	79.03	60.79	0.22	4745.75	Singapore
CSA6	43.05	70.19	62.99	62.89	0.23	5,520	Jakarta
CSA7	59.12	32.12	69.05	77.95	1.06	6573.36	Osaka
CSA8	36.85	35.85	103.04	133.17	1.55	4,426	Kuala Lampur
CSA9	41.84	60.13	175.1	96.86	0.21	5780.31	Seoul
CSA10	4.88	134.01	81.91	84.14	0.12	4792.12	Hong Kong
CSA11	5.89	48	84.06	80.13	0.06	1908.42	Chennai

Fig. 2 Modified Dataset with distance and location

We shall be using the above data shown in figure 2 for evaluating and selecting the cloud services.

4. The Proposed Algorithm

For the proposed algorithm, we have used the TOPSIS method which is quite a common MCDM method with some basic modifications for evaluating and selecting cloud services.

The steps of the algorithm are as follows:

Step-1: Input of the User Preferences (Best and Least Important User Criteria)
User will be asked to provide their QoS preferences i.e., the best criteria and least important criteria that are to be considered for evaluation and selection of cloud services.

Step-2: Sorting the Dataset Based on the Best Criteria
The cloud services dataset set which comprises of the QoS parameters (Response Time, Reliability, Throughput, Best Practices, Cost and Location) will be sorted (ascending or descending order) based on the best criteria (provided by the user) and ranks from 1 to 11 (eleven are the number of cloud services in our dataset to be evaluated) will be allocated to each cloud service. The sorting will be in ascending order if the criterion is negative like cost, location, and response time. And the sorting will be in descending order if the criterion is positive like reliability, best practices, and throughput.

Step-3: Sorting the Dataset Based on the Distance
Next the cloud dataset will be sorted in ascending order based on the distance of the cloud services and ranks will be assigned to each cloud service. In this step the cloud service having the closest distance to the user, will be assigned rank of 1 and the next closest will be assigned a rank of 2 and so on and so forth. In this way, all the cloud services will be ranked based on their distance from the cloud user.

Now we will have two different types of rankings for each cloud service, one ranking is based on the best criteria selected by the user and the next ranking based on the closest distance of the cloud service from the user.

Step-4 Applying TOPSIS Method on the Remaining Criteria
Till now, we have ranked the cloud services based on the best criteria input by the user and the distance. We still have the least important criteria input by the user and three other criteria. We will apply the TOPSIS method on these remaining four criteria and rank the cloud services as per the TOPSIS method.

In this way we will get another ranking of cloud services, based on the TOPSIS method on the remaining criteria.

Step-5 Summation of the Three Different Cloud Rankings
In this step we will sum three different rankings of cloud services to get a final rank score against each cloud service. The cloud service having the least rank score will be considered as the most suitable cloud service for the user since it will be having the best rank in all different criteria scenarios. In-case of a tie in the rank scores of cloud services, the cloud service having a better / higher value in the best criteria selected by the user will be assigned the higher rank.

Step-6 Final Ranked List of Cloud Services
In the last step, the cloud services with the lowest rank score will be given a final rank of one (best cloud service) and the next cloud service will be two and so on and so forth. In this way the final list of cloud services will be generated for the users which will be according to the user preferences and location of the cloud services.

5. Results and Discussions

In this section we present two case studies of cloud evaluation and selection related to the proposed algorithm and compare the results with another framework [13]. The competing framework uses the Best Worst Method and TOPSIS method to evaluate and select cloud services, whereas our algorithm uses the TOPSIS method with some modifications to evaluate and select cloud services. The results of the cloud service rankings from both the methods are considerably similar showing the effectiveness of our approach, wherever our results differ, we have mentioned the specific reasons.

We have conducted the experiments on a 2.2Ghz Intel Pentium 11^{th} Generation desktop machine with 8GB of RAM and 500GB HDD. The proposed algorithm is implemented in MATLAB R2021a since most cloud selection frameworks have been simulated in MATLAB.

The QWS dataset from the study [13] has been used to test the algorithm; this dataset has been modified by adding the distance and location of cloud services. For this study we have assumed our users are from Karachi. This dataset consists of five QoS parameters namely response time c1, reliability c2, throughout c3, best practices c4 and cost c5 for eleven cloud services CSA1…CSA11.

5.1 Case Study-1

In the first case study one user uses our algorithm and the competing framework for evaluating and selecting cloud services. The cloud service rankings and results of our algorithm are explained as follows.

Step-1: Input of the User Preferences (Best and Least Important User Criteria)
The user inputs the best and least important criteria as follows

Best criteria input by user: response time

Least important criteria input by user: cost

Step-2: Sorting the Dataset Based on the Best Criteria
Dataset is sorted as per the best criteria response time. Below fig. 3 shows the response time was input as best criteria and the data is sorted accordingly with cloud service 10 having the lowest response time with rank 1 and cloud service 2 having the maximum response time having rank 11.

Response Time	Reliability	Throughput	Best Practices	Cost	Distance	Cloud Service ID	Rank of Cloud Service
4.88	134.01	81.91	84.14	0.12	4792.12	10	1
5.89	48	84.06	80.13	0.06	1908.42	11	2
6.18	79.05	111.15	83.88	0.12	890.15	4	3
36.85	35.85	103.04	133.17	1.55	4426	8	4
41.84	60.13	175.1	96.86	0.21	5780.31	9	5
43.05	70.19	62.99	62.89	0.23	5520	6	6
59.12	32.12	69.05	77.95	1.06	6573.36	7	7
62.27	65.88	56.9	91	0.13	6935.43	1	8
78.09	24.03	41.03	81.07	0.13	5337.3	3	9
80.29	68	79.03	60.79	0.22	4745.75	5	10
122.05	119.03	101.1	131.01	0.41	4861.5	2	11

Fig. 3 Dataset sorted as per best criteria (Case Study-1)

Step-3: Sorting the Dataset Based on the Distance
The dataset is then sorted as per the location distance and the cloud service nearest to the user is ranked 1 and the next closest is rank 2 and so on and so forth. Fig. 4 shows that the cloud service 4 that has the nearest distance is ranked 1 and cloud service 1 that is farthest away has a rank of 11.

Response Time	Reliability	Throughput	Best Practices	Cost	Distance	Cloud Service ID	Rank of Cloud Service
6.18	79.05	111.15	83.88	0.12	890.15	4	1
5.89	48	84.06	80.13	0.06	1908.42	11	2
36.85	35.85	103.04	133.17	1.55	4426	8	3
80.29	68	79.03	60.79	0.22	4745.75	5	4
4.88	134.01	81.91	84.14	0.12	4792.12	10	5
122.05	119.03	101.1	131.01	0.41	4861.5	2	6
78.09	24.03	41.03	81.07	0.13	5337.3	3	7
43.05	70.19	62.99	62.89	0.23	5520	6	8
41.84	60.13	175.1	96.86	0.21	5780.31	9	9
59.12	32.12	69.05	77.95	1.06	6573.36	7	10
62.27	65.88	56.9	91	0.13	6935.43	1	11

Fig. 4 Dataset sorted as per distance (Case Study-1)

Step-4: Applying TOPSIS Method on the Remaining Criteria
TOPSIS method is applied on the remaining criteria and the cloud services are ranked accordingly. Fig. 5 shows the result of applying TOPSIS on other remaining criteria. The cloud service 2 is ranked 1 based on other remaining criteria and cloud service 7 is ranked last as per other criteria.

Response Time	Reliability	Throughput	Best Practices	Cost	Distance	Cloud Service ID	Closeness Value	Rank of Cloud Service
122.05	119.03	101.1	131.01	0.41	4861.5	2	0.675492303	1
41.84	60.13	175.1	96.86	0.21	5780.31	9	0.617191053	2
4.88	134.01	81.91	84.14	0.12	4792.12	10	0.609200442	3
6.18	79.05	111.15	83.88	0.12	890.15	4	0.541472922	4
80.29	68	79.03	60.79	0.22	4745.75	5	0.397259466	5
62.27	65.88	56.9	91	0.13	6935.43	1	0.391132838	6
5.89	48	84.06	80.13	0.06	1908.42	11	0.388757934	7
43.05	70.19	62.99	62.89	0.23	5520	6	0.374620933	8
36.85	35.85	103.04	133.17	1.55	4426	8	0.373943151	9
78.09	24.03	41.03	81.07	0.13	5337.3	3	0.279233608	10
59.12	32.12	69.05	77.95	1.06	6573.36	7	0.190187066	11

Fig. 5 Dataset sorted as per TOPSIS method (Case Study-1)

Step-5: Summation of the Three Different Cloud Rankings
Now we have three different rankings of cloud services which are based on 1) Best criteria selected by user, 2) Location / distance of cloud service from the user and 3) TOPSIS method on remaining criteria. Fig. 6 shows the rankings of each cloud service based on the above criteria.

Cloud ID	Rank as per Best Criteria	Rank as per Distance	Rank as per TOPSIS on other criteria
1	8	11	6
2	11	6	1
3	9	7	10
4	3	1	4
5	10	4	5
6	6	8	8
7	7	10	11
8	4	3	9
9	5	9	2
10	1	5	3
11	2	2	7

Fig. 6 Individual cloud service rankings (Case Study-1)

We will sum these rankings to get the rank score of each cloud service.

Fig. 7 shows the sum of ranks of the cloud services. Cloud service 4 has the best rank score of 8 and cloud service 7 has the lowest rank score of 28.

Cloud ID	Rank as per Best Criteria	Rank as per Distance	Rank as per TOPSIS on other criteria	Sum of Ranks of Cloud Service
1	8	11	6	25
2	11	6	1	18
3	9	7	10	26
4	3	1	4	8
5	10	4	5	19
6	6	8	8	22
7	7	10	11	28
8	4	3	9	16
9	5	9	2	16
10	1	5	3	9
11	2	2	7	11

Fig. 7 Sum of rank scores of cloud services (Case Study-1)

Step-6: Final Ranked List of Cloud Services
Finally, the cloud service with the lowest rank score will be assigned the best rank i.e., rank (1) one since it will be the most suitable cloud service and the cloud service with the next lowest rank score will be assigned a rank of two and so on and so forth. In-case of a tie in rank scores, the cloud service with higher values in the best criteria will be assigned a greater rank. Based on above data, the final ranks of cloud services are below fig. 8.

Response Time	Reliability	Throughput	Best Practices	Cost	Distance	Cloud Service ID	Rank of Cloud Service
6.18	79.05	111.15	83.88	0.12	890.15	4	1
4.88	134.01	81.91	84.14	0.12	4792.12	10	2
5.89	48	84.06	80.13	0.06	1908.42	11	3
36.85	35.85	103.04	133.17	1.55	4426	8	4
41.84	60.13	175.1	96.86	0.21	5780.31	9	5
122.05	119.03	101.1	131.01	0.41	4861.5	2	6
80.29	68	79.03	60.79	0.22	4745.75	5	7
43.05	70.19	62.99	62.89	0.23	5520	6	8
62.27	65.88	56.9	91	0.13	6935.43	1	9
78.09	24.03	41.03	81.07	0.13	5337.3	3	10
59.12	32.12	69.05	77.95	1.06	6573.36	7	11

Fig. 8 Final ranks of cloud services as per proposed algorithm (Case Study-1)

Based on the proposed algorithm, the cloud service-4 is the best suited for the user and cloud service-7 is the least suitable cloud service for the user.

The cloud service rankings from the proposed algorithm are compared with the competing framework from the study [13] that uses BWM-TOPSIS approach.

The following preference criteria (Best to others and Other to Worst) as shown in Fig. 9, were input in the Best Worst Method (BWM) to generate the criteria weights. Further TOPSIS was used to generate the cloud service rankings in the competing framework.

Best to Others	Location	Response Time	Throughput	Cost	Reliability	Best Practices
Response Time	4	1	4	7	4	4

Others to the Worst	Cost
Location	4
Response Time	7
Throughput	4
Cost	1
Reliability	4
Best Practices	4

Fig. 9 Best Worst Method criteria preference by user

Based on the above criteria preference the following rankings as shown in fig. 10 were achieved in the competing method.

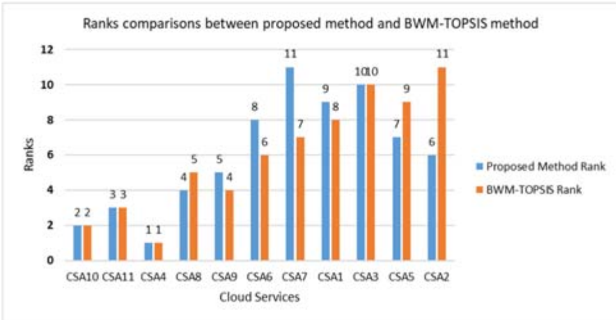

Fig. 10 Cloud service rank comparisons (Case Study-1)

Based on Fig. 10, the cloud service rankings of both frameworks are somewhat similar. Cloud Service 4 is the best cloud service on both the frameworks. The second and third best cloud services are also the same. In majority of the cloud services the difference of the rank is at most of one or two ranks.

Around 9 out of 11 cloud service ranks are either similar or within a difference of two ranks, which is around 81% accuracy. Therefore, it is safe to conclude that the proposed algorithm is quite accurate and reliable in ranking cloud services.

5.2 Case Study-2

In the second case study another user used our algorithm and the competing framework for evaluating and selecting cloud services. The cloud service rankings and results of our algorithm are explained as follows.

Step-1: Input of the User Preferences (Best and Least Important User Criteria)
The user inputs the best and least important criteria as follows

Best criteria input by user: throughput

Least important criteria input by user: response time

Step-2: Sorting the Dataset Based on the Best Criteria
Dataset is sorted as per the best criteria throughput. Fig. 11 shows the data is sorted according to the best criteria throughput, with cloud service-9 having the highest throughput with rank 1 and cloud service-3 having the lowest throughput having rank 11.

Response Time	Reliability	Throughput	Best Practices	Cost	Distance	Cloud Service ID	Rank of Cloud Service
41.84	60.13	175.1	96.86	0.21	5780.31	9	1
6.18	79.05	111.15	83.88	0.12	890.15	4	2
36.85	35.85	103.04	133.17	1.55	4426	8	3
122.05	119.03	101.1	131.01	0.41	4861.5	2	4
5.89	48	84.06	80.13	0.06	1908.42	11	5
4.88	134.01	81.91	84.14	0.12	4792.12	10	6
80.29	68	79.03	60.79	0.22	4745.75	5	7
59.12	32.12	69.05	77.95	1.06	6573.36	7	8
43.05	70.19	62.99	62.89	0.23	5520	6	9
62.27	65.88	56.9	91	0.13	6935.43	1	10
78.09	24.03	41.03	81.07	0.13	5337.3	3	11

Fig. 11 Dataset sorted as per best criteria (Case Study-2)

Step-3: Sorting the Dataset Based on the Distance

The dataset is then sorted as per the location distance and the cloud service nearest to the user is ranked 1 and the next closest is rank 2 and so on and so forth. Fig. 12 shows that the cloud service-4 that has the nearest distance is ranked 1 and cloud service-1 that is farthest away has a rank of 11.

Response Time	Reliability	Throughput	Best Practices	Cost	Distance	Cloud Service ID	Rank of Cloud Service
6.18	79.05	111.15	83.88	0.12	890.15	4	1
5.89	48	84.06	80.13	0.06	1908.42	11	2
36.85	35.85	103.04	133.17	1.55	4426	8	3
80.29	68	79.03	60.79	0.22	4745.75	5	4
4.88	134.01	81.91	84.14	0.12	4792.12	10	5
122.05	119.03	101.1	131.01	0.41	4861.5	2	6
78.09	24.03	41.03	81.07	0.13	5337.3	3	7
43.05	70.19	62.99	62.89	0.23	5520	6	8
41.84	60.13	175.1	96.86	0.21	5780.31	9	9
59.12	32.12	69.05	77.95	1.06	6573.36	7	10
62.27	65.88	56.9	91	0.13	6935.43	1	11

Fig. 12 Dataset sorted as per distance (Case Study-2)

Step-4: Applying TOPSIS Method on the Remaining Criteria

TOPSIS method is applied on the remaining criteria and the cloud services are ranked accordingly. Fig. 13 shows the result of applying TOPSIS on other remaining criteria. The cloud service-10 is ranked 1st based on other remaining criteria and cloud service-8 is ranked last as per the other criteria.

Response Time	Reliability	Throughput	Best Practices	Cost	Distance	Cloud Service ID	Closeness Value	Rank of Cloud Service
4.88	134.01	81.91	84.14	0.12	4792.12	10	0.842743087	1
6.18	79.05	111.15	83.88	0.12	890.15	4	0.739597318	2
122.05	119.03	101.1	131.01	0.41	4861.5	2	0.729470828	3
62.27	65.88	56.9	91	0.13	6935.43	1	0.698237176	4
41.84	60.13	175.1	96.86	0.21	5780.31	9	0.680520854	5
5.89	48	84.06	80.13	0.06	1908.42	11	0.66928768	6
43.05	70.19	62.99	62.89	0.23	5520	6	0.661061666	7
80.29	68	79.03	60.79	0.22	4745.75	5	0.643786479	8
78.09	24.03	41.03	81.07	0.13	5337.3	3	0.595219762	9
59.12	32.12	69.05	77.95	1.06	6573.36	7	0.288469269	10
36.85	35.85	103.04	133.17	1.55	4426	8	0.247200553	11

Fig. 13 Dataset sorted as per TOPSIS method (Case Study-2)

Step-5: Summation of the Three Different Cloud Rankings

Now we have three different rankings of cloud services which are based on 1) Best criteria selected by user, 2) Location / distance of cloud service from the user and 3) TOPSIS method on remaining criteria. Fig. 14 shows the rankings of each cloud service based on the above criteria. We will sum these rankings to get the rank score of each cloud service.

Cloud ID	Rank as per Best Criteria	Rank as per Distance	Rank as per TOPSIS on other criteria
1	10	11	4
2	4	6	3
3	11	7	9
4	2	1	2
5	7	4	8
6	9	8	7
7	8	10	10
8	3	3	11
9	1	9	5
10	6	5	1
11	5	2	6

Fig. 14 Individual cloud service rankings (Case Study-2)

Fig. 15 shows the sum of ranks of the cloud services. Cloud service-4 has the best rank score of 5 and cloud service-7 has the lowest rank score of 28.

Cloud ID	Rank as per Best Criteria	Rank as per Distance	Rank as per TOPSIS on other criteria	Sum of Ranks of Cloud Service
1	10	11	4	25
2	4	6	3	13
3	11	7	9	27
4	2	1	2	5
5	7	4	8	19
6	9	8	7	24
7	8	10	10	28
8	3	3	11	17
9	1	9	5	15
10	6	5	1	12
11	5	2	6	13

Fig. 15 Sum of rank scores of cloud services (Case Study-2)

Step-6: Final Ranked List of Cloud Services

Finally, the cloud service with the lowest rank score will be assigned the best rank i.e., rank one since it will be the most suitable cloud service and the cloud service with the next lowest rank score will be assigned a rank of two and so on and so forth. In-case of a tie in rank scores, the cloud service with higher values in the best criteria will be assigned a greater rank. Based on above data, the final ranks of cloud services are shown in Fig. 16.

Response Time	Reliability	Throughput	Best Practices	Cost	Distance	Cloud Service ID	Rank of Cloud Service
6.18	79.05	111.15	83.88	0.12	890.15	4	1
4.88	134.01	81.91	84.14	0.12	4792.12	10	2
122.05	119.03	101.1	131.01	0.41	4861.5	2	3
5.89	48	84.06	80.13	0.06	1908.42	11	4
41.84	60.13	175.1	96.86	0.21	5780.31	9	5
36.85	35.85	103.04	133.17	1.55	4426	8	6
80.29	68	79.03	60.79	0.22	4745.75	5	7
43.05	70.19	62.99	62.89	0.23	5520	6	8
62.27	65.88	56.9	91	0.13	6935.43	1	9
78.09	24.03	41.03	81.07	0.13	5337.3	3	10
59.12	32.12	69.05	77.95	1.06	6573.36	7	11

Fig. 16 Final ranks of cloud services as per proposed algorithm (Case Study-2)

Based on the proposed algorithm, the cloud service-4 is the best suited for the user and cloud service-7 is the least suitable cloud service for the user.

The comparisons of the above results with the results from the competing framework are given below.

The cloud service rankings from the proposed algorithm are compared with the competing framework from the study [13] that uses BWM-TOPSIS approach.

The following preference criteria (Best to others and Other to Worst) as shown in fig. 17, were input in the Best Worst Method (BWM) to generate the criteria weights. Further TOPSIS was used to generate the cloud service rankings in the competing framework.

Best to Others	Location	Response Time	Throughput	Cost	Reliability	Best Practices
Throughput	3	7	1	4	3	4

Others to the Worst	Response Time
Location	5
Response Time	1
Throughput	7
Cost	5
Reliability	4
Best Practices	5

Fig. 17 Best Worst Method criteria preference by user (Case Study-2)

Based on the above criteria preference the below rankings as shown in fig. 18, were achieved in the competing method.

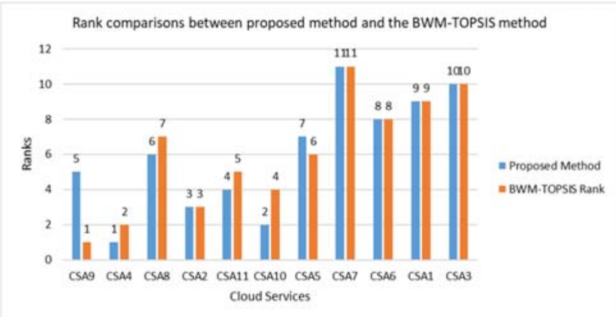

Fig. 18 Cloud service rank comparisons (Case Study-2)

Based on fig. 18, the cloud service rankings of both frameworks are somewhat similar. Cloud Service-4 is the best cloud service in the proposed algorithm whereas it is ranked 2nd in the competing framework. Cloud Service-10 is the 2nd most suitable cloud service in the proposed algorithm, and it is ranked 4th in the competing framework, a difference of two ranks only. The only major rank difference is in the cloud service-9 which is ranked 5th in the proposed algorithm and 1st in the competing framework.

Nine out of eleven cloud services are ranked either similar or within a difference of a single rank between the proposed and competing framework. This leads to an accuracy of around 81% in the results of the proposed algorithm. Therefore, it is safe to conclude that the proposed algorithm is quite accurate and reliable in ranking cloud services.

6. Conclusions

Cloud service is an important part of technology and is widely used in the IT and business industry. The main issue the users are facing is the selection of a suitable cloud service based on their requirements. For this purpose, researchers have proposed many Clouds Service Evaluation and Selection strategies. This research tries to provide a simple and effective solution that allows the user to evaluate and select cloud services based on his preferences and location. The proposed algorithm is compared with a competing solution and shows consistent, accurate and reliable results. More than 80% of the cloud rankings are similar or with a double rank difference. Therefore, it is safe to conclude that the proposed algorithm is quite accurate and reliable in ranking cloud services.

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