Service Measurement Index-Based Cloud Service Selection Using Order Preference by Similarity to Ideal Solution Based on Intuitionistic Fuzzy Values

T. Thasni, C. Kalaiarasan, and K. A. Venkatesh

Abstract Cloud Service Providers are vendors that offer IT services on the Internet. Cloud computing is a concept used to store and access data over Internet. As more and more IT systems are externalized, it has become important for long-term success to ensure that you choose the right cloud providers. Huge number of services are provided by industry leaders such as Microsoft, Amazon and Google to smaller niche players. But, choosing the right cloud provider out of so many is a defined selection and procurement process appropriately weighted towards your unique set of needs. The selection of best cloud service provider is an MCDM approach; several ranking methods such as AHP, TOPSIS etc. have been introduced by researchers. In order to reliably evaluate cloud resources, CSMIC introduced the service measurement index attributes. The aim of this chapter is to compare cloud service providers based on SMI attributes using a ranking approach. The suggested method uses the algorithm called Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and the uncertainty involved in data is addressed by intuitionistic fuzzy values. The SMI attributes are used as the criteria for the ranking and selection of the best cloud provider.

Keywords CSMIC · MCDM · SMI · Intuitionistic · CSP · TOPSIS

1 Introduction

The next wave of computer architecture is called cloud computing. It is in effect an Internet-enabled confluence of computing resources. Amazon, Google, the sales and Microsoft services are the main commercial cloud computing services. Examples

T. Thasni (✉) · C. Kalaiarasan
Presidency University, Bengaluru, India
e-mail: thasni.t@presidencyuniversity.in; kalaiarasan@presidencyuniversity.in

K. A. Venkatesh
Myanmar Institute of Information Technology, Mandalay, Myanmar
e-mail: ka_venkatesh@miit.edu.mm

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of common technology options are applications, platforms and infrastructure. The storage, information and customer data services are focused on the Internet cloud computing. Those that would like to use cloud providers should receive them across the network. There are several cloud services based on their utility and are nearly the same. It is an essential challenge to select the right cloud service. The various authors suggest various cloud services rating strategies. MCDM approaches such as AHP, TOPSIS are the few approaches used in the literature. It is important to select the best Cloud provider among the available ones accurately so that clients and service providers can boost their trust. The SMI (Service Measurement Index) developed by CSMIC (Cloud Service Measurement Initiative Consortium) has developed a set of main cloud service assessment indicators (KPIs) [1]. The cloud provider's selection problem is a multicriteria decision-making problem (MCDM) in which many QoS factors play an important role, in particular determining the best cloud service among choices. Thus, a multicriteria decision-making methodology may be suitable for dealing with consumer or customer requirements and assessing the services provided by the cloud provider as suitable. In this chapter, the authors proposed a ranking and selection approach for selecting the best cloud provider using the TOPSIS method. The SMI attributes like Accountability, Billing, Security, Usability and Performance are used as the criteria for selection of CSPs. The ranking approaches that are called as MCDM techniques such as Fuzzy AHP with Delphi, AHP, Fuzzy ELECTRE (Elimination and Option Expressing Reality)–Fuzzy TOPSIS have been proposed by different researchers in the literature in [2–6], respectively. But in the case of cloud provider dataset, it is impractical to get accurate data. So the uncertainty in the data is handled by intuitionistic fuzzy values in this chapter. This method does not exist in the literature. Based on the following way, the next section of this chapter is organized. Section 2 provides a short description of the works relevant to the cloud service selection. The assessment criteria required for the measurement of cloud providers are specified in Sect. 3. Section 4 presents some basic and fundamental concepts that are essential for our work, and Sect. 5 explains the proposed structure with its main elements and results.

2 Related Work

Service quality (QoS) is the key factor in the selection of a cloud provider according to users' needs. The article [4] addresses the fuzzy Analytical Hierarchy method (Fuzzy-AHP), in order for the selection of cloud service providers to effectively resolve both the quantitative and qualitative factors of preference. When meeting the conditions and criteria of cloud provider selection, the decision maker must select the best option. This issue could be modelled like a problem of decision-making with several parameters (MCDM). A pilot case study was carried out in this research in which the issue of selection of the CC provider was modelled as an MCDM. Multicriteria decision-making techniques for the right cloud service were proposed by Rehman et al. [7] in IaaS, but those multicriteria decision-making strategies are not adequate for fuzzy data. Garg et al. [8] have built the AHP framework for selection of cloud providers. Cloud-Service Metrics-Consortium (CSMIC) QoS criteria were determined by the authors, and main performance indicators (KPIs) were used to evaluate the cloud service. However, the selection and rankings of the same service is solely based on the CSMIC quantifiable parameters and does not take into account the attributes that cannot be quantified in the selection of trustable CSPs from QoS. In this paper, the researcher neglected to consider the fuzziness associated with the assessment criteria for cloud service selection. In [9], researchers identified an Elimination and Selection Expressing Reality (ELECTRE) multicriteria decision-making method that was using user preferences. In [10], authors proposed a mechanism for the selection of cloud services based on multidimensional trust. An evidential reasoning strategy that combines both trust value based on perceptions and trust value based on reputation is based on direct and indirect trust data, respectively, to define trustworthy services. In the form of historical customer feedback scores, multidimensional confidence evidence reinforcing the trustworthiness of cloud services on the different aspects are presented. The ER approach then adds multidimensional confidential valuations in order to achieve the confidence attribute in real time such that certain types of trustworthy cloud services are chosen for active users. R. Ranjan Kumar et al. [11] proposed a hybrid approach that combines AHP and TOPSIS to choose the most suitable service for customers by addressing the significance and importance of better service in the cloud, and had compared the previous methods and identified the drawbacks of those techniques. Five criteria were used by the authors to identify the best cloud services among the many acceptable cloud services. The weights of the parameters allocated in this proposed system by AHP and even TOPSIS are used to evaluate the cloud services. The weights derived using the AHP approach are utilized in the TOPSIS-based selection procedure to determine the rankings of cloud alternatives. Vague assessment criteria were not also taken into account in this paper. In choosing the right cloud service provider, the experience of current customers can also be helpful. The article [12] describes and defines QoS metrics so that consumers and suppliers can both communicate their desires and bid in a quantified way. A versatile, dynamic structure is proposed using the Ranked Voting method that takes inputs and provides the best provider for output requirements from the user. Users have different types of applications on relevant cloud platforms that should be carried out. As a consequence, users could experience problems choosing the best service. Therefore, the choice of a system for comparing services and selecting the best service have been seen as a challenge.

3 Evaluation Criteria

According to the specifications of the International Organization for Standardization (ISO) [1], CSMIC has established SMI attributes. Based on SMI characteristics such as Agility, Service Assurance, Price, Cost, Security, Privacy, Usability and

Accountability, the client will be able to select the best cloud provider that meets the QoS criteria.

3.1 Security and Privacy

The safety of data is one of the key issues about security and privacy in cloud computing. In these clouds, millions of users have stored their important data, which is what makes it more risky to encrypt every bit of information. Data protection has become a major problem in cloud computing, with different data being transmitted to various storage devices and computers, including PCs, servers, and various mobile devices, such as smart phones and wireless sensor networks. The benefits that cloud computing gives us have become an important part of our lives. This is why, if users want to trust the system again, protection and privacy in cloud computing need to take action. To be able to become a part of the cloud computing environment, it is necessary to gain the trust of these users.

3.2 Usability

Usability is the degree to which specified users may use a device, product, or service to achieve specified objectives with performance, effectiveness, and satisfaction in a specified context of use Although users experience the cloud through a user interface, by setting up the cloud service and its features, organizations allow the end-user experience. Via its applications, the end user communicates with the cloud and its cloud-based services. These applications are carried out by cloud and service attributes and will display behaviours that can be tracked back to the cloud. Application testing shows the usability of the cloud and cloud applications that the end user has access.

3.3 Accountability

In the business context, accountability is about complying with measures that give effect to practices articulated in the given guidelines. The complexities of compliance with data security and business regulations are an obstacle to delivering cloud services for the cloud service provider (CSP), and the costs and implications of non-compliance are a serious concern for the cloud service provider (CSP). Accountability will assist us in overcoming these issues in terms of trust and complexity. It is particularly useful to protect sensitive or confidential information, increase customer confidence, clarify the legal situation in cloud computing and promote cloud computing. Accountability offers a way forward in resolving data security issues resulting from the cloud handling of personal data, but these problems surpass the handling of personal data and generalize it to all forms of data, beyond privacy concerns.

3.4 Billing

The aim of the providers is to optimize revenue through their pricing schemes, while the primary objective of the consumers is to have a fair price for quality of services (QoS). Cloud Computing‘s pricing model is more flexible than traditional models. Each cloud provider has its own pricing mechanism. Cloud Computing is mainly based on fulfilling and achieving Quality of service (QoS) assurance for clients.

3.5 Performance

Performance is one of the main considerations to take into consideration when evaluating a cloud application, since it can have a direct effect on the user experience. Usually, this test practice is conducted to determine such performance characteristics such as output, reactivity, bottleneck, limitations, and latency when the application is under different workloads.

4 Fuzzy TOPSIS

The performance-based scores and the parameter weights are defined by intuitionistic fuzzy values, are calculated in terms of language. Below is the suggested IFTOPSIS form.

4.1 Normalize and Aggregate the Performance Ratings

Let $a_{ijk} = \left(p_{a_{ijs}}, 1 - f_{a_{ijs}} \right), a_{ijk} \geq 0, s = 1, 2, \ldots \ldots k, j = 1, 2, \ldots . m, i = 1, 2, \ldots n$, It is the performance rating provided by decision-maker *Dk* for criterion *Cj* to alternative *Ai*.

$a_{ij} = \left(p_{a_{ij}}, f_{a_{ij}} \right)$ of alternative A_i under criterion C_j is the aggregated performance rating which can be evaluated as:

$$a_{ij} = \left(\frac{1}{k}\right) \otimes \left(a_{ij1} + a_{ij2} + a_{ij3} + \ldots a_{ijk} \right) \tag{1}$$

$$a_{ij} = \left(p_{ij}, 1 - f_{ij} \right) \text{ can be normalized as follows :}$$

$$r_{ij} = \left(\frac{p_{aij}}{p^{+}{}_{aij}}, \frac{\left(1 - f_{aij}\right)}{\left(1 - f_{aij}\right)^{+}} \right), \tag{2}$$

$$p^{+}{}_{ij} = \max_i p_{ij} \text{ and } \left(1 - f_{aij}\right)^{+} = \max_i \left(1 - f_{a_{ij}}\right) \text{ for } j \in B$$

$$r_{ij} = \left(\frac{p^{-}{}_{ij}}{p_{aij}}, \frac{\left(1 - f_{aij}\right)^{-}}{\left(1 - f_{aij}\right)} \right), \tag{3}$$

$$p^{-}{}_{ij} = \min_i p_{ij} \text{ and } \left(1 - f_{aij}\right)^{-} = \min_i \left(1 - f_{a_{ij}}\right) \text{ for } j \in C$$

4.2 Normalize by Aggregating the Importance Weights

Let $wt_{jk} = \left(p_{wt_{js}}, 1 - f_{wt\,js} \right), x_{ijs} \geq 0, j = 1, 2, \ldots .m, s = 1, 2, \ldots .k$, the weight that decision-makers give to criterion *Cj. And* also the aggregated importance weight is given as $wt_j = \left(p_{w_{tj}}, 1 - ft_{w\,j} \right)$ of criterion C_j can be calculated as:

$$wt_j = \left(\frac{1}{k}\right) \otimes \left(wt_{j1} + wt_{j2} + wt_{j3} + \ldots wt_{jk} \right) \tag{4}$$

And the aggregated weights can be normalized as follows:

$$wt'_j = \frac{wt_j}{\sum_{j=1}^{m} wt_j} = \left(\frac{p_{wtj}}{\sum_{j=1}^{m} p_{wtj}}, \frac{\left(1 - f_{wt_j}\right)}{m - \sum_{j=1}^{m} \left(1 - f_{xij}\right)^{+}} \right) \tag{5}$$

where $wt'_j is$denoting the normalized wt_j

4.3 Normalized Decision Matrix (NDM) Calculation

The NDM is given as $V_{ij} = [v_{ij}]_{n \times m}$ where $v_{ij} = r_{ij} \otimes wt_j$.

$$v_{ij} = \left[p_{\left(r_{ij \times wt'_j}\right)}, (1-f)_{\left(r_{ij \times wt'_j}\right)} \right]$$
$$= \left[p_{r_{ij}} \times p_{wt'_j}, \left(1 - f_{rij}\right) \times \left(1 - f_{wt'_j}\right) \right] \tag{6}$$

4.4 Determine Ideal Positive and Ideal Negative Solutions

$+$ ideal and $-$ ideal solutions are described as:

$IA^{+} = (1,1), j \in \Omega_b$
$IA^{-} = (0,0), j \in \Omega_c$

And also the distance between each alternative IA^{+} and IA^{-} can be obtained as:

$$dt_i^{+} = \sqrt{\frac{1}{2m} \sum_{j=1}^{m} \left[\left(p_{vij} - 1\right)^2 + \left(f_{v_{ij}}\right)^2 \right]}, i = 1, 2 \ldots n \tag{7}$$

$$dt_i^{-} = \sqrt{\frac{1}{2m} \sum_{j=1}^{m} \left[\left(f_{vij} - 1\right)^2 + \left(p_{v_{ij}}\right)^2 \right]}, j = 1, 2 \ldots . n \tag{8}$$

where dt_i^{+} gives the value that represents the separation between IA^{+} and each alternative, and the separation between each alternative and IA^{-} is denoted by dt_i^{-}.

4.5 Closeness Coefficient Computation

The closeness coefficient may be computed as:

$$Cl_i = \frac{dt_i^{-}}{dt_i^{-} + dt_i^{+}}, \mathrm{i} = 1, 2 \ldots\ldots . n \tag{9}$$

Authors can rank all the alternatives as per the closeness coefficient, and can select the best alternative from them.

5 Ranking and Selection Process

A simple success metric for cloud service providers is the quality of service. In promoting the various services provided by the CSPs, high service quality can have a major impact. The assessment of cloud service providers based on the quality of services has, therefore, become an important issue in the choice of providers. Recently, clients such as business organizations have been interested in assessing the service quality of the providers required to pick the best CSP. The selection of quality of service-based criteria is an important factor in the ranking and selection of cloud service providers. The CSMIC consortium had proposed service measurement index attributes as an important criterion for the ranking and the selection of the Cloud Service providers. The SMI attributes are accountability, usability, performance, billing and security as given in Fig. 1.

Fuzzy TOPSIS is a decision-making approach with several parameters, and the principle of linguistic TOPSIS combined with the intuitionistic fuzzy values addresses the fuzziness involved in the problem. This is the first work according to the literature that uses the TOPSIS method and fuzzy intuitionistic values to compare multiple cloud providers based on SMI attributes. In this work, Intuitionistic Fuzzy Valued Technique for Order Preference by Similarity to Ideal Solution is used for ranking the CSPs based on SMI attributes. The ranking of services based on SMI characteristics such as usability, performance, billing, security and accountability performed in this work is not yet published in the literature. Figure 2 shows the steps in the evaluation and selection of the providers.

5.1 Steps Included in Suggested Approach

The ranking of the service provider is done using the Fuzzy TOPSIS method. The detailed step-by-step process involved in the ranking and selection of cloud service provider is shown in Fig. 2.

As mentioned above, the cloud service providers are ranked by IFTOPSIS. Service Measurement Index characteristics are the parameters used for rating and choosing the relevant cloud service providers in this chapter. The dataset of indi-

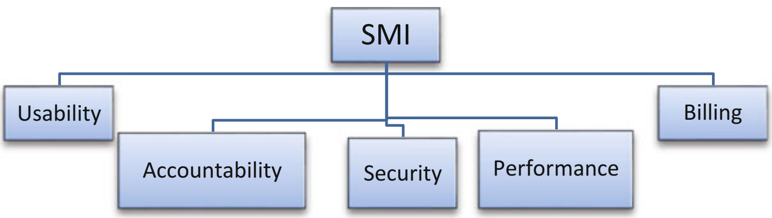

Fig. 1 The SMI attributes

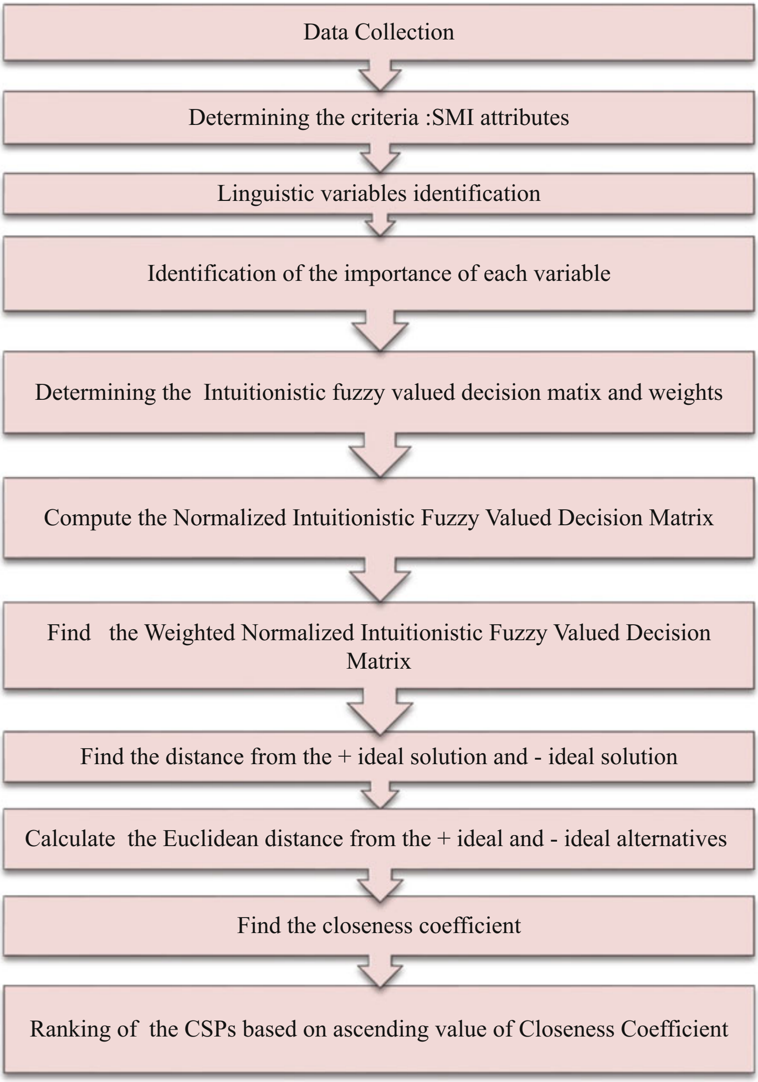

Fig. 2 Proposed ranking and selection approach

vidual cloud providers is gathered from the providers' websites and documentation. The linguistic variables for rating the performance of CSP and the significance of each criterion are shown in Table 1. An intuitionistic fuzzy value is associated with each linguistic variable.

In Table 2, the cloud service providers are indicated by CP1, CP2 etc. The columns acc, bil, sec, us and per are the criteria accountability, billing, security, usability and performance, respectively. By considering the importance of each

Table 1 Linguistic variables for rating the performance of CSP

Sl no	Variable	Value
1	Very high	(7,9,9)
2	Average	(3,5,7)
3	Low	(1,3,5)
4	Very low	(1,1,3)

Table 2 Performance of CSPs in linguistic variable terms

Importance	High	Very low	Very high	Very high	Very high
Cloud provider	Acc	Bil	Sec	Us	Per
CP1	H	L	VL	L	VL
CP2	L	L	VL	L	H
CP3	H	H	L	L	L
CP4	L	H	L	VH	VL
CP5	L	VH	VH	H	L
CP6	L	VL	VL	VL	VH
CP7	VL	VH	H	H	L
CP8	H	VL	H	VL	VL
CP9	H	L	VL	L	H
CP10	VL	L	VL	VH	L
CP11	H	H	H	H	H
CP12	H	VL	H	H	H
CP13	H	H	H	VH	H
CP14	VH	L	H	VH	H
CP15	L	L	VH	H	VH
CP16	H	H	VH	L	H

factor, the weighted normalized intuitionistic fuzzy valued matrix can be obtained. Table 3 shows the weighted normalized decision matrix.

Using formulas given in Eqs. (7) and (8), the authors will find the Euclidean distance between the alternatives and + and – ideal solutions, respectively. Table 4 displays the results.

Figure 3 shows the distance of each alternative from – and + ideal solutions.

Hence, by applying Eq. (9), the coefficient of closeness of each provider can be computed. Table 5 shows the results.

The graphical representation of the comparison of the closeness coefficients is shown in Fig. 4, as per the results shown above. The graph and table show that the coefficient of closeness of CSP 14 and CSP 13 is high and is followed by CSP 12 and CSP 11, and so on.

The final results are shown in Table 5. The results show that with regard to SMI criteria such as Accountability, Billing, Performance, Security and Usability, Providers 14 and 13 are the best among all available providers.

Figure 5 shows that the provider with the highest closeness coefficient has the first rank, and providers 14 and 13 are the best providers suitable for the consumer. The lowest rank is held by Provider 1.

Table 3 Fuzzy valued weighted normalized intuitionistic decision matrix

Weighted normalized fuzzy decision matrix															
Wt	5	7	9	1	1	3	7	9	9	7	9	9	7	9	9
CSP	Acc			Bill			Sec			Us			Per		
CP1	3.6	5.4	9.0	1.0	0.3	1.8	1.0	1.0	3.0	1.0	3.0	5.0	1.0	1.0	3.0
CP2	0.7	2.3	5.0	1.0	0.3	1.8	1.0	1.0	3.0	1.0	3.0	5.0	5.0	7.0	9.0
CP3	3.6	5.4	9.0	0.2	0.1	1.0	1.0	3.0	5.0	1.0	3.0	5.0	1.0	3.0	5.0
CP4	0.7	2.3	5.0	0.2	0.1	1.0	1.0	3.0	5.0	7.0	9.0	9.0	1.0	1.0	3.0
CP5	0.7	2.3	5.0	0.1	0.1	1.0	7.0	9.0	9.0	5.0	7.0	9.0	1.0	3.0	5.0
CP6	0.7	2.3	5.0	1.0	1.0	3.0	1.0	1.0	3.0	1.0	1.0	3.0	7.0	9.0	9.0
CP7	0.7	0.8	3.0	0.1	0.1	1.0	5.0	7.0	9.0	5.0	7.0	9.0	1.0	3.0	5.0
CP8	3.6	5.4	9.0	1.0	1.0	3.0	5.0	7.0	9.0	1.0	1.0	3.0	1.0	1.0	3.0
CP9	3.6	5.4	9.0	1.0	0.3	1.8	1.0	1.0	3.0	1.0	3.0	5.0	5.0	7.0	9.0
CP10	0.7	0.8	3.0	1.0	0.3	1.8	1.0	1.0	3.0	7.0	9.0	9.0	1.0	3.0	5.0
CP11	3.6	5.4	9.0	0.2	0.1	1.0	5.0	7.0	9.0	5.0	7.0	9.0	5.0	7.0	9.0
CP12	3.6	5.4	9.0	1.0	1.0	3.0	5.0	7.0	9.0	5.0	7.0	9.0	5.0	7.0	9.0
CP13	3.6	5.4	9.0	0.2	0.1	1.0	5.0	7.0	9.0	7.0	9.0	9.0	5.0	7.0	9.0
CP14	5.0	7.0	9.0	1.0	0.3	1.8	5.0	7.0	9.0	7.0	9.0	9.0	5.0	7.0	9.0
CP15	0.7	2.3	5.0	1.0	0.3	1.8	7.0	9.0	9.0	5.0	7.0	9.0	7.0	9.0	9.0
CP16	3.6	5.4	9.0	0.2	0.1	1.0	7.0	9.0	9.0	1.0	3.0	5.0	5.0	7.0	9.0
A*	5	7	9	1	1	3	7	9	9	7	9	9	7	9	9
A-	0.7	1	3	0	0	1	1	1	3	1	1	3	1	1	3

Table 4 Computed distance from the + ideal as well as – ideal solution

CSP	*dt+*	*dt−*
CP1	20.89	7.01
CP2	18.90	10.14
CP3	18.81	15.00
CP4	17.81	16.56
CP5	12.73	20.66
CP6	17.79	8.20
CP7	15.61	17.88
CP8	16.32	16.84
CP9	15.79	13.37
CP10	18.51	13.78
CP11	7.46	22.57
CP12	6.12	22.57
CP13	5.82	23.89
CP14	4.06	24.77
CP15	6.75	20.34
CP16	9.61	20.10

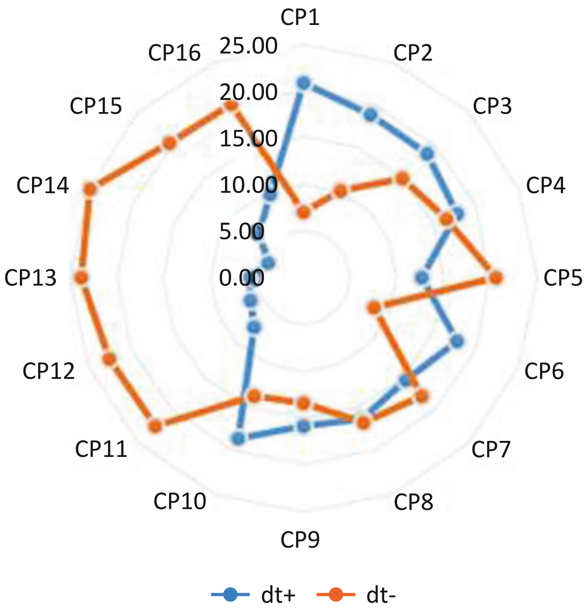

Fig. 3 Distance from + and − ideal solutions

Table 5 Coefficient of closeness of CSPs and ranks

CSP	CCi	Rank
CP1	0.25	16
CP2	0.35	14
CP3	0.44	12
CP4	0.48	10
CP5	0.62	7
CP6	0.32	15
CP7	0.53	8
CP8	0.51	9
CP9	0.46	11
CP10	0.43	13
CP11	0.75	4
CP12	0.79	3
CP13	0.80	2
CP14	0.86	1
CP15	0.75	5
CP16	0.68	6

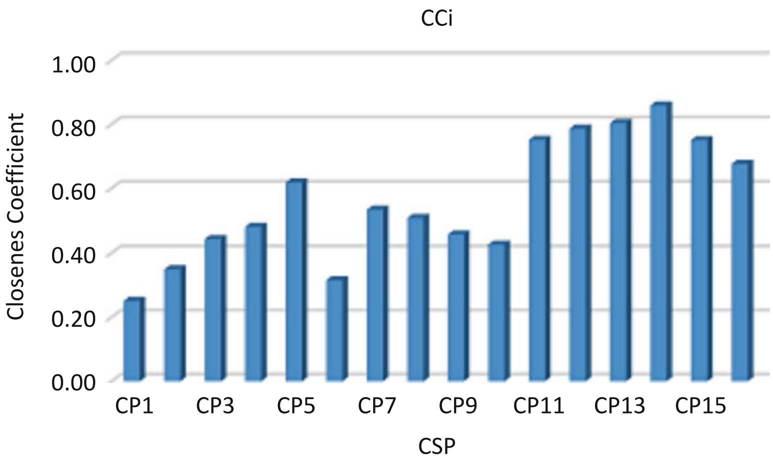

Fig. 4 CSPs and closeness coefficients

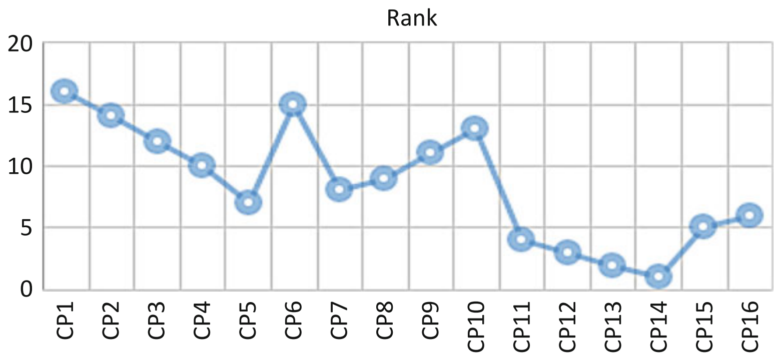

Fig. 5 CSPs and ranks

6 Conclusion

The choice of the best available Cloud Service Provider based on QoS attributes is a challenge for users especially. Qualitative and quantitative varieties fall under the selection criterion. The Cloud Service Provider selection based on SMI characteristics such as Usability, Billing, Accountability, Performance and Security was suggested in this chapter. The technique for order preference approach using the intuitionist fuzzy values is used for ranking the available providers based on the SMI attributes in this work. Using the respective linguistic variables, the ratings are interpreted and translated to intuitionist fuzzy values that efficiently rate the cloud providers. In the future, this research may be expanded to rate cloud services based on various MCDM approaches. By using new methods, fuzziness in selection can be managed effectively.

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