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Identification and Prioritization of Factors Contributing in Cloud Service Selection Using Fuzzy Best-worst Method (FBWM)

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Abstract

The introduction of cloud computing techniques revolutionized the current of information processing and storing. Cloud computing as a competitive edge provides easy and automated access to the vast ocean of resources through standard network mechanisms to businesses and organizations. Due to the vast diversity of service providers and their respective variety of available services with different qualities, top managements often face difficulty for choosing the best available option. So, considering the growing significance of the mentioned issue, this study aims to identify and rank contributing factors in selection of cloud service providers. In that attempt, this research approaches its goal by going through three major phases. Firstly, in phase one, prior studies are reviewed for extracting related elements of selection. Secondly, by employing Fuzzy Delphi method and obtaining results by interviewing experts in this field such as IT managers and technicians, this study tries to finalize the list of contributing factors. Lastly, by utilizing Fuzzy best-worst multi-criteria decision-making method, which is one of the most recent techniques employed to statistically rank variables, this research introduces a list of vital factors for cloud service selection. Based on the findings of this study, there are five major categories involved in the selection process which are: performance, security, data management, personal data protection and environmental-organizational. The finalized result of ranking shows that, performance related factors such as accessibility, response time and capacity are the first priority. The runner-up is security with reliability and governance. Environmental-organizational variables lands in the third place by considering rental and network costs.

Keywords: Cloud service selection, Cloud service providers, Fuzzy Best-worst Method, Multi-criteria decision-making method, Fuzzy Delphi.

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Introduction

In recent years cloud-based infrastructure and its application has been employed in large corporations' strategies. Top managers in these organizations are constantly reviewing different approaches to lower their overall expenditures using cloud base systems. It's due to the fact that selection of an appropriate cloud service can potentially lower their overhead costs. On the other hand, if the cloud base service fails, it can have an adverse effect on their business bottom line. Cyense organization estimated that in 28th of February 2017, the blackout that was initiated in Amazon primary servers which lasted for 4 hours had a devastating effect on more than 500 commercial corporations and its cost was approximated to be around 150 million dollars (Condliffe, 2017). In addition, Apica (an organization that monitors and reports network traffics on the internet) stated that out of 100 resellers, 54 of them experienced performance decline of about 20 percent. Data centers blackout in 2015 cost from 1.25 to 2.5 million dollars for 1000 commercial corporations (Condliffe, 2017). However, with the catastrophic effect of all negligence and mistakes in terms of service selection, cloud computing market is growing rapidly (Mac Gillivray et al. 2016). In the age of Internet of Things, the level of dependency to cloud service providers is growing significantly due to the processing facilities which are available only through cloud services. Considering all factors, it becomes clear that a successful service selection process depends essentially on a vivid picture of contributing factors and how they rank. Based on these facts, the information technology research community becomes more and more active in the field of cloud service selection which resulted in numerous conducted researches which each of them is investigating different aspects of the field. Accordingly, the literature review of this paper reveals the following points: Firstly, most of the literatures are focused on a handful of parameters relevant to the quality of services and other organizational and environmental variables are mostly neglected. In a selective range of studies, a wholesome look into the contributing variables was considered but a reliable and systematic literature review is often lacking. Secondly, since different perspectives count when it comes to service selection because of different level of knowledge and experience, considering experience and knowledge of the organizations' experts in this procedure stands tall (Yu-Lung Hsu et al. 2010). Thirdly, in the most decision-making methods, coming to an agreement in relation to effective factors proves to be a chore and requires large number of paired comparisons (Ghoushchi et al. 2019). Lastly, in many real-life situations, value judgments of experts cannot be captured and recorded using numerical values. In other words, using quantitative methods prove to be inefficient because of high level of uncertainty in real life scenarios (Kannan et al. 2014). In this study, to fill the mentioned gap in research literature, initially a systematic literature review covering a large number of researches in this area was employed to extract contributing factors in cloud service selection, then a panel of experts working in the field of cloud computing consisted of academics, IT managers, and IT technicians was utilized, and contributing factors through exploiting Fuzzy Delphi Method were evaluated and finalized, finally Fuzzy Best-Worst technique was employed which resulted in the list of the most significant variables in terms of cloud service selection and their respective importance toward each other. One of the advantages of the employed technique would be its ease of use compared to other similar methods such as AHP, and also it provides higher level of reliability in results which is worth to point out. Such advantage is ensued because of the fewer number of paired comparisons that would give a great aid to avoid incompatibility in comparisons. In addition, it can be more beneficial for the experts who have limited time to respond (Rezaei, 2015).

Literature Review

This section provides an overview of the relevant work that has been completed so far, and moreover discusses the literature review technique which has been used to investigate the research background.

Systematic Literature Review

In order to implement an exhaustive literature review, and cover a broader range of researches in the field of Cloud Computing, this research has taken advantage of Systematic Literature Review methodology. Based on the conducted studies on the topic of Structural Literature Review, the process of performing a systematic literature review consists of several stages which are indicated below:

1. First stage: Research question development

The question to be answered in the review should be clear and unambiguous, so in the first step we clarified the problem explicitly and investigated different facets of it .

2. Second stage: Identifying relevant researches

An extensive search for relevant studies should be done, and such a search should comply with three conditions mentioned below:

- Multiple numbers of resources should be investigated.
- Searching in such resources should not have language restrictions .
- Reasons for inclusion and exclusion of the selection of researches should be presented clearly.

To progress this stage while the aforementioned conditions are satisfied, first we gathered a list of relevant keywords with the research topic. Essentially, such a list should be extracted based on investigation of relevant areas with the research title (Sidaoui, 2014), and in order to achieve higher level of search efficiency scholars should search them with every possible arrangements. Accordingly, we set up the following list of key words for this research and use them for search in Persian and English resources:

Cloud Computing, Cloud Service, Cloud Selection, Cloud Service Selection, Cloud Framework, Cloud Service Framework, Cloud Selection Framework

Adhering to the above-mentioned first condition, following Databases were investigated for relevant researches:

- IEEE
- Elsevier
- Scopus
- Google Scholar
- Research Gate
- LinkedIn

Considering the presented key words list, search results provided us with 1068 relevant publications from the above list of research databases.

3. Third stage: Assessing the quality of studies

In this stage of Systematic Literature Review, scholar should scrutinize the quality of gathered publications to pick out appropriate ones. For this purpose, following three steps is required:

- Initial assessment should be done by evaluation of the titles and abstracts of gathered publications.
- Selected Researches' implications should be assessed afterward.
- In the final step, evaluation of each publication should be done by completely investigating the article.

In according to these steps, in the first move, by exploring the titles and abstract of the researches, 433 articles were selected. Then, after investigation of implication of each research, impertinent articles were discarded and 262 publications remained. Ultimately, all remained researches were wholly examined, and 175 items which were directly connected with the research title and its domain, were kept as the qualified publications.

4. Fourth stage: Preparing an overall summary of the previous stage findings

5. Fifth stage: Interpretation of the findings

In the last stage, Highlighted issues in all of previous stages were assembled and presented in the overall summary in order to make a clear image of conducted studies and also suggest a plan for paving the path of other chapters.

Background

In the following section, to acquire a better understanding of the effective factors in cloud service selection and their relations, implications of relevant researches is concisely presented and the results of the review are summarized in table 1 at the end of this section.

Saravanan et al. (2015) presented a framework for ranking cloud services called SMI. The parameters considered are: service response time, cloud impact on the environment (the amount of carbon dioxide produced), degree of cloud service compliance with customer needs, accuracy (the number of times a cloud service responds to the user without breach of agreement), Transparency (Impact of Service Changes on Customer Process Performance), Degree of interoperability of a service with other services, availability, reliability, stability (non-variation in service performance), virtual machine renting costs, Adaptability, Usability, Efficiency and Scalability (Response to the number of requests).

Karim, Ding, and Miri (2013) introduced a service selection system based on end-to-end quality assurance. The link used in this paper is the three-tier model of the end user, the software provider as the interface, and the infrastructure provider. The quality of services considered in this study is divided into three general categories: functional, systematic, and customer service. In addition to the parameters that were identified in (Garg, Versteeg, and Buyya, 2013) they added the security and reputation of the service provider.

Byrne (2013) measures the effect of six following components in selecting cloud services for users, these components are: communication, value of information technology, senior management, cooperation, the architecture of service presentation, and ability of work with technology. Rajendran (2013) evaluates some of organization challenges in management, security, dependency, level and state and staff knowledge and related issues to technology in organization. The goal his study proposes a suitable organizational structure for accepting cloud technology to face minimum challenge in transfer of process from classic form to cloud service in organization.

Rehman et al. (2014) identifies the best cloud service provider by prioritizing them due to the service quality components. These components introduce and subsequently for measuring every provided practical properties by each cloud service, to gain the best option according to price, processing speed, memory amount and response time. Yarlikas (2014) developed a model for effective evaluation of cloud processing. The components used in the model include technical, organization, economical indexes and external components. All of these components both from user`s viewpoint and service providers has been evaluated. Mary and Jayapriya (2014) completed a comprehensive evaluation of all cloud processing technology study. And to study the main problem in cloud service provider’s corporation, that is making a new layer.

Whaiduzzaman et al. (2014) focuses on choosing the most optimal computing service provider using multifactorial decision-making methods. In this research, the various kinds of multifactorial decision-making methods have been studied and the weaknesses-strengths of each method have been expressed.

Cao et al. (2015) developed a comprehensive model for offering suitable cloud service that matches users request has been studied. This research studies components and process of cloud service selection in the direction of implementation and cloud service offering, indexes of this research include: time, quality, cost and service. Esposito et al. (2016) used Fuzzy Logic Theory to choose required resources to determine desired quality of service for users. Esposito et al. (2016) utilizes Dempster-Shafer evidences theory in order to come up with the most optimal cloud service that matches with user’s demand. Finally, it proposes a distribution formula for more effective selection of the most optimal cloud service provider.

Alsanea (2015) reviewed internal and external pressures, technical and organizational readiness and perceived benefit components which facilitate acceptance of cloud processing technology. Tang et al. (2016) introduces trust-based method for evaluation and selection of cloud service provider. This method focuses on service quality indexes for reliability. Also, this method checks user’s feedback for cloud service provider evaluation. Ding et al. (2016) In this study, propose an innovation approach to prioritize cloud service providers. Instead of paying attention to time-consuming and costly estimations, suggested approach of this study is selection based on customers and cloud service consumer’s feedback.

Jagli, Purohit, and Chandra (2016) In this paper they have reported problems with cloud service acceptance. These problems include: 1) Not all cloud selection models have considered all components. 2) There is not any complete model that encompasses all qualitative and quantitative indicators of cloud service selection. 3) Not all ISO 9126 standards are considered in terms of Software as a Service (SaaS) implementation. 4) There is no set of standards used to evaluate the quality of cloud service provider in SaaS mode.

Anu (2016) provides a qualitative model based on decision-aiding system for selecting the best cloud service provider. Evaluations of the previous qualitative extracted components are: response time service durability, needs and services proportion, availability amount, transparency and reliability. The practical components of this research include: memory capacity, saving space, and bandwidth.

Hioual and Hemam (2016) proposes a model that focuses on quantity of workload in relation to each feedback of applicants. Hioual and Hemam (2016) used multifactor decision-making technic and Markov Chain to evaluate the components. Kumar et al. (2017) proposes a model of selecting cloud computing in Fuzzy environment using AHP method. This creates a framework for a model of suitable cloud service selection employing Fuzzy TOPSIS method, where it prioritizes output results. This model considers quality of service providing as the main factor. Test results that have been done on cloud service providers show that the presented model superior an efficient comparison to similar models. Finally, sensitivity analysis of this model exhibits a high durability in different situations.

Ezenwoke, Daramola, and Adigun (2017) presents a framework for correct selection of cloud service based on urgency of environmental management of cloud service, graphic user interface of service presentation quality, and evaluation indexes of service presentation quality. Al-Khater (2017) presents a comprehensive model that includes main and vital components of cloud service from organizational viewpoint such as: technology related components (service presentation quality, security, privacy, protection, trust, competitive, abilities, identification, being experimental ability), organizational components (supporting senior managers, technical readiness of staff), environmental components (similarity with rules, external protection industrial environment), and social components (culture).

Elhabbash et al. (2018) identifies effective components in designing allocators of cloud service such as decision system, resources evaluation, performing policies, agreements evaluation, sending practical structures description, and virtual machine's internal function. Dahouei et al. (2018) provides a scientific frame work for selecting an appropriate software to implement Cloud computing approach at the infrastructure level. The results suggest that the "OpenStack" Cloud computing system is the best available option. This is because the system focuses in factors such as function, Assurance ability, system security, system sustainability and stability and usability.

Senarathna et al. (2018) evaluates effective components of selecting cloud processing technology for small and medium size organizations (SME) In Australia. The presented model in this research is a combination of technology, organization and environment model (TOE) and technology innovation transference model. Studied components include: relative advantage, service quality, knowledge, security, personal privacy, and flexibility.

Al-Faifi (2018) In this study, the challenge of choosing the best cloud service provider is fully automated according to the needs of the organization. This automation process is done according to the workload of the organization and the number of resources needed. Wu (2018) focuses on selecting the most reliable and optimal cloud service provider in the mobile cloud computing space. SSRM model used for this research is based on the rating of the preferences and content of users' requests.

Maeser (2018) provides a review of Service Level Standards (SLAs) and security requirements in order to identify an indicator to measure the reliability of cloud service providers. It is also a comprehensive model for predicting the performance of any cloud service provided. Indicators evaluated include provider reliability, provider geographic location, provider capacity and cloud service provider performance.

Jatoth et al. (2018) chooses the best cloud service provider which studied indexes including price, speed, information processing, the amount of memory deployment, function of saving disk, and speed of information input/output.

Hakim (2018) identifies the effective components of corporate adoption of cloud computing. Interview results of IT managers in technology companies showed that financial risks, lack of knowledge and awareness and Organization Resistance to Changes, and Security Risks were the major factors in not using cloud computing technology. On the other hand, interview results of managers at non-technological organizations revealed investing heavily on existing systems of the organization, training courses, Security risks and lack of awareness of the benefits of cloud computing were identified as major factors in the lack of acceptance of cloud computing technology.

Nedev (2018) identifies effective components in accepting the cloud processing technology and implementation challenges in organization. TOE model was employed in this qualitative research. This model uses technology, organization, and environment as the three main branches of related components with utilization of cloud processing technology: The identified components underlying the technology in this study are comparative advantage, rework, efficiency, complexity, adaptability, and security. The identified components of the organization's subgroup in this study are senior management support in the organization, size of the organization, technical readiness of the organization to adopt technology. Finally, the identified components of the environmental subgroup in this study are external pressure from competitors and business partners. RajKumar and Balaji (2018) provides a review of algorithms and previous researches completed on cloud service selection. The three types of cloud services that are being offered are: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Yoo and Kim (2018) research shows that cloud service providers place the highest importance on environmental components and service providers place great importance on organizational components. Cloud applicants prioritize choice on factors such as Alignment, Rivalry, and Technology Infrastructure. On the other hand, effective factors identified for cloud providers are: competitive factors, support from senior managers and pressure from competitors.

Saravanan et al. (2015) focus on comprehensive, 360-degree survey on different aspects of the cloud service agreements. The service level agreement (SLA) is a commitment between a service provider and a client. Cloud Service level agreements act as a key liaison between consumers and providers on renting anything as a Service (AaaS). There are several standards and practices proposed to define and structure the cloud SLA. Standards such as Cloud Industry Forum (CIF), Cloud Standard Customer Council (CSCC) & Cloud Select Industry Group (CSIG) and Open Cloud Computing Interface (OCCI) provide the guidelines for drafting a cloud SLA. Studying these industry standards can help to identify the components as well as their classification. Therefore, in this paper, two standards CSIG and NIST were investigated in order to identify and categorize the factors affecting cloud service selection. Table 1 provides a summary of these component; which are categorized by purpose into four general categories: performance, security, data management and personal data protection.

Table 1. Summary of contributing factors toward cloud service selection

Dimensions/Criteria	Performance								Security							Data Management				Personal Data Protection					Organization & Environment						
	Availability	Response Time	Capacity	Capability	Support	Easy to use	Scalability	Reversibility and Termination Process	Reliability	Authentication and Authorization	Cryptography	Security Incident Management	Logging and Monitoring	Vulnerability Management	Governance	Data Classification	Backup & Restore	Data Life Cycle	Data Portability	Standards and Certifications Mechanisms	Use, Retention, and Disclosure Limitation	Transparency & Notice	Accountability	Geographical Data Location	Environmental Effect	Training Cost	Reputation	Rent Cost	ISP and Data Transfer Cost	Users Feedback	Organization policy
CSIG, 2016	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•				•	•		
NIST,2015	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•				•	•		
Byrne ,2013	•					•		•																	•						
Rajendran, 2013										•																•					
Rehman, 2014		•																										•	•		
Yarlikas, 2014	•																											•	•		•
Mary , 2014	•	•	•		•		•																				•			•	
Whaiduzzaman , 2014	•								•	•				•									•					•			
Lee, 2014									•																					•	
Cao, 2015		•																										•	•		
Esposito, 2015						•																									
Alsanea, 2015	•					•																									•
Tang , 2016									•																						
Ding, 2016	•	•			•																					•					
Ding, 2016	•		•																												
Anu, 2016		•	•						•	•												•									
Hioual ,2016			•							•			•													•	•				
Kumar, 2017	•	•							•																						
Ezenwoke , 2017	•	•	•																						•	•	•				
Al-Khater, 2017									•	•														•							
Elhabbash , 2018															•					•											
Dahouei, 2018	•			•		•			•																						
Senarathna, 2018				•					•	•																					
Al-Faifi, 2018		•	•																												
Mahmood, 2018									•																•						
Wu X, 2018									•																					•	
Maeser, 2018	•		•						•															•							
Jatoth , 2018		•	•																									•	•		
Hakim, 2018									•						•																•
Nedev, 2018						•			•																					•	•
RajKumar, 2018																						•	•								
Abdel-Basset, 2018	•				•	•	•																				•		•		
Yoo , 2018																									•	•				•	•

Methodology

In order to identify and rank contributing factors in cloud service selection, we propose a MADM framework utilizing FDM and FBWM. As it is shown in Figure 1, the research framework consists of three key phases: in phase one, prior studies are reviewed utilizing Systematic Literature Review for extracting relevant elements of selection (Section 2). In phase two, by employing Fuzzy Delphi method and obtaining results by interviewing experts in this field such as IT managers and technicians, this study tries to finalize the list of contributing factors (Section 3.1). Lastly, by utilizing Fuzzy best-worst multi-criteria decision-making method which is one of the most recent techniques employed to statistically rank variables (Section 3.2), this research attempts to present a capsulated list of vital factors for cloud service selection and they respective importance toward each other.

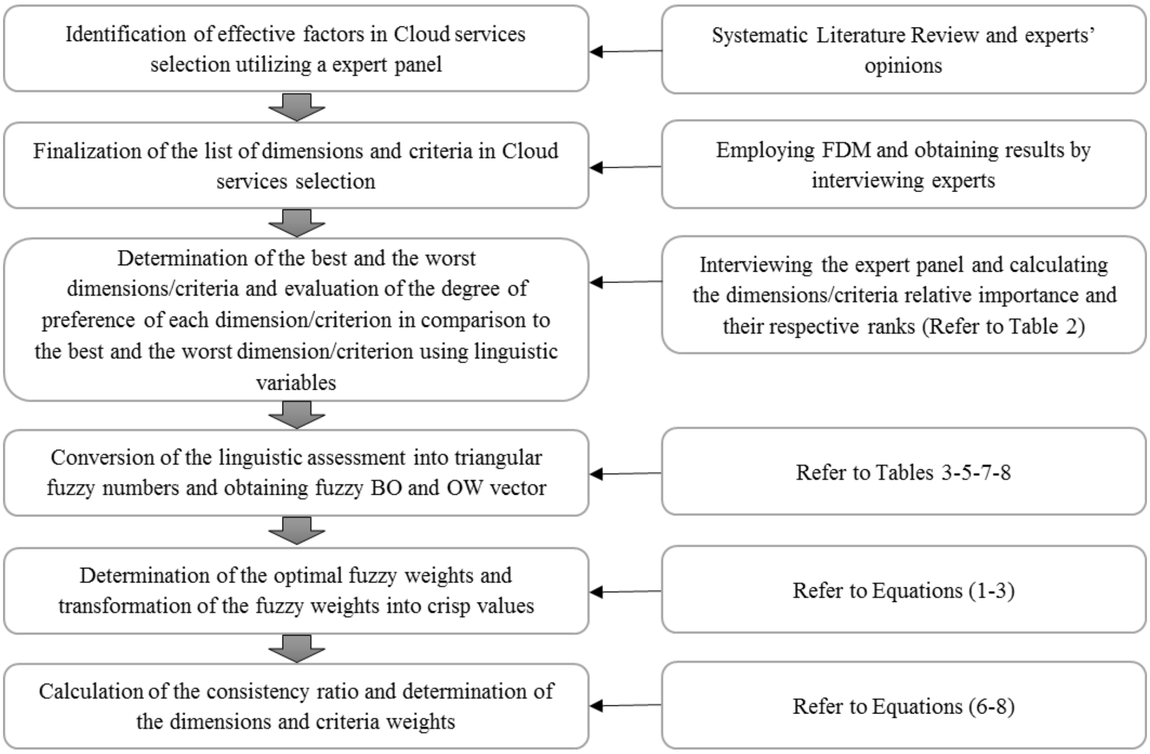


Figure 1. Research framework

Fuzzy Delphi Method

This technique is a survey based on expert opinions and it has four main features: nameless response, repetition, controlled feedback, and finally statistical group response. (Hsu et al. 2010) In many real situations, expert judgments cannot be expressed as definitive quantitative numbers. In order to overcome this problem, the fuzzy set theory proposed by (Zadeh 1965) is an appropriate tool to deal with the ambiguity and uncertainty of the decision-making process (Bouzon et al. 2016). Fuzzy Delphi Method was proposed by (Ishikawa et al. 1993) and it was derived from the traditional Delphi technique and the fuzzy set theory. (Noorderhaben 1995) indicated that applying the Fuzzy Delphi Method to group decision can solve the fuzziness of common understanding achieved from expert opinions. Similar to the selection of fuzzy membership functions, previous researches were usually relied on triangular fuzzy numbers and Gaussian fuzzy numbers. This study applied the triangular membership functions and the fuzzy theory to solve the group decision and used FDM for the screening of alternate factors of the first step. The Fuzzy Delphi Method steps are as follows:

1. **Collect opinions of decision group:** the evaluation score of each alternate factor's significance given by each expert should be calculated using linguistic variables presented in questionnaires.

2. **Set up triangular fuzzy numbers (TFNs):** in this stage the evaluation value of triangular fuzzy number of each alternate factor given by experts should be computed, and the significance triangular fuzzy number of the alternate factors should be driven.

In this study, the geometric mean model of the general mean model presented by (Klir and Yuan 1995) for FDM is used to reach common understanding in group decision making procedure. The computing formula is illustrated below:

Assuming the evaluation value of the significance of No. j element given by No. i expert of n experts is:

$$\tilde{w}\text{ij} = (aij, bij, cij)\ ;\ \forall i = 1,2,\dots,n\ , \forall j = 1,2,\dots,m \tag{1}$$

Then fuzzy weight $\widetilde{w_j}$ of No. j element $\tilde{w}j = (aj, bj, cj), j = 1,2,\dots,m,$ among which:

$$a_j = \min(a_{ij})\ , bj = \left(\frac{1}{n}\sum_{i=1}^{n} b_{ij}\right), c = \max(c_{ij}) \tag{2}$$

3. **Defuzzification:** simple center of gravity method should be implemented to defuzzify the fuzzy weight $(\widetilde{wj})$ of each alternate element to definite value S_j, the following are achieved:

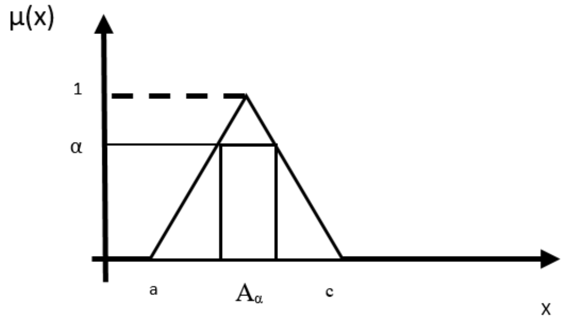
$$s_j = \frac{a_j + b_j + c_j}{3}\ , j = 1,2,\dots,m \tag{3}$$

4. **Screen evaluation indexes:** Finally, proper factors can be screened out from numerous factors by setting the threshold α. The principle of screening is as follows:

- If Sj ≥ α, then No. j factor is the evaluation index.
- If Sj < α, then delete No. j factor.

Schematic diagram of FDM threshold is shown in Figure 2.

Figure 2. Schematic diagram of FDM threshold



Fuzzy Best and Worst Method

The basic MADM methods for calculating weights are analytic hierarchy process (AHP), analytic network process (ANP), decision-making trial and evaluation laboratory-based ANP, and hybrid methods such as fuzzy AHP and fuzzy ANP. However, when an evaluation system has a very large number of indicators, the number of paired comparisons between indicators are similarly excessive, thus rendering weight calculation becomes extremely difficult. Rezaei (2015) introduced BWM as a relatively new MADM method, BWM can obtain criterion weights more easily and accurately with less required comparison time and higher consistency. Guo and Zhao (2017) proposed a hybrid model that combines fuzzy methods with BWM to improve decision accuracy.

Mou et al. (2016) proposed an intuitionist fuzzy multiplicative BWM for group decision-making. Hafezalkotob and Hafezalkotob (2017) suggested a new method that combines individual and group decisions based on FBWM. In this study, we examined the fuzzy preference degrees of all criteria in the form of triangular fuzzy sets. Triangular fuzzy set theory was developed to solve fuzzy and uncertain problems and can improve data accuracy based on fuzzy mathematics. A triangular-shape membership function is easy to understand and can sort uncertain datasets via lower bound, middle bound and upper bound, which is more consistent with the semantics of human thought expression. Linguistic variables such as “equally important (EI)”, “slightly important (SI)”, “fairly important (FI)”, “very important (VI)”, and “absolutely important (AI)” are used to reflect the degree of preference between the best or worst criteria and other criteria. Therefore, the linguistic variables must be transformed into triangular fuzzy numbers (TFNs), with the rules of transformation listed in Table 2.

Table 2. Transformation rules of linguistic variables

Linguistic Variables	Membership Function
Equally importance (EI)	(1,1,1)
Between the two	(1,2,3)
Weakly important (WI)	(2,3,4)
Between the two	(3,4,5)
Fairly Important (FI)	(4,5,6)
Between the two	(5,6,7)
Very important (VI)	(6,7,8)
Between the two	(7,8,9)
Absolutely important (AI)	(8,9,10)

We next built a fuzzy mathematical programming model to obtain the weights of dimensions and criteria, as follows:

Step 1: Set up a decision standard system

In this step, the criteria evaluation system should be extracted through implementation of literature review and by obtaining expert opinions. It is supposed that n criteria $\{s_1, s_1, \ldots, s_n\}$ are considered for a research.

Step 2: Determine the best (most important) dimension or criterion and the worst one (the least important)

In this step, the decision-maker determines the best and worst criteria based on the decision system.

Step 3: Derive the best-to-others (BO) vectors

Determine the fuzzy preferences of the best criterion to all the others using TFNs, as listed in Table 3. The BO vectors can be described as $\tilde{Q}_b = (\tilde{q}_{b1}, \tilde{q}_{b2}, \ldots, \tilde{q}_{bn})$ where b is the index of the best criterion, and $\tilde{q}_{bi}$ is a TNF indicating the degree of importance of the best criterion C_b over criterionC_i. Clearly, $\tilde{q}_{bb}$ = (1,1,1).

Step 4: Derive the others-to-worst (OW) vectors

Following the same procedure as in step 3, the decision-maker determines the fuzzy preferences of all other criteria to the worst criterion using the TFNs listed in Table 3. The OW vectors can be described as $\tilde{Q}_w = (\tilde{q}_{1w}, \tilde{q}_{2w}, \ldots, \tilde{q}_{nw})$, where w is the index of the worst criterion, and $\tilde{q}_{iw}$ is a TFN indicating the importance degree of another criterion C_i over the worst criterion C_w. It is clear that $\tilde{q}_{ww}$ = (1,1,1).

Step 5: Determine the optimal fuzzy weights $(\boldsymbol{\omega_1^*, \omega_2^*, \ldots, \omega_n^*})$

The ideal fuzzy weight value of each criterion satisfies the following equations: $\widetilde{\omega}_b/\widetilde{\omega}_i$ = $\tilde{q}_{bi}$ and $\widetilde{\omega}_i/\widetilde{\omega}_w = \tilde{q}_{bi}$. We can obtain the dimension and criterion weights by minimizing the maximum absolute differences $\left|\frac{\widetilde{\omega}_b}{\widetilde{\omega}_i} - \tilde{q}_{bi}\right|$ and $\left|\frac{\widetilde{\omega}_i}{\widetilde{\omega}_w} - \tilde{q}_{iw}\right|$, where $\widetilde{\omega}_b$, $\widetilde{\omega}_i$ and $\widetilde{\omega}_w$ are TFNs and $\widetilde{\omega}_i = (l_i^{\omega}, m_i^{\omega}, u_i^{\omega})$, l_i^{ω} is the lower bound of the weight value of dimension or criterion i, m_i^{ω} is the middle bound, and u_i^{ω} is the upper bound.

Then, the optimal weight can be obtained by solving the following nonlinear constrained optimization problem.

$$\min \zeta^* \tag{4}$$

$$s.t = \begin{cases} \left|\frac{\widetilde{\omega}_i}{\widetilde{\omega}_b} - \tilde{q}_{bi}\right| \le \zeta^* \\ \left|\frac{\widetilde{\omega}_i}{\widetilde{\omega}_w} - \tilde{q}_{iw}\right| \le \zeta^* \\ \sum_{i=1}^{n} R(\omega_i) = 1 \\ l_i^{\omega} \le m_i^{\omega} \le u_i^{\omega} \\ l_i^{\omega} \ge 0 \\ i = 1,2 \dots, n \end{cases}$$

Where $\zeta^* = (h^*, h^*, h^*)$, and $R(\omega_i) = \frac{l_i + 4m_i + u_i}{6}$. This equation can be transformed to have greater detail into Equation (5):

$$s.t = \begin{cases} \left|\frac{(l_b^{\omega}, m_b^{\omega}, u_b^{\omega})}{(l_i^{\omega}, m_i^{\omega}, u_i^{\omega})} - (l_{bi}, m_{bi}, u_{bi})\right| \le (h^*, h^*, h^*) \\ \left|\frac{(l_i^{\omega}, m_i^{\omega}, u_i^{\omega})}{(l_w^{\omega}, m_w^{\omega}, u_w^{\omega})} - (l_{iw}, m_{iw}, u_{iw})\right| \le (h^*, h^*, h^*) \\ \sum_{i=1}^{n} R(\omega_i) = 1 \\ l_i^{\omega} \le m_i^{\omega} \le u_i^{\omega} \\ l_i^{\omega} \ge 0 \\ i = 1,2 \dots, n \end{cases} \tag{5}$$

where $\tilde{q}_{bi} = (l_{bi}, m_{bi}, u_{bi})$, and $\tilde{q}_{iw} = (l_{iw}, m_{iw}, u_{iw})$.

We transform the fuzzy criterion weight represented by TFN $\widetilde{\omega}_i = (l_i^{\omega}, m_i^{\omega}, u_i^{\omega})$ into a crisp value. The function $R(\widetilde{\omega}_i)$ is used to resolve ambiguous numbers, so that the weight of each dimension and criterion can be obtained.

Step 6: Determine the consistency ratio (CR) for BWM

CR is a crucial indicator for determining the consistency of pairwise comparisons. A comparison is fully consistent when $\tilde{q}_{bi} \times \tilde{q}_{iw} = \tilde{q}_{bw}$, where $\tilde{q}_{bi}$, $\tilde{q}_{iw}$, and $\tilde{q}_{bw}$ are the fuzzy preference of the best criterion over criterion i, the fuzzy preference of criterion i over the worst criterion, and the fuzzy preference of the best criterion over the worst criterion, respectively. CR can indicate the degree of consistency of a fuzzy pairwise comparison. Guo and Zhao (Guo,2017) proposed a method for calculating CR. Given that inconsistency in a fuzzy pairwise comparison occurs when $\tilde{q}_{bi} \times \tilde{q}_{iw} \ne \tilde{q}_{bw}$, the maximum inconsistency occurs when $\tilde{q}_{bi} = \tilde{q}_{iw} = \tilde{q}_{bw}$, and the variable ζ can be obtained to satisfy Equation (6).

$$\widetilde{(q}_{b\omega} - \zeta) \times (\tilde{q}_{bw} - \zeta) = (\tilde{q}_{bw} + \zeta) \tag{6}$$

Guo and Zhao (2017) considered that the upper boundary u_{bw} could be used to calculate the CR, and thus Equation (6) can be transformed into Equation (7):

$$\zeta^2 - (1 + 2u_{bw})\zeta + (u_{bw}^2 - u_{bw}) = 0 \quad (7)$$

Where $\tilde{q}_{bw} = (l_{bw}, m_{bw}, u_{bw})$. According to Table 3, the values of u_{bw} are as follows:

$u_{bw} = 1,2,3,4,5,6,7,8,9,10$. The maximum possible ζ, which is considered to be consistency index (CI), can be derived using Equation (7). The CIs for different u_{bw} values are listed in Table 3.

Table 3. CI for FBWM

Linguistic terms	q ̃_(bw)	CI
Equally importance (EI)	(1,1,1)	3.00
Between the two	(1,2,3)	6.00
Weakly important (WI)	(2,3,4)	7.36
Between the two	(3,4,5)	8.69
Fairly Important (FI)	(4,5,6)	10.00
Between the two	(5,6,7)	11.27
Very important (VI)	(6,7,8)	12.53
Between the two	(7,8,9)	13.77
Absolutely important (AI)	(8,9,10)	15.00

Step 7: Determine the dimension or criterion weights.

It is supposed that there are k experts. Accordingly, the weight of dimension or criterion j can be identified by vector $\widetilde{\omega}_j = \{\omega_j^1, \omega_j^2, \dots, \omega_j^k\}$, and the dimension or criterion weight can be obtained by averaging the elements $\widetilde{\omega}_j$:

$$\omega = \frac{1}{k}[\,\omega_j^1 + \omega_j^2 + \omega_j^3 + \cdots + \omega_j^k] \quad (8)$$

Results Analysis

In this section, we apply the proposed hybrid model combining FDM and FBWM. To perform a comprehensive evaluation, we do these steps:

1. Reviewing relevant literature of cloud service selection and proposing important criteria

According to conducted literature review and relevant publications, and by obtaining opinions of experts, more than 31 criteria in 5 dimensions for cloud service selection are proposed. Definitions of these criteria are presented in Table 4.

Table 4. Descriptions of dimensions and criteria

Criteria	definitions	sources
Availability	The property of being accessible and usable upon demand by an authorized entity.	(Yarlikas,2014), (Alsanea,2015), (Ding,2016), (Dahouei,2018), (Maeser,2018)
Response Time	The time interval between a cloud service customer-initiated event (stimulus) and a cloud service provider-initiated event in response to that stimulus.	(Rehman,2013), (Cao,2015), (Anu,2016), (Al-Faifi,2018), (Jatoth,2018), (K.Saravanan,2015)
Capacity	The maximum amount of some property of a cloud service.	(Anu,2016), (Al-Faifi,2018), (Maeser,2018), (Jatoth,2018), (K.Saravanan,2015)
Capability	Service level objectives which promise specific functionality relating to the cloud service.	(Dahouei,2018), (Senarathna,2018), (K.Saravanan,2015)
Support	An interface made available by the cloud service provider to handle issues and queries raised by the cloud service customer.	(K.Saravanan,2015)
Easy to Use	is the degree to which a service can be used by specified consumers to achieve quantified objectives with effectiveness, efficiency, and satisfaction in a quantified context of use	(Esposito,2016), (Alsanea,2015), (Dahouei,2018), (Nedev,2018)
Scalability	is the property of a cloud service to handle a growing amount of work by adding resources to the service	(K.Saravanan,2015)
Reversibility and Termination Process	includes a series of steps which enable the customer to retrieve their data within a stated period of time before the cloud service provider deletes it from the provider's systems	(K.Saravanan,2015)
Reliability	The property of a cloud service to perform its function correctly and without failure, typically over some period of time.	(Tang,2016), (Al-Khater,2017), (Dahouei,2018), (Senarathna,2018), (WuX,2018), (Maeser,2018), (Hakim,2018)
Authentication and Authorization	The verification of the claimed identity of an entity and it permission to access and use a particular resource based on predefined user privileges.	(Rajendran,2013), (Tang,2016), (Al-Khater,2017), (Senarathna,2018)
Cryptography	A discipline which embodies principles, means and methods for the transformation of data in order to hide its information content, prevent its undetected modification and/or prevent its unauthorized use.	(K.Saravanan,2015)
Security Incident Management	The processes for detecting, reporting, assessing, responding to, dealing with, and learning from information security incidents.	(K.Saravanan,2015)

Criteria	definitions	sources
Logging and Monitoring	The recording of data related to the operation and use of a cloud service and determining the status of one or more parameters of a cloud service.	(K.Saravanan,2015)
Vulnerability Management	That information about technical vulnerabilities of information systems being used should be obtained in a timely fashion to address the associated risk.	(K.Saravanan,2015)
Governance	System by which cloud service is directed and controlled.	(Elhabbash,2018), (Hakim,2018), (K.Saravanan,2015)
Data Classification	A description of the classes of data which are associated with the cloud service: customer data, provider data, derived data.	(K.Saravanan,2015)
Backup & Restore	Actual mechanisms used to guarantee that the customers' data is available.	(K.Saravanan,2015)
Data Life Cycle	Mechanisms for data handling and deletion.	(K.Saravanan,2015)
Data Portability	Capabilities to export data.	(K.Saravanan,2015)
Standards and Certifications Mechanisms	Obligation to assess the lawfulness of the processing of personal data in the cloud legislation.	(Elhabbash,2018), (K.Saravanan,2015)
Use, Retention, and Disclosure Limitation	inform the customer if compelled to disclose the personal data by a law enforcement or governmental authority	(K.Saravanan,2015)
Transparency & Notice	Informs the customer about all relevant issues and an adequate notice about the processing of their personal data, as required by law.	(Tang,2016), (K.Saravanan,2015)
Accountability	Ability to demonstrate that providers took appropriate steps to ensure that data protection principles have been implemented.	(K.Saravanan,2015)
Geographical Data Location	The cloud service customer shall be made aware of the location of data processed in the cloud and cloud provider guarantees lawfulness of cross-border data transfers.	(Al-Khater,2017), (Maeser,2018), (K.Saravanan,2015)
Environmental Effect	the assessment of the environmental consequences of a cloud service e.g. Carbon dioxide production rate	(Garg,2013), (R.Karim,2013)
Training Cost	Costs of training technical staff and implementing cloud services in the organization	(Rajendran,2013)
Reputation	the most popular cloud services and providers	(R.Karim,2013)
Rent Cost	The cost of renting a cloud service to an organization based on the service level agreement	(Rehman,2013), (Yarlikas,2014), (Cao,2015), (Jatoth,2018), (K.Saravanan,2015)
ISP and Data Transfer Cost	the costs of Data transfer based on the service level agreement and Cost of connecting to the Internet	(Rehman,2013), (Yarlikas,2014), (Cao,2015), (Jatoth,2018)
Users Feedback	all the information, Includes a history of comments on the use of a particular service	(Mary N,2014), (Wu X,2018), (Nedev,2018)
Organization policy	A set of guidelines for data protection and use of cloud services in organization	(Yarlikas,2014), (Hakim,2018), (Nedev,2018)

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2. Screening important criteria using Fuzzy Delphi Method

This step includes three phases. Firstly, a list of 5 dimensions and 31 criteria as the key elements of cloud service selection was extracted from literature. A panel consisted of 12 experts with abundant experience in the field of cloud computing was assembled afterward.

Table 5. Evaluation criteria after FDM screening

Dimension	Criteria	Min-Max	average	De-fuzzy
Performance D1	C11 Availability	4-10	9.051	8.762
	C12 Response Time	4-10	8.988	8.045
	C13 Capacity	3-10	8.003	7.414
	C14 Capability	2-10	7.524	7.052
	C15 Support	1-10	7.220	7.008
	C16 Easy to Use	2-10	8.053	7.892
	C17 Scalability	3-10	8.230	8.018
Security D2	C21 Reliability	4-10	8.704	8.037
	C22 Authentication and Authorization	1-10	7.005	7.020
	C23 Security Incident Management	2-10	7.052	7.522
	C24 Logging and Monitoring	2-10	7.125	7.085
	C25 Vulnerability Management	1-10	7.019	7.011
	C26 Governance	4-10	8.560	8.014
Data management D3	C31 Backup & Restore	2-10	7.055	7.092
	C32 Data Life Cycle	1-10	7.041	7.080
	C33 Data Portability	2-10	8.013	8.002
Personal Data Protection D4	C41 Use, Retention, and Disclosure Limitation	1-10	7.520	7.091
	C42 Transparency & Notice	3-10	8.250	8.055
	C43 Accountability	2-10	7.918	7.010
	C44 Geographical Data Location	4-10	8.751	8.015
Organization and Environment D5	C51 Environmental Effect	3-10	7.521	7.029
	C52 Training Cost	4-10	8.790	8.120
	C53 Reputation	2-10	8.025	7.504
	C54 Rent Cost	4-10	9.039	8.522
	C55 ISP and Data Transfer Cost	4-10	8.870	8.213
	C56 Users Feedback	4-10	8.560	7.988
	C57 Organization policy	3-10	7.952	7.025

This group of experts comprised four professors from academic community, two managers at SME Companies, three researchers in cloud computing field, and three executive IT experts with sufficient experience of utilizing cloud services at SME Companies. All of these members had more than 8 years of relevant work experience. In the next phase, interview sections was conducted. Delphi Method aims at attaining common group understanding through conducting several rounds of questionnaire development. FDM enhanced by using Fuzzy theory, not only maintains the advantages of Delphi Method, but also reduces required questionnaire development times and implementation costs. In the third phase, the opinions of experts acquired via FDM questionnaires should be converted to triangular fuzzy numbers, and after calculation, defuzzified values can be figured out. In order to screen elements of extracted list of contributing factors in cloud service selection, in this step items with higher values than 7 threshold are accepted and others are eliminated from the list. Screened key elements are shown in the Table 5.

In this research, the aforementioned experts were asked to answer a two-part questionnaire. The first part of the questionnaire was used to assess the importance of the 5 dimensions and 31 criteria, and the second part was employed to rate the performance of the dimensions with respect to the criteria. It is worth to mention here that it took three months from November 2017 to January 2018 to collect completed questionnaire.

3. Determination of Criteria Weights

The analytical processes of the seven steps of Fuzzy Best and Worst Method introduced in Section 3.2 were exploited to obtain the weights of the dimensions and criteria in order to rank contributing factors in cloud service selection. The experts were asked to identify the most important dimension in Table 5 and the most important criterion within each dimension. Similarly, the least important dimension and criterion were selected based on the experts' opinions. Table 6 displays the best and the worst dimensions identified by the experts. Two expert stated that security (D2) was the most important dimension, six expert argued that Performance (D1) was the best. The five other experts, all selected Organization and Environment (D5) as the best dimension. All experts unanimously deemed Data management (D3) as the worst item among the five dimensions. In the same manner, the best and the worst criteria within each dimension were obtained.

Table 6. Best and worst dimensions determined by the 12 experts

Dimension	Determined as "Best" by Expert No.	Determined as "Worst" by Expert No.
D1	1,3,4,11,12,7	
D2	2,8	
D3		1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
D4		
D5	5,6,7,10	

After selecting the best and the worst dimensions and criteria, the experts were asked to determine the preference of the best ones over all others and the preferences of all others over the worst dimension or criterion using the linguistic variables proposed in Section 3. The results are shown in Table 7 and Table 8.

Table 7. BO dimension vectors for the 12 experts

Expert No.	Best	D1	D2	D3	D4	D5
1	D1	(1,1,1)	(2,3,4)	(5,6,7)	(3,4,5)	(1,2,3)
2	D2	(1,2,3)	(1,1,1)	(7,8,9)	(2,3,4)	(1,1,1)
3	D1	(1,1,1)	(1,2,3)	(6,7,8)	(1,2,3)	(2,3,4)
4	D1	(1,1,1)	(2,3,4)	(7,8,9)	(2,3,4)	(1,1,1)
5	D5	(1,2,3)	(1,1,1)	(8,9,10)	(4,5,6)	(1,1,1)
6	D5	(1,1,1)	(3,4,5)	(5,6,7)	(2,3,4)	(1,1,1)
7	D1	(1,1,1)	(3,4,5)	(6,7,8)	(4,5,6)	(1,2,3)
8	D2	(1,2,3)	(1,1,1)	(6,7,8)	(1,1,1)	(2,3,4)
9	D1	(1,1,1)	(2,3,4)	(4,5,6)	(2,3,4)	(1,1,1)
10	D5	(2,3,4)	(4,5,6)	(7,8,9)	(4,5,6)	(1,1,1)
11	D1	(1,1,1)	(1,2,3)	(8,9,10)	(2,3,4)	(4,5,6)
12	D1	(1,1,1)	(2,3,4)	(6,7,8)	(2,3,4)	(2,3,4)

Table 8. OW dimension vectors for the 12 experts

Expert No.	1	2	3	4	5	6	7	8	9	10	11	12
Worst	**D3**	**D3**	**D3**	**D3**	**D3**	**D3**	**D3**	**D3**	**D3**	**D3**	**D3**	**D3**
D1	(5,6,7)	(6,7,8)	(6,7,8)	(7,8,9)	(7,8,9)	(5,6,7)	(6,7,8)	(4,5,6)	(4,5,6)	(5,6,7)	(8,9,10)	(6,7,8)
D2	(4,5,6)	(7,8,9)	(5,6,7)	(6,7,8)	(8,9,10)	(4,5,6)	(3,4,5)	(6,7,8)	(2,3,4)	(4,5,6)	(2,3,4)	(5,6,7)
D3	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
D4	(3,4,5)	(4,5,6)	(5,6,7)	(6,7,8)	(8,9,10)	(3,4,5)	(2,3,4)	(6,7,8)	(2,3,4)	(4,5,6)	(3,4,5)	(5,6,7)
D5	(4,5,6)	(5,6,7)	(3,4,5)	(7,8,9)	(8,9,10)	(5,6,7)	(4,5,6)	(3,4,5)	(4,5,6)	(7,8,9)	(5,6,7)	(5,6,7)

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According to the equation (2) weights of the dimensions and the criteria were calculated using a linear model. Since the experts came from different organizations and had different job responsibilities, their assessments reflected different perspectives. All of the experts had sufficient relevant work experience in the cloud computing field, and the importance of each expert's opinion was considered equal (Noorderhaben,1995). After all, the average weight for each item was obtained, and subsequently dimensions and criteria were ranked with respect to the calculated values.

Table 9. Overall weights of dimensions and criteria

Dimensions	Weights	Criteria	Local Weights	Global Weights	Ranking
Performance D1	0.348	C11 Availability	0.322	0.112056	1
		C12 Response Time	0.279	0.097092	2
		C13 Capacity	0.148	0.051504	5
		C14 Capability	0.025	0.0087	26
		C15 Support	0.03	0.01044	25
		C16 Easy to Use	0.107	0.037236	12
		C17 Scalability	0.089	0.030972	13
Security D2	0.221	C21 Reliability	0.324	0.071604	3
		C22 Authentication and Authorization	0.062	0.013702	23
		C23 Security Incident Management	0.133	0.029393	14
		C24 Logging and Monitoring	0.089	0.019669	21
		C25 Vulnerability Management	0.189	0.041769	9
		C26 Governance	0.203	0.044863	7
Data management D3	0.067	C31 Backup & Restore	0.422	0.028274	15
		C32 Data Life Cycle	0.185	0.012395	24
		C33 Data Portability	0.393	0.026331	17
Personal Data Protection D4	0.161	C41 Use, Retention, and Disclosure Limitation	0.173	0.027853	16
		C42 Transparency & Notice	0.27	0.04347	8
		C43 Accountability	0.255	0.041055	11
		C44 Geographical Data Location	0.302	0.048622	6
Organization and Environment D5	0.203	C51 Environmental Effect	0.075	0.015225	22
		C52 Training Cost	0.109	0.022127	19
		C53 Reputation	0.125	0.025375	18
		C54 Rent Cost	0.341	0.069223	4
		C55 ISP and Data Transfer Cost	0.203	0.041209	10
		C56 Users Feedback	0.107	0.021721	20
		C57 Organization policy	0.04	0.00812	27

After Calculation of the CRs of the dimensions based on the experts' opinions, all values were below 0.1. A smaller value indicates a higher consistency in pairwise comparisons. Overall weights of dimensions and criteria are presented in Table 9. The results shows that Performance (D1, 34.8%) accounted for the highest weight in the evaluation system, and Availability (C11, 11.2%) and Response Time (C12, 9.2%) ranked as the first and the second among the 27 criteria. Therefore, more attention should be given to Performance in cloud service selection. Security (D2, 22.1%) is the second dimension that should be considered in cloud service selection. Reliability (C21, 8.9%) and Governance (C26, 4.5%) and Vulnerability Management (C25, 4.2%) are the most important factors of Security. This means that enterprises should consider the effect of this dimension in their decisions. Organization and Environment (D5, 20.3%) is the third dimension that is important in service selection procedure. The results implies that Rent Cost (C54, 6.9%), and ISP and Data

Transfer Cost (C55, 4.1%) are the fourth and the tenth criterion. This indicates that cost have very important role in cloud service selection and organizations should devise efficient plans to reduce the total cost of service selection. This cost consists of rent and ISP and transfer cost of service. Moreover, Personal Data Protection (D4, 16.1%) cannot be neglected. It is necessary that IT managers should implement adjustment organizational policies which include Geographical Data Location (C44, 4.9%), and Transparency & Notice (C42, 4.3%) to rent appropriate cloud services from service providers.

Conclusion

In order to satisfy their infrastructural and organizational needs, nowadays, businesses are constantly looking for appropriate cloud services. According to the 2018 survey conducted by “Right Scale”, 96% of the survey population including technical managers, managers and users demonstrated that they use cloud services in their organizations. This means that businesses are interested in using cloud computing models these days. However, due to the large number and vast diversity of available cloud services, choosing a right service for businesses is becoming more and more challenging. So, considering the importance of this topic, in this study, identifying and ranking of cloud services were discussed. At first, a comprehensive literature review was implemented and contributing factors in cloud service selection were identified. Then, by utilizing Fuzzy Delphi Method and gathering experts’ opinions, the identified factors were adjusted and finalized. Next, Fuzzy Best-Worst Method was applied to evaluate and rank the contributing factors in cloud service selection. The main reason for choosing this method in this study is the simplicity of its implementation compared to other available methods such as AHP, ANP which require a lot of paired comparisons. This advantage makes this method able to yield more reliable results as it requires fewer comparative data, which is beneficial to avoid incompatibility. Moreover, this method is more helpful for gathering required information from experts who have limited time to respond, and this is one of the advantages of this study. Based on the results of this research, performance, security, data management, personal data protection, and organization & environment are identified as the contributing factors in cloud service selection. In addition, the most important performance indicators are availability, response time, and capacity. In terms of security, the most important indicators are reliability and governance. Important Organization and Environment characteristics are the costs of renting an ISP and transfer cost. Finally, the geographical location of the data is the most important criterion of data protection.

To conclude, the results of this study can be interpreted as follows. The most important features to be considered when choosing an organization's cloud service should be availability and reliability. In other words, accessibility of cloud service when requested, sustainability of the service performance without any interruption and its proper function complying with service level agreements is of paramount importance. The next priority is network parameters such as delay in response that are not directly controllable by suppliers. The other important factor that should be considered is governance. Governance mainly pertains to management of changes and updates of cloud services. Therefore, using updated services and having the means and knowledge of how to control them is really crucial. Service hardware features such as throughput and memory are the next factor which is important for choosing a service. The other important factor is geographical location of the organization's data which should comply with organization's policies and provides the required level of security in terms of information protection. Organizations are always seeking for some ways to reduce their operating costs. One of the advantages of this research which is worth to be mentioned here is that in addition to the renting cost of the service this study considers operating costs such as the cost of the internet connection, and the cost of information transmission between virtual machines (network cost) in its proposed framework. In other words, the cost function in this research includes the total rental cost and the network cost; which is not considered in many other cloud service selection approaches. Finally, the ease of use of service interface and the ability of the service provider to automatically increase resources when needed (scalability) is another important factor.

There were some challenges and limitations to this study. Although based on the experts' opinions and their professional experiences in relevant field, and as it is included in many ISO Standards, Data Compression and Reduction is introduced as one of the important factors in cloud service selection, this factor is neglected in the literature, and it is not investigated in this research too. Moreover, only Fuzzy methods are used to weight identified criteria, and this could be counted as a limitation of this study. The other important factor which is worth to be mentioned here is that due to the existing limitations in time and financial resources, and the lack of access to organizations using cloud services, a case study or empirical examination of the research's implications is not included in this research. So, based on these limitations, it is recommended to researchers in this field to follow:

- Conduct researches considering the effect of Data Compression and Reduction and its relevant criteria as it is neglected in implemented studies so far.
- Make use of other MADM[1] methods and do some comparisons with the results of this study.
- Considering the increase in the application of the group decision-making approaches in recent years, these days many researches take advantage of such methods. The group decision-making methods aggregate the individual preferences and present the best agreement using mathematical models. So, it is recommended that researchers use extended group decision-making method based on Fuzzy BWM (Fuzzy GBWM) in the proposed framework.

1. Multi-Attribute Decision-Making

- Employ Grey Numbers and a combination of this method with Fuzzy Numbers to weight identified dimensions and criteria.
- The result in this research could be used to develop models and implement systems for selecting dynamic cloud services in any organization.

Other contributing factors in cloud service selection can be identified by a wholesome investigation of IEC, ISO, ENISA and EC standards and existing service level agreements in order to evaluate their influence on cloud service selection and enrich the proposed framework.

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