ICIC Express Letters
Volume **13**, Number **11**, November **2019**
 ISSN 1881-803X
pp. **1005–1014**

A PROPOSED CLOUD COMPUTING QUALITY MODEL: S3MQUAL (SERVICE MEASUREMENT METRICS MODEL)

Hussam Hourani, Raneem Dawood, Lana Sadaqa, Mohammad Abdallah and Abdelfatah Tamimi

Faculty of Science and IT
AL-Zaytoonah University of Jordan
P.O. Box 130, Amman 11733, Jordan
Hussam.hourani@gmail.com

Received April 2019; accepted July 2019

Abstract. *Cloud computing helps organizations to move fast and adopts different services that accelerate building and hosting their services and reach more customers and third parties quickly. Cloud computing is gaining a considerable attention nowadays due to its accelerated adopting, deployment models and the variety of services it provides to customers. The quality model for cloud computing is becoming a critical area that needs to be secured to preserve the expected Quality of Service (QoS). The characteristics of the chosen quality model indicate the likelihood of a cloud computing service performing as expected and promised in the agreed Service Level Agreement (SLA) between the services providers and customers. This paper highlights the cloud computing famous quality models and introduces a quality model called S3MQual (Service Measurement Metrics Model) quality model that can add a great value to the customers and meet or exceed customer's expectation. Customers start giving more and more attention on the quality of services of cloud computing as it affects their business growth and continuity.*
Keywords: Cloud computing, Quality model, S3M, Quality of Service (QoS)

1. **Introduction.** Cloud Computing (CC) has emerged rapidly in the recent years. Cloud computing is defined as a large-scale distributed computing paradigm. It provides on-demand resources including infrastructure, platform, and software. Cloud computing is becoming an important topic for businesses and organizations, where different types of services are provided in a competitive time frame over the Internet, which accelerates operating the businesses to deliver faster and to scale up in a competitive time frame. Also cloud computing cost reduction benefit is becoming a target for business by moving from capital expenditure to operational expenditure [1,2]. There is a crucial need to better understand how customers of cloud computing solutions services measure and determine the quality of the services and how this will influence the cloud computing services creation, adoption, deployment, use and future enhancement. Could computing offers the following three main services.

- Infrastructure as a Service (IaaS): In this type, infrastructure is provided as a service to clients, where the client handles all software and application installed on the provided infrastructure.
- Platform as a Service (PaaS): By using PaaS, the clients develop their applications on the provided platforms and toolkits that are hosted by the cloud service providers.
- Software as a Service (SaaS): The client in this model will be using the software that is provided and hosted by service providers.

Figure 1 highlights these services. A client can choose which service model to adopt based on business and technical needs and the nature of the business [2,3].

DOI: 10.24507/icicel.13.11.1005

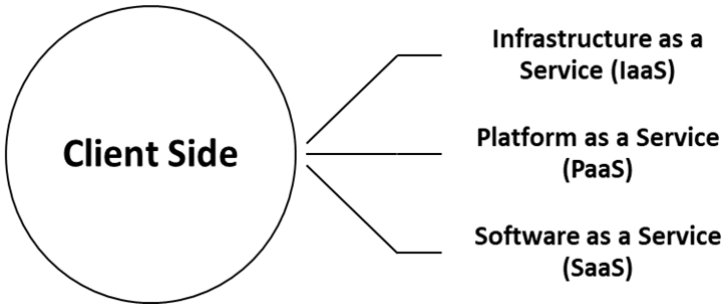

FIGURE 1. Cloud services model

There are three deployment models in cloud computing as the following: private cloud, public cloud and hybrid cloud. Organizations and customers must evaluate the suitability of deployment models to choose from based on the business needs and requirements. According to IEEE, the software quality is "The degree to which a system, component, or process meets specified requirements" or "The degree to which a system, component, or process meets customer or user needs or expectations". It is important to better understand how cloud computing's customers realize the quality of the provided services so they secure their businesses and bring innovation and insights to their end users. Along with the advantage of getting a new service that is cost effective and easy to adopt and deploy, organizations and firms have started to look at cloud computing as a strategic move that impacts their businesses growth and continuity. As a result of this, quality models and measurement metrics became key factors for organizations to embrace and adopt. The key contribution of this paper is to propose a new quality model for cloud computing that is more comprehensive that fulfills the end user's expectations and at the same time derives and governs the overall working framework for the cloud computing service providers.

The paper has been organized into different sections as the following: literature review section for cloud computing quality models, then the new proposed model section, then the models comparisons section, and finally the conclusion section.

2. **Review of Cloud Computing Quality Models.**

Cloud computing offers innovation and agility to the end users. There are different quality models for the cloud computing and in this section we will highlight the main models and the key characteristics for each model. The ultimate goal when choosing the quality metrics is to ensure the end user or customer's satisfaction. In addition, the cloud computing architecture needs to count for the best deployment architecture to meet or exceed client's expectations. The following are the most famous cloud computing quality models that we have chosen to highlight in this paper [4].

2.1. **SMI-Cloud.**

The Service Measurement Index (SMI) has been developed by Cloud Services Measurement Initiatives Consortium (CSMIC). It consists of a set of related business Key Performance Indicators (KPIs) that provides a method for measuring business services. It has key characteristics (dimensions) and sub attributes. The following are the key characteristics for SMI model: Accountability, Agility, Assurance, Cost, Performance, Security and Privacy and Usability as shown in Figure 2 [5-10]. SMI framework has 7 characteristics and 51 attributes. Covering the 51 attributes might be difficult or not applicable for all customers to use and adopt. Furthermore, there are some criticism to the "Cost" dimension in this model that researchers raised, as the quality model should exclude the cost because fulfilling all dimensions and attributes might even increase the cost. By excluding the cost, the quality model will be enhanced regardless of the cost of the service [6].

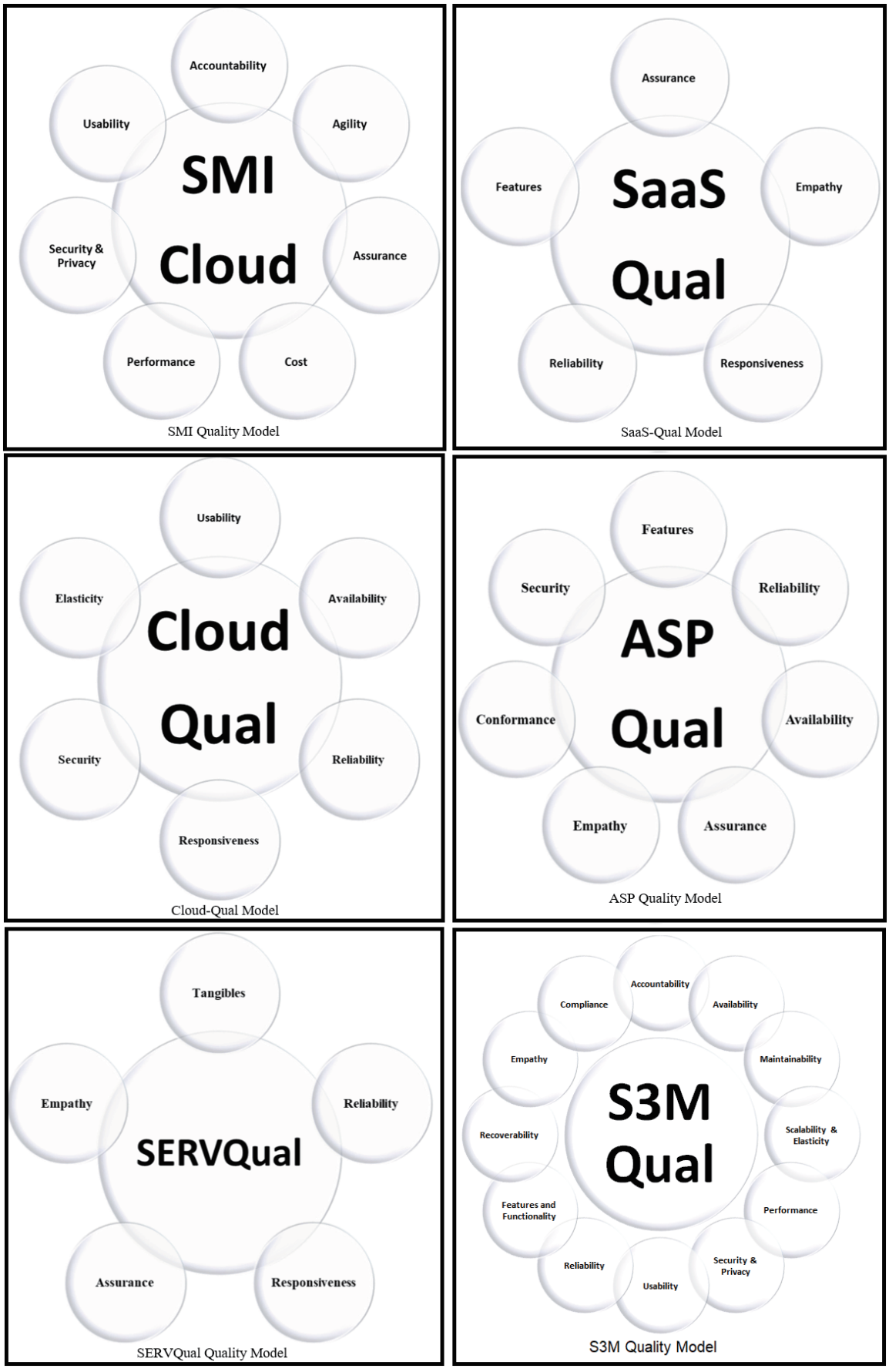

FIGURE 2. Cloud services models

2.2. **SaaS-Qual.** The Software-as-a-Service SaaS-Qual consists of the following characteristics as shown in Figure 2: Assurance, Empathy, Responsiveness, Reliability and Features. It was derived from SERVQual Model [6,7]. For SaaS-Qual Model, [7] has provided both a service quality measurement instrument with practical significance and applications, as well as some important theoretical contributions in IS continuance research and service science in general [7].

2.3. **Cloud-Qual.** The Cloud-Qual model suggests the following key characteristics: Usability, Availability, Reliability, Responsiveness, Security and Elasticity as shown in Figure 2. Cloud-Qual is a model that targets general cloud services and it has a subjective quality dimension "Usability", whereas the other dimensions are objective [11]. Research [8] has introduced this model, it demonstrated the effectiveness of CLOUDQUAL and conducted empirical case studies on clouds services involving three real-world storage clouds. They used a method to formally validate a quality model using standard criteria, namely, correlation, consistency and discriminative power [11].

2.4. **ASP-Qual.** Application Service Provider (ASP) quality model proposes the following key characteristics: Features, Reliability, Availability, Assurance, Empathy, Conformance and Security as shown in Figure 2 [6,12]. It is intended for a general service including cloud computing SaaS services.

2.5. **SERVQual.** The Service Quality Model or SERVQual Model was developed and implemented by the American marketing gurus Valarie Zeithaml, A. Parasuraman and Leonard Berry in 1988. The key characteristics of the model are shown in Figure 2 and as the following: Tangibles, Reliability, Responsiveness, Assurance and Empathy. The Model measure has also received some amount of criticism [12]. The SERVQual Model has been used to measure customers' perceptions of service quality in traditional service field in general which includes for example: Hotel service, Food service and other industries. SERVQual model has also been modified to evaluate some e-services, such as library e-service [13]. The model is used to be as a reference for the newer models, and some of the new models in the eservices have key dimensions derived from SERVQual Model [11].

2.6. **Other cloud computing quality models.** Other models have been introduced other than the previous models, in which some of them focus only on specific side of the cloud computing services. The following are some of the models to be highlighted [14,15]:

- "CRM Cloud Solutions" that has the following characteristics: Accuracy, Functionality, Suitability, Interoperability, and Service Response Time.
- "AHP hierarchy for SaaS-based Ranking" that has the following characteristics: Performance, Usability, Maintainability, Provider Reputation and Cost.
- ISO 9126 is an international standard for the evaluation of product quality in general. This model standard provides three aspects for evaluating software products: internal quality, external quality and quality-in-use. Organization can take this quality model and customize it to meet the cloud computing services requirements or software products in general [25].
- Also there are many other customized and proposed quality models for cloud computing services. Many research papers have highlighted those models. Each model took the quality model from a different perspective and proposed some related characteristics and sub attributes. Some of these models were just proposed models and not clear if they were ever used or not.

In the next section, we will propose a new quality model that we believe it fits for cloud computing services including: SaaS, IaaS and PaaS. Also we will provide some definitions and justification why we have chosen the selected characteristics and attributes. The

new model will be competitive to the previous models and focus on all important quality characteristics and attributes that fulfill customer's satisfactions.

3. **The Proposed Quality Model.** We have created and introduced a quality model called S3MQual that stands for "Service Measurement Metrics Model" for cloud computing. In this model, we have considered the twelve most important characteristics that the cloud computing service must at least provide. The proposed model is highlighted in Figure 2 and it includes the following key characteristics and attributes: Accountability, Availability, Maintainability, Scalability & Elasticity, Performance, Security & Privacy, Usability, Reliability, Features and Functionality, Recoverability, Empathy and Compliance. The business risk associated with migrating local applications and services into the cloud computing is considered as a high risk for organizations. The proposed S3MQual model takes this into consideration and complies with the most critical dimensions and characteristics for business to lower the risks. There should be a synergy, cooperation, openness and understandability between cloud computing services providers and the customers for adopting a quality model that meets the targeted Key Performance Indicators (KPIs). Adopting S3MQual model will secure the most important customers' requirements and needs and will govern the relationship between the different cloud computing parties through a proper Service Level Agreement (SLA). The proposed cloud computing quality model S3MQual can be applied on all cloud computing services: IaaS, PaaS and SaaS. The proposed model takes consideration of the most critical quality factors that we believe they are all crucial to secure and protect the end users and customers' businesses. The contract and the service level agreement between cloud computing services providers and customers must highlight all the characteristics and the key performance indicators and targets for each dimension. This must be considered depending on each customer's business needs and expectation.

3.1. **The proposed model's dimensions selection criteria.** The proposed model was based on the following key criteria as shown in Figure 3.

- The relevance of the characteristics for the cloud computing services and offering. This is related to cloud computing services' perspective and how the characteristics are related to the provided services.
- The relevance of the characteristic for the customer related services. This is related to the customer and its businesses perspective.
- The relevance of the selected characteristics in quality models in general and the cloud computing quality models precisely. This is related to quality model and best practices perspective.
- Dimensions correlation: This criterion measures the correlation and the relationships between the selected characteristic across all other selected characteristics.
- Practicality and achievability: This is related to the characteristics in regards of the possibility and feasibility of applying and measuring the characteristics.

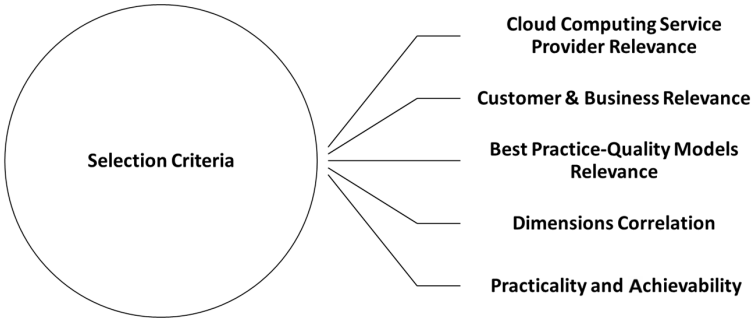

FIGURE 3. Model's selection criteria

The above selection criteria govern and control the chosen characteristics and attributes. There have been significant efforts and work exercise for applying the selection criteria and coming up with the proposed quality model. In the next section, we will provide characteristics definition for the proposed model and will provide a justification why we have chosen the characteristics for the proposed model.

3.2. **The proposed model's dimensions clarification.** The proposed model has the following key characteristics that highlight the importance for each characteristic and attribute in the proposed S3MQual (Most of the definitions are based on ISO/IEC 25010 & ISO/IEC 9126-1).

- Accountability: "The degree to which the actions of an entity can be traced uniquely to the entity" [16]. Organizations want to deploy their applications and data in a place where there is accountability of security exposures and compliance [17].
- Availability: "The degree to which a system, product or component is operational and accessible when required for use" [16]. This dimension assesses the ratio of the total time to the time which a service is capable of being functional and cloud computing vendors' aims to achieve high availability of services [18,19].
- Maintainability: "The degree of effectiveness and efficiency with which a product or system can be modified to improve it, correct it or adapt it to changes in environment, and in requirements" [16]. The provided cloud computing services must be easy to maintain and provide a continuous maintainability and as per the agreed SLA [20].
- Scalability & Elasticity: Scalability is "The ease with which an application or component can be modified to expand its existing capabilities. It includes the ability to accommodate major volumes of data" [16,21]. Elasticity can be defined in terms of how easy and how much a cloud service can be scaled during peak times [17].
- Performance: "The degree to which the software product provides appropriate performance, relative to the amount of resources used, under stated conditions [16]. The deployment model determines if the performance will meet the customer's expectation or not [17]. The performance factor will measure how fast and successfully the cloud can provide the requested service [18]. The provided cloud computing services must perform well and use required resources as per the agreed SLA [19,20].
- Security & Privacy: "The degree to which a product or system protects information and data so that persons or other products or systems have the degree of data access appropriate to their types and levels of authorization" [16]. The key attributes of security are integrity, confidentiality and traceability [13].
- Usability: "The degree to which a product or system can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [16]. Usability key attributes are accessibility, installability, learnability, and operability [17]. The provided services must be easy to use by experienced and inexperienced users [20].
- Reliability: "The degree to which a system, product or component performs specified functions under specified conditions for a specified period of time" [16]. The key attributes of the reliability are completeness, correctness, continuity, stability and consistency. Reliability reflects how a service operates without failure and thus, this is a key dimension in the model and considered as a primary factor for the customers.
- Features and Functionality: "The degree to which the software product provides functions that meet stated and implied needs when the software is used under specified conditions" [16].
- Recoverability: "The degree to which the software product can re-establish a specified level of performance and recover the data directly affected in the case of a failure" [16].

- Compliance: "The degree to which the software product adheres to standards, conventions, style guides or regulations relating to a main factor" [16].
- Empathy: "The degree to which the cloud service adapts the service to the needs of individual customers" [13].

Table 1 highlights the justification for choosing each characteristic in the proposed model. It highlights the importance of the selected characteristics in relevance to the cloud computing services.

Table 1. S3MQual's characteristics selection justification

Category	Justification of choosing model's characteristics
Accountability	Accountability builds trust between customers and service providers and it also ensures ownership, confidence and commitment. This dimension is considered as a corner store for cloud computing quality model.
Availability	Availability is one of the key aspects of customer satisfaction and business success. This will reduce risk of data loss, it measures the ratio of the total time to the time which a service is capable of being functional. The aim is to reduce customer impact during planned maintenance or in situations like server crash, failover, or other data disasters.
Maintainability	Being highly maintainable means how easy the software system or a component can be modified, to correct faults, improve performance or other attributes, or adapt to a changed environment [22].
Scalability & Elasticity	Cloud computing services must be rendered with high scalability. Organizations need also to make sure that the service is elastic and can adapt any future changes that the organizations require.
Performance	The performance factor will measure how fast and successfully the cloud can provide the requested service in a greed response time as per the SLA.
Security & Privacy	Cloud computing data protection, privacy and security are considered the key drivers and critical factors for choosing cloud computing service provider.
Usability	Usability key attributes are accessibility, installability, learnability, and operability [14]. The provided services must be easy to use by experienced and inexperienced users in cloud computing [20].
Reliability	Reliability reflects how a service operates without failure and therefore, this is a key dimension in the model and considered as a primary factor for the customers.
Features and Functionality	This will measure the degree to which the cloud computing services provide functions and features that meet stated requirements and implied needs when the services is used under specified conditions.
Recoverability	This will measure the degree to which the cloud computing services can re-establish a specified level of performance and recover the data directly affected in the case of a failure.
Compliance	Taking in consideration and fully understanding the various rules, regulations and laws that govern the cloud computing services will be meeting the legal obligations for all related parties across countries.
Empathy	This is related to customer experience based on customer expectations. This dimension is about caring and providing attention to customers individually.

4. **Cloud Computing Quality Models Comparisons.** The following is the comparison of the highlighted quality models and the proposed S3MQual as shown in Table 2. There are some notes to highlight as the following:

- Some characteristics have different interpretations from model to another, like assurance characteristics. The scope and coverage for assurance has different meanings from model to another; however, we assumed and considered the assurance characteristic as independent dimension in our comparison table.
- Some key characteristics have sub-attributes inside that considered in other models as key characteristics.

TABLE 2. Cloud computing quality models comparison (X: Comply with Model; A: Attribute inside a category)

Category	SMI-Cloud	SaaS-Qual	Cloud-Qual	ASP-Qual	SERV	S3MQual
Accountability	X					X
Agility	X					
Assurance	X	X		X	X	
Cost	X					
Performance	X					X
Security	X		X	X		X
Privacy	X					X
Usability	X		X			X
Empathy		X		X	X	X
Responsiveness	A	X	X		X	X
Elasticity	A		X			X
Features	A	X		X		X
Availability	A		X	X		X
Reliability	A	X	X	X	X	X
Conformance				X		
Tangibles					X	
Maintainability	A					X
Scalability	A					X
Recoverability	A					X
Compliance	A					X

As shown in Table 2, each model focuses on specific dimensions and characteristics. Table 1 highlights the justification for selecting the proposed S3MQual dimensions. The selected S3MQual twelve dimensions are the most critical characteristics that we have chosen for our quality model. We have chosen our quality model characteristics based on our selection criteria highlighted in Figure 3. We believe that we have introduced a competitive quality model for cloud computing that fulfills the end user's expectations and at the same time derives and governs the overall working framework for the cloud computing service providers. All the highlighted characteristics and dimensions can be agreed in SLA between the cloud computing service providers and the customers.

5. **Conclusions.** In this paper, we highlighted the main quality models for cloud computing services and we introduced a quality model named S3MQual. We are living in the world that changes very quickly and organizations are keen to expand their businesses and provide better services to their customers by adopting new services that can meet or exceed client's expectations; however the quality of the services is the key driver for customer's satisfaction and business continuation. The proposed model S3MQual has introduced the twelve most important dimensions and characteristics that the organization

need to consider to have a proper and better quality of services. From the cloud service provider's perspective, the proposed model will support their customers and will attract even more customers as it brings innovations and agility to their services. From the customers' perspective, this will assure getting better services to their end users and their clients, and this will result in securing and expanding their businesses. The business risk associated with migrating local applications and services into the cloud computing platforms is considered as a high risk for organizations, The proposed S3MQual model takes this into consideration and complies with the most critical dimensions and characteristics for business to lower risks. The future work can focus on applying the proposed quality model S3MQual on selected cloud computing service providers and organizations and can highlight the quality metrics outcome after implementations.

REFERENCES

[1] U. Moghe, P. Lakkadwala and D. K. Mishra, Cloud computing: Survey of different utilization techniques, *CSI Sixth International Conference on Software Engineering (CONSEG)*, 2012.

[2] H. Hourani and M. Abdallah, Cloud computing: Legal and security issues, *The 8th International Conference on Computer Science and Information Technology (CSIT)*, 2018.

[3] M. U. Bokhari, Q. Makki and Y. K. Tamandani, A survey on cloud computing, *Big Data Analytics*, pp.149-164, 2017.

[4] E. Saiz, E. Ibarrola, L. Cristobo and I. Taboada, A cloud platform for QoE evaluation: QoXcloud, *Proc. of the 2014 ITU Kaleidoscope Academic Conference: Living in a Converged World – Impossible without Standards?*, 2014.

[5] CSMIC, *Service Measurement Index Framework 2.1*, 2014.

[6] U. Sener, *A Quality Model for Cloud-Based Enterprise Information Systems*, Mater Thesis, The Middle East Technical University, 2016.

[7] A. Benlian, M. Koufaris and T. Hess, Service quality in software-as-a-service: Developing the SaaS-Qual measure and examining its role in usage continuance, *Journal of Management Information Systems*, vol.28, no.3, pp.85-126, 2011.

[8] S. Totiya and T. Senivongse, Framework to support cloud service selection based on service measurement index, *Proc. of the World Congress on Engineering and Computer Science*, 2017.

[9] S. Shirur and A. Swamy, A cloud service measure index framework to evaluate efficient candidate with ranked technology, *International Journal of Science and Research (IJSR)*, 2013.

[10] L. Mohammadkhanli and A. Jahani, Ranking approaches for cloud computing services based on quality of service: A review, *ARPN Journal of Systems and Software*, 2014.

[11] X. Zheng, P. Martin, K. Brohman and L. D. Xu, CLOUDQUAL: A quality model for cloud services, *IEEE Trans. Industrial Informatics*, vol.10, no.2, pp.1527-1536, 2014.

[12] H. Roine, *Service Quality of ASPs (Application Service Providers): Case of an E-accounting Service*, Lappeenranta University of Technology, 2008.

[13] P. Zhou, Z. Wang, W. Li and N. Jiang, Quality model of cloud service, *IEEE 17th International Conference on High Performance Computing and Communications (HPCC)*, 2015.

[14] Y. M. Afify, I. F. Moawad, N. L. Badr and M. F. Tolba, Cloud services discovery and selection: Survey and new semantic-based system, in *Bio-inspiring Cyber Security and Cloud Services: Trends and Innovations Intelligent Systems Reference Library*, 2014.

[15] S. A. Elmubarak, A. Yousif and M. B. Bashir, Performance based ranking model for cloud SaaS services, *International Journal of Information Technology and Computer Science*, vol.9, no.1, pp.65-71, 2017.

[16] J. P. Miguel, D. Mauricio and G. Rodríguez, A review of software quality models for the evaluation of software products, *International Journal of Software Engineering & Applications*, vol.5, no.6, pp.31-53, 2014.

[17] S. K. Garg, S. Versteeg and R. Buyya, A framework for ranking of cloud computing services, *Future Generation Computer Systems*, vol.29, no.4, pp.1012-1023, 2013.

[18] P. Nadanam and R. Rajmohan, QoS evaluation for web services in cloud computing, *The 3rd International Conference on Computing, Communication and Networking Technologies (ICCCNT'12)*, 2012.

[19] D. Bao, Z. Xiao, Y. Sun and J. Zhao, A method and framework for quality of cloud services measurement, *The 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE)*, 2010.

[20] J. Kiruthika, G. Horgan and S. Khaddaj, Quality measurement for cloud based e-commerce applications, *The 11th International Symposium on Distributed Computing and Applications to Business, Engineering & Science*, 2012.

[21] A. Abdeladim, S. Baina and K. Baina, Elasticity and scalability centric quality model for the cloud, *The 3rd IEEE International Colloquium in Information Science and Technology (CIST)*, 2014.

[22] C. Chen, R. Alfayez, K. Srisopha, B. Boehm and L. Shi, Why is it important to measure maintainability and what are the best ways to do it?, *IEEE/ACM 39th International Conference on Software Engineering Companion (ICSE-C)*, 2017.

[23] D. Serrano, S. Bouchenak, Y. Kouki, T. Ledoux, J. Lejeune, J. Sopena, L. Arantes and P. Sens, Towards QoS-oriented SLA guarantees for online cloud services, *The 13th IEEE/ACM International Symposium on Cluster, Cloud, and Grid Computing*, 2013.

[24] S. S. Wagle, M. Guzek, P. Bouvry and R. Bisdorff, An evaluation model for selecting cloud services from commercially available cloud providers, *IEEE 7th International Conference on Cloud Computing Technology and Science (CloudCom)*, 2015.

[25] S. Banerjee and S. Jain, A survey on software as a service (SaaS) using quality model in cloud computing, *International Journal of Engineering and Computer Science*, vol.3, no.1, pp.3598-3602, 2014.