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Performance and Cost Based Model for Cloud SaaS Service Selection

النموذج المبني علي الأداء والتكلفة لإختيار الخدمة السحابية

A Thesis Submitted in Partial Fulfillment of the requirements for the degree of M.Sc.in Information Technology

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الأيــــــــــــة

قال تعالى:

"ن وَالْقَلَمِ وَمَا يَسْطُرُونَ"(1) القلم

صدق الله العظيم

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Abstract

Selecting the appropriate cloud services and cloud providers according to the cloud user's requirements is becoming a complex task, as the number of cloud providers increases. Cloud providers offer similar kinds of cloud services, but they are different in terms of quality of service; performance, cost, security, privacy, etc. The most challenging issue of the current cloud computing business is that cloud providers offer services that vary in terms of performance quality and cost, to cloud users, but there is little or no verification models to measure performance and cost of services provided by cloud service providers. In the current literature, there is a lack of models in terms of classification of cloud services depending on the quality of performance and cost together. The objective of this research is to propose performance and cost based model for cloud software as a service selection to help users choose the best service they need. Finally, Service measurement index cloud Toolkit has been used to test the applicability of the proposed model. Results obtained from case study data containing three SaaS service providers are Google, Microsoft office365 and Amazon EC2 are visualized in an ordered SaaS service according performance and cost, showing the services in a decreasing ordering of service quality. In this way, the proposed performance and cost based model for cloud SaaS service selection represents a model capable of choosing services for cloud service users from cloud service providers.

المستخلص

أصبحت عملية اختيار الخدمة السحابية المناسبة من مقدمي الخدمات السحابية وفقاً لمتطلبات مستخدم السحابة معقدة جداً. في ظل زيادة عدد مقدمي الخدمات السحابية والخدمات السحابية المماثلة التي يقدمونها ولكنهم يختلفون من حيث جودة الخدمة المتمثلة في الاداء والتكلفة والأمن والخصوصية و... وغيرها.والمشكلة القائمة في مجال الحوسبة السحابية الحالي في ان مقدمي الخدمات السحابية يقدمون خدمات تختلف من حيث جودة الاداء والتكلفة للخدمة المقدمة لمستخدمي الخدمات السحابية. هنالك القليل من الدراسات السابقة لحساب جودة الخدمة متمثلة في الأداء أو التكلفة ولكن تكاد تفتقر لوجود نموذج يحسب جودة الخدمة من حيت الأداء والتكلفة معاً.الهدف من هذا البحث هو اقتراح نموذج الأداء والتكلفة على أساس اختيار خدمة البرمجيات السحابية لمساعدة المستخدمين على اختيار أفضل الخدمات التي يحتاجونها. وآخيراً ، تم اختبارقابيلة تطبيق النموذج المقترح بإستخدام اداة مؤشر قياس الخدمات السحابية (سمي).النتائج التي تحصلنا عليها من بيانات دراسة الحالة التي تحتوي على ثلاثة لمقدمي الخدمات السحابية ؛ جوجل، مايكروسوفت والأمازون تصوراً لخدمة البرمجيات السحابية علي حسب الأداء والتكلفة معاً.والتي تبين الخدمات مرتبة ترتيباً تنازلياً على حسب جودة الخدمة. وبهذة الطريقة، يمثل النموذج القائم على الأداء والتكلفة لإختيار خدمة البرمجيات السحابية نموذجاً قادراً على اختيار خدمة البرمجيات السحابية لمستخدمي السحابة من مقدمي الخدمات السحابية.

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List of Abbreviations

Abbreviations	Explanation
AHP	Analytical Hieratical Process
API	Application Programming Interface
ASMAN	Appropriate Selection of Software as a service Model According to Need
CACP	Commercially Available Cloud Providers
CloudEval	Cloud Evaluator
CPU	Central Processing Unite
CSB	Cloud Service Broker
CSMIC	Cloud Service Measurement Index Consortium
CSP	Cloud Service Provider
DD	Demand Driven
DF	Derivative Follower
EC2	Elastic computing Cloud
ESS	Enterprise Software Service
GBP	Grate British Pound
GRA	Gray Relational Analysis
GRC	Gray Relational Coefficient
GRG	Gray Relational Grate
IaaS	Infrastructure as a Service
ISO	International Organization for Standard
KPI	Key Performance Indicators
MADM	Multi Attribute Decision Making
MAUT	Multi Attribute Utility Theory
MCDM	Multi Criteria Decision Making
MODM	Multi Objective Decision Making
NIST	National Institute of Standard and Technology
OS	Operating System

PaaS	Platform as a Service
PN	Penetration
PS	Provider Service
QoS	Quality of Service
RSRM	Relative Service Ranking Matrix
RSRV	Relative Service Ranking Vector
SaaS	Software as a Service
SCs	Service Consumers
SK	Skimming
SLA	Service Level Agreement
SMEs	Small and Medium Enterprises
SMI	Service Measurement Index
SSP	Software as a Service Provider
TCO	Total Cost Ownership
USD	United State Dollar
V	Vector
VDO	Vereinigta Deuta Ota
VM	Virtual Machine

Chapter One
Introduction

1.1 Overview

This chapter introduces the research work, states the problem, defines research objectives, significant and describes the thesis structure.

1.2 Problem Background

Cloud computing refers to both the applications delivered as services over the Internet and the system hardware and software that provide these services. The service itself is referred to as Software as a Service (SaaS). Various cloud providers are now available. These providers offer different cloud services to their enterprise. Balance between Performances and cost of service is a crucial aspect of cloud service. Cloud services from different providers have different cost and performance characteristics. From the enterprise point of view, it becomes difficult to determine which provider is best performance and lower cost (Elmubarak et al., 2017).

Because the issue of performance and cost for businesses is one of the main challenges to select the cloud service provider according to the requirements of the enterprise.

1.3 Problem Statement

Cloud services have become a rapidly growing and nontransparent market with many service providers, each with its own service model. The selection of appropriate cloud services and cloud providers according to the requirements of cloud users has become a complex task, with the number of cloud service providers increasing. Cloud service providers offer similar types of cloud services, but differ in quality; performance, cost security and privacy of service and…etc. The performance and cost of these services is critical for customers to determine which cloud provider to choose.

This makes it difficult to compare service providers in this way and their service offerings and the lack of models in terms of classification of cloud services depending on the quality of performance and cost together. Because of the different quality of services for cloud service providers the question is how to choose the right providers based on the best service performance and cost criteria for service?

1.4 Research Objectives

The objectives of this research are:

i. To review and analyze the current cloud service selection models.

ii. To propose a new performance and cost based model for cloud SaaS service selection to help users choose the best service they need.

iii. To test the applicability of the proposed model using SMI cloud Toolkit.

1.5 Research Questions

The questions of this research are:

i. How to choose the appropriate cloud providers based on the quality of service performance and cost?

ii. Is the proposed model able to choose the appropriate service provider based on user requirements?

1.6 Scope

This study was conducted for the service provider selection model to measure performance and cost of the service (SaaS). This is done for a number of cloud service providers to determine specific values in order to distinguish between the best quality services.

1.7 Thesis Structure

This thesis contains six chapters. Chapter two gives an overall idea of cloud computing and SaaS selection in cloud computing. Chapter three describes the research methodology. Chapter four describes the proposed selection model for measuring SaaS performance and cost. Chapter five applicability of the proposed model. Chapter six provide the conclusion and lessons learned.

Chapter Two

Literature Review

2.1 Introduction

This chapter reviews the current literature, describes of cloud computing and selection cloud service.

2.2 Introduction of Cloud Computing

NIST Definition Cloud computing is a model for enabling ubiquitous, convenient, on demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Mell and Grance, 2011).

Finance Definition Cloud computing is emerging as a promising field offering a variety of computing services to end users. These services are offered at different prices using various pricing schemes and techniques. End users will favor the service provider offering the best QoS with the lowest price. Therefore, applying a fair pricing model will attract more customers and achieve higher revenues for service providers (Ibrahimi, 2017).

Other Definition cloud computing as a large scale distributed computing paradigm that is driven by economies of scale, in which a pool of abstracted, virtualized, dynamically scalable, managed computing power, storage, platforms, and services are delivered on demand to external customers over the Internet. Cloud computing provides various computing services online based on SLAs between the provider and the consumer. including infrastructure as a service (IaaS), platform as a service (PaaS), software as a service (SaaS) (Ibrahimi, 2017).

Cloud Computing is a new paradigm which has changed the traditional business schemes plans and incorporating new economic and financial models of IT services market. This technology allows end users to process store and manage their data efficiently with fast and reasonably price. Cloud computing customers do not need to install different software and they could access their data wherever they are via the Internet (Mazrekaj et al., 2016).

2.3 Characteristics of Cloud Computing

Cloud computing infrastructures are built on large scale and cheap server cluster. To reach maximum efficiency of hardware resources it is preferred to build infrastructures cooperated with top applications. Improving the access ability of services basically depends on separating computation resource from business logic. This is provided by virtualization technology. The pay-as-you-go model can make computation resource gain dynamic and high expandability and immensely improve utilization rate for cloud computing service. This leads to energy consumption per service can be reduced effectively. It is provided in the form of service (infrastructures, application or platforms applications) (Garg et al., 2013).

2.4 Main Services of Cloud Computing

General, First software as a Service (SaaS) provides access to complete applications as a service such as customer relationship management. The second is Platform as a Service (PaaS) provides a platform for developing other applications on top of it, such as the Google App Engine. Finally, infrastructure as a service (IaaS) provides an environment for deploying, running and managing virtual machines and storage (Garg et al., 2011).

Technically, IaaS offers incremental scalability of computing resources and on demand storage. Cloud computing aims to deliver a network of virtual services so that users can access them from any where in the world on subscription at competitive costs depending on their quality of service (QoS) requirements; Software as a Service or SaaS, deliver the services to users through browsers. From the view point of providers, they can reduce costs of maintenance of software. In the other hand, from users' view, they can reduce expenses on setting up the server and buying software licenses. Generally, SaaS is often used in the field of human resources management and ERP (Elmubarak et al., 2017).

Delivery service classify cloud services into four types: Software as a Service (SaaS) Enterprises will have software licenses to support the various applications used in their daily business. These applications could be in human resources, finance, or customer relationship management. The traditional option is to obtain the desktop and server licenses for the software products used. Software as a Service (SaaS) allows the enterprise to obtain the same functions through a hosted service from a provider through a network connection. Consumer services include social platforms (e.g. Facebook) or online email services (e.g. Gmail). There are also increasing numbers of business services being delivered as a service (e.g. software package rendering through VDO / Citrix server to the mass public). Centralized services typically designed to cater for large numbers of end users over internet. SaaS reduces the complexity of software installation, maintenance, upgrades, and patches for the IT team within the enterprise, because the software is now managed centrally at the SaaS provider's facilities. SaaS providers are responsible to monitor the application delivery performance; Platform as a Service (PaaS) Unlike the fixed application functionality offered by SaaS, Platform as a Service (PaaS) provides a software platform on which users can build their own applications and host them on the PaaS provider's infrastructure (e.g. Google with its App Engine or Force.com APIs). The software platform is used as a development framework to provide services for use by applications. PaaS is a true cloud model in that applications do not need to worry about the scalability of the underlying hardware and software platform. PaaS providers are responsible to monitor the application delivery performance elasticity and scalability; Infrastructure as a Service (IaaS) An Infrastructure as a Service

(IaaS) provider offers you raw computing, storage, and network infrastructure so that you can load your own software, including operating systems and applications, on to this infrastructure (e.g. Amazon's Elastic Computing Cloud (EC2) service). This scenario is equivalent to a hosting provider provisioning physical servers and storage, and letting you install your own OS, web services, and database applications over the provisioned machines. Greatest degree of control of the three models, resource requirement management, is required to exploit IaaS well. Scaling and elasticity are user's responsibility and not the provider's responsibility (Paliwal, 2014).

2.5 Selection Cloud Computing Services

One of the most important features of the SMI Cloud framework is enabling accurate QoS measurement and Cloud service selection for Cloud customers. It is the process of arranging and classification services within the cloud, then computes the relative ranking values of several Cloud services based on the Quality of Service (QoS) requirements by the customer and features of the Cloud services. Cloud providers can identify how they perform compared to their competitors and therefore they can improve their services (Garg et al., 2011).

2.6 Benefits of the Selection

Selection effective and efficient way to find best cloud service provider based on QoS parameters. It is greatly useful for cloud users to identify best cloud provider without any confusion

2.7 Approaches and Modeling for Service Selection

The following subsections describe the different approaches and models for cloud service selection.

2.7.1 Analytical Hieratical Process (AHP)

AHP is the most popular and prominent methodology due to its effectiveness and ease of use. For vendor selection problems the AHP approach is suggested by many researchers, mainly because of its inherent capability to handle quantitative and qualitative criteria. Additionally, it can be easily applied and understood, and provides a systematical support to identify and prioritize relevant criteria. The AHP model was developed by Saaty in 1990 in order to solve multi criteria decision problems and to provide a structured and systematical approach. When formulating the AHP model, the hierarchical structure can enable single or multiple persons to visualize the problem systematically in terms of relevant criteria and sub criteria. The AHP modeling process involves four phases. For this purpose, a complex problem is decomposed and modeled as a hierarchical structure, divided into sub problems. Elements of this hierarchy can be divided into groups and are compared pairwise on each level of the hierarchy. The results will be translated into the corresponding pairwise comparison judgment matrices and the eigenvector with the highest eigenvalue is calculated.

Figure 2.1 AHP modeling process involves four phases (Tummala, Wan 1994)

In order to structure the decision problem, the motivation (1st level) is defined. Assigned to the motivation there are several target dimensions on the second level. Each target dimension is broken down into abstract requirements (3rd level) and further evaluation criteria (4th level). For the weighting of an element (criterion) all sub criteria on the level below are compared pairwise, whereby the calculated importance behaves reciprocally. If element i is twice as important as element j, then element j is only half as important as element i. For reasons of complexity, more than seven elements per hierarchy level should be avoided. Then the column entries for each column sum ci are added. The matrix is then normalized which involves that each entry (aij) is divided by the sum of its column (aij / ci). The last step is to form the row sums from the normalized entries and divide these by the number of elements, resulting in the eigenvector. Using the AHP, decision makers can systematically determine the priorities of the criteria and are able to compare several providers effectively in order to select the best provider (Repschlaeger et al., 2013). They use monitoring tools for obtain QoS features value. Monitoring tools in cloud computing environment are very useful and freely available on internet (Lee, 2014). they use The summation of the weighted QoS attributes must be one, social networks attributes are concerned with storage at first then CPU then security then the rest of attributes according to social network type and preferences, scientific social networks are concerned with performance and cost but less security (Shaat and Wassif, 2015).

2.7.2 Service Level Agreements (SLA) Matching

All SaaS and cloud based applications must provide a predefined service level agreement (SLA) as a contract to clients and customers concerning the quality of services. Since the quality requirements about system performance and scalability must be addressed as a part of a SLA, they must be validated and measured based on the contracted SLA. Current cloud vendors provide a predefined SLA to their clients for their provided cloud infrastructure and service software. Similarly, SaaS vendors also provide a SLA to clients for their offered applications in a cloud (Gao et al., 2011). Analyzed probable parameters that can form or act as a SLA for entire cloud system. These parameters vary from lowest level to highest level of computing stack along with the services offered (Pandey et al.).

2.7.3 MCDA Methods

MCDA methods can be categorized into two types: (1) multi attribute utility theory (MAUT). (2) out ranking methods. MAUT attempts to find a function reflecting the utility or usefulness of a particular alternative. Each action is assigned a marginal utility, with a real number representing the prefer ability of the considered action. The returned utility is the sum of these marginal utilities. Outranking methods decide whether one alternative is ranked higher than another by employing a pair wise comparison.

MCDA methods are divided into multi objective decision making (MODM) and multi attribute decision making (MADM).The two methods differ mainly by how the alternatives are enumerated. In MODM, they are not predetermined but arise from the optimization of a set of objective functions. In MADM, they are predetermined, and a small subset is evaluated against a set of attributes. In both methods, the best alternative is chosen by comparing the rankings of each alternative/attribute combination (Whaiduzzaman et al., 2014).

2.7.4 A Brokerage-Based Model

Cloud Service Provider (CSP) index is responsible for the service selection adopting to design a unique indexing technique for managing the information of a large number of Cloud service providers, Cloud Service Provider (CSP) index The CSP-index is developed using the B+-tree (Sundareswaran et al., 2012).

2.7.5 Variability Modeling

This approach is based on extended feature modeling to represent the commonalities and interactions of cloud services. And content three models a domain model: Initially, a domain model must be devised to fix a feature hierarchy for future service and requirements models, multiple service models and a requirements model. Define service models and requirements model: Given a complete domain model, next, the current Cloud service landscape can be reflected in service models that follow the domain model's structure (Ruiz-Alvarez and Humphrey, 2011).

2.7.6 CloudEval Model

This model is consists of two components; (1) selection process is as follows: 1st step, Setting user selection criteria, goals and their weights: a user sets one's selection criteria of cloud service, acting as inference sequence in GRA, and sets weight and goal for each attribute. The goals are represented with preference for value of an attribute of the selection criteria. 2nd step; Normalizing the candidate list: they had normalized each cloud service acting as a comparable sequence of the candidate list in GRG method. 3rd step; Calculating Gray Relational Coefficient (GRC) of the attributes of each service: They used Deng's method to calculate all GRCs of the attributes of each cloud service based on the comparison between each compared sequence and the referenced sequence. 4th step; Calculating gray relational grade for each service: they calculated a gray relational grade for each cloud service by averaging all the gray relational coefficients of each attribute. As for the way of averaging all the gray relational coefficients, they use both Deng's equal-weighted average method and weighted average method. 5th step; Ranking the list: they rank the candidate list by ordering gray relational grade of each service. Finally, they ranked the largest gray relational grade in the ranked list as the optimal service which satisfies user specified service level most; and(2) data structure Each cloud service of provider j is a compared sequence, $X[j] = (x1, x2, \ldots, xm) \in \text{Domain}(A1) \times \ldots \times$

Domain(Ai) × …× Domain(Am), where j = 1..n. X[0] is a referenced sequence in GRA.Both X[0] and X[j] have a fixed-length vector with attribute-value pairs of a data instance, Ai is an attribute of X, i =1..m. As mentioned in Section 2.2, we have designed the seven main attributes of selection criteria. The attributes availability, response time, network performance, system performance and financial credit are QOS related and the attribute user rating and price are not QOS related. As for the goals for each attribute of the selection criteria, the bigger the better are the attributes availability, user rating, network performance, system performance and financial credit; the less the better are the attributes response time and price. well-known multi-attribute decision making technique, Gray Relational Analysis, to the selection process (Hsu).

2.8 Frameworks for Service Selection

The following subsections describe the different frameworks for cloud service selection.

2.8.1 Service Level Agreement

This framework for SLA based service provisioning. The main components of the framework are: Service consumers (SCs), Cloud Service Broker (CSB), Measurement Services, and SAAS Providers (CSPs). The framework relies on a cloud service broker, which is in charge of mediating between service customers and SAAS providers and negotiating the SLA terms. The proposed SAAS providers selection algorithm uses a linear aggregate utility function, which assumes that the various QOS parameters are independent, to rank the potential SAAS offering by matching them against the quality requirement of the service consumer (Badidi, 2013).

2.8.2 Cloud Service Selection for SMEs

This framework for Identify the main factors that relate to the adoption of CRM cloud systems by small and medium-sized enterprises in Taiwan. Adopts two steps to build five steps: (1) Defining criteria and sub criteria for supplier selection;(2) Comparing pairwise for all criteria and sub criteria; (3) Checking the consistency of the input data through the maximum eigen value method; (4) Computing the relative weights of the decision criteria and sub criteria; (5) Prioritizing the order of criteria or sub criteria and Structuring the hierarchical model (Lee, 2014).

2.8.3 Assessment Criteria and Requirements

This framework is the assessment of software service providers. It contains a library of criteria and requirements that can be used to evaluate and compare various characteristics of cloud service providers when searching for a suitable Enterprise software services ESS offering. The results of the conducted expert survey indicate that the proposed assessment criteria and the requirements are effective in supporting the assessment of software service providers and can help enterprises to identify a suitable ESS offering (Schlauderer and Overhage, 2015).

2.8.4 ASMAN

ASMAN framework provides optimal software as service provider selection from the more number of SSP's. Quality of service parameters provides better selection of SSP among many. The proposed model uses: Cost, Speed, Usability, Reliability, Availability. This architecture contains three-tiers: Application Layer, Business Logic Layer and Database Layer (figure 2). In first layer, user inputs parameters for searching SAAS and submits form online for processing. Then all the parameters are processed and compared at Business Layer and values of these parameters are fetched from the database. Lastly the output is provided to the user and rating is submitted to the database (Repschlaeger et al., 2012) .

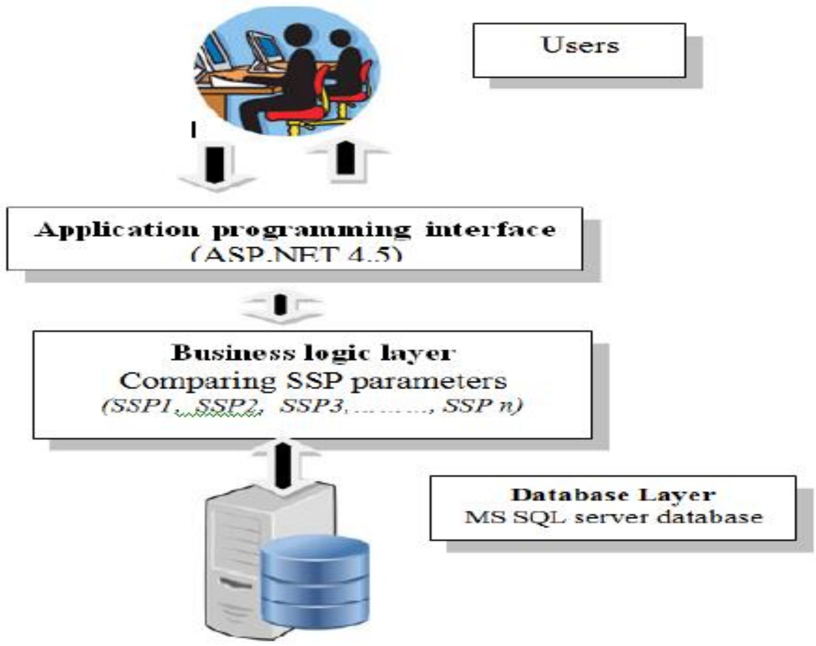

Figure (2.2) ASMAN Framework 3-tire Architecture

2.8.5 Service Measurement Index SMI

SMI framework is based on ISO standards and defines seven groups of QoS attributes which act as a foundation on which different providers can be cross compared. The top level groups of the SMI framework include Accountability, Agility, Cost, Performance, Assurance, Security and Privacy, Usability. Within each of these groups lower level attributes are defined. These attributes act as Key Performance indicators of the providers' efficiency. Thus SMI acts as a road map which instigates towards better overall judgment. Customers provide their requirements and get a sorted list of Cloud services. Fig. 2.2 shows the key elements of the framework: 1) Users: This real user who register to coordinators to get the information of service providers for their requirements; 2) Cloud Coordinator: this component is responsible for interaction with customers and understanding their application needs. It collects all their requirements and performs discovery and ranking of suitable services and display to the users;3) Service Catalogue: stores the services and their features advertised by various Cloud providers; Service Provider: this component is the real registered service providers who like to advertise about their services (Kumar and Agarwal, 2014).

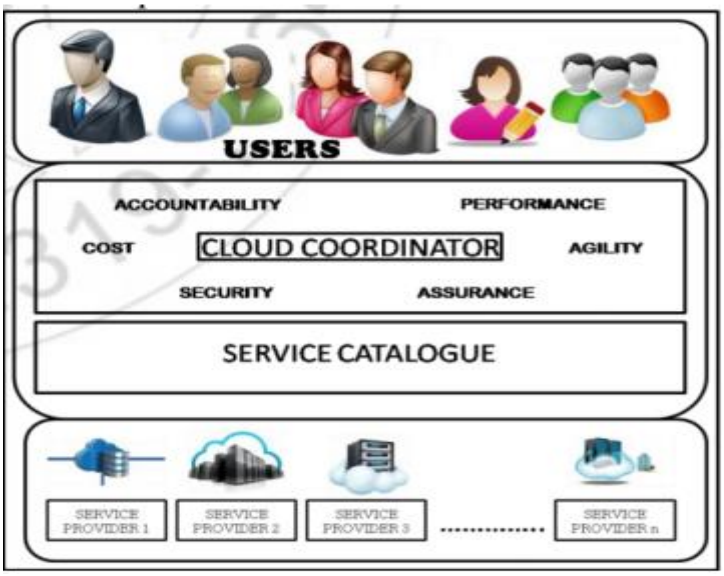

Figure (2.3) SMI Cloud framework Architecture

2.9 The Cost and Pricing in Cloud Service

Cost is the amount paid or payable for the acquisition of materials or services. Cost of service therefore is measured by the resources used to attain it. Money cost is not necessarily the same as economic cost. Economic cost implies the use of resources virtual machines, storage, etc. Currencies (such as USD/GBP) are used merely as a convenient common denominator for aggregating numerous heterogeneous physical quantities into meaningful packages for purposes of analysis and decision making. The art of approximating the probable worth of acquisition of materials or services on the hand is called cost estimation; and proposed Total Cost of Ownership (TCO) approach for Cloud Computing Services, for the development and evaluation of the formal mathematical model for the practical requirements and support decision making in Cloud Computing (Aminullah and Molina-Jimenez, 2012).

Pricing in cloud computing has two intertwined aspects. On the one hand, pricing has its root in system design and optimization. Resource-consumption based pricing is particularly sensitive to how a system is designed, configured, optimized, monitored, and measured. On the other hand, pricing also has its root in economics, where key concepts such as fairness and competitive pricing in a multi-provider marketplace affect the actual pricing. The pricing-induced interplay between systems and economics has fundamental implications on cloud computing, an important angle that should be explored by researchers; Recent cloud providers (e.g., Amazon Web Services, Google App Engine, and Windows Azure) have enabled users to perform their computation tasks in a public cloud. These providers use a pricing scheme according to incurred resource consumption. For example, Amazon EC2 provides a virtual machine with a single CPU core at the price of $0.095 per hour. This pay-as-you-go model lets users utilize a public cloud at a fraction of the cost of owning a dedicated private one, while allowing providers to profit by serving a large number of users (Wang et al., 2010).

Simulation of a software market that allows trading of two types of software licensing models (SaaS and PS) under four different dynamic pricing schemes. The four dynamic pricing schemes that have been considered are: derivative-follower (DF) pricing scheme, demand-driven (DD) pricing scheme, penetration (PN) pricing scheme, and skimming (SK) pricing scheme. The simulation involves two types of agents: customer agents and vendor agents. The task of customer agents is to score and rank software options offered by vendor agents, using the Analytic Hierarchy Process (AHP) method. The customer agent parameters are set based on the European Commission's SME guide. There are three categories of customer agents, representing small-sized, medium-sized, or large-sized enterprises. Vendor agents set prices for their software offerings according to the pricing scheme deployed. Vendor agent parameters are based on real world products from popular vendors such as Salesforce.com and Microsoft. Vendor agents are further categorized into SaaS vendors and PS vendors (Rohitratana and Altmann, 2012).

2.10 Summary of Features in Previous Studies

Table (2.1) describe the all feature of SaaS cloud in previous studies

No	Pepper Name	SaaS Feature
1.	A Framework For Software-As-A-Service Selection And (CSP) Provisioning (Badidi, 2013)	availability, response-time, reliability, throughput
2.	Selecting Cloud Service Providers - Towards a Framework of Assessment Criteria and Requirements (Schlauderer and Overhage, 2015)	availability ,performance ,cost
3.	A Decision Framework for Cloud Service Selection for SMEs: AHP Analysis (Lee, 2014)	Cost, Performance, Security , Privacy, Usability.
4.	A Brokerage-Based Approach for Cloud Service Selection (Sundareswaran et al., 2012)	Service type, Storage Cost, Service quality, Privacy protection
5.	Selection Criteria for Software as a Service: An Explorative Analysis of Provider Requirements (Repschlaeger et al., 2012)	service cycle, the functional coverage, service category, the user scaling,

		the portability of data and the browser compatibility.
6.	A Cloud Service Selection Model Based On User-Specified Quality Of Service Level (Hsu)	Availability, Response Time, User Rating, Price, Network Performance, System Performance, Financial Credit
7.	An Evaluation Model for Selecting Cloud Services from Commercially Available Cloud Providers (Wagle et al., 2015)	Availability, Reliability, Performance(Latency, Response time, Throughput), Cost(Storage Cost ,VM instance cost) and Security
8.	Cloud Model for Service Selection (Wang et al., 2011)	Price, Response time, Throughput , Reputation, Availability, Reliability)
9.	Global Trust: A Trust Model for Cloud Service Selection (Filali and Yagoubi, 2015)	availability, ,integrity ,Turnaround Efficiency, power, cost, response time, efficiency, transparency, interoperability, reliability, security
10.	A Framework for Selecting Suitable Software as a Service(ASMAN framework) (Dadhich and Rathore, October 2016)	Cost, Speed, Usability, Reliability, Availability
11.	An Automated Approach to Cloud Storage Service Selection(Ruiz-Alvarez and Humphrey, 2011)	Cost, performance
12.	Costing of Cloud Computing Services: A Total Cost of Ownership Approach (Martens et al., 2012)	Cost(Implementation, Configuration, Integration and Migration)
13.	Impact of Pricing Schemes on a Market for Software-as-a-Service and Perpetual Software (Rohitratana and Altmann, 2012)	Cost ,Reliable, Security
14.	Need of SLA Parameters in Cloud Environment. An Evaluation (Pandey et al.)	COST, Availability, Response time , mean response time, Query response time, Tuning cloud response time, Data Transfer Time, Delay time, Throughput
15.	SMICloud: A Framework for Comparing and Ranking Cloud Services (Garg et al., 2011)	Service Response Time , Sustainability Suitability, Accuracy, Transparency, Interoperability, Availability, Reliability,

		Stability, Cost, Adaptability, Elasticity, Usability
16.	W_SR: A QoS Based Ranking Approach for Cloud Computing Service (Jahani et al., 2014)	Accountability, Agility, Assurance of Service, Cost, Performance, Security and Privacy, and Usability
17.	Conceptual SLA Framework for Cloud Computing (Alhamad et al., 2010)	Reliability , Usability ,Scalability , Availability , Customizability
18.	Decision Model for Selecting a Cloud Provider:A Study of Service Model Decision Priorities (Repschlaeger et al., 2013)	Cost , Service Charging , Performance ,Reliability, Security, Interoperability
19.	Enhanced Cloud Service Provisioning for Social Networks (Shaat and Wassif, 2015)	Cost ,Flexibility ,Security ,Reliability ,Performance
20.	Evaluation Criteria for Cloud Services (Costa et al., 2013)	SMI feature
21.	Performance Challenges in Cloud Computing (Paliwal, 2014)	reliability , availability, scalability, Performance.
22.	Quality of Service Attributes for Software as a Service (Burkon, 2013)	Availability, Performance Reliability, Scalability, Security, Support, Interoperability, Modifiability, Usability, and Testability.
23.	SLA in Cloud Computing Architectures: A Comprehensive Study (Aljoumah et al., 2015)	Reliability, Usability, Scalability , Availability, Customizability)
24.	SaaS performance and scalability evaluation in Clouds (Gao et al., 2011)	Performance Reliability, availability, throughput, and scalability ,Cost
25.	IEEE Standard for a Software Quality Metrics Methodology (Committee, 1998 #75)	speed, efficiency, resource needs, throughput, and response time (Reliability, Usability, Integration, Survivability, Efficiency)

2.11 Related Works

Measuring the performance and cost of cloud service is a challenging task due to the diverse and numerous number of attributes. The following subsections describe the related work.

2.11.1 Service Measurement Index (SMI v2.1)

This model as shown in Figure (2.4) represents a step in the framework of quality for any kind of service and SMI attributes are designed based on the International Organization for Standardization (ISO) standards by the CSMIC consortium. It consists of a set of business relevant Key Performance Indicators (KPIs) that provide a standardized method for measuring. The SMI framework provides a holistic view of QoS needed by the customers for selecting a Cloud service provider (Garg et al., 2011).

2.11.2 ASMAN Model

This framework as shown in Figure (2.4) shows the key elements of the framework provides optimal software as service provider selection from the more number of SSP's. Uses five feature to measurer: Cost, Speed, Usability, Reliability, Availability(Dadhich and Rathore, October 2016) .

2.11.3 SMEs Model

Adopted two steps to building the structure of decision model with the analytic hierarchy process method and evaluate Cloud offerings and rank them based on Accountability, Agility, Assurance of Service, Cost, Performance, Security and Privacy, and Usability (Lee, 2014).

2.11.4 TCO Model

TCO the model implementing on a website that is open for the general public. And analysis of relevant cost types and factors of Cloud Computing Services ,the evaluation of quality by sub attribute for cost are Implementation, Configuration, Integration, Migration (Martens et al., 2012).

2.11.5 Performance Challenges in Cloud Computing

Performance considerations are vital for the overall success of cloud computing, including the optimum cost of cloud services, reliability and scalability. SaaS performance measures are directly perceived by users as business transaction response times and throughput, technical service reliability and availability, and by scalability of the applications (Paliwal, 2014).

2.11.6 Service Level Agreement (SLA)

Service Level Agreement (SLA) between consumers and providers becomes of paramount importance to guarantee that service quality is preserved at satisfactory levels regardless of the dynamic nature of the cloud environment. SLA parameters for QoS are Accuracy, Interoperability, Latency, Availability, Reliability, Scalability, Usability, cost (Aljoumah et al., 2015).

2.11.7 SaaS QoS Dimensions

This model explained the difference between the traditional outsourcing of information technology services and software as a service and it proposed a set of appropriate quality characteristics of quality management software as a service QoS testability is the percentage of QoS dimensions that are accessible to be tested Application testability consists of the list of feature for performance like Availability, Performance Reliability, Scalability, Security, Support, Interoperability, Modifiability, Usability, and Testability (Burkon, 2013).

2.11.8 Evaluation Model for Selecting Cloud Services

Performance criteria are chosen as important requirements to measure QoS for the cloud users: Availability, Reliability, Performance, Cost and Security. Under each main criteria, sub critera, which are directly measurable from cloud provider premises, are defined (Wagle et al., 2015).

2.11.9 IEEE Standard for a Software Quality Metrics Methodology

IEEE Standards documents are developed within the technical committees of the IEEE societies and the standards coordinating committees of the IEEE standards board. The performance factors in (speed, efficiency, resource needs, throughput, and response time are the high-priority sub factors associated with the high-priority factor performance)(Committee, 1998 #75).

Table (2.2) Related Works

		Cloud Computing							
Measurement	**Model** / **Attribute**	**SMI**	**SMEs**	**Evaluation Model for CACP**	**ASMAN**	**TCO**	**QoS SaaS**	**SLA**	**Performance Challenges**
Performance	Accuracy	×						×	
	Functionality	×							
	Suitability	×							
	Interoperability	×						×	
	Service Response Time	×		×			×		×
	Latency			×				×	
	Throughput			×			×		×
	Availability			×	×			×	×
	Reliability			×	×		×	×	×
	Transparency								×
	Scalability						×	×	
	Security		×	×			×		
	Speed				×				
	Usability		×		×		×	×	
Cost	acquisition	×	×					×	
	ongoing	×	×					×	
	maintenance		×			×		×	
	Storage			×	×				
	VM instance			×	×				
	Migration					×			
	licenses								×

Chapter Three
Research Methodology

3.1 Introduction

This chapter describes all phases of research methods that have been applied to develop the proposed model and tools used in the research work.

3.2 Operational Framework

This research aims to proposed new model that selection engine framework which performance and cost SMI attributes to rank the available service providers and select the one which satisfies QoS performance and cost criteria most consistently. The operational framework of the study is described in Figure (3.1).

3.2.1 Problem Formulation

This research aims to proposed new model that classifies cloud services based on performance quality and cost criteria.

3.2.2 Proposal Writing

In this step, the study identified all the research objectives of review and analyze the current cloud service selection models showing in Table(2.1), propose a new performance and cost based model for cloud SaaS service selection to help users choose the best service they need and test the applicability of the proposed model using SMI cloud Toolkit.

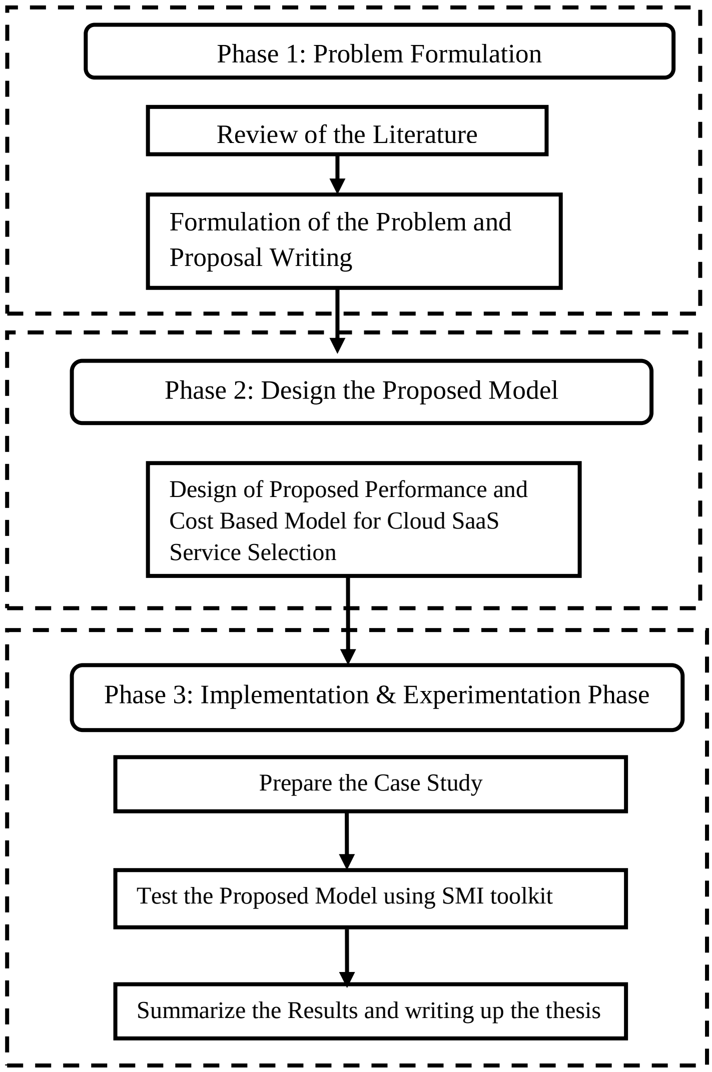

Figure (3.1): Research Operational Framework

3.2.3 Design of Proposed Framework

In the design phase the research focus on how to enhance the measurement of selecting service quality models by reviewing all previous models and compare them to find the most attributes that are shared and directly affect the performance and cost of the selection process showing in Table (2.2) and selection algorithm of this model based on the calculation for ranking cloud SaaS Service (Shaat and Wassif, 2015).

3.3 Implementation

In this phase the design of the proposed model and its application tool was implemented using a tool named SMI Cloud toolkit. This phase was started by calculating the weights for the performance and cost attributes by the percentage theory based on the sub attribute to the target attribute of the case study that will be used in the testing process.

3.4 Tool Used in This Methodology

Use in SMI Cloud Service Measurement Index that help users to enquire about a unique service from a group of services. It depends the Service Level Agreements and user requirements

Chapter Four

Performance and Cost Based Model for Cloud SaaS Service Selection

4.1 Introduction

Quality of Service (QoS) is related to the service capabilities. Service capabilities include performance, availability, security, reliability and dependability. QoS requirements are associated with service providers and end users. Service Level Agreements (SLAs) are an effective means for assuring QoS between service providers and end-users. In the context of cloud service provider, QoS should emphasize the performance of virtualization and monitoring tools for resources, network, storage, service migration, virtual machine and fault tolerance (Xu, 2012). But the Cost is first question that arises in the mind of organizations before switching to Cloud computing is whether it is cost effective or not. Therefore, cost is clearly one of the vital attributes for IT and the business. Cost tends to be the single most quantifiable metric today, but it is important to express cost in the characteristics which are relevant to a particular business organization (Sysmans, 2006).To define the performance and cost attributes there are many models of that have been measured, such as SMI , ASMAN, TCO, SLA and SMEs model as shown in table (2.1) in chapter two.

4.2 Common Performance Characteristics

The term performance and cost refers to methods for improving performance during the design process with cost. The following table lists the most common attributes of performance and cost. These 21 attributes were obtained from eight different models. They are as in Table (4.2).

Table (4.1): Performance and cost attributes in previous model

No	The Model	Attributes
1.	Service Measurement Index (SMI v2.1)	Accuracy, Functionality, Suitability, Interoperability, Service Response Time, acquisition cost ,ongoing cost
2.	SMESs	Cost: acquisition cost, ongoing and Maintenance cost, Performance, Security , Privacy, Usability.
3.	Evaluation Model for CACP	Availability, Reliability, Performance(Latency, Response time, Throughput), Cost(Storage Cost, VM instance cost) and Security
4.	ASMAN	Cost, Speed, Usability, Reliability, Availability
5.	TCO	Cost(Implementation and Migration)
6.	QoS attribute	Availability, Performance Reliability, Scalability, Security, Support, Interoperability, Modifiability, Usability, and Testability.
7.	SLA	Reliability, Usability, Scalability, Availability, Customizability.
8.	Performance Challenges in Cloud Computing	Reliability, availability, scalability, Performance.
9.	IEEE Standard for a Software Quality Metrics Methodology	speed, efficiency, resource needs, throughput, and response time (Reliability, Usability, Integration, Survivability, Efficiency)

Table (4.2) The Common Attributes of Cost and Performance Factor

		Cloud Computing								Software
Measurement	**Attribute** / **Model**	**SMI**	**SMEs**	**Evaluation Model for CACP**	**ASMAN**	**TCO**	**QoS SaaS**	**SLA**	**Performance Challenges**	**IEEE Standard**
Performance	Accuracy	×						×		
	Functionality	×								
	Suitability	×								
	Interoperability	×						×		
	Service Response Time	×		×			×		×	×
	Latency			×				×		
	Throughput			×			×		×	×
	Availability			×	×			×	×	
	Reliability			×	×		×	×	×	
	Transparency								×	×
	Scalability						×	×		
	Security		×	×			×			
	Speed				×					×
	Usability		×		×		×	×		×
Cost	acquisition	×	×					×		
	ongoing	×	×					×		
	maintenance		×			×		×		
	Storage			×	×					
	VM instance			×	×					
	Migration					×				
	licenses								×	

4.3 The Definitions of Performance and Cost Attributes as Set out in the Previous Models

As an introductory part of the study, the features related to performance and cost is described in details in the following subsections.

4.3.1 Performance

Performance category covers the features and functions of the services being provided. Dimensions proposed by O'Brien, Merson and Bass consist of response time, throughput, and timeliness (Sysmans, 2006). Cloud providers scope of services and performance are described to select the cloud provider which best meets the user requirements, that’s why the knowledge about their service and performance is very crucial and important (Shaat and Wassif, 2015) .

4.3.2 Accuracy

Accuracy is defined as the extent in which a service adheres its requirements(Costa et al., 2013). Accuracy can be given by dividing the number of features provided by the service by the number of features required by the customer (Colomo-Palacios and Rodríguez, 2014).It’s also known as software attributes that provide the required precision in calculations and outputs. To say the information is accurate, it must be free from mistakes or errors and it has the value that the user expects. If the information has been intentionally or unintentionally modified, it has lost its accuracy.

4.3.3 Suitability

Suitability is defined as how closely the features needed by the client match the capability of the proposed service. Also it can be defined as the number of nonessential features provided by the service divided by the number of essential features required by the customer. If all features are only non-essentials, the value will be zero (Colomo-Palacios and Rodríguez, 2014). Another definition is to evaluate the data management suitability of the cloud providers' solutions for the organizational data concerned and the ability to control access to data, secure it while resting, transmitting and in use (McCall et al., 1977) .

4.3.4 Interoperability

In cloud and SaaS context, interoperability is referred as the ability of service to easily interact with other services, either from the same cloud service provider or from another provider. Interoperability be calculated as the number of platforms that can connect to the service divided by the number of platforms customer needs to connect to (Colomo-Palacios and Rodríguez, 2014) .Also it can be defined as the capability of a service to interact with (Costa et al., 2013).Interoperability is generally defined as the ability to exchange data and to make use of these data within the receiving system (Stanton et al., 2015).

4.3.5 Service Response Time

Service response time is defined as an indicator of the time between when a service is requested and when the response is available .Service response time is the calculation of the average time to perform an operation. It is measured by dividing the time for an operation by the average time of all operations available in the service (Colomo-Palacios and Rodríguez, 2014). Also it can be defined as the maximum promised response time by the cloud provider for the service to be done. Service response time failure is being calculated by the percentage of occasions when the response time was higher than the promised maximum response time: 100 * (n' /n). Where n' is the number of times when the service provider was not able to fulfill their promise (Colomo-Palacios and Rodríguez, 2014).Response time is measured in milliseconds; it is an attribute for SaaS services that specifying how long does it take to process a request (Burkon, 2013). Also it can be defined as is the time between requesting a service and responding to that (Costa et al., 2013).

4.3.6 Throughput

Throughput is defined as is the number of requests that can be processed per the unit of time. Throughput is connected to the scalability of service very tightly, and it can be adjusted dynamically based on the service customer needs (Burkon, 2013).

4.3.7 Functionality

Functionality is the specific features provided by a service .Functionality can be defined as the number of nonessential features provided by the service divided by the number of all features provided by service (Colomo-Palacios and Rodríguez, 2014) .Also it can be defined as the effectiveness and productivity usage of leased services (Costa et al., 2013) .

4.3.8 Usability

Usability attribute is the relative effort for software operation and training like execution and output interpretation (Burkon, 2013).

4.3.9 Availability

Software availability is defined as a fraction of the total time during which the system can support critical functions. It is the probability of a system to be operating satisfactorily at any point of time, when used under stated conditions. Also can be defined as the degree to which a software remain operable in the presence of system failures (Burkon, 2013) . Availability enables authorized users or computer systems to access the desired information without interference or obstruction, and to receive it in the required format (Wang et al., 2008).

4.3.10 Reliability

Reliability is the attribute that bears on the capability of software to maintain its level of performing perfectly under stated conditions for a stated period of time (Burkon, 2013) . It is also defined as the extent to which a software can perform without failures within a specific time period (Committee, 1998) , or the extent to which programs expected to perform its intended function with the required precision . Reliability is also defined also as the capability of a service to be operating without failure or errors (Costa et al., 2013) . Another definition to reliability is that it is a set of attributes that bear on the capability of software, in order to maintain its level of performance under stated conditions for a stated period of time (Scholtz and Consolvo, 2004). Reliability is the ability of a system or component to perform its required functions under stated conditions for a specified period of time (Wang et al., 2008).

4.3.11 Transparency

Transparency is defined as Policies and technologies of cloud service providers should be transparent to the cloud users, which mean they should have access, as needed, to the cloud datacenter and have details about the cloud platform's capabilities and the changes plan. This feature is important for building trust between cloud providers and cloud consumers (Caporin et al., 2014).

4.3.12 Scalability

Scale the infrastructure of the SaaS application delivery to support growing number of tenants with well managed cost increase, performance and availability guarantee (Jansen and Grance, 2011). Scalability is related to effectiveness of interaction with large numbers of users and entities(Tolk, 2013).

4.3.13 Security

Security is defined as the degree in which a software can detect and prevent information's leak, loss, illegal use and system resource destruction (Burkon, 2013). Security is the quality or state of being secure and free from danger, protected against adversaries from those who would do harm, either intentionally or otherwise (Wang et al., 2008).

4.3.14 Cost

Cost The amount of money spent on the service by the client depends on two attributes: acquisition and on-going (Garg et al., 2011) (Lee, 2014) (B, 2013).

4.3.15 Acquisition Cost

Acquisition cost of the storage you buy is inarguably a huge aspect of the total cost. It's not the only factor in how much it costs you to deploy storage internally, but I&O teams probably pay too much attention to it compared with operating cost, Hardware cost refers to the acquisition of hardware resources. In particular, it distinguishes between the purchasing cost of computing hardware needed in-house and the purchasing cost of network devices (e.g., switches, routers) needed in-house (Reichman, 2011). In SMI Cloud toolkit called a service cost.

4.3.16 Ongoing Cost

Can be calculated as the sum of data communication ,storage and compute usage for that particular Cloud provider and service, and is The client's cost to consume a service over time. This includes cost of transition of the service along with recurring costs (e.g., monthly access fees) and usage-based costs. (Garg et al., 2011) (Lee, 2014, B, 2013). In SMI Cloud toolkit called a Financial Competitiveness over Time.

4.3.17 Maintenance Cost

Maintenance and Modification : This cost type depends on the expenditure of time (eot) for the general maintenance and for modifications made to the service implementation (Martens et al., 2012) ; Maintenance cost refers to the costs for keeping the software operating smoothly (including hardware, software, and network) (Altmann and Rohitratana, 2010).

4.3.18 Migration Cost

The migration cost is costs of the initial transfer of data to the Cloud for the purpose of system migration belong to this cost type. They are calculated by multiplying the data volume per unit (i. e. gigabyte) by the price of one unit (Martens et al., 2012).

4.3.19 License Cost

License cost the purchasing price of licenses (Kashef and Altmann, 2011). and associated with the base cost estimation is due to license payment (Galani and Tsonas).

4.3.20 Storage Cost

Storage cost based on the number of I/O operations per second (IOPS) being consumed; cost of storage allocated for a service Instance Cost of virtual machines described for a software components deployment Network Bandwidth Cost Total cost of data transferred from and to a deployed service (Aminullah and Molina-Jimenez, 2012).

Table (4.3) Attribute that has been Included in the Proposed Model

Measurement	Attribute \ Model	SMI	SMEs	Evaluation Model for CACP	ASMAN	TCO	QoS SaaS	SLA	Performance Challenges
Performance	Accuracy	×						×	
	Suitability	×							
	Interoperability	×						×	
	Service Response Time	×		×			×		×
	Reliability			×	×		×	×	×
Cost	acquisition	×	×					×	
	ongoing	×	×					×	

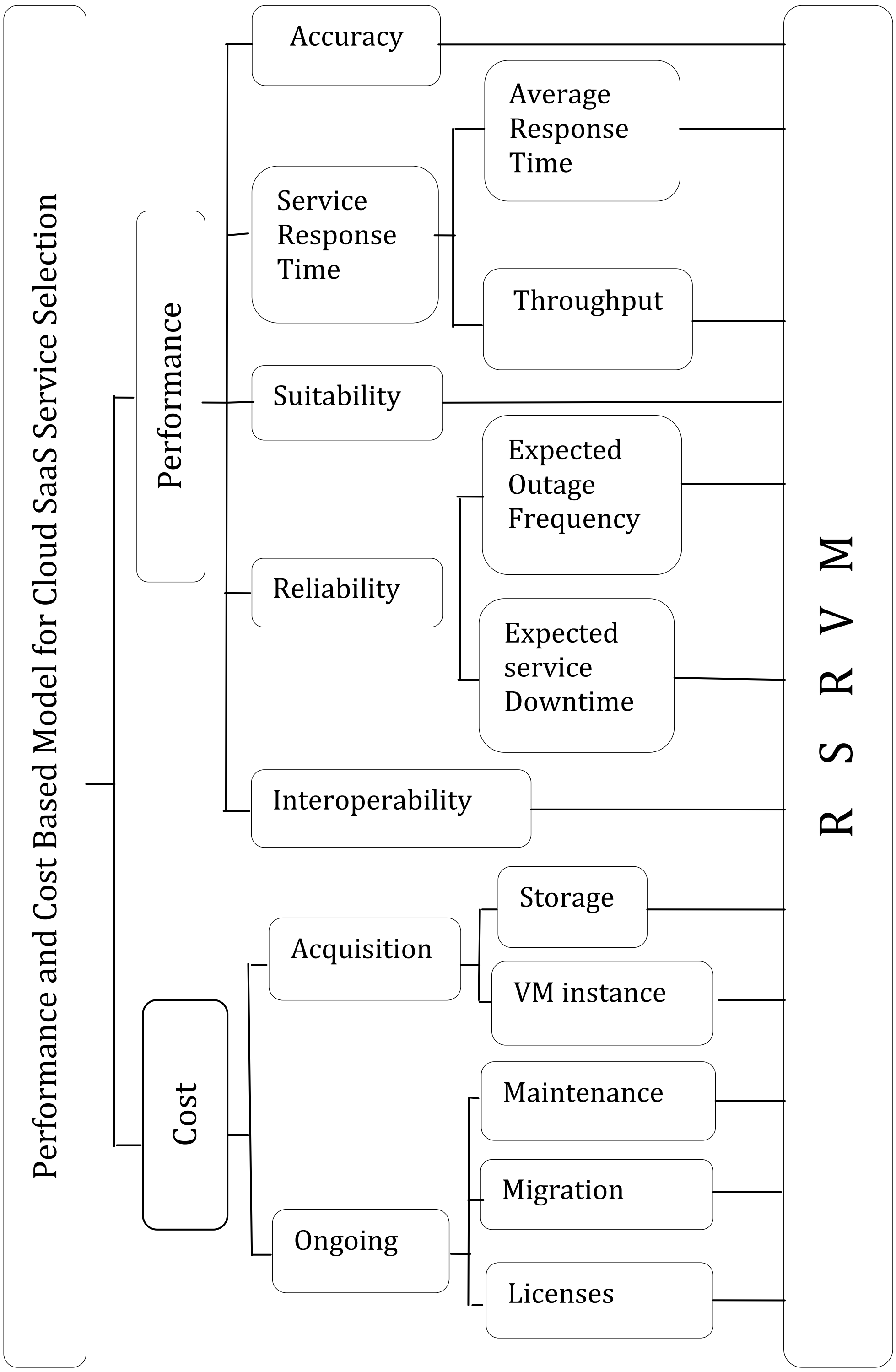

Figure (4.1) The Proposed Model

4.4 The Proposed Model Description

This study proposed Performance and Cost Based Model for Cloud SaaS Service Selection. The aim of the proposed model is to select best service (SaaS) offered, based on performance and cost criteria. The proposed model is mainly an enhancement to SMI cloud model it has modified SMI cloud model and included the attributes that have the highest effects on the service performance from software engineering field and cloud SaaS field and cost from cloud SaaS field. Furthermore, some sub attributes are also modified to enhance the SMI cloud model. Mainly the modification to SMI cloud model is based on merging the attributes from SaaS field and the attributes used in cost service. All attributes and sub attributes in table (4.3) and Figure (4.1) has been included in the proposed model

The proposed model measures the quality of service performance and its cost. Quality of service performance means service features and its expected functions. The model use five criteria’s to measure the quality of service performance ; accuracy ,response time , Suitability , Reliability and Interoperability .As explained in Table(4.3).Where cost means the value paid by the cloud user to the cloud provider for using cloud service. The cost values measured by two criteria; Acquisition and Ongoing as explained in table (4.3).

Performance and Cost measurement model provides the quality measurement in a simple performance and cost scale. This scale begins from 0% and ends at 100%. In this scale 0% indicates a very poor quality of performance and expensive cost and 100% shows the best quality of it and cheap cost. In this model, the weight was distributed depending to sub attributes for both the performance and cost.

The weight of both performance and cost was calculated according to percent proportional mathematical law (Tobey and Slater, 2005)as shown in Table 4.4.

The percent proportional is: part / whole = percent / 100

Where:

Part denote to number of sub attribute for target attribute.

Whole denote to sum of all sub attribute.

Percent denote to weight required.

Example:

For calculate the weigh performance: 5/7=percent / 100

Percent = 5/7*100 = 71/ 10=7.

Table (4.4) Weight for Attribute

No Sub Attributes	Attribute	Weight
5	Performance	7
2	Cost	3

Table (4.5) Weight for All Attributes and Sub Attribute

Category	Attributes	Sub Attributes	Weight
performance	Accuracy		1
	Service Response Time		2
		Average Response Time	1
		Throughput	1
	Suitability		1
	Reliability		2
		Expected Outage Frequency	1
		Expected service Downtime	1
	Interoperability		1
Cost	Acquisition		1.2
		Storage	0.6
		VM instance	0.6
	Ongoing		1.8
		Maintenance	0.6
		Migration	0.6
		Licenses	0.6

4.5 Steps of Implementing the Selection Algorithm

The steps of the selection algorithm of the proposed model is based on the calculation for ranking cloud SaaS services described in (Shaat and Wassif, 2015) .

1. Use the numbers of services to establish a quadrate metrics, this matrix will be called Relative Service Ranking Matrix (RSRM) to illustrate the degree of similarity between service providers

$$\mathbf{RSRV} = \begin{vmatrix} S1/S1 & S1/S2 & S1/S3 \\ S2/S1 & S2/S2 & S2/S3 \\ S3/S1 & S3/S2 & S3/S3 \end{vmatrix}$$

2. Then calculate the summation of the elements for each column C_i separately to get the similarity rate between each service and other services

$$C1 = S1/S1 + S2/S1 + S1/S1$$

$$C2 = S1/S2 + S2/S2 + S3/S2$$

$$C3 = S1/S3 + S2/S3 + S3/S3$$

3. Conduct a new matrix Z, its' elements are the result of dividing each element from the main matrices (RSRM) by the sum of its own column, to get the differentiating rate between each service and all other services

$$\mathbf{Z}= \begin{vmatrix} \frac{S1}{S1} / C1 & \frac{S1}{S2} / C2 & \frac{S1}{S3} / C3 \\ \frac{S2}{S1} / C1 & \frac{S2}{S2} / C2 & \frac{S2}{S3} / C3 \\ \frac{S3}{S1} / C1 & \frac{S3}{S2} / C2 & \frac{S3}{S3} / C3 \end{vmatrix}$$

4. The next step is to divide the resulting matrices Z by the number of elements n, to obtain the rating average

$$Y= \begin{vmatrix} \frac{A}{n} & \frac{B}{n} & \frac{C}{n} \\ \frac{D}{n} & \frac{E}{n} & \frac{F}{n} \\ \frac{G}{n} & \frac{H}{n} & \frac{I}{n} \end{vmatrix} = \begin{vmatrix} A & B & C \\ D & E & F \\ G & H & I \\ J & K & L \end{vmatrix}$$

5. Sum each row separately to establish the ranking vector

R1= $A/n + B/n + C/n$

R2= $D/n + E/n + F/n$

R3= $G/n + H/n + I/n$

6. From the above step we get the following vector (V)

$$\textbf{Vector (V)} = \begin{matrix} \textbf{R1} \\ \textbf{R2} \\ \textbf{R3} \end{matrix}$$

7. Multiply the vector (V) with the Relative Service Ranking Metrics (RSRM)

8. The result is the Relative Service Ranking Vector metrics (RSRV).

9. Repeat the steps for each service

10. Combine all the resulting matrices (RSRMs) in a new one called (RSRV) and multiply it with the weigh column taken from the above table.

11. Finally compare between values in the RSRV and select the service is max value.

4.6 Demonstration

Considering three cloud providers S1, S2 and S3 with values of performance attributes as Accuracy, Service Response Time and cost attribute as ongoing as described in Table (4.6)

Table (4.6) Demonstration Example

Attribute	Name service / Sub Attribute	S1	S2	S3
Performance	Accuracy	4	4	2
	Service Response Time	3	2	5
Cost	ongoing	3	3	4

Step1: Find the matrix RSRM

$$\textbf{RSRM} = \begin{matrix} 4/4 & 4/4 & 4/2 \\ 4/4 & 4/4 & 4/2 \\ 2/4 & 2/4 & 2/2 \end{matrix} = \begin{matrix} 1 & 1 & 2 \\ 1 & 1 & 2 \\ 0.5 & 0.5 & 1 \end{matrix}$$

Step2: Calculate C1,C2 and C3

C1 = 1 + 1 + 2=4

C2 = 1+ 1 + 2=4

C3 = 0.5 +0.5+ 1=2

Step3: Derive the matrix RSRV

$$\text{RSRV}_{(accuracy)} = \begin{matrix} 1/4 & 1/4 & 2/2 \\ 1/4 & 1/4 & 2/2 \\ 0.5/4 & 0.5/4 & 1/2 \end{matrix} = \begin{matrix} 0.25 & 0.25 & 1 \\ 0.25 & 0.25 & 1 \\ 0.125 & 0.125 & 0.5 \end{matrix}$$

$$Y = \begin{matrix} \frac{0.25}{9} & \frac{0.25}{9} & \frac{1}{9} \\ \frac{0.25}{9} & \frac{0.25}{9} & \frac{1}{9} \\ \frac{0.125}{9} & \frac{0.125}{9} & \frac{0.5}{9} \end{matrix} = \begin{matrix} 0.02778 & 0.02778 & 0.11111 \\ 0.02778 & 0.02778 & 0.11111 \\ 0.01389 & 0.01389 & 0.05556 \end{matrix}$$

Step4: Calculate R1, R2 and R3

R1 0.0278 + 0.0278 + 0.1111 = **0.16667**

R2 0.0278 + 0.0278 + 0.1111 = **0.16667**

R3 0.0139 + 0.0139 + 0.5556 = **0.08333**

$$\begin{matrix} 1 & 1 & 2 \\ 1 & 1 & 2 \\ 0.5 & 0.5 & 1 \end{matrix} \times \begin{matrix} 0.16667 \\ 0.16667 \\ 0.08333 \end{matrix} = \mathbf{0.5 \quad 0.5 \quad 0.25}$$

Step5: Enter in the example data of the features and attributes.

RSRV $_{(accuracy)}$ = (**0.5 0.5 0.25**)

RSRV $_{(Service\ Response\ Time)}$ = (**0.38817 0.25 878 0.64695**)

Step6: Combine RSRV in one matrix for calculate RSRV to performance

$$\begin{pmatrix} 0.5 & 0.38817 \\ 0.5 & 0.25\,878 \\ 0.25 & 0.64695 \end{pmatrix} \times \begin{pmatrix} 1 \\ \\ 2 \end{pmatrix} = \mathbf{1.27634 \quad 1.01756 \quad 1.54391}$$

RSRV $_{\text{(Performance)}}$ = (1. 27634 1. 01756 1. 54391)

Step7: Repeated steps (1), (2),(3),(4),(5)and (6) to calculate RSRV to Cost.

RSRV $_{\text{(Cost)}}$ = (0.55909 0.55909 0.74545)

Final step: Combine RSRV for performance and cost to calculate ranking services

$$\begin{pmatrix} 1.27634 & 0.55909 \\ 1.01756 & 0.55909 \\ 1.54391 & 0.74545 \end{pmatrix} \times \begin{pmatrix} 7 \\ \\ 3 \end{pmatrix} = \mathbf{10.6 \quad 8.8 \quad 13.0}$$

From the above example we found that provider Three is the best providers.

Chapter Five

Applicability of the Proposed Model

5.1. Introduction

This chapter describes the case study as well as the steps used to test the applicability of the proposed model using Cloud SMI toolkit.

5.2. Case Study

To test applicability of the proposed model a case study is needed to evaluate the model. As described in table (5.1) The QoS data is collected from various evaluation studies for three Cloud providers Google, Microsoft Office 365 and Amazon EC2 with deferent attribute values described in (Costa et al., 2013) (Reixa et al., 2012) (Schlauderer and Overhage, 2015). The values of attribute and measurements as described in Table (5.1).

Table (5.1): The Case Study Data

Attribute	Services / Sub Attribute	Google (S1)	Microsoft Office 365(S2)	Amazon EC2 (S3)
Performance	Accuracy	4	4	5
	Reliability	5	4	5
	Service Response Time	5	4	4
	Interoperability	5	5	4
	Suitability	3	3	2
Cost	Acquisition	4	3	2
	Ongoing	4	3	3

5.3 SMI Cloud Toolkit Testing

As described in the research methodology phase this study use of SMI Cloud toolkit as a testing tool. The process starts with creating three providers as described in Figures (5.1) and (5.2). Then the values of the weights, attributes and measurements will be key in as in Figures (5.3), (5.4), (5.5), (5.6), (5.7), (5.8), (5.9), (5.10) and (5.11).

5.4 Steps for the walk-through SMI-Tool software:

Step1: In this step, the user enters his/her personal information and basic fields to describe the service that is being measured.

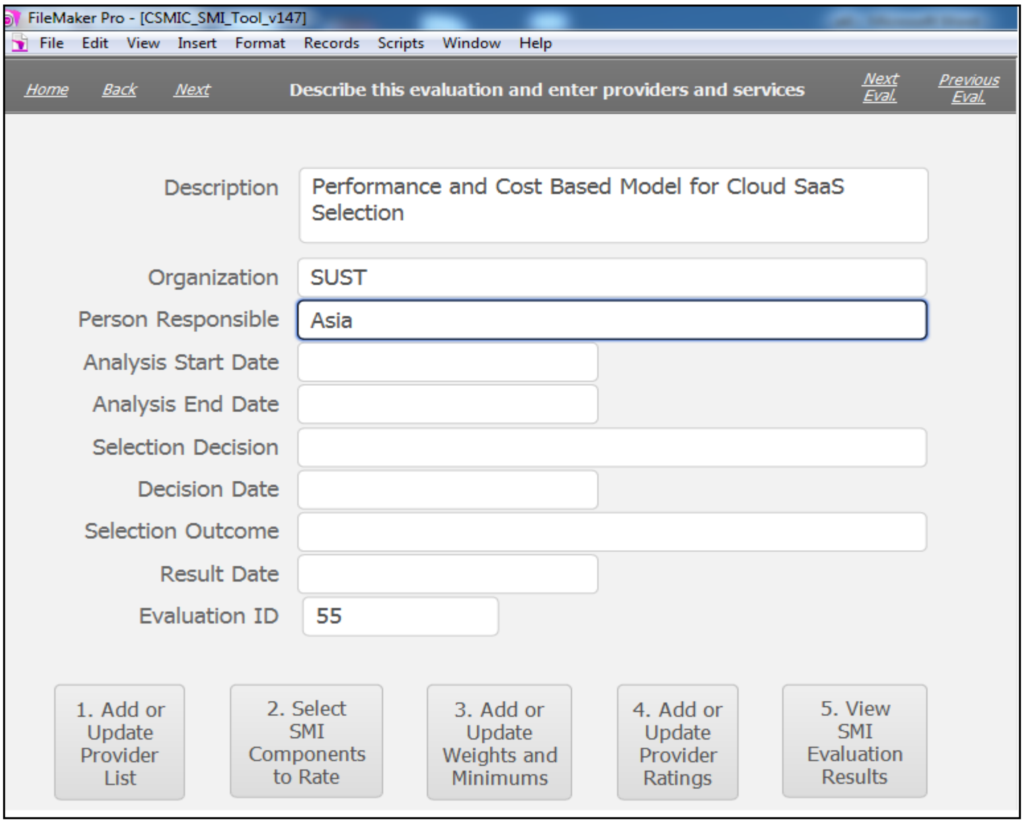

Figure (5.1) SMI Personal Information Entry

Step2: In this step, the user enters the provider and service names.

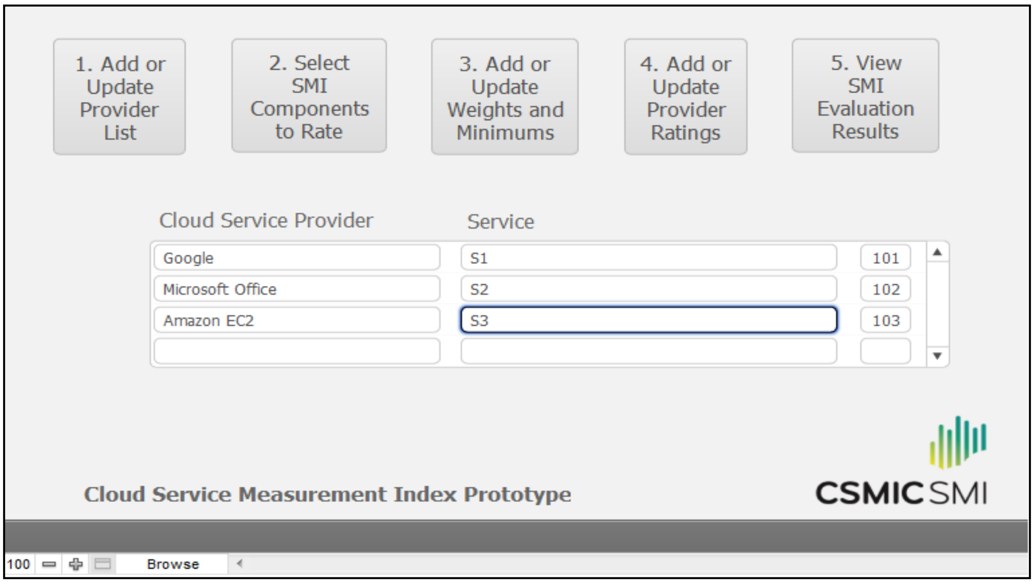

Figure (5.2) Entering of Service Provider Numbers

Step3: In the following step, the user chooses the attributes of the service and enters the value of its weight.

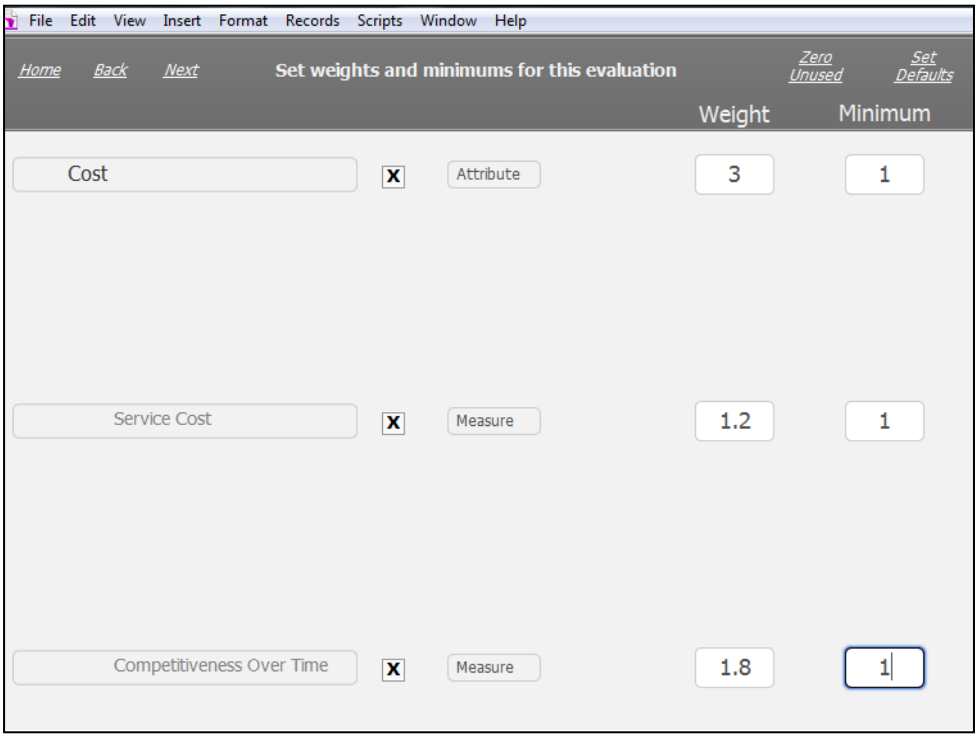

Figure (5.3) Entering the Weight to Cost Attributes and Minimum Requirements

Continuous of the step3

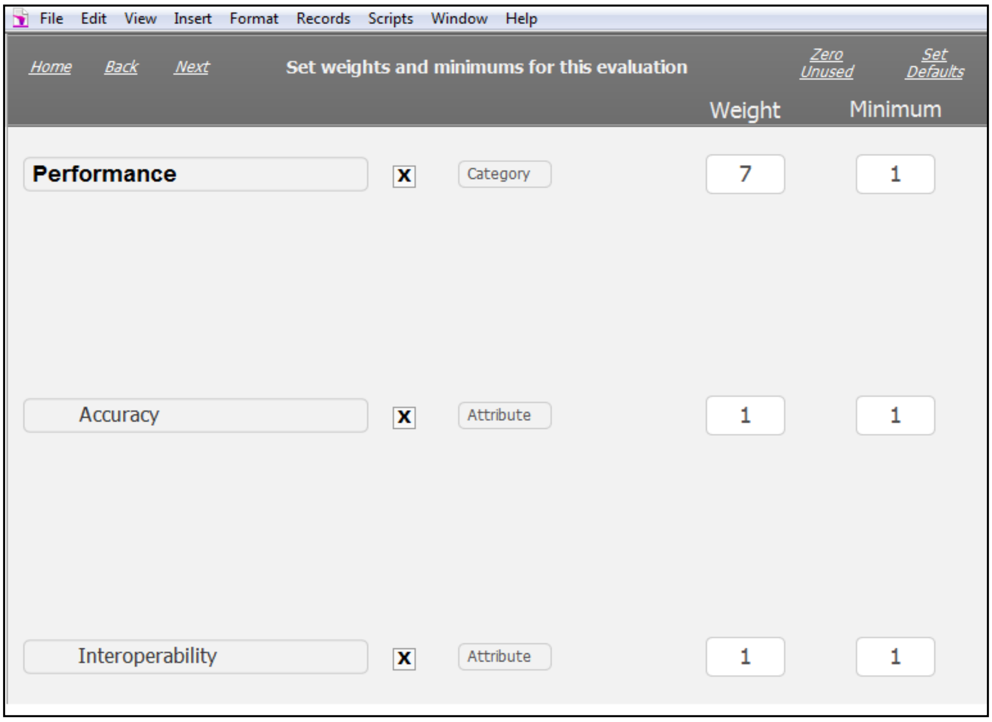

Figure (5.4): Continue of Entering Weight to Performance Attribute

Continuous of the step3

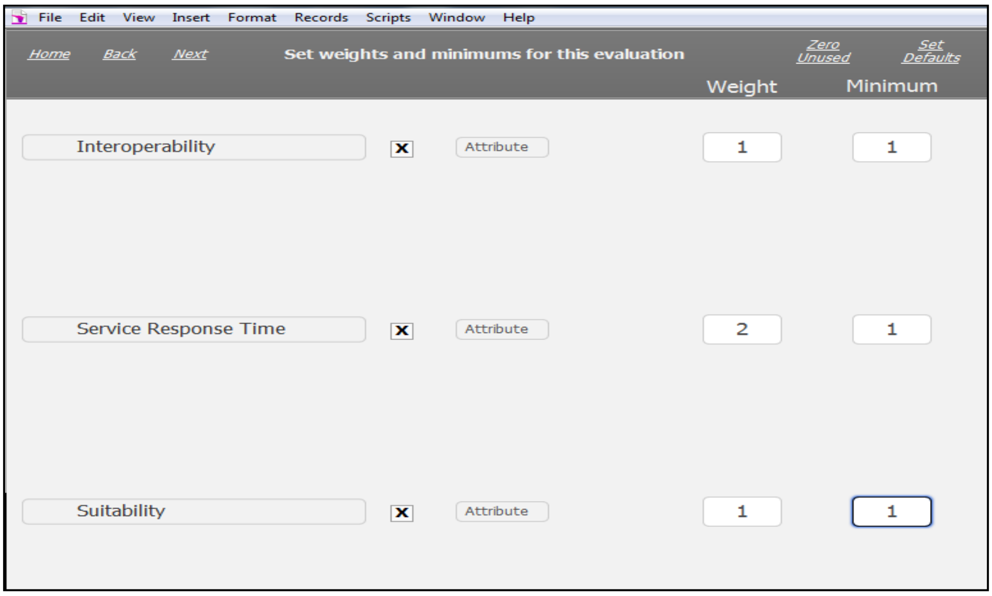

Figure (5.5): Continue of Entering Weight to Performance Attribute

Continuous of the step3

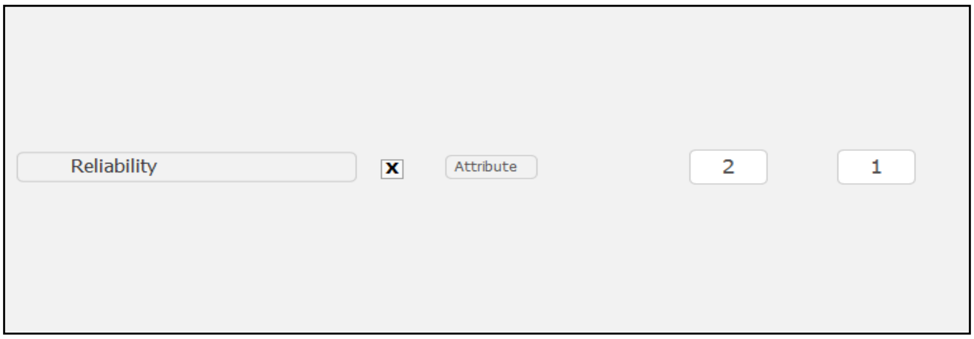

Figure (5.6): Continue of Entering Weight to Performance Attribute

Step4: Entering the values of the service. This step is repeated for each provider to be measured by the software.

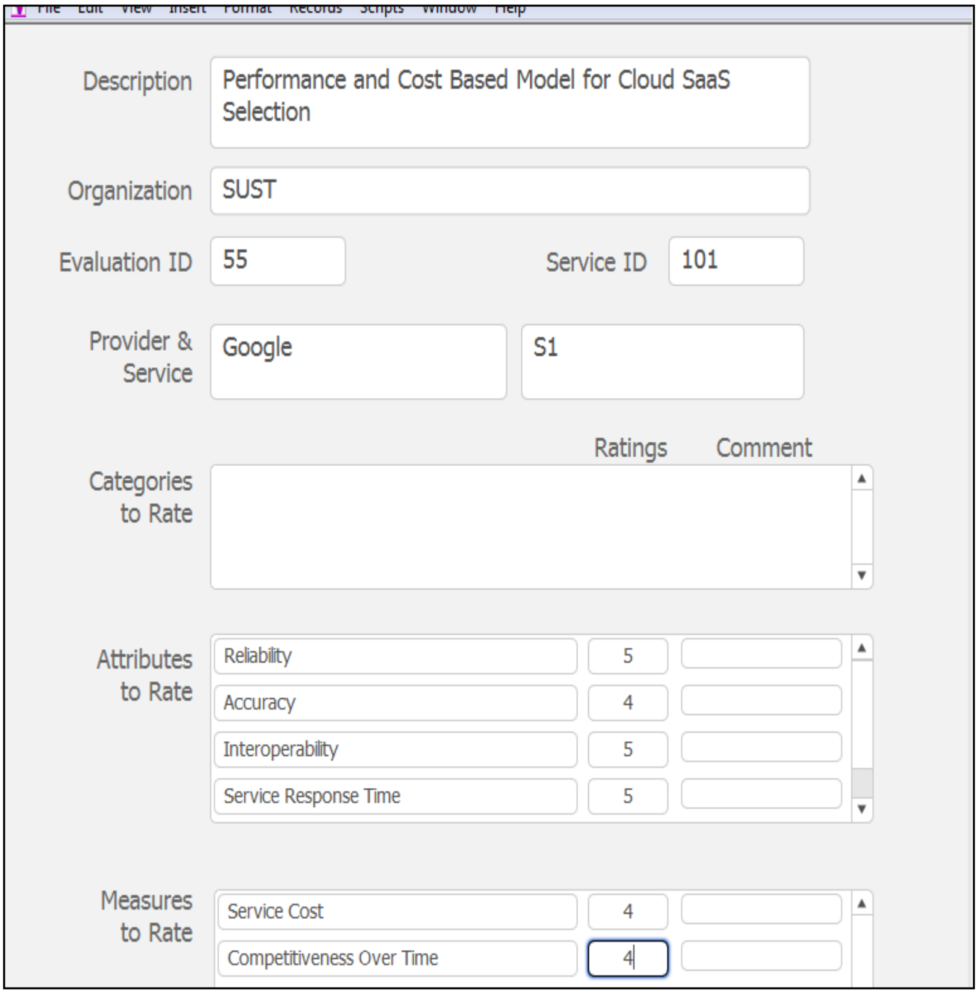

Figure (5.7): Entering Rate for Google Provider

Step5: The following steps show the output resulting for each service:

Google

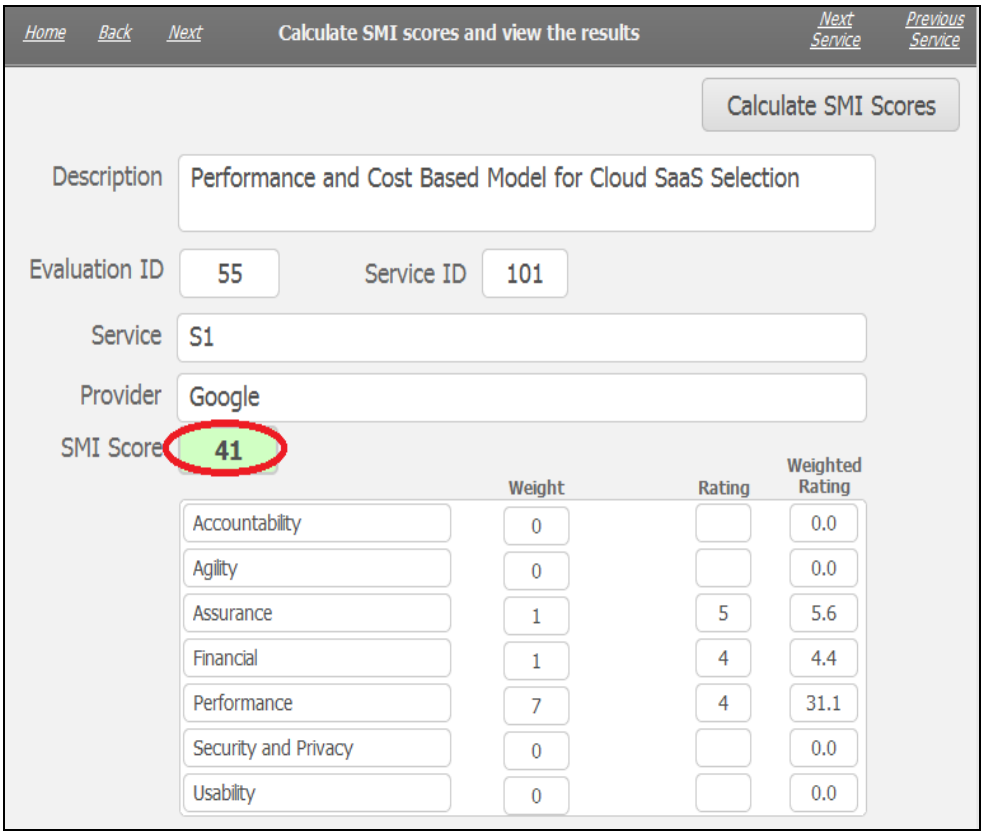

Figure (5.8): Calculating SMI Scores for S1 to Google

Microsoft Office

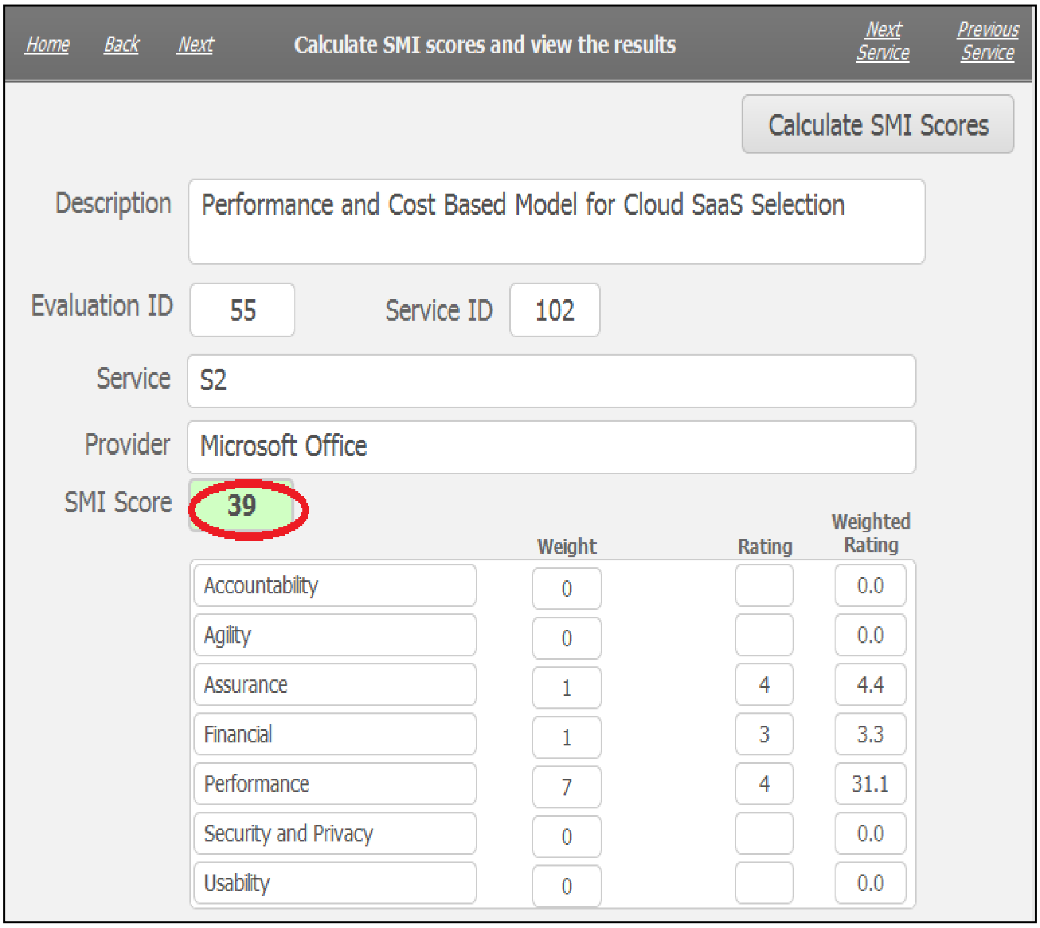

Figure (5.9): Calculating SMI Scores for S2 to Microsoft Office

Amazon EC2

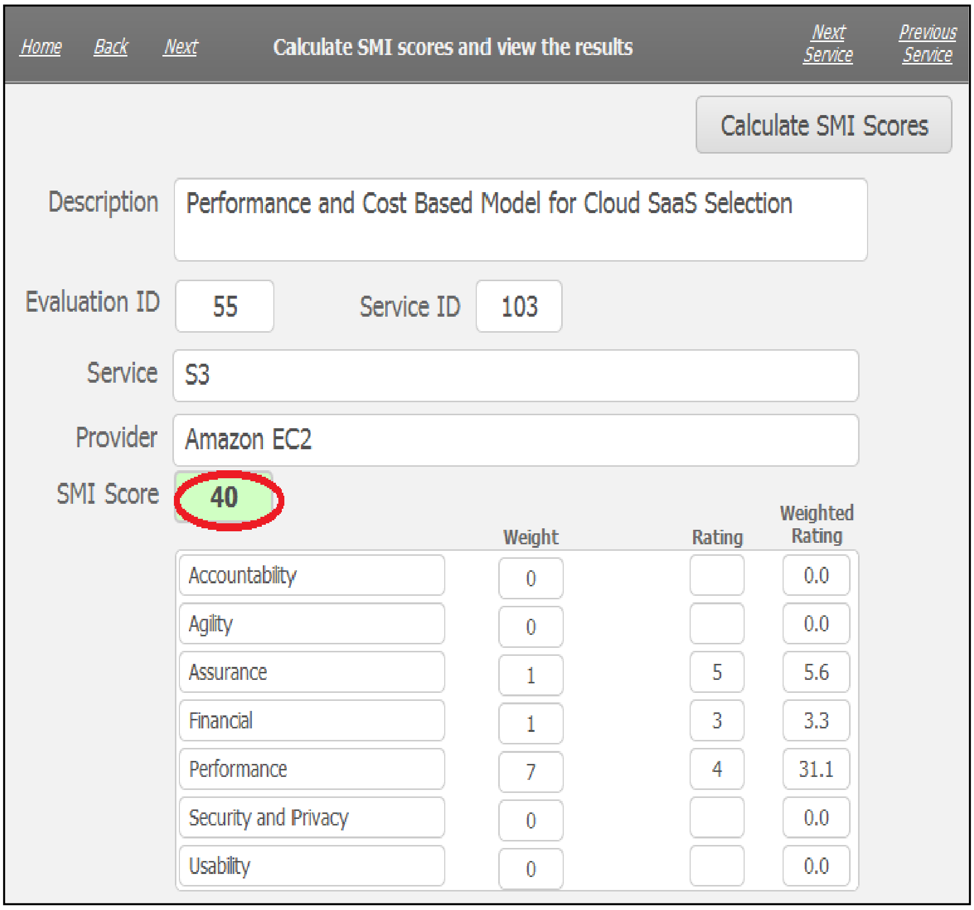

Figure (5.10): Calculating SMI Scores for S3 to Amazon

Step 6: This step shows the final result and produces it in a flowchart.

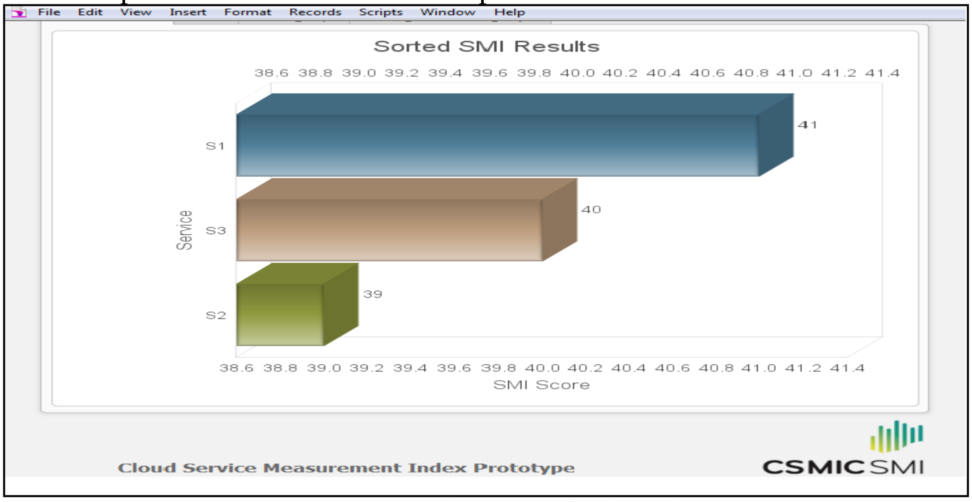

Figure (5.11): Ranking Result Flowchart

Table (5.2): Experiment Results

Measured features / Provider name	Performance	Cost
Google	36.7	4.4
Microsoft Office	35.5	3.3
Amazon EC2	36.7	3.3

5.5 Discussion

As shown in Figure (5.11) Google, Microsoft Office and Amazon EC2 have ranking values 41, 39 and 40, respectively. Suggesting that Google's ranking provider has the highest value of all. In Table (5.2), Google, Microsoft Office and Amazon EC2 have the performance values collected by the values shown in Fig(5. 8), Figure(5.9) and Figure(5.10) The result is 36.7, 35.5 and 36.7, respectively. As well as the cost values in Fig (5. 8), Figure (5.9) and Figure (5.10) respectively in Table 4.4, 3.3, and 3.37. Indicating that the performance values of Google and Amazon EC2 have the same value, Microsoft Office but Google is cheaper than Amazon EC2 and is therefore the best cloud service provider that the customer can choose.

Chapter Six
Conclusions and Lessons Learned

6.1 Conclusion

The proposed performance and cost based model for cloud SaaS selection that facilitates selection of the most appropriate cloud service provider to cloud users. The following important aspects are quality service for cloud provider: The proposed model considers both performance and cost attributes during the selection of the cloud provider. It verifies the quality of services delivered by cloud providers according to measurers the performance and cost attribute. Quality of service performance means service features and its expected functions. The model use fives criteria's to measure the quality of service performance; accuracy, response time, Suitability, Reliability and Interoperability. Where cost means the value paid by the cloud user to the cloud provider for using cloud service. The cost values measures by two criteria; Acquisition and Ongoing. The objective of this research is to propose performance and cost based model for cloud SaaS selection to help users choose the best service they need. Finally, SMI cloud Toolkit has been used to test the applicability of the proposed model. Results obtained from case study data are visualized in an ordered SaaS service according performance and cost, showing the services in a decreasing ordering of service quality. In this way, the performance and cost based model for cloud SaaS service selection represents a model capable of choosing the service for cloud service users from cloud service providers.

6.2 Lessons Learned

I. Building enhanced models based on existing model is a challenging task.

II. It is important to evaluate services accurately.

III. Building enhanced selecting model demands analysis skills.

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