TOWARDS SERVICE EVALUATION AND RANKING MODEL FOR CLOUD INFRASTRUCTURE SELECTION

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In the name of Allah most beneficent most merciful

وَلَا يُحِيطُونَ بِشَيْءٍ مِّنْ عِلْمِهِۦٓ إِلَّا بِمَا شَآءَ

And they can’t encompass anything from His knowledge, but to extend He wills [2:255]

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.

To my Guardians, Mentors and Associates

ABSTRACT

Cloud computing, comparatively a new computing paradigm is bringing revolution to Information Technology by offering on-demand publicly available desired computing resources to the cloud customers. As, there are multiple cloud service providers available in the market and are increasing exponentially, it becomes very difficult for customer to select the most appropriate option from the web repository based on his personalized quality requirements. Also, the dynamic nature of cloud services makes it even more difficult for customers to assess resource provider and its service quality ensured in Service Level Agreement. Currently no model exists that allow the customer to evaluate and rank service providers on their consistency in performance level.

In this context, this paper presents Cloud Service Evaluation and Ranking Model (CSERM), which utilizes service measurement index, consistency checking and multiple criteria decision making techniques to evaluate service performance (cloud resource providers) based on user-defined requirements and generate ranked list from where the customer can select the top most ranked option for deploying their applications. Such a model can make significant impact on service performance and compel cloud providers to satisfy their promised quality of services. A case study in this paper describes the whole model implementation.

Keywords – *Cloud computing, multiple criteria decision making, quality of service, service measurement, ranking*

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Contents

ACKNOWLEDGEMENTS ... iv

ABSTRACT ... vi

Chapter 1 ... 11

INTRODUCTION ... 11

1.1 Overview ... 11

1.2 Background and Motivation ... 11

1.3 Objective and Contribution ... 12

1.4 Outline ... 13

Chapter 2 ... 14

LITERATURE REVIEW ... 14

2.1 Overview ... 14

2.2 Essential Characteristics ... 14

2.2.1 On-demand self-service ... 14

2.2.2 Broad network access ... 14

2.2.3 Resource pooling ... 14

2.2.4 Rapid elasticity ... 15

2.2.5 Measured service ... 15

2.3 Service Models ... 15

2.3.1 Software as a Service (SaaS) ... 15

2.3.2 Platform as a Service (PaaS) ... 15

2.3.3 Infrastructure as a Service (IaaS) ... 15

2.4 Deployment Models ... 16

2.4.1 Private cloud ... 16

2.4.2 Community cloud ... 16

2.4.3 Public cloud ... 16

2.4.4 Hybrid cloud ... 16

2.5 Service Measurement Index ... 16

2.5.1 Accountability ... 17

2.5.2 Agility ... 19

2.5.3 Assurance ... 19

2.5.4 Financial ... 20

2.5.5 Performance 21
2.5.6 Security and Privacy 21
2.5.7 Usability 22
2.6 Related work 23
2.7 Multiple Criteria Decision Making (MCDM) 25
2.8 Multiple Criteria Decision Making Techniques 26
Chapter 3 29
PROPOSED EVALUATION AND RANKING MODEL 29
3.1 Overview 29
3.2 Cloud Service Evaluation and Ranking Model (CSERM) 29
3.2.1 Service Call 29
3.2.2 Service Agent 30
3.2.3 Certainty Evaluation 30
3.2.4 Filtered Service Providers 30
3.2.5 Ranking 30
3.2.6 Ranked List of Service Providers 30
3.2.7 Selected alternative 31
3.2.8 Service Catalog 31
3.3 Ranking Cloud Service Providers 31
3.3.1 Analytic Hierarchy Process 32
3.3.2 Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) 33
Chapter 4 34
MODEL EVALUATION AND RESULTS (CASE STUDY) 35
4.1 Overview 35
4.2 Case Study 35
Chapter 5 49
CONCLUSION AND FUTURE WORK 49
5.1 Conclusion 49
5.2 Future Work 50
REFERENCES 51

List of Figures

Figure 3.1: Cloud Service Evaluation and Ranking Model.. 32
Figure 3.2: Table of Random Index. 34
Figure 4.1: Accuracy of Service Providers 47
Figure 4.2: Accountability of Service Providers 47
Figure 4.3: Capacity of Service Providers.. 48
Figure 4.4: Availability of Service Providers.. 48
Figure 4.5: Security of Service Providers. 49
Figure 4.6: Service Response Time of Service Providers.. 49
Figure 4.7: Cost of Service Providers 50
Figure 4.8: Relative Closeness of Service Providers to Ideal Solution 50

List of Tables

Table 2.1: Service Measurement Index 24
Table 3.1: Satty Scale of Relative Importance 34
Table 4.1: User Requirements with Relative Preferences 38
Table 4.2: pair-wise criteria comparison matrix 38
Table 4.3: Column Summation........ 39
Table 4.4: Data Normalization 39
Table 4.5: Weights Identification 40
Table 4.6: Identification of Priority Vector 40
Table 4.7: Lambda Values Calculation 41
Table 4.8: Log entries of SP1 and SP2 against Service Response Time........ 42
Table 4.9: Decision Matrix 43
Table 4.10: Computing Normalized Decision Matrix 43
Table 4.11: Weighted Normalized Matrix........ 44
Table 4.12: Ideal Solution Calculation........ 44
Table 4.13: Separation Measuremet from Positive Ideal Solution 45
Table 4.14: Separation Measurement from Negative Ideal Solution 46
Table 4.15: Identification of Relative Closeness and Ranking 46

Chapter 1
INTRODUCTION

1.1 Overview

Cloud computing is basically modifying the presumptions for how and when computing, storage and networking services should be assigned, governed, utilize and permit user to consume resources exhaustively. Due to the vigorous computing and storage, high accessibility and security, time and cost effective cloud computing is the top requirement for existing world. A client, organization or a trade that adopting emerging cloud environment can choose a well suitable infrastructure, platform, software and a network service, for any trade, where each one has some unique characteristics and benefits.

1.2 Background and Motivation

Cloud computing is an unrolled model bringing revolution to the IT industry by delivering pay-as-per-use services to the consumer identical to other services like gas, electricity, water and telephony. Many definitions are proposed by different cloud vendors depending upon the services they offered, but the definition presented by NIST is believed to be an appropriate one as it characterizes most of the critical aspects of cloud computing in its definition. It describe cloud computing as, " A model that enable ubiquitous, continent, pay-as-per-use network access to configurable computing facilities which can be promptly assigned and set free with reasonable cost and reduced management effort" [1]. This actually means the provision of cost effective, on demand resources quickly with minimal effort to support end users requirements. A service can be considered as cloud service if it holds following characteristics such as pay-as-per-use self-usage, wide network access, right service grouping, quick flexibility and restrained service [2]. Cloud paradigm also offer three main services depending upon the customer requirements which are Infrastructure service, platform service and software service [3], [4].

Traditionally, low budget organizations had to make heavy initial investment for managing Information Technology Infrastructure, hiring skilled administrators and developers [11]. Cloud computing promise to resolve this issue by providing global essential services which is accessible to the customer with reasonable charges depending on their service quality needs [3]. Therefore low and medium budget organizations have no need to invest heavy amount upfront in hardware deployment and on human resource. Cloud computing help these organizations by shifting their focus more towards innovation rather low level tasks [6]. Due to such advantages offered by cloud environment, enterprises are developing their applications on cloud infrastructure. But transforming business setup to cloud is not an easy task as applications possess special needs and attributes that require to be encountered by service provider. Also with increase in public cloud services [7], it is very difficult for consumer to select appropriate option among numerous choices that offer the same services at disparate price and performance level [18]. With diversity in service offerings, it is indeed a challenging task for consumers to identify cloud service provider that meet their quality of service requirements. Mostly, conflict come in requirements which make difficult to explore cloud provider service level in an objective way [8]. Therefore it is not just enough to explore different cloud service providers but to evaluate the most suitable option [9].

In order to perform comparative evaluation, Cloud services measurement initiative consortium (CSMIC) has identified metrics, Service Measurement Index (SMI), which is utilized by customer for comparing publicly available cloud platforms [10] by using different metrics [14] which monitors historical records along with service level agreements to find real values of each SMI criteria. Requirements that user deliver are sometimes not easy to measure. Moreover, identifying the best match to customer requirements and giving rank to cloud service provider is a decision problem and requires Multiple Criteria Decision Making (MCDM) [19].

1.3 Objective and Contribution

The research work aimed to improve cloud infrastructure selection process by proposing novel service evaluation and ranking model. We intend to create a model that can serve as a framework of an intermediate system, which provides support to the cloud customer in selecting the best alternative among multiple to deploy their application in cloud environment.

So our main contributions are as follows:

1. We present a novel paradigm which can be viewed as a framework of cloud provider selection system. It takes standardized quality requirements from customer and by passing through several phases, shrinks and ranks the most appropriate list of cloud service providers available in the market. The research presents the-state-of-art use of

multiple criteria decision making and certainty evaluation techniques for ranking cloud service providers.

2. We validated the proposed approach with a simple Case study which demonstrates that the implementation of this model is simple and final candidate for application deployment can be quickly obtained with less computational effort.

1.4 Outline

Chapter 2 discusses the related work. Chapter 3 explains the proposed model with its essential features which are described through case study in chapter 4. Eventually chapter 5 windup this research work and suggest an opinion of possible augmentation, advancement and refinement as future task.

Chapter 2
LITERATURE REVIEW

In this segment, we provide concise overview on the futuristic paradigms of cloud service provider evaluation and selection. It contains a detail review of all the techniques assist as an initial step in proposing model of providers' selection. We mainly considered the work which is based on Cloud computing and Multiple Criteria Decision Making.

2.1 Overview

Cloud computation is comparatively latest terminology, raised on decades of analysis in networking, utility computing, clusterization and service oriented softwares. It involves a service directed architecture, excellent malleability, reduction in ownership cost and aerials, pay-as-per-use services and many other things. Cloud computing is basically a paradigm for licensing pervasive , appropriate, pay-as-per-use network access to a distributed pool of configurable enumerating resources that can be quickly provided and set free with minimum organizational endeavor.

2.2 Essential Characteristics

The cloud paradigm contains five essential features which are listed below:

2.2.1 Pay-as-per-use self-service

A customer can independently provide with computing features, such as server interval and network repository as required accordingly without asking human synergy with each service provider.

2.2.2 Extensive network accessibility

Features are accessible over the web and attained via quality procedures that encourage use by miscellaneous thin or thick client platforms.

2.2.3 Service amalgamation

The donor computational facilities are grouped to facilitate several customers using a multi-occupant paradigm, with distinct tangible and facet resources effectually located and lifted according to customer need. There exists a perception of position freedom in which the customer usually has no authority over the pointed position of supplied amenity but might be eligible to identify position at higher abstraction.

2.2.4 Swift flexibility

Abilities could be flexibly delivered and set free in few cases naturally for ranging quickly exteriorly and internally sufficient for application. To the customer the abilities accessible for supplying often seem to be extensive and can be allocated in any amount any interval.

2.2.5 Measured service

Cloud applications naturally command, advance ability use by advantaging a measuring features at some stage of absorption suitable to the kind of help. Ability custom could be check, reserved and stated, supply clearness for both the donor and client of applied services.

2.3 Service Models

Common services that are often been offered by cloud service providers are:

2.3.1 Application Service

Abilities delivered to customer are to use the donor's application executing on cloud framework. Software found from distinct consumer tool via either a web browser or an application network. The client cannot organize the fundamental cloud framework including repository, OS and even distinctive software abilities, with exception of defined user essential software arrangement ambience

2.3.2 Platform Service

Ability given to the client is to expand on cloud environment customer build or collected software build using high level languages and tools provided by provider. The customer does not conduct the basic cloud framework but has to manage up the deployed software and arrangement settings

2.3.3 Infrastructure Service

Abilities provisioned to the customer are to arrange basic computational assets where the customer is able to put and execute chance application. Customer do not conduct or manage the basic cloud environment but has eye over OS, repository and expand software.

2.4 Deployment Models

Four deployment models are available in cloud environment for application deployment:

2.4.1 Private cloud

Cloud framework provided for a separate grouping composes different customers. It might possess, manage, and operate by the grouping external source.

2.4.2 Community cloud

Cloud framework provided for unshared usage by a definite association of customers from grouping that possesses common interest. It might be owned, governed and executed by one or more of enterprises in a region and may be on or off bounds.

2.4.3 Public cloud

Cloud infrastructure provided for free usage by the common people. It might be owned, governed and executed by an academic or government enterprises. It exists on the bounds of the cloud donor.

2.4.4 Hybrid cloud

Cloud infrastructure, design of different cloud infrastructures that remains different objects, but are stick together by regulated recovery technique that allow information and software flexibility (e.g., cloud brushing).

2.5 Service Measurement Index

In order to measure and analyze business services, a group of range is expected service providers with no defined standard to help in measuring service act especially in cloud-based business benefit. Cloud benefit measurement Action Corporation took first step by establishing a regulated ordered framework known as Service Measurement Index (SMI) shown in table 2.1. The Service Measurement Index developed by cloud services measurement initiative consortium. It is a hierarchical framework divided into seven groups. Each category is civilized by three or more aspects. Then within attribute a set of KPI's are defined that show the information to be clustered. Version 1.0 of CSMIC SMI contains the first two layer of this hierarchy, the categories and attributes. Each category and related attributes are given below in details.

2.5.1 Accountability

Organization always prefers such cloud environment to save their demanding information and to expand their application, where there is hazard of liability. This group contains different quality aspect for measuring specific features of service providers.

- ***Auditability***

  The capability of customer to validate that the service donor is complies to the basic, action, and strategies that they rely on.

- ***Compliance***

  Policies and processes devoted to by the service donor are replaced.

- ***Contracting experience***

  Clue of clients avert and gratification with procedure of go in arrangement needed to utilize a serviceability.

- ***Data ownership***

  The extent of birthright the customer has concluded customer information interrelated with serviceability

- ***Ease of doing business***

  Client gratification with quality to perform business with service donor.

- ***Governance***

  The procedure utilized by the service donor to carry out customer expectancy, distribute and facility presentation.

- ***Ownership***

  The extent of privileges the customer has over application authorization, rational estate and information integrated with the facility.

- ***Provider business stability***

  Probability that the service donor will proceed to sustain end to end and contractile terminology.

- ***Provider certifications***

The facility provider carries current authorization for standards relevant to their client responsibility/duty.

- ***Provider contract***

The service provider makes accessible to client SLA's satisfactory to organize the facility and excuse hazards of service error.

- ***Provider ethicality***

Ethicality involves the form in which the facility donor manages work. Ethicality contains fair training with providers, consumers and workers.

- ***Provider personnel requirements***

The extent to which service provider personnel have the skills, experience, education and certifications required to effectively deliver a service.

- ***Provider supply chain***

The service provider ensures that any SLA's that must be supported by its suppliers are supported.

- ***Security capabilities***

The capability of service provider to ensure application, data and infrastructure security based on the security requirements of the client.

- ***Sustainability***

Sustainability is the impact of the economy, society and the environment of the service provider.

2.5.2 Agility

It shows the influence of facility on a customers' ability to alter tactics quickly and with minimum disruption. It can be found as a speed of difference information measure, evidence fast group action of new capabilities of IT.

- ***Adaptability***

It is the quality of facility supplier to justify to difference in client needs.

- ***Capacity***

The supreme quantity of a facility that a facility supplier can get while merging united SLA’s.

- ***Elasticity***

It is the quality of a service to justify its resort depletion to fit bespeak.

- ***Extensibility***

The quality to combine new services to existing services.

- ***Flexibility***

Quality to include or cutoff predefined features from a facility.

- ***Portability***

Ability of a customer to with ease take away a facility from one facility donor to another with tokenizes interruption.

- ***Scalability***

Ability of a facility donor to maximize or minimize the quantity of a facility accessible to fit customer needs.

2.5.3 Assurance

This group shows the likelihood of service availability as framed in Service Level Agreement. Every organization tries to provide better services to gain customer satisfaction and to spread their business, therefore, attributes related to this group plays a vital role in cloud service selection.

- ***Availability***

Quantity of interval in which a customer can use a facility.

- ***Maintainability***

Quality for a facility donor to make revolution to the facility to keep the facility in a fettle of well mend.

- ***Recoverability***

An extent, to which a facility is eligible to rapidly continue a usual sovereign quality of function after an unintentional interruption.

- ***Reliability***

It shows how a facility runs without unsuccessful execution under given constraint during a specific time span.

- ***Fault Tolerance***

Ability of a facility to continue to work accurately when failure occurs in one or more of it parts.

- ***Service Stability***

The level to which the facility is immune to alter.

- ***Serviceability***

The ease of correcting issues with service.

2.5.4 Financial

Amount spent by a consumer on a service. Initial query that comes to expert mind before moving to cloud infrastructure is whether it is financially beneficial or not. Therefore, financial behavior of service provider is clearly one of the vital attribute to assess it during selection.

- ***Acquisition and Transition cost***

Any client cost to acquire the rights and ability to use a service and to move from an existing service to the new one.

- ***On-going cost***

The client cost to operate a service. This includes both recurring flat costs and usage- based cost.

- ***Profit or Cost sharing***

Arrangement between clients and providers under which costs or profits of a service are shared by the involved parties, according to an agreed upon formula.

2.5.5 Performance

Cloud providers depending upon enterprise requirements; offer numerous solutions with different performance level. Enterprises need to understand the application behavior on different platforms and to identify whether it fulfill their expectations.

- ***Accuracy***

  The level to which the facility fulfill its needs.

- ***Functionality***

  The particular characteristics provided by the facility.

- ***Suitability***

  How nearly do the abilities of the facility resemble the requirement of the customer?

- ***Interoperability***

  The quality of the facility to smoothly interface with other facilities.

- ***Service Response Time***

  An indication of the interval between when a facility is requested and when the reply is available.

2.5.6 Security and Privacy

This group has many dimensions and shows the ability to monitor and control the access privileges to the services and data. Hosting data in some other enterprise is quite risky and critical task which may affect the integrity of stored data. Therefore, inflexible privacy and security policy is required to be adopted by service provider and must be the part of SLA.

- ***Access control & Privilege management***

  Standards and processes in use by the facility donors to make sure that only the donor and customer with appropriate status to make use or rework end results may do so.

- ***Data Geographic/Political***

  The customer's restrictions on facility area are politically or geographically oriented.

- ***Data integrity***

Keeping the information in its appropriate format so that the customers feel that it is correct and authentic.

- ***Data privacy & Data loss***

Restriction on usage of customer information are imposed by the facility provider. Any fault to these protective measures are quickly located and reported to the customer.

- ***Physical & Environmental security***

Strategies and procedures used by the facility donor to make safe the provider's services from unofficial usage and block.

- ***Proactive threats & Vulnerability management***

Mechanism to make sure that the facility is well secured against commonly occurring risks as well as new emerging problems.

- ***Retention/Disposition***

The facility donor information retention process meets the client's needs.

2.5.7 Usability

This group indicates the ability of a service to be used with less effort. Ease of using and learning cloud service are the important aspects to be considered for quick service adaptability.

- ***Accessibility***

The level to which the service is practicable by users with in capacity.

- ***Client personnel requirements***

The least amount of human resource fulfilling roles, abilities, expertise and qualification required of the customer to completely use a facility.

- ***Installability***

It typifies the interval and attempt to buy facility ready for carriage.

- ***Learnability***

Effort need of user to discover to use the facility.

- ***Operability***

Capacity of resource to provide ease of usage to the person who uses it.

- ***Suitability***

How nearly does the ability of the facility is similar to the customer need.

- ***Transparency***

Area to which user are enabled to resolve when modification in a phase of a service happens and weather this modifications crash usage.

- ***Understandability***

Effortlessness which the user can comprehend the abilities and functioning of the facility.

Table 2.1: Service Measurement Index (SMI)

S.no	Categories	Attributes
1	Accountability	Auditability, Compliance, Contracting experience, Data ownership, Ease of doing business, Governance, Ownership, Provider business stability, Provider certification, Provider contract / SLA verification, Provider ethicality, Provider personnel requirements, Provider supply chain, Security capabilities, Sustainability
2	Agility	Adaptability, Capacity, Elasticity, Extensibility, Flexibility, Portability, Scalability
3	Assurance	Availability, Data geographic / political, Maintainability, Recoverability, Reliability, Fault tolerance, Service stability, Serviceability
4	Financial	Acquisition & transition cost, On-going cost, Profit or cost sharing
5	Performance	Accuracy, Functionality, Suitability, Interoperability, Service response time
6	Security & privacy	Access control and privilege management, Data integrity, Data privacy & data loss, Physical & environmental security, Proactive threat & vulnerability management, Retention, Data Geographic/ Political
7	Usability	Accessibility, Client personnel requirements, Installability, Learnability, Operability, Suitability, Transparency, Understandability

2.6 Related work

In 1969, Leonard Kleinrock [1], one of the chief scientists of the original Advance Research Projects Agency Network (ARPANET) project which seeded the internet said: “As of now, computer networks are still in their babyhood, but as they grew up and become up to the minute, chances are the spread of computer utilities which like present electric and telephone utilities, will service solitary homes and offices across the country". This perception of computational utilities based on the service provisioning model anticipates the monumental transfiguration of the undivided computing production in the 21st century whereby computing services will be eagerly unengaged on stipulation, like other utility service available in today's civilization.

Remigiusz Olenjik [19] proposed a solution of computer network design problem for small enterprise by using two established multifarious criteria Decision Making (MCDM) methods: Weighted Sum Model (WSM) and Weighted Product Model (WPM), which could help the designer in comparing ready network projects. YongChang Li [20] presented multi criteria Interactive Decision Making Advisor and Synthesis Process (MIDAS), which is competent to catalyze the preference of the most opportune settlement making method and which provide acuity to the user for fulfilling different favorites and an self-governing decision making mentor which is adept of commerce conditions.

A framework for making cloud services is presented by S.Kumar Garg, S.Versteeg, R.Kumar Buyya [21]. The work presents SIMICloud , to systematically asses all the QoS traits proposed by CSMIC and standing Cloud services based on these attributes. Also a multiple criteria decision making technique, An analytical Hierarchical Process (AHP) based ranking appliance is used which can gauge the cloud service station established on different application depending on QoS requirements.

T.Rojahn, R.Lebsack, C.Pavlovski [22], proposed a classifier for determining the most appropriate infrastructure where an application workload may be deployed. It shows that the decision of where the workload may resides often involves a much fuller discussion and takes into account number of additional inputs such as a more comprehensive analysis of non-functional requirements, costs and other local factors.

A method for unravel a MCDM stumbling block with the engender information about the criteria of special form has been come up with by Lev V.Utkin [23]. The main peculiarity of the tactic that it is based on bringing down a set of Pareto optimal solutions and does not maneuver combination of criteria for solving the problem. It introduced two global criteria of decision making. The first criteria based on lower prospects uses the second outer model as a main tool for determining whether a preference is valid or not. The second criteria is based on regulating the convictional reasonable function in framework of Dempster-Shafter theory. It uses the so called threshold prospect for the eventual decision making.

Anatomy for market oriented sharing of capitals within cloud and vision for the fabrication of global billow trafficking dealing services are presented by R.Buyya, C.S.Yeo, S.Venugopal, J.Broberg [24],[25] presented an idea, design and implementation of a simulator for ranking newly elected succession contributor put forward that may be pertinent for non-fictional cloud offers. The simulator sanction testing various algorithms for ranking providers with easy refine to other algorithms or even filters within the algorithms.

Elarbi Badidi [26] has presented scaffolding for SaaS selection and donation. The framework reckon on cloud good turn that is in charge of mediating between service consumers and SaaS providers and negotiating the SLA terms. The selection algorithm uses linear aggregate utility function to rank the potential SaaS offerings. Chang-Ling Hsu [27] presented the cloud service selection model, CloudEval, to evaluate the non-functional trait and select the optimal service which gratifies both user-itemized service flush and intent most. The design of data sources for CloudEval is SLAs from providers and any trusted third party broker, such as Cloud-Harmony. Two ranking augury algorithms for computing the service ranking based on the cloud solicitation designers, proclivity are presented by Priyanka V., Sabari V.G., Prithiviraj S., Christopher A. [28].

Pedro Costa [29] proposed a method to judge cloud facilities with an MCDA approach called MACBETH that simplifies the decision-making process in enterprises adopting Cloud facilities. The proposal is based on the defined criteria and forces DM to value judgments in order to find out the most overall attractive Cloud Service..

2.7 Multiple Criteria Decision Making (MCDM)

MCDM is a undertaking that serves as a useful tool to assist decision maker to make resolution in existence of multiple usually diversion criteria [30]. It involves several objective functions within a predefined set of constraints. MCDM is basically categorized into two main categories:

- **Multiple Object Decision Making (MODM)**

  It involves large amount of alternative options and the decision variable values are determined in an integer domain.

- **Multiple Attribute Decision Making (MADM)**

  This technique is discrete in nature with limited number of pre-defined alternatives described in terms of multiple features.

2.8 Multiple Criteria Decision Making Techniques

Of the many MADM methods, six methods are commonly used in MCDM. These techniques includes: Simple Additive Method (SAW), Weighted Product Method (WPM), a Compromise ranking method (VIKOR), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Analytical Hierarchy Process (AHP), and Techniques for Order Preference by Similarity to Identical Solution (TOPSIS)

2.8.1 Simple Additive Weighting (SAW) Method

This is also called the weighted sum method (Fishburn, 1967) and is the simplest and still the widest used MADM method. In this method, each attribute is given a weight and the sum of all weights must be 1. Each alternative is assessed with regard to every attribute. The overall or composite performance score of an alternative is given by the equation previously it was argued that SAW method should be used only when the decision attributes can be expressed in identical units of measure. However, if all the elements of the decision table are normalized, then SAW can be used for any type and any number of the next-least important attribute is chosen, more points are assigned to it, and so on, to reflect their relative importance. The final weights are obtained by normalizing the sum of the points to one. Edwards et al (1982) proposed a simple method to assess weights for each attribute to reflect its relative importance to the decision. For a start, the attributes are ranked in order of importance and 10 points are assigned to the least important attribute. Then, the next-least important attribute is chosen, more points are assigned to it, and so on to reflect their relative importance. The final weights are obtained by normalizing the sum of the points to one (R. Venkot Rao, 2007).

2.8.2 Weighted Product method (WPM)

This method is similar to Simple Additive method. The main difference is that, instead of addition in the model, there is multiplication (Miller and Starr, 1969). The normalized values are calculated as explained under the SAW method. Each normalized value of an alternative with respect to an attribute, i.e (m)ij normal is raised to the power of the relative weight of corresponding attribute. The alternative with the highest Pi value is considered the best alternative. (R. venkto Rao, 2007)

2.8.3 Compromise Ranking method (VIKOR)

The foundation for compromise solution was established by Yu (1973) and Zeleny (1982) and later advocated by Oprocovic and Tzeng (2002, 2007) and Tzeng et al (2002, 2005). The compromise solution is a feasible solution that is the closest to the identical solution and a compromise means an agreement established by manual concession.(Serafim et al 2012).The compromise solution method is also known as the VIKOR method, was introduced as one applicable technique to implement within MADM. The multiple attribute merit for compromise ranking was developed from the Lp-metric used in the compromise programming method (Zeleny, 1982). VIKOR is a helpful tool in MADM, particularly in a situation where the decision maker is not able or does not know how to express preference at the beginning of system design.

2.8.4 Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

It is a well-established decision support system which deals with the appraisal and selection of a set of options on the basis of several criteria with the objective of obtaining a ranking among them. PROMETHEE can simultaneously deal with qualitative and quantitative criteria. It can deal with uncertain and fuzzy information. It is founded by Brans & Vincke in 1985.The preference ranking organization method for enrichment evaluation (PROMETHEE) methods of decision analysis. PROMETHEE II method was used to solve a facility location problem in which there were eight criteria against four alternative locations solutions (Athawale and Chakraborty, 2010). At the end, the most cost-effective and highest yielding location alternative was identified and selected. Maragoudaki and Tsakiris (2005) identified PROMETHEE methodology as one of the most efficient MCDA outranking techniques that could be used to arrive at the optimal flood mitigation plan for a river basin. Four alternative irrigation projects for the East Macedonia-Thrace district were evaluated using analytic hierarchy process (AHP) and PROMETHEE multicriteria methods (Anagnostopoulos et al., 2005).

2.8.5 Analytical Hierarchy Process (AHP)

The most well-known analytical method for puzzle decision oriented issues is the analytical grading procedure. Saaty (1980, 2000) developed AHP which roots a decision oriented issues into a system of hierarchies of purpose characteristics and alternatives. It has many levels as required to fully divided a particularly decision situation. Many distinct qualities of AHP makes it an attractive option. These include the skill to handle decision condition linking individual decision, multiple decisions makers and the ability to provide events of consistency of partiality (Triantaphyllou, 2000). AHP can efficiently deal with touchable as well as non-touchable attributes, especially where the individual decision of different personalities order a vital part of the decision procedure.

2.8.6 Technique for Order Preference by Similarity to Identical Solution (TOPSIS)

The TOPSIS technique was developed by Hwang and Yoon (1981). This technique comprises of idea that the selected option must have the minimum Euclidean distance from ideal solution and the maximum distance from negative ideal solution.(S. K. Amposh et al 2012). The ideal solution is a hypothetical solution for which all characteristic values corresponds to the maximum characteristic values in the database containing the satisfying results; the negative ideal solutions the hypothetical solution for which all characteristic values corresponds to the smallest attribute values in the database. TOPSIS thus gives a solution that is not only nearer to the hypothetically best, that is also the away from hypothetically worst. (Cathy Mecharis et al, 2004).

Chapter 3
PROPOSED EVALUATION AND RANKING MODEL

In this chapter, we present a detailed description of our approach and explain that how we carried out the service provider selection process by using service measurement index attributes and multiple criteria decision making techniques.

3.1 Overview

We build a model for an intermediate system to help cloud customer in selecting the most suitable candidate to deploy their application(s). Our proposed model mainly consists of eight components.

- Service call
- Service agent
- Certainty evaluation
- Filtered service providers
- Ranking
- Ranked list of service providers
- Selected alternative
- Service catalog

3.2 Cloud Service Evaluation and Ranking Model (CSERM)

CSERM is cloud service providers' evaluation and ranking model. It is a tool that aims to determine a suitable candidate in a finite set of service providers in order to deploy customer application on cloud infrastructure. Model consists of several building blocks shown in Figure 3.1.

3.2.1 Service Call

Service call for various cloud resources emerges from different parts of the world. For the sake of simplicity, I considered a single cloud resource request in my service evaluation model. Customer possesses certain QoS limitations for deploying their application on cloud infrastructure, and not all service providers are licensed to assure customers' needs. Therefore other components in the model select those alternatives that are best suited to the customers' quality constraints.

3.2.2 Service Agent

It serves as an interface between the service consumer and selection paradigm by collecting the quality requirements from user to discover service providers (by exploring service catalog) that fulfill user defined needs. Also receive information of relative preferences to compute weight of each criteria using AHP method discussed in subsequent sections.

3.2.3 Certainty Evaluation

This component filters the available list by eliminating inconsistent resource providers and helps to reach final choice rapidly with reduced time consumption. Main purpose of Certainty Evaluation is to find how far the delivered quality service values are from promised values as per service level agreement and the fluctuation in data entries stored in service catalog to identify the level of service consistency.

3.2.4 Filtered Service Providers

In this phase we have a shirked list of consistent service providers from where the final decision has to be made. This list is modified periodically to add new members to the group showed rise in performance level and remove those with drop in performance level by keeping track to the recent past consistency record of resource providers.

3.2.5 Ranking

After having shortlisted consistent service providers, our main goal is to perform ranking based on quality attributes. Since, there are multiple attributes/ criteria of comparison, therefore ranking can be viewed as Multiple Criteria Decision Making problem (MCDM). To solve this problem, a well-known method TOPSIS is used. Detail of implementation is given in Section IV.

3.2.6 Ranked List of Service Providers

This component contain ranked list of resource providers obtained after applying TOPSIS method. It only includes those candidates that best match the users' quality requirements.

3.2.7 Selected alternative

The last phase where the top candidate from the ranked list is selected and presented before the customer as a best option.

3.2.8 Service Catalog

It is a repository that contains complete information about worldwide available cloud service providers and their services; also the information of past customer usage and their experience with the service .This information is dynamically modified to satisfy the changing performance. Service agent scan all the records stored in repository to find suitable candidates and respond to service request.

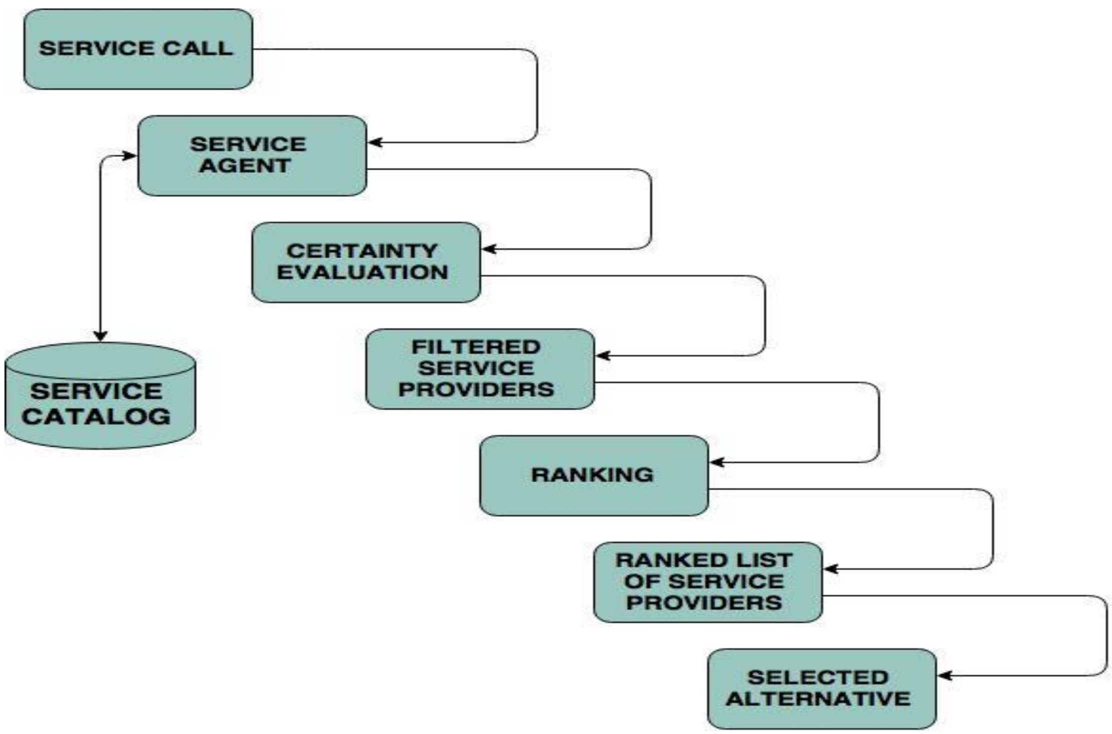

Figure 3.1: Cloud Service Evaluation and Ranking Model (CSERM)

3.3 Ranking Cloud Service Providers

Assigning Rank to the service provider is one of the key features of my proposed model [16]. It has become more and more difficult to see the world around us in a uni-dimensional way and to see only single criterion when judging what we see [12]. Therefore, Criterion and sub-criterion described in SMI framework is considered to evaluate cloud services and to Rank them consequently makes Ranking process quite complicated, hence the problem falls in the category of Multiple Criteria Decision Making (MCDM) problem. In cloud computing there are finite number of Infrastructure choices among which the consumer has to select the one that fit their requirements, measured in terms of SMI attributes of comparison. Therefore, our proposed model uses two MADM techniques for ranking cloud service providers: Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), former method is used to identify weight of each criterion or attribute and the later technique consider and utilize these weights to rank each alternative by performing series of selective steps which are given in upcoming subsections.

3.3.1 Analytic Hierarchy Process

We have used the following steps of AHP to determine the weights of various criteria:

Step 1- Construct pair-wise decision matrix (M) using SMI attributes shown in Table 2.1 and Satty Scale of Relative Preference mentioned in Table 3.1

Step 2-Calculate the sum of each column

$$\text{Column sum} = \sum_i C_{ij} \qquad \text{(eq 3.1)}$$

Step 3-Normalize each cell of a matrix by dividing it with column sum

$$X_{ij} = C_{ij} \Big/ \sum_i C_{ij} \qquad \text{(eq 3.2)}$$

Step 4-Compute the weight W_i of each row by taking its average

$$W_i = \frac{\sum_j X_{ij}}{n} \qquad \text{(eq 3.3)}$$

Where n = number of candidates

Step 5-Calculate the priority vector

$$V_i = (M).W_i \qquad \text{(eq 3.4)}$$

Step6-Find λ_i by dividing each row priority V_i with its weight W_i and $\lambda_{\max}$ by averaging λ_i

$$\lambda_i = V_i \big/ W_i \qquad \text{(eq 3.5)}$$

Step 7-Calculate Consistency Index and Consistency Ratio to find consistency of judgment

$$CI = \frac{\lambda_{\max} - n}{n-1} \qquad \text{(eq 3.6)}$$

$$CR = \frac{CI}{RI} \qquad \text{(eq 3.7)}$$

If CR < 0.10, the subjective judgment is correct, in other case we revise this judgment.

Table 3.1: Satty scale of Relative Importance

Numerical Value (s)	Option
1	Equally preferred
2	Equally to moderately
3	Moderately preferred
4	Moderately to strongly
5	Strongly Preferred
6	Strongly to very strongly
7	Very strongly preferred
8	Very strongly to extremely
9	Extremely preferred
Reciprocals	If criteria i has one of the above value assigned to it when compared to criteria j, then j has a reciprocal value when compared with i.

Size	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I	0.00	0.00	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.57	1.59

Figure 3.2: Table of Random Index [18]

3.3.2 Technique of Order Preference by Similarity to Ideal Solution (TOPSIS)

Steps of TOPSIS technique used in a proposed model of infrastructure selection are mentioned below:

Step 1- Construct a decision matrix by using attributes and alternatives remained.

$$DM = \begin{bmatrix} & X_1 & X_2 & X_j & X_n \\ A_1 & x_{11} & x_{12} & x_{1j} & x_{1n} \\ A_2 & x_{21} & x_{22} & x_{2j} & x_{2n} \\ A_i & x_{i1} & x_{i2} & x_{ij} & x_{in} \\ A_m & x_{m1} & x_{m2} & x_{mj} & x_{mn} \end{bmatrix} \qquad \text{(eq 3.8)}$$

Step 2-Design normalized decision matrix using formula

$$r_{ij} = x_{ij} \Big/ \left(\sum_{i=1}^{m} x_{ij}^2 \right) \quad \text{For i = 1, ..., m ; j = 1, ...,n} \qquad \text{(eq 3.9)}$$

Step 3-Using the weights w_j calculated in AHP, construct weighted normalized decision matrix.

The weighted normalized value v_{ij} is calculated as

$$v_{ij} = w_j r_{ij} \qquad \text{(eq 3.10)}$$

Step 4-Find positive and negative ideal solutions

- Positive ideal solution:

$$A^* = \{v_1^*, \ldots, v_n^*\}, \text{ where} \qquad \text{(eq 3.11)}$$

$$v_j^* = \{\max(v_{ij}) \text{ If } j \in J \; ; \; \min(v_{ij}) \text{ If } j \in J'\}$$

- Negative ideal solution:

$$A' = \{v_1', \ldots, v_n'\}, \text{ where} \qquad \text{(eq 3.12)}$$

$$v_j' = \{\min(v_{ij}) \text{ If } j \in J \; ; \; \max(v_{ij}) \text{ If } j \in J'\}$$

J = 1, 2, 3,..., n (associated with benefit criteria)

J' =1, 2, 3,..., n (associated with cost criteria)

Step 5-Compute separation measures for each alternative

- Separation from positive ideal alternative is:

$$S_i^* = \left[\sum_{j=1}^{n} (v_j^* - v_{ij})^2\right]^{\frac{1}{2}} \quad i = 1, 2, 3, ..., m \qquad \text{(eq 3.13)}$$

- Separation from negative ideal alternative is:

$$S_i' = \left[\sum_{j=1}^{n} (v_j' - v_{ij})^2\right]^{\frac{1}{2}} \quad i = 1, 2, 3, ..., m \qquad \text{(eq 3.14)}$$

Step 6-Calculate the relative closeness to the ideal solution C_i^*

$$C_i^* = S_i' / (S_i^* + S_i') \qquad 0 < C_i^* < 1 \qquad \text{(eq 3.15)}$$

Where i = 1, 2, 3, ..., m

Select the option with C_i^* closest to 1.

Step 7-Rank the preference order.

Chapter 4

MODEL EVALUATION AND RESULTS (CASE STUDY)

Now when we have already gone through several procedural steps, this chapter will focus on evaluating the effectiveness of our proposed approach by conducting a case study.

4.1 Overview

This case study is based on common quality parameters that are usually being offered by public cloud service providers. These parameters are described in Service Measurement Index (1.0), designed by Cloud Service Measurement Intuitive Consortium (CSMIC) and authorized by International Organization of Standardization (ISO). Also, there are finite public service providers that allow customer to use cloud infrastructure for deploying application. The proposed model will help this process of service provider selection by shrinking the number of available resource providers to make the final decision with ease and high precision. Although multiple requests come around the globe, but for simplicity a single request is considered to evaluate my proposed paradigm.

4.2 Case Study

A customer is willing to transform his on-premises IT setup to cloud environment. By doing so he may come up with several challenges and one of which is selecting the perfect or near to perfect service provider, whom facilitate customer with best service opportunity cost effectively and offer full advantage of cloud facility. An intermediate system based on CSERM is described here: (*note- user and customer used here alternatively*).

Service agent collect service request in terms of Quality requirements and user preferences. After collecting requirements from user- end, service agent explore service catalog to discover possible list of resource providers. Also, service agent analyzes user preferences and find weight of attributes by using AHP along with Satty scale of relative preferences. These weights are later use in ranking phase. User defined requirements with relative preference of SMI attributes are given below in Table 4.1

Table 4.1: User requirements with relative preferences

Attribute / Criteria	User-defined requirement	Relative preference
Accuracy	0.990 / 99.0%	Equally to moderately
Accountability	4	Moderately preferred
Capacity	12 GB	Moderately to strongly
Availability	0.995 / 99.5%	Moderately preferred
Security	4	Strongly preferred
Service Response Time	20 sec	Moderately to strongly
Cost	< 0.8 dollar/hour	Very strongly preferred

Now its turn to compute weight of attributes and finding consistency of judgment matrix using Analytic Hierarchy Process (AHP) which is given down under:

- Construct pair-wise criteria comparison matrix using step 1, shown in Table 4.2

Table 4.2: Pair-wise criteria comparison matrix

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost
Accuracy	1.0000	0.6666	0.5000	0.6666	0.4000	0.5000	0.2857
Accountability	1.5000	1.0000	0.7500	1.0000	0.6000	0.7500	0.4285
Capacity	2.0000	1.3333	1.0000	1.3333	0.8000	1.0000	0.5714
Availability	1.5000	1.0000	0.7500	1.0000	0.6000	0.7500	0.4285
Security	2.5000	1.6666	1.2500	1.6666	1.0000	1.2500	0.7142
Service Response Time	2.0000	1.3333	1.0000	1.3333	0.8000	1.0000	0.5714
Cost	3.5000	2.3333	1.7500	2.3333	1.4000	1.7500	1.0000

- Calculate column sum using Equation 3.1, computed in Table 4.3

Table 4.3: Column summation

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost
Accuracy	1.0000	0.6666	0.5000	0.6666	0.4000	0.5000	0.2857
Accountability	1.5000	1.0000	0.7500	1.0000	0.6000	0.7500	0.4285
Capacity	2.0000	1.3333	1.0000	1.3333	0.8000	1.0000	0.5714
Availability	1.5000	1.0000	0.7500	1.0000	0.6000	0.7500	0.4285
Security	2.5000	1.6666	1.2500	1.6666	1.0000	1.2500	0.7142
Service Response Time	2.0000	1.3333	1.0000	1.3333	0.8000	1.0000	0.5714
Cost	3.5000	2.3333	1.7500	2.3333	1.4000	1.7500	1.0000
Sum	14.0000	9.3331	7.0000	9.3331	5.6000	7.0000	3.9997

- Standardize each cell following Equation 3.2 calculated in Table 4.4

Table 4.4: Data normalization

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost
Accuracy	0.0714	0.0714	0.0714	0.0714	0.0714	0.0714	0.0714
Accountability	0.1071	0.1071	0.1071	0.1071	0.1071	0.1071	0.1071
Capacity	0.1428	0.1428	0.1428	0.1428	0.1428	0.1428	0.1428
Availability	0.1071	0.1071	0.1071	0.1071	0.1071	0.1071	0.1071
Security	0.1785	0.1785	0.1785	0.1785	0.1785	0.1785	0.1785
Service Response Time	0.1428	0.1428	0.1428	0.1428	0.1428	0.1428	0.1428
Cost	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500

- Weight identification using step Equation 3.3, figured in Table 4.5

Table 4.5: Weights identification

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost	Sum	Weight
Accuracy	0.0714	0.0714	0.0714	0.0714	0.0714	0.0714	0.0714	0.4998	0.0714
Accountability	0.1071	0.1071	0.1071	0.1071	0.1071	0.1071	0.1071	0.7497	0.1071
Capacity	0.1428	0.1428	0.1428	0.1428	0.1428	0.1428	0.1428	0.9996	0.1428
Availability	0.1071	0.1071	0.1071	0.1071	0.1071	0.1071	0.1071	0.7497	0.1071
Security	0.1785	0.1785	0.1785	0.1785	0.1785	0.1785	0.1785	1.2495	0.1785
Service Response Time	0.1428	0.1428	0.1428	0.1428	0.1428	0.1428	0.1428	0.9996	0.1428
Cost	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	1.7500	0.2500

- Finding priority vector by following Equation 3.4, calculated in Table 4.6

Table 4.6: Identification of priority vector

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost	Weight	P.V
Accuracy	1.0000	0.6666	0.5000	0.6666	0.4000	0.5000	0.2857	0.0714	0.4996
Accountability	1.5000	1.0000	0.7500	1.0000	0.6000	0.7500	0.4285	0.1071	0.7494
Capacity	2.0000	1.3333	1.0000	1.3333	0.8000	1.0000	0.5714	0.1428	0.9993
Availability	1.5000	1.0000	0.7500	1.0000	0.6000	0.7500	0.4285	0.1071	0.7494
Security	2.5000	1.6666	1.2500	1.6666	1.0000	1.2500	0.7142	0.1785	1.2491
Service Response Time	2.0000	1.3333	1.0000	1.3333	0.8000	1.0000	0.5714	0.1428	0.9993
Cost	3.5000	2.3333	1.7500	2.3333	1.4000	1.7500	1.0000	0.2500	1.7494
Sum	14.0000	9.3331	7.0000	9.3331	5.6000	7.0000	3.9997	1.0000	6.9955

- Finding lambda values using Equation 3.5, computed in Table 4.7

Table 4.7: Lambda values calculation

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost	Lambda	Max
Accuracy	1.0000	0.6666	0.5000	0.6666	0.4000	0.5000	0.2857	6.9971	6.9974
Accountability	1.5000	1.0000	0.7500	1.0000	0.6000	0.7500	0.4285	6.9971	
Capacity	2.0000	1.3333	1.0000	1.3333	0.8000	1.0000	0.5714	6.9978	
Availability	1.5000	1.0000	0.7500	1.0000	0.6000	0.7500	0.4285	6.9971	
Security	2.5000	1.6666	1.2500	1.6666	1.0000	1.2500	0.7142	6.9977	
Service Response Time	2.0000	1.3333	1.0000	1.3333	0.8000	1.0000	0.5714	6.9978	
Cost	3.5000	2.3333	1.7500	2.3333	1.4000	1.7500	1.0000	6.9976	

- For finding consistency of judgment, calculate consistency index and consistency ratio using Equation 3.6 and Equation 3.7:

$$CI = \frac{6.9974 - 7}{7 - 1} = -4.3333$$

$$RI = 1.36$$

$$CR = {-4.3333}/{1.36} = -3.18 < 0.10$$

Hence the weights computed are acceptable as consistency ratio of a judgment matrix is within acceptable tolerance.

During user-defined requirements comparison conducted against service level agreement of various publicly available cloud resource providers contained in service catalog, a list of twenty alternatives is generated for future processing. After having shrink list containing twenty resource providers, next step to follow is of certainty evaluation. It actually involves two steps. Firstly, the average of service performance of each provider against specific criteria is calculated. Secondly, the variation or fluctuation in record is computed by comparing tuples of services performance in different times. Lower the fluctuation, higher would be the consistency of service and vice versa. Let's have a look on two service providers, SP1 and SP2. These two are judged against Service Response Time (SRT) for consistency measurement. Performance of service providers is stored in a set of log entries which reflect the values delivered by each provider. Five entries of each provider are taken to illustrate the idea in Table 4.8

Table 4.8: Log entries of SP1 and SP2 against Service Response Time

SERVICE RESPONSE TIME			
Service Provider 1 (SP1)		Service Provider 2 (SP2)	
Transaction	Value	Transaction	Value
1	29	1	16
2	26	2	40
3	30	3	31
4	26	4	34
5	26	5	12
Average value	27.4	Average value	26.6

The table shows that average Service Response Time value of SP1 is greater than SP2, so SP2 seems to be preferred over SP1. But further analysis of individual transactions shows that three out of five times, SP1 has given lesser value of SRT than SP2. This declares SP2 with more fluctuation, therefore, SP1 prove to be the better consistent option when compared with SP2. This phase eliminate the inconsistent options from the list and generate filtered list of service providers.

We assume that after consistency checking, we come up with 10 most appropriate alternatives, which are SP0,..., SP9. Now its turn to rank each alternative using SMI attributes and their weights (computed earlier) by using TOPSIS technique explained in chapter 3.

- In the first step, a Decision Matrix is constructed using SMI attributes along with data and remaining possible choices defined in Equation 3.8 , calculated in Table 4.9

Table 4.9: Decision matrix

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost
SP0	0.9995	5	14	0.9960	4	22.8	0.75
SP1	0.9920	7	12	0.9975	6	27.4	0.50
SP2	0.9998	4	18	0.9995	8	26.6	0.60
SP3	0.9955	4	15	0.9955	5	30.5	0.45
SP4	0.9930	6	12	0.9980	7	29.4	0.70
SP5	0.9940	8	16	0.9965	4	23.0	0.55
SP6	0.9945	7	15	0.9990	9	35.2	0.80
SP7	0.9970	5	12	0.9960	7	33.7	0.65
SP8	0.9950	9	16	0.9985	4	20.5	0.30
SP9	0.9965	4	14	0.9950	5	25.8	0.35

- Normalized Decision Matrix using Equation 3.9 is computed, shown in Table 4.10

Table 4.10: Computing normalized decision matrix

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost
SP0	0.99900025	25	196	0.99201600	16	519.84	0.5625
SP1	0.98406400	49	144	0.99500625	36	750.76	0.2500
SP2	0.99960004	16	324	0.99900025	64	707.56	0.3600
SP3	0.99102025	16	225	0.99102025	25	930.25	0.2025
SP4	0.98604900	36	144	0.99600400	49	864.36	0.4900
SP5	0.98803600	64	256	0.99301225	16	529.00	0.3025
SP6	0.98903025	49	225	0.99800100	81	1239.04	0.6400
SP7	0.99400900	25	144	0.99201600	49	1135.69	0.4225
SP8	0.99002500	81	256	0.99700225	16	420.25	0.0900
SP9	0.99301225	16	196	0.99002500	25	665.64	0.1225
$\sum_i x_{ij}^2$	9.91384604	377	2110	9.94310325	377	7762.39	3.4425
$\left(\sum_i x_{ij}^2\right)^{\frac{1}{2}}$	3.15	19.42	45.93	3.15	19.42	88.10	1.86

- Next, weighted normalized matrix is designed using Equation 3.10, given in Table 4.11

Table 4.11: Weighted normalized matrix

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost
Weight	0.0714	0.1071	0.1428	0.1071	0.1785	0.1428	0.2500
SP0	0.3173	0.2575	0.3048	0.3162	0.2059	0.2588	0.4032
SP1	0.3149	0.3605	0.2613	0.3167	0.3089	0.3110	0.2688
SP2	0.3174	0.2059	0.3919	0.3173	0.4119	0.3019	0.3226
SP3	0.3160	0.2059	0.3266	0.3160	0.2575	0.3462	0.2419
SP4	0.3152	0.3089	0.2613	0.3168	0.3605	0.3337	0.3763
SP5	0.3156	0.4119	0.3484	0.3163	0.2059	0.2611	0.2957
SP6	0.3157	0.3605	0.3266	0.3171	0.4634	0.3995	0.4301
SP7	0.3165	0.2575	0.2613	0.3162	0.3605	0.3825	0.3495
SP8	0.3159	0.4634	0.3484	0.3169	0.2059	0.2327	0.1613
SP9	0.3163	0.2059	0.3048	0.3159	0.2575	0.2928	0.1882

- Identification of positive and negative ideal solution sets using weighted normalized matrix given in Table 4.12 and Equations 3.11, 3.12

Table 4.12: Ideal solutions calculation

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost
SP0	0.0227	0.0276	0.0435	0.0339	0.0368	0.0369	0.1008
SP1	0.0225	0.0386	0.0373	0.0339	0.0551	0.0444	0.0672
SP2	0.0227	0.0220	0.0559	0.0340	0.0735	0.0431	0.0807
SP3	0.0226	0.0220	0.0466	0.0338	0.0459	0.0494	0.0605
SP4	0.0225	0.0331	0.0373	0.0339	0.0643	0.0478	0.0941
SP5	0.0225	0.0441	0.0498	0.0338	0.0368	0.0373	0.0739
SP6	0.0225	0.0386	0.0466	0.0340	0.0827	0.0570	0.1075
SP7	0.0226	0.0276	0.0373	0.0339	0.0643	0.0546	0.0874
SP8	0.0226	0.0496	0.0498	0.0339	0.0368	0.0332	0.0403
SP9	0.0226	0.0221	0.0435	0.0338	0.0459	0.0418	0.0470

$$A^* = \{0.0227, 0.0496, 0.0559, 0.0340, 0.0827, 0.0332, 0.0403\}$$

$$A' = \{0.0225, 0.0220, 0.0373, 0.0338, 0.0368, 0.0570, 0.1075\}$$

- Separation measures of each alternative from positive and negative ideal solutions are calculated by using Equation 3.13 and Equation 3.14. Given in Table 4.13 and Table 4.14

Table 4.13: Separation measurement from positive ideal solution

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost	$\sum\left(v_j^* - v_{ij}\right)^2$	$\left[\sum\left(v_j^* - v_{ij}\right)^2\right]^{\frac{1}{2}}$
SP0	0.00000000	0.00048400	0.00015376	0.00000001	0.00210681	0.00001369	0.00366025	0.00641852	0.0801
SP1	0.00000004	0.00012100	0.00034596	0.00000001	0.00076176	0.00012544	0.00072361	0.00207782	0.0456
SP2	0.00000000	0.00076176	0.00000000	0.00000000	0.00008464	0.00009801	0.00163216	0.00257657	0.0508
SP3	0.00000001	0.00076176	0.00008649	0.00000004	0.00135424	0.00026896	0.00040804	0.00287954	0.0537
SP4	0.00000004	0.00027225	0.00034596	0.00000001	0.00033856	0.00021025	0.00289444	0.00406151	0.0637
SP5	0.00000004	0.00003025	0.00003721	0.00000004	0.00210681	0.00001681	0.00112896	0.00332012	0.0576
SP6	0.00000004	0.00012100	0.00008649	0.00000000	0.00000000	0.00056644	0.00451584	0.00528981	0.0727
SP7	0.00000001	0.00048400	0.00034596	0.00000001	0.00033856	0.00045796	0.00221841	0.00384491	0.0620
SP8	0.00000001	0.00000000	0.00003721	0.00000001	0.00210681	0.00000000	0.00000000	0.00214404	0.0463
SP9	0.00000001	0.00075625	0.00015376	0.00000004	0.00135424	0.00007396	0.00004489	0.00238315	0.0488

Table 4.14: Separation measurement from negative ideal solution

	Accuracy	Accountability	Capacity	Availability	Security	Service Response Time	Cost	$\sum\left(v_j^{'} - v_{ij}\right)^2$	$\left[\sum\left(v_j^{'} - v_{ij}\right)^2\right]^{\frac{1}{2}}$
SP0	0.00000004	0.00003136	0.00003844	0.00000001	0.00000000	0.00040401	0.00004489	0.00051875	0.0228
SP1	0.00000000	0.00027556	0.00000000	0.00000001	0.00033489	0.00015876	0.00162409	0.00239331	0.0489
SP2	0.00000004	0.00000000	0.00034596	0.00000004	0.00134689	0.00019321	0.00071824	0.00260438	0.0510
SP3	0.00000001	0.00000000	0.00008649	0.00000000	0.00008281	0.00005776	0.00220900	0.00243607	0.0494
SP4	0.00000000	0.00012321	0.00000000	0.00000001	0.00075625	0.00008464	0.00017959	0.00114370	0.0338
SP5	0.00000000	0.00048841	0.00015625	0.00000000	0.00000000	0.00038809	0.00112896	0.00216171	0.0465
SP6	0.00000000	0.00027556	0.00008649	0.00000004	0.00210681	0.00000000	0.00000000	0.00246890	0.0497
SP7	0.00000001	0.00003136	0.00000000	0.00000001	0.00075625	0.00000576	0.00040401	0.00119740	0.0346
SP8	0.00000001	0.00076176	0.00015625	0.00000001	0.00000000	0.00056644	0.00451584	0.00600031	0.0775
SP9	0.00000001	0.00000001	0.00003844	0.00000000	0.00008281	0.00023104	0.00366025	0.00401256	0.0633

- Finally the relative closeness to ideal solutions is found using Equation 3.15 and performed ranking. Calculations are given in Table 4.15

Table 4.15: Identification of relative closeness and ranking

SERVICE PROVIDER	$S_i^* = \left[\sum \left(v_j^* - v_{ij}\right)^2\right]^{\frac{1}{2}}$	$S_i^{'} = \left[\sum \left(v_j^{'} - v_{ij}\right)^2\right]^{\frac{1}{2}}$	$S_i^* + S_i^{'}$	$C_i^* = S_i^{'} / \left(S_i^* + S_i^{'}\right)$	RANK
SP0	0.0801	0.0228	0.1029	0.2216	10
SP1	0.0456	0.0489	0.0945	0.5175	3
SP2	0.0508	0.0510	0.1018	0.5009	4
SP3	0.0537	0.0494	0.1031	0.4791	5
SP4	0.0637	0.0338	0.0975	0.3467	9
SP5	0.0576	0.0465	0.1041	0.4467	6
SP6	0.0727	0.0497	0.1224	0.4060	7
SP7	0.0620	0.0346	0.0966	0.3582	8
SP8	0.0463	0.0775	0.1238	0.6260	1
SP9	0.0488	0.0633	0.1121	0.5647	2

Service quality measured in terms of accuracy, accountability, capacity, availability, security, service response time and cost, offered by several cloud service providers SP0,..., SP9 analyzed in a case study is shown in figures below:

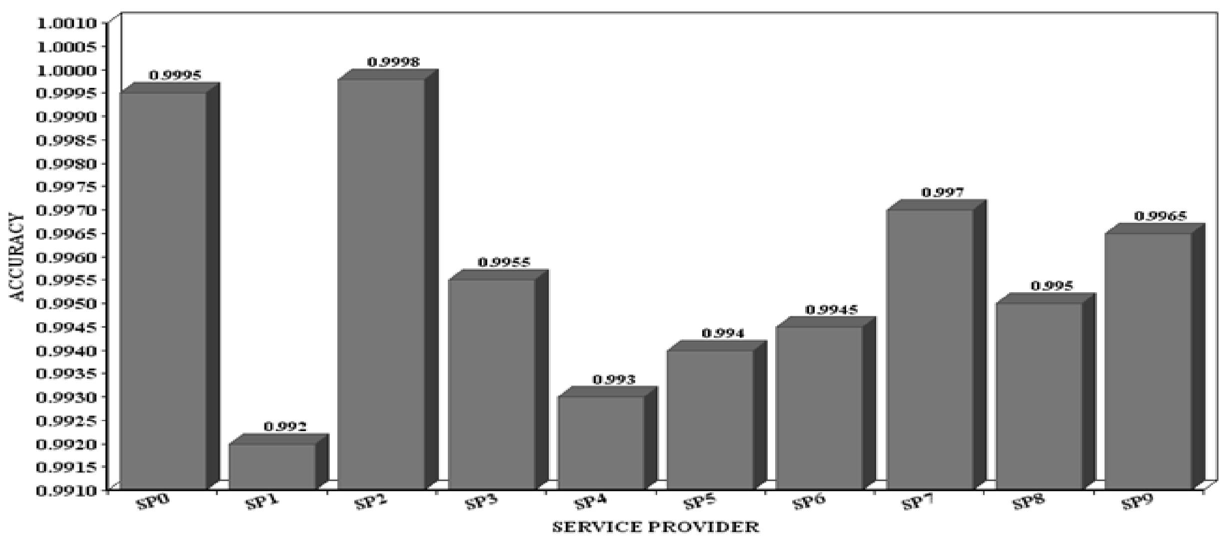

Figure 4.1: Accuracy of service providers

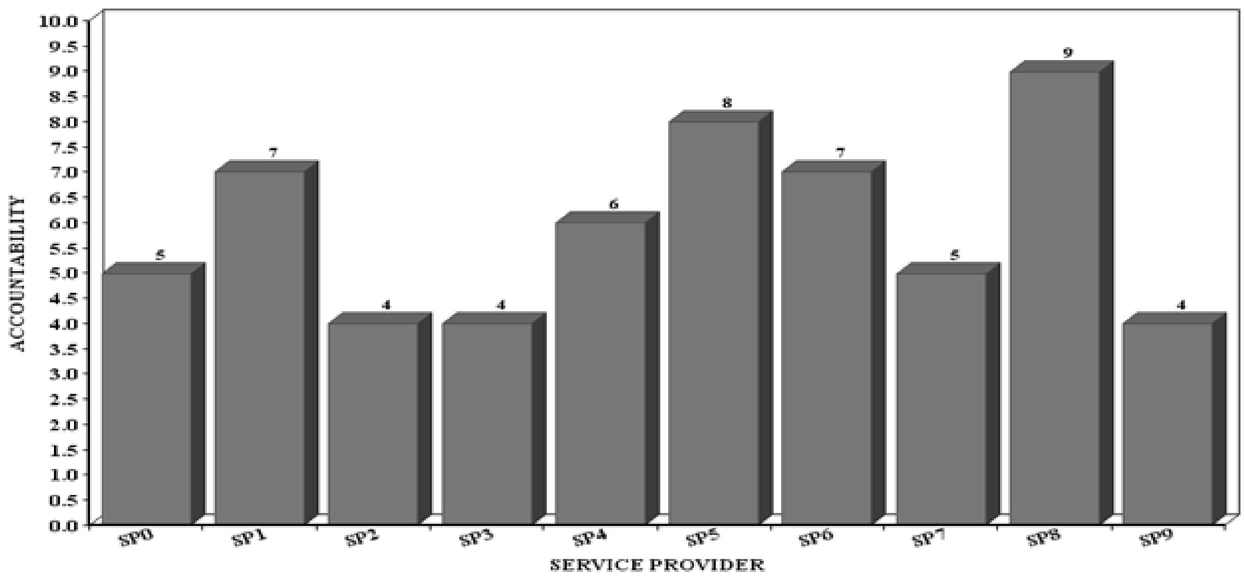

Figure 4.2: Accountability of service providers

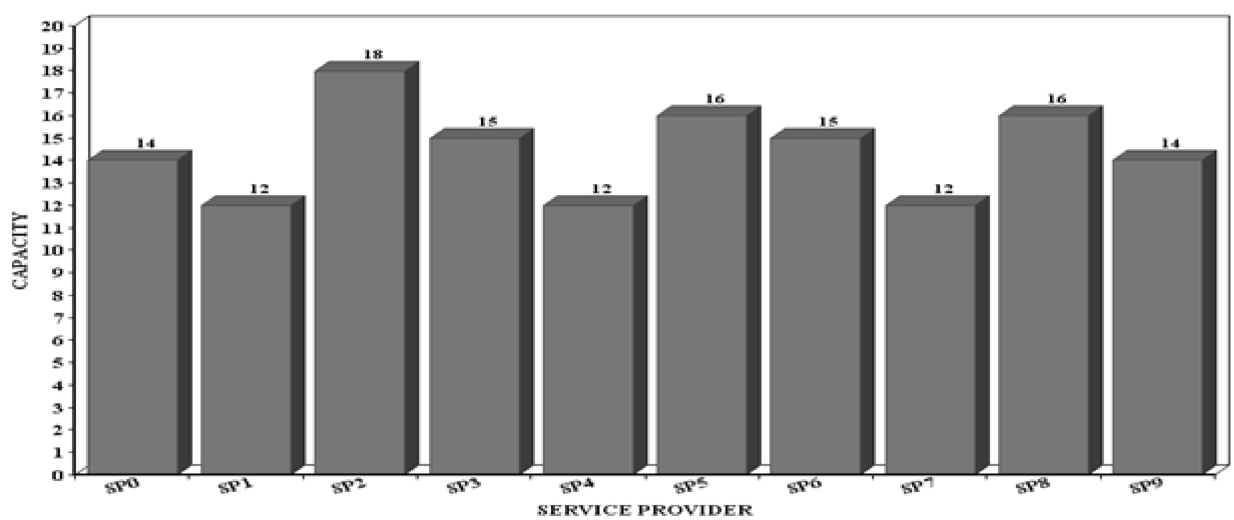

Figure 4.3: Capacity of service providers

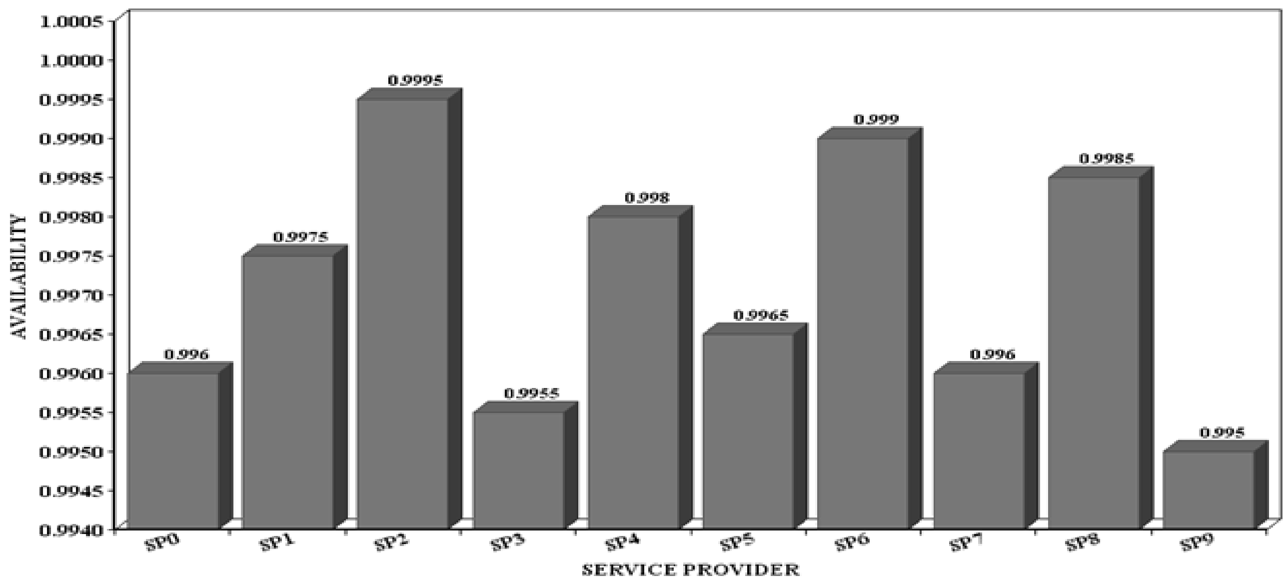

Figure 4.4: Availability of service providers

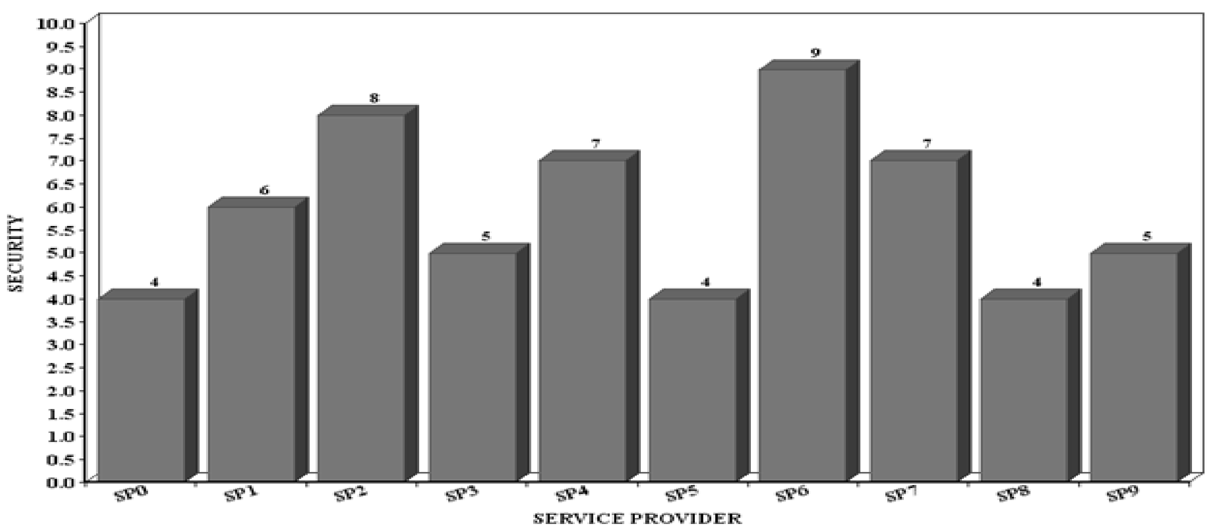

Figure 4.5: Security of service providers

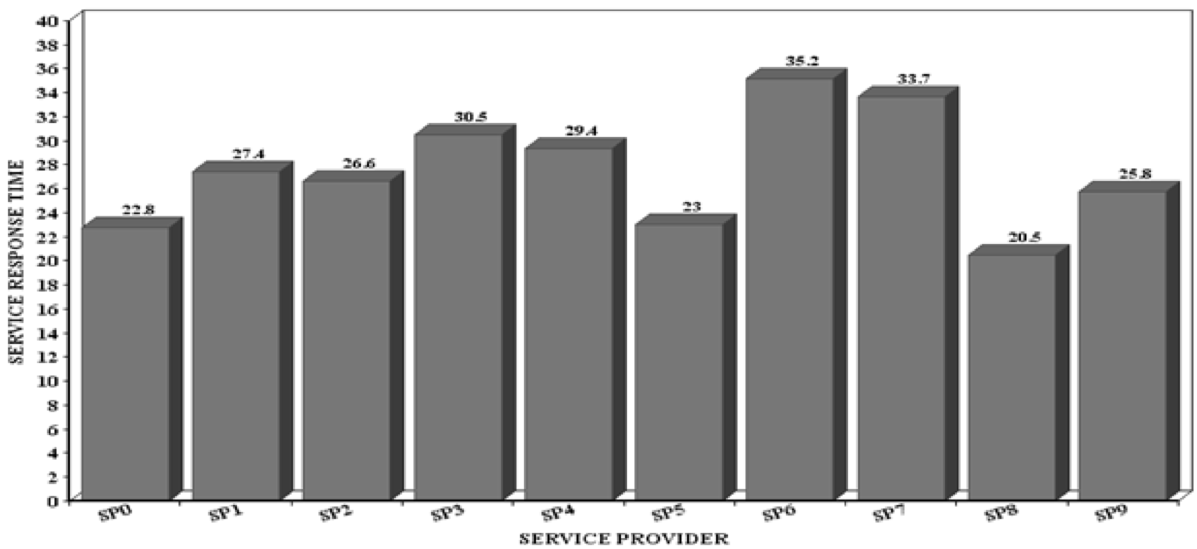

Figure 4.6: Service response time of service providers

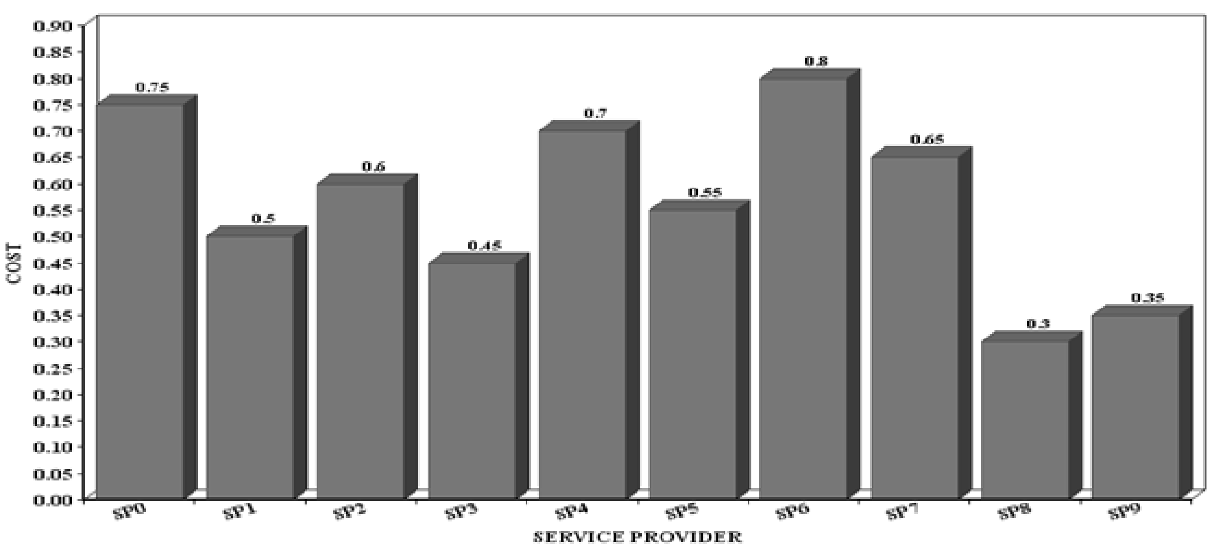

Figure 4.7: Cost of service providers

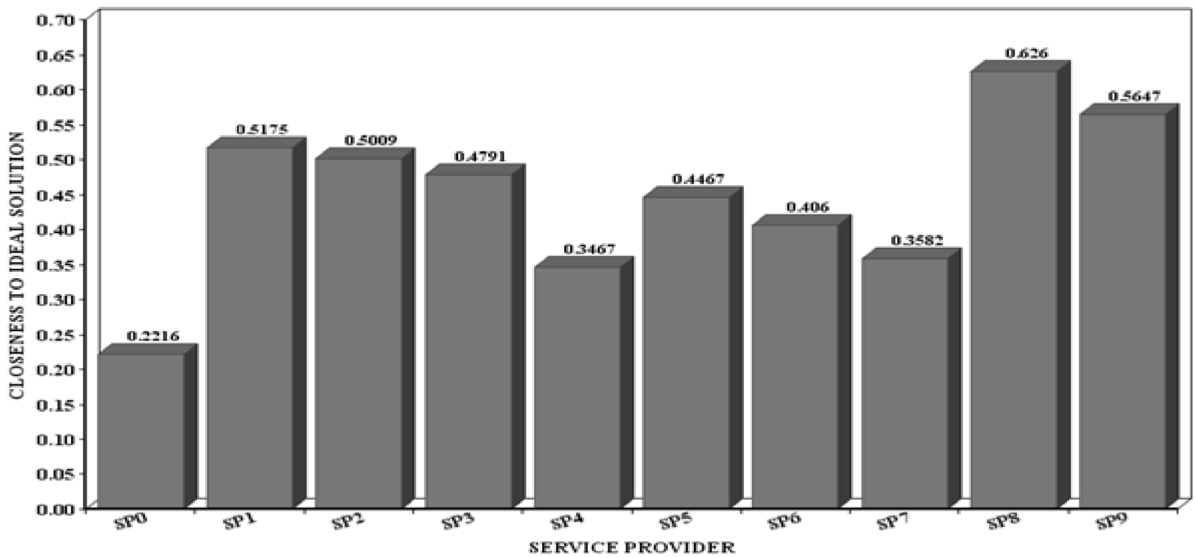

Figure 4.8: Relative closeness of service providers to ideal solution

Chapter 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion

Cloud computing is fast growing computing model which provides pay-as-per-use resource provisioning facility to its customer with reasonable cost and comfort level as compared to local computing infrastructure. There are various service providers publicly available in cloud market; the major challenge for cloud customer is to pick the right option for application deployment.

Existing models focus on evaluating a number of alternatives in accordance to the different criteria which are expressed in a same unit and deals with single dimensional problems. Therefore, the main driving force of this research work was to

1. Introduce multi-criteria in decision making
2. Give relative weightage to user preferences
3. Identify platforms with higher certainty in performance using service level agreement for offered services verification
4. Use standardized features of comparison for assessing service quality of cloud service providers
5. Provide a more compact and accurate infrastructure selection approach
6. Minimize subjectivity and maximize objectivity in quality judgment
7. Use functional, reliable and intelligent MCDM method (TOPSIS) for ranking process

In this context, this paper presents novel Cloud Service Evaluation and Ranking Model which can be viewed as a framework for an intermediate cloud service selection system. It receive service request from client side and evaluates service providers on a number of quality parameters, also assess their consistency level and provide rank to each candidate.

For minimizing subjectivity and maximizing objectivity of quality judgment, we measured weights of criterion using AHP technique. Also, for ranking we used TOPSIS method. Case study demonstrates that the implementation of this model is simple and final candidate for application deployment can be quickly obtained with less computational effort.

Our proposed model is more consistence and accurate in terms of ranking cloud service providers and making candidate selection by Using standardized quality parameters for service quality comparison. Also, it respects user-defined quality requirements and preferences in infrastructure selection. Support fast computing by eliminating service providers from consideration list that shows variation in performance and provide simplest, reliable and consistent ranking and selection approach using AHP and TOPSIS techniques.

5.2 Future Work

In future, we will extend this work by implementing this model on a real world data set. Also other techniques of Multiple Criteria Decision Making will be applied and comparison will be made against the present work. More capabilities to a proposed model will be added for performing ranking and selection process with high performance reliability and less computational effort.

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