SME ADOPTION OF CLOUD SERVICES:

A NOVEL ONTOLOGICAL FRAMEWORK (Nigeria as a case Study).

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Abstract

The future of Information Technology lies in cloud computing, whose primary objective is to reduce the cost of IT services while increasing production output, availability, reliability, flexibility as well as a decrease in processing time. Owing to few exploratory studies that explain the adoption of cloud services, this research tends to understand the factors affecting cloud service adoption decision by SMEs in Nigeria. Also, it proposes a solution based framework to tackle the identified factors in view of promoting cloud service adoption by Nigerian SMEs.

In view of the above, this thesis investigates the reason for slow adoption of cloud services with specific emphasis on Nigeria SMEs. Firstly, the existing literature in cloud service adoption by SME is examined based on Systematic Literature Review (SLR) method. This helps to inform the research gap in relation to cloud service adoption technique. Secondly, the thesis uses a mixed method approach integrating quantitative and qualitative methods to gather data through four stages of data gathering approach. The primary data gathering is based on quantitative (survey) stage 1 and qualitative (Focus Group) stage 2, which involves the studies identifying the cloud service adoption challenges specific to Nigeria SMEs.

Furthermore, a solution framework CLOUDSME which includes an ontologically developed Decision Support System(DSS) is proposed to tackle the challenge identified in Primary data gathering stage 1and 2. The proposed framework consists of four phases: The first phase deals with gathering information on how various cloud services address dynamic SME user requirements identified in the primary data gathering stage, this phase forms the building block through which the framework is built upon. The second phase which is the prioritisation phase Adopts Analytical Hierarchical Process (AHP) approach to deal with the issue of complex comparison, also the third stage of data gathering

(quantitative) is performed whereby a group interview is carried-out to compare and assign weights to service provider offering in addressing user requirements using pairwise comparison scale. The Third phase addressing the issue of cloud service ranking. In this phase, the major contribution of this research is introduced, whereby a new formalism is proposed using rational relationships to tackle the issue of rank reversal associated with the traditional AHP approach. The fourth phase of the framework is the development of the ontological proposed DSS which comprises of the information gathered in phase 1, 2 and 3. The proposed DSS promotes cloud service Knowledge management, service recommendation and service ranking toward cloud service adoption decision making by SME managers.

The final stage of the research is the validation phase which comprises of construct validation. As well as user opinion and expert opinion and researcher opinion validation based on a survey (Quantitative) which makes up the fourth stage of the data gathering stages. The findings from the user opinion evaluation and validation prove the CLOUDSME has the capability to tackle the slow adoption of cloud services by Nigeria SMEs.

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Acronyms

SME	Small and Medium scale Enterprises
SLA	Service Level Agreement
SaaS	Software as a Service
PaaS	Platform as a Service
IaaS	Infrastructure as a Service
CRM	Customer Relationship Management
DSS	Decision Support System
AHP	Analytical Hierarchical Process
MCDM	Multi-Criteria Decision Method
XML	eXentensible Markup Language
RDF	Resource Description Framework
OWL	Web Ontology Language
NIST	National Institute of Standard and Technology
ERP	Enterprise Resource Planning
S3	Simple Storage Services
FGD	Focus Group Discussion
EBS	Elastic Block Storage
EC2	Elastic compute Cloud
SWOT	Strength, Weakness Opportunity ant Threat
NERFUND	National Economic Reconstruction Fund
SMEDAN	Small and Medium Sized Development Agency of Nigeria
ICT	Information and Communication Technology
IT	Information Technology

AWS	Amazon Web Services
VPN	Virtual Private Network
ISO	International Organization on Standardization
WSRF	Web Service Resource Framework
WSMO	Web Service Modelling Ontology Matchmaking
WSMX	Web Service modelling eXecution Environment
SOA	System Oriented Architecture (SOA)
QoS	Quality of Service
UDDI	Universal Discovery Description and Integration
MAUT	Multiple Attribute Utility Theory
MAV	Multi-Attribute Value
SLR	Systematic Literature Review
IC	Inclusion Criteria
EC	Exclusion Criteria
ISIC	International Standard for Industrial Classification
TOE	Technology- Organization-Environment
TAM	Technology Adoption Model
UML	Universal Modelling Language
KPI	Key Performance Indicator
CI	Consistency Index
CR	Consistency Ratio
RSRM	Relative Service Ranking Matrix
RSRV	Relative Service Ranking Vector
RI	Average Random Consistency

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Dedication

I would like to dedicate this thesis to my lovely wife, Dr (Mrs) Obianuju Emechebe-Otuka for without your constant love, patience, support and encouragement, I could not have completed this research process.

Chapter 1: Introduction

1.1 Motivation

Cloud computing is contemporarily seen as one of the biggest technological breakthroughs in computing. A large number of cloud service providers exist with each prioritising on various aspects of cloud services (Google mail, Google App Engine, Amazon EC2) provided by Google and Amazon respectively (Armbrust et al., 2010, Buyya et al., 2008). To remain competitive in cloud technology offerings, these service providers have made avenues in view of easy accessibility to their services, which are known to offer great benefits such as reduction in operational cost and eradication of upfront investment for small businesses. However, despite the aforementioned development, Small and Medium scale Enterprises (SMEs) are still slow in the adoption of this promising technology (Aljabre, 2012, Rath et al., 2012, Khan, 2014). In this thesis, slow adoption of cloud service is considered as the lack of awareness, lack of investment in technology infrastructure and unclear cooperate governance thereby leading to low penetration rate of cloud service usage by SMEs. In this context, lack of awareness includes technology no-how, no standardised naming convention and heterogeneous types and features of cloud services. Secondly, lack of investment in technology infrastructure by the government includes Telecommunication infrastructure and inadequate power supply which leads to increase in the cost of cloud service adoption. Thirdly, unclear cooperate governance includes the issues such as lack of clear government policy towards cloud service adoption(Zhang et al., 2012a, Awosan, 2014).

This research focus on the aspect of lack of awareness of cloud services by Nigerian SMEs. Lack of investment in technology infrastructure and unclear cooperate governance is not addressed in this research. Investigation conducted reveals the necessity to address the slow adoption of this promising technology by Nigeria SMEs. Therefore, this is the

major motivation for this research. For example, the (Verizon, 2009) survey on ICT adoption by small businesses, reported that 39% of small businesses implemented technology to advertise and promote their business compared to 9% who adopted technology for their business process. Against the above background, the SME owners and managers who are also willing to adopt this technology are faced with the challenge of selecting the appropriate cloud service from the numerous service provider offerings that meet their business requirements(Jagannathan, 2012). At the moment, potential adopters go to service provider websites or blogs to manually gain knowledge about the available cloud service offerings, price per usage as well as what Service Level Agreement(SLAs) are available. The complex search of service provider website towards gaining cloud service knowledge can be viewed as a barrier to cloud service adoption particularly for SMEs with limited knowledge and experience on services provided because service providers use different vocabulary to represent similar user requirements (Rodríguez-García et al., 2014).

Cloud services are divided into three layers Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). (Buyya et al., 2009). The top layer focuses on application services (SaaS) which are usually the cloud interface that allows computer users have access using a web browser and thin computer terminals. The SaaS and PaaS layer known as application and software environment layers are built upon the lower layer which is the IaaS layer. The upper layers are mostly developed and provided by a third party service provider while the service suppliers of the IaaS are different as they focus more on the data centre (Fortis et al., 2012).Cloud services adoption depends on an organisation's needs. As such, SaaS services can be adopted based on service application requirements, an example is the Customer Relationship Management(CRM) application provided by Salesforce, Storage application services such as Dropbox, Google Drive, One Drive (Drago et al., 2012, Cusumano, 2010).Again, PaaS offers a platform

for adoption in instances where a business is interested in the development of other applications on top of it, an example is Google App Engine (Ciurana, 2009). While IaaS is adopted as an environment for the deployment, running and management of virtual machines and storages. Again, it is the IaaS layer that offers on-demand storage in terms of incremental scalability of computer resources (Buyya et al., 2009).

Furthermore, cloud service provider offerings create complexity in terms of decision making for SME owners who are trying to determine what cloud services meet their business process requirements. Most cloud service providers offer similar services in different packages, such as pricing, file size restriction, storage services, operating systems, fault tolerance, interoperability, security, Service Level Agreement (SLA), programming framework etc. (Rimal et al., 2009). While one service is better on one feature it might not be on another or even more expensive for the same service. Finding the convenient cloud service that satisfies user requirements has subsequently become a significant challenge especially to SMEs (Peng et al., 2009, Dillon et al., 2010). It is important that SME managers who want to adopt cloud services are able to evaluate which cloud service is most suitable for their business based on certain criteria's and also the ability to choose a cloud service in real time.

In view of finding a solution to the slow adoption of cloud services, an ontological cloud service framework (CLOUDSME) is proposed. The proposed framework which is equipped with a cloud service ontology of advertised service provider requirement offerings is developed to act as a Decision Support System (DSS). The proposed ontological framework aims to tackles the issue of slow adoption by promoting cloud service awareness through knowledge management. The use of the semantic model gives the framework ontology the ability to transform human language to machine readable language with the aid of a descriptive logic reasoning engine as "pellet" which has reasoning capabilities to infer knowledge based on concepts and their relationships in

view of retrieving accurate and timely information to aid SME owner in cloud service adoption decision making. Again, in view of tackling the issue of complex comparison of service provider requirement offerings which is Multi-criteria decision problems, an extension of the Analytical Hierarchical Process (AHP) is proposed. The proposed AHP extension is achieved by introducing benchmarks for enhancing Service Recommendation(ur Rehman et al., 2011) and Rational Relationships to tackle the issue of rank reversal associated with AHP ranking(Bouchet and Sansonnet, 2009, Jun et al., 2004). The proposed ranking approach is implemented within the DSS with the integration of semantic rules and presented in machine readable form.

The remainder of this chapter discusses the research problems, aim & objectives, research hypothesis, research questions, contribution to knowledge and thesis organisation.

1.2 Research Challenges

In view of finding a solution to the slow cloud service adoption by SMEs, The following challenges are identified:

1.2.1 Cloud service discovery

1 How to semantically build a cloud service knowledge management system so that properties of cloud services (e.g. security, Interoperability, availability) are understood by all parties (Users, cloud service providers) in view of promoting cloud service knowledge among SMEs?

2 How to address the issue of complex comparison of cloud service offerings by different service providers offering similar services. Also, how to implement the possible solution within a decision support system? As a DSS will help in creating awareness thereby increasing the adoption of cloud services.

1.2.2 Cloud Service Selection

1. How to overcome the challenges of standardisation of cloud computing service offerings as each provider uses a different protocol, vocabulary and formats?
2. Can cloud computing services be classified based on a different taxonomy of their characteristics to compare them in a bid to find a service that best satisfies user requirements? As service providers use different vocabulary to advertise user requirements. This, in turn, creates confusion for potential cloud service adopters.
3. SME owners hardly consult complex systems especially when they try to retrieve a required business information. How will the system minimise the use of complex retrieval of information process knowing that the users are non-experts?

1.2.3 Data Gathering

1. What method of data gathering will help achieve the research aim and objectives?
2. How to determine the acceptable sample size for the survey?
3. How to make the focus group participants comfortable enough to air their opinion during the Focus Group Discussion?
4. How to formulate questions for participants and stay focused on the research objectives?
5. How to choose participants and convince them to participate while putting ethical issues into consideration?
6. How to verify the data captured during the survey?

1.3 Research Aim

This research aims to develop a new solution based approach for cloud service adoption to meet the needs of Nigeria SMEs.

1.4 Research Objectives

Driven by the above challenges, the following objectives have been identified:

- To investigate the causes and challenges of slow adoption rate of cloud services by SMEs in developing countries using Nigeria as a case study. The research findings will be analysed to determine the significant challenges of cloud service adoption in Nigeria. The result of the survey findings will be compared with the adoption of cloud services among SMEs in the United Kingdom.
- To design a framework which includes a semantically developed DSS ontology of SaaS storage cloud services, as advertised by service providers to aid SME owners towards the adoption of cloud services for their businesses.
- To develop generic cloud service knowledge model of advertised cloud services as advertised by service providers and ranked using a proposed Multi-Criteria Decision Method (MCDM). The proposed ranking method is an extension of the traditional ranking AHP ranking approach for solving Multi-criteria decision problems.
- To develop a system that has the capability to multi-task bearing in mind the dynamic nature of SMEs requirements.
- To adopt a knowledge engineering approach for natural language processing to translate human sentences to machine readable language.

1.5 Research Hypothesis

To achieve the research aim, we demonstrate that a Framework, which includes semantically developed DSS and equipped with cloud service ranking capabilities can assist in aiding the decision-making process of cloud services adoption by SMEs. In view of tackling the slow adoption of cloud services by SMEs especially in Nigeria.

The matching of SME requirement against the proposed semantic model was achieved using three kinds of reasoning methods as follows:

Concept similarity reasoning

This is based on the conceptual modelling of cloud services and their requirement parameters as advertised by service providers within the ontology. This reasoning method interacts with different domain aspects of the ontology to retrieve information that best meets user requirements.

Object property similarity reasoning

This is based on the relationship among domain concepts. It is determined by the properties and parameters that distinguish the domain classes to discover which requirement parameters are specific to a domain in the process of information retrieval when the system is consulted.

Data property similarity reasoning

This is based on the relationship between individual and eXentensible Markup Language (xml) schema datatype or Resource Description Framework (RDF) literal. This reasoning method retrieves information in relation to machine readable data. Furthermore, it matches the datatype specific to all individuals and retrieves information that best matches the user requirement.

1.6 Research Questions

1. What is the current state, impact and challenges of cloud service adoption in Nigeria (developing country) compared to England (Developed country)
2. What techniques have been proposed to represent cloud service adoption

3. What uniqueness will CLOUDSME have over other cloud service adoption techniques presently used?
4. What advantage does the use of semantic web have towards decision making against a generic web search and service provider website with specific the emphasis on the adoption of cloud services by SMEs?

1.7 Contribution to Knowledge

The main contributions of this research thesis are summarised as follows:

C1 This research attempts to adopt an inclusive approach to the development of a knowledge based system and the processing of knowledge toward the adoption of SaaS storage cloud services by SMEs in Nigeria. Although this research topic is not new in its entirety; however, the research approach adopted and the context within which the research is conducted is new. The adoption of stakeholder approach whereby the SME owners and managers are involved in the information gathering and validation phase of this research is unique. The findings have important consequences for the development and improvement of national strategic planning to incorporate policies that support to successful adoption and evaluation of cloud services among Nigerian SMEs.

C2 The first proposed semantic framework designed specifically for SMEs to promote cloud service Knowledge management, recommendation and service ranking in view of tackling the slow adoption of cloud services by SMEs in Nigeria. As there is presently no framework for cloud service adoption for SMEs in Nigeria. At the moment, possible adopters have to go on service provider websites or search generic search engines on the internet for possible cloud services. This process is complicated as there are many service providers offering similar services and there is no method for the SME owner to evaluate

the quality of the advertised services. Also, different provider uses different vocabulary for their services thereby increasing the complication of cloud service knowledge. The proposed system has the capability to address the present challenges being experienced by Nigerian SMEs cloud service possible adopters.

C3 A systematic investigation and identification of the state-of-the-art on methods that can be utilised in tackling the slow adoption of cloud services. This study is a contribution to the body of knowledge as it conducts a systematic review of the present methods and provides a conclusive evaluation of this methods. The findings will further enable researchers to adopt the best available method based on their suitability for particular research task. The analysis of the methods identifies the gaps that should be researched in further studies. Based on the SLR findings the method required for the development of CLOUDSME was identified.

C4 The complexity involved in comparing the QoS offered by various service providers offering similar services is known as a multi-criteria-decision problem. To tackle such problem a multi-criteria decision method (MCDM) is applied. The most commonly applied MCDM is the Analytical Hierarchical Process (AHP) because of its ability to check consistencies. However, the AHP method has the issue of rank reversal. In this research, an extension of the AHP approach is being proposed. The proposed approach introduces the use of rational relationships to tackle the issue of rank reversal associated with the traditional AHP method. In addition, algorithms in form of semantic rules are proposed to aid in the implementation of the extended AHP approach within the ontology.

C5 The proposed DSS within the framework cannot be considered as complete if it cannot address the dynamic nature of SME requirements, considering that the SME sector

comprises of various categories. To address this challenge, a semantically developed DSS which has the capability to transform human language to machine readable language using Web Ontology Language(OWL) ontology supported by description logic reasoning engine such as (pellet or hermit) allows inferring knowledge based on concepts and relationships. This aids the retrieval of accurate and timely information in decision-making process in a dynamic user environment. A set of concepts and their relationships have been integrated within the DSS to address the challenge of dynamic SME requirements.

C6 The research context distribution presented in chapter 4 Table 4.3 and illustrated in figure 4.5 signifies that there is need to close the research gap between academia and industry by means of collaboration. From the SLR findings, majority of the studies (67%) was conducted via academia, while 12% of the studies were conducted via industrial context and a small percentage of 9% were joint studies between academia and researchers. Please see details of this contribution in chapter 4 of this research

1.8 Thesis Organization

The thesis is structured into nine chapters, each devoted to describing a specific aspect of the research. The structure of this research is illustrated in Figure 1.1:

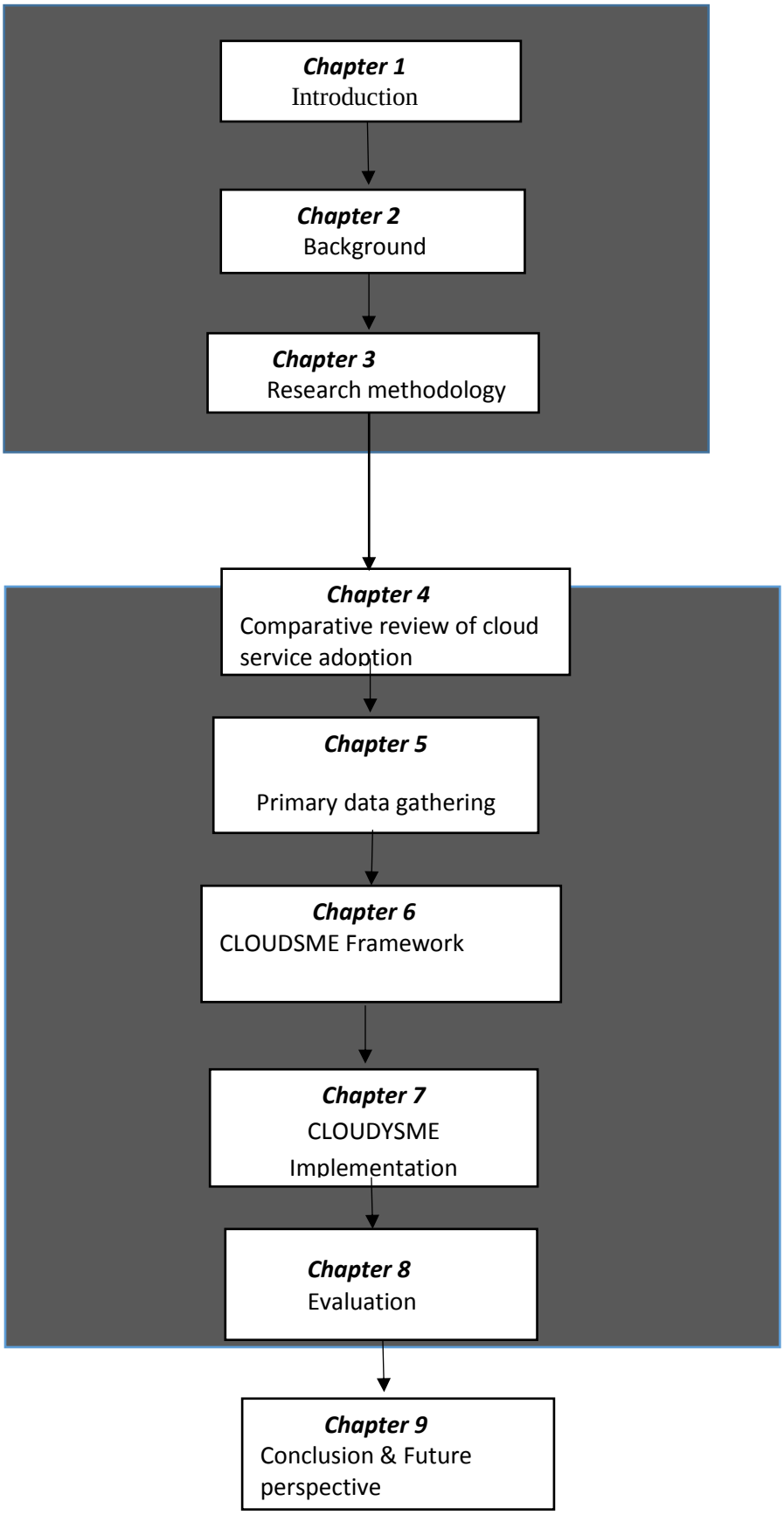


Figure 1.1 Organisation of Thesis

Chapter 2: This chapter provides background information on the research areas of this thesis. The definition and the economic importance Small and Medium Sized Enterprises (SMEs), Taxonomy of cloud services, Semantic technology as well as decision making approaches are discussed in this chapter.

Chapter 3: This chapter is divided into two main parts. The first part discusses the secondary data gathering using SLR this includes the research questions, quality criteria, demography, search protocol, quality criteria, inclusion and exclusion criteria as well as Data extraction and synthesis process. While the second part discusses the research methodology used for primary data gathering which is a mixed method approach which includes both quantitative (Survey) and Qualitative (Focus Group Discussion) data gathering methods.

Chapter 4: Presents a detailed analysis of the primary studies discussed in chapter 3. The types of techniques currently used in tackling slow adoption of cloud services. The quality of research work conducted, the research context area and the limitation within which the studies are measured.

Chapter 5 This chapter, the primary data gathering technique was discussed and analysed, the quantitative (survey) and qualitative (focus group discussion) identified themes were analysed. A comparative study on the cloud service adoption between SMEs in Nigeria (developing country) and SMEs in England (Developed country) was carried-out to determine the adoption trend and the similarities and differences in cloud service adoption challenges between both countries.

Chapter 6 The proposed CLOUDSME framework which includes a decision support system is presented and discussed in phases. Furthermore, the description of the conceptual model together with the developmental process towards tackling the research objective is also discussed in this chapter.

Chapter 7 This chapter presents CLOUDSME implementation. The implementation is done in three main phases. The first phase deals with knowledge management. The second phase deals with the implementation of the prioritisation phase. The third phase focuses on the implementation of the cloud service ranking procedure. Also, the developed DSS is also tested in this phase using possible SME case study scenario to check for possible system errors for refinement.

Chapter 8 This chapter deals with the system evaluation. Construct validity evaluation was used to evaluate the completeness of the proposed system. 29 SMEs who participated in the data gathering phase of this research were selected randomly to determine if the system has enough knowledge to meet their Business requirement and to determine if the use of cloud SME can influence their cloud service adoption. Furthermore, expert opinion evaluation was performed to determine the correctness of context categories and the definition of dynamic user requirements. In addition, researcher opinion evaluation was conducted to evaluate the CLOUDSME ranking approach compared to AHP and outranking approaches.

Chapter 9 This chapter concludes this thesis by providing a comprehensive summary of the proposed cloud service adoption approach. The chapter also discusses the limitation and future direction for this research.

Chapter 2: Background

This chapter presents an overview of service adoption techniques and methods. Several approaches with a variety of architecture and algorithms have been proposed to tackle the challenge of slow adoption of cloud services by SMEs. The aim of this chapter is to categorise this approach and present them in view of identifying the gap in cloud service adoption techniques.

2.1 Introduction

Cloud computing generally refers to the application delivered as a service over the internet as well as the hardware and software in the datacentre where these services are being provided. According to (Armbrust et al., 2010), Cloud computing is a technology model in which any and all resources application software, processing power, Data storage, back-up facilities, development tools etc. Literally, everything is delivered as a set of services via the internet. Similarly,(Calheiros et al., 2011) in their own perspective suggest that cloud computing delivers infrastructure platform and software (applications) as services which are made available as subscription based services in a pay as you go model to consumers. Against the above background, we can understand that researchers view cloud computing differently but from the concept of cloud computing they are all acceptable definitions. This is because no specific definition has been accepted for cloud computing. The most generally accepted cloud service definition is that proposed by the united states National Institute of Standard and Technology (NIST) which states that "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to 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 services provider interaction"(Mell and Grance, 2011). The most common classification of cloud services is usually known as the SPI (Software, Platform and Infrastructure as a service) model (Mell and Grance, 2011, Youseff et al., 2008, Buyya et al., 2008).

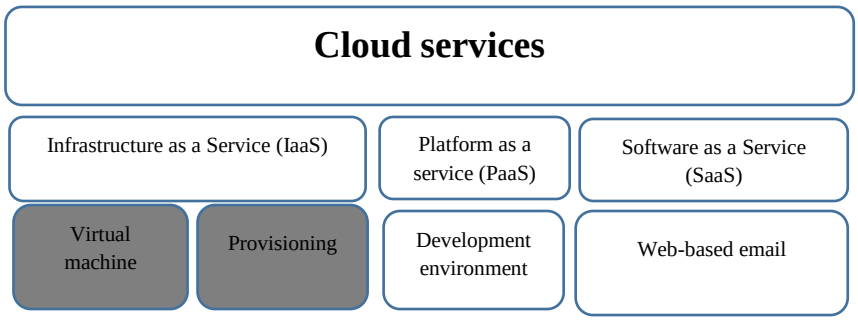


Figure 2.1 Cloud service model

Cloud services are similar to an electrical grid, whereby resources such as hardware, software and information are pooled and shared with end-users via the internet (Li et al., 2011).The approach of this technology technically implies that software is being rented via the internet rather than an in-house software development team(Kaufman, 2009).This further results in a minimal in-house IT personnel's (Li et al., 2011, Marston et al., 2011, Rath et al., 2012). Cloud computing generally comprises of three main services:

- Software- as-a-Service (SaaS): This service is usually the cloud interface layer that allows computer users have service access using a web browser and thin computer terminals. It overcomes the challenge of installing software on a client machine and updating regularly. Applications like Customer Relationship Management (CRM), word processing, Enterprise Resource Planning (ERP) are made available on the internet for end-user consumption. It is the biggest and most mature cloud model. Commercial vendors offering this service are Gmail,

Dropbox, iCloud, salesforce.com, Yahoo mail, Facebook, etc.(Cusumano, 2010, Drago et al., 2012).

- Platform –as-a –Service (PaaS): Provides a platform for adoption for instances where a business needs to develop other applications on top of it. Instead of buying software platform licences such as database and mild ware, operating systems and software development tools like .Net, Python, Java, ruby on rails available over the internet. Commercial vendors include Google App Engine platform, Microsoft Azure services, and Amazon web services etc.(Boniface et al., 2010, Armbrust et al., 2010).
- Infrastructure-as-a –Service (IaaS): This service layer refers to physical devices (raw computing) such as storage device, virtual computers, network transfers physically located in a central place (datacentre). They can be accessed via the internet using login authentication systems and passwords from any device. It is the layer that offers on-demand storage based on the incremental scalability of computer resources. Commercial vendors include Simple Storage Services (S3), Elastic Block Storage (EBS) and Amazon Elastic Compute Cloud (EC2)(Moreno-Vozmediano et al., 2012, Li et al., 2012).

Furthermore, besides the three major classifications of cloud computing services as seen in Fig 2.1, they can further be classified based on their deployment models as follows:

1. Public cloud – Makes full use of the cloud model

NIST (Mell and Grance, 2011) have expanded on these two deployment options with the notion of community cloud and hybrid cloud. Although most cloud experts still consider public cloud as a quintessential paradigm for cloud computing it is still important to give some merit to other options.

2. Private cloud

This is regarded as an extension of the current enterprise data centre. A private cloud is one that only leverages some of the aspects of cloud computing mostly through hundreds or thousands of nodes connected primarily to the servers. In addition, from a business perspective, the application provided primarily supports the business but do not directly give additional revenue. It is regarded as a solution for financial cost centre rather than revenue or profit centre.

Table 2.1: The difference between private and public cloud .source:(Rhoton, 2013)

	Private	**Public**
Location	On premise	off premise
Connection	connected to private network	internet based delivery
Scale direction	Scale out (applications)	Scale up (users)
Maximum scale	100-1000 nodes	10,000 nodes
Sharing	Single tenant	Multitenant
Pricing	Capacity prizing	Utility prizing
Financial centre	Cost centre	Revenue/profit centre

Relationship between private and public cloud

The most obvious area of interception is around resource pooling as it is known that resources are shared across customers in public environment and across departments or cost centre in a private implementation. There are 3 different sources of cloud computing

- **Co –location** - This is a co-location of servers in an external data centre not necessarily the consuming organisation itself.
- **Outsourcing** -Large IT providers such as HP enterprise services& IBM global services have been in the business of running data centre operation for large customers for many years. These servers are either managed in their own facility or another premise or third party.
- **Partner cloud**- This is another point of the continuum between private & public cloud. Large outsourcers can pass on some of their benefits of scale, standardisation, specialisation and this points in the experience curve.

3. Community cloud or vertical cloud

Community cloud caters for a group of organisations that require some set of objectives and services, the most common is the government cloud that are open to feedback and municipal agencies. In time to come various industries may decide to work together to leverage common resources an example of an existing government cloud is seen in the united states whereby Terre-mark has opened a cloud –computing facility that caters specifically for US Government customers and addresses some of their common requirement around security and reliability(Staten, 2009).

4. Hybrid cloud

- Organisational – Different part of the organisation using different cloud services
- Application-Email, CRM, ERP, ACCOUNTING
- Services –Identify management monitoring pool
- Resources-This describes the virtual cloud by extending the perimeter of the organisation's internal network into the cloud to take advantage of resources with

more elastic capacity than the internal system. The extension is also invisible to the end users(Mell and Grance, 2011, Armbrust et al., 2010).

As mentioned in chapter 1, this research aims to investigate and find a solution to the issues related to slow adoption of cloud services by Small and Medium Sized Enterprises (SMEs) with specific emphasis to Nigeria SMEs. This will be achieved through the investigation of the challenges associated with cloud service adoption by different categories of SMEs in the six geopolitical zones of Nigeria, Analyses of the present techniques that has been proposed towards finding a solution to the slow adoption of cloud services as well as to identify the research Gap and propose a solution. It is essential to understand the importance of SMEs around the world. Therefore, in the next section an overview of the importance of SMEs around the world and the Strength, Weakness Opportunity ant Threat (SWOT) analysis of cloud service adoption by SMEs is discussed.

2.2 Definition of SMEs

SMEs are a very important entity in any country; they play a critical role in the economic development of every country. However, there is no universal definition for SMEs as the definition is dynamic and is viewed based on a countries level of development(Aruwa and Gugong, 2012). Different Researchers views SMEs in various ways. According to (Jutla et al., 2002) they ascertained that even though SMEs vary from country to country, they are defined based on certain criteria which are value of assets, employment and the use of energy. The views of (Rahman, 2001) is in agreement with the perspective of (Jutla et al., 2002) However,(Rahman, 2001) in his own assertion went further to elaborate on the criteria and introduced some other factors such as location, size, age, structure, number of employees, sales volume, worth of assets, ownership, innovation and technology. On the contrary, (Aruwa and Gugong, 2012) attribute SMEs to be based on the role SMEs are expected to play in a particular economy.

Looking at SMEs from a worldwide perspective, Bolton committee in its 1971 report described SMEs as small firms. They went further to define a small firm as an independent business, managed by its owner or part-owner and having a small market share. The report further adopted some statistical definitions, it recognized size as a very important factor to the sector by noting that a given firm maybe small in size where the market is large with many competitors; however, a firm of similar size maybe considered as large in another sector with fewer players or smaller firms within that sector. It further attributes number of employees as an alternative measure of size as well as use of turnovers in others. The committee stressed the need to view SMEs according to the number of full-time employees or its equivalent when looking at SMEs from a government perspective(Lukács, 2005).

2.2.1 SMEs in the United States and Canada

The United States of America which has the world's largest economy depends on SMEs for "Innovation, productivity and employment. SMEs represent about 99% of employers, with 51% from the private sector,38% from hi-tech occupations and provides 75% of new jobs from the private sector and 96% of exported goods(Ayyagari et al., 2007). Based on findings from Net impact study Canada (2002), SMEs account for 60% of the country's economic output, generates 80% of new jobs and creates 85% of new jobs.

2.2.2 SMEs in the UK and Europe

In the United Kingdom SMEs account for 99.8% of businesses including those without employees, 55.6% of employment and 52.0% of turnover(Fraser, 2004).The Companies Act in the UK of 1985 states that a company is 'small' if it satisfies at least two of the following criteria: (Small Business Service, UK)

• A turnover of not more than £5.6 million;

• A balance sheet total of not more than £2.8 million;

• Not more than 50 employees

A medium sized company must satisfy at least two of the following criteria:

• A turnover of not more than £22.8 million;

• A balance sheet total of not more than £11.4 million;

• Not more than 250 employees

For statistical purposes, the Department of Trade and Industry in the UK and government all-around EU usually uses the following definitions:

• Micro firm: 0 - 9 employees

• Small firm: 0 - 49 employees (includes micro)

• Medium firm: 50 - 249 employees

• Large firm: over 250 employees

2.2.3 SMES In the developing world

The international corporation sees developing countries almost generally comprised of private SMEs and also consider them as the only realistic employment opportunity for millions of poor and underprivileged people globally. Some researchers explained that a section of SMEs in developing countries remains in traditional activities with a generally low level of productivity, low-quality products serving small localised markets. This group poses little or no technological input with few graduates into large size or modern technologies.

2.2.4 SMEs in Nigeria

In the Nigeria context, there is no clear-cut definition of the small scale enterprise and the medium scale enterprise. The central bank of Nigeria defined small scale enterprise as having an annual turnover not exceeding 500,000 naira (1Naira equals 160usd at the time of this paper write up) in its monetary policy circular no.22 of 1998. While the Federal government of Nigeria in its budget defined small –scale enterprise as organisations with an annual turnover not exceeding 500,000 naira for purpose of commercial bank loans. Which conforms with the view of the central bank. However, the National Economic Reconstruction Fund (NERFUND) Further put a ceiling for small and medium scale industries at 10million naira. Section 37b (2) of the Companies and Allied Matters Decree of 1990 defines

A small company as one with:

(a) An annual turnover of not more than 2 million naira;

(b) Net asset value of not more than 1 million naira

The national council of industries refers to SME's as enterprises that have a total cost (excluding land cost) of less than two hundred million naira (N200,000,000.00) (Onugu, 2005).The Small and Medium Sized Development Agency of Nigeria (SMEDAN) defers in its definition, it defines SME's based on the following criteria: A micro enterprise which refers to a business with less than 10people with an annual turnover of below five million Naira(N5,000,000.00) , A small enterprise as a business with 10 – 49 people with an annual turnover of N5 to 49,000,000.00 and a medium enterprise as a business with 50 – 199people with an annual turnover of N50 to 499,000,000.00.

2.2.5 The impact of ICT IN SMEs Globally

The internet has the potential to provide an effective medium through which organisations can advertise, market and perform direct distribution of goods and services(Lin and Hsieh, 2001). Although SMEs keep striving to emulate large organisations in their adoption of the internet without full knowledge of its implication. However, they can be more innovative, flexible and responsive to environmental changes regardless of less human, technological and financial resources compared to large organisations (Julien and Raymond, 1994). In the Asian Pacific region, the acquisition and utilisation of Information and Communication Technology (ICT) in business have brought a sharp rise in the number of "off-shore" businesses that help service the Information Technology (IT) needs of developed countries in Europe and North America. The government of the Asian region makes frantic effort to promote the usage of computer and internet awareness amongst the populace(Ojukwu, 2006).The positive impact of ICT usage by SMEs in India can be evident in the use of technology in providing services such as email, voicemail, telemedicine clinics and e-government, others include payphone and Gyandoot rural intranet(Bhatnagar, 2003).According to Grameen communication(1998) A village internet programme set-up by the green bank in Bangladesh has succeeded in bringing cellular telephone to rural areas which in turn has brought about an opportunity for SMEs to succeed by promoting poverty alleviation, reducing rural to urban migration, creating information-technology driven job opportunities for the rural poor as well as improving computer awareness amongst the country's rural population(Madon, 2000).

According to(Irani et al., 2007), the use of ICT offers great benefits to SMEs in different levels (operational, tactical and strategic).While (Skoko et al., 2008) views ICT as a catalyst for organisational change. (Berisha-Namani, 2009) argues that without ICT utilisation it will be difficult for SMEs in the modern world to compete in the highly competitive business environment as ICT has a huge impact on SMEs operation and is

very important for its sustainability. Also (Sundén and Wicander, 2007) argue that ICT plays a significant role in reducing transaction costs which in-.turn increases efficiency. Again, market access is increased where new products are increasingly found on mobile and internet platforms. The usage of ICT has made it easier for customers to find new products and increase awareness of available products around the world.

2.3 Discovery

Service discovery can be described as a procedure whereby required functional and non-functional semantics of services are being searched to meet a user goal. In an SOA perspective, three major roles make up the typical architecture of web services which are as follows the service user, broker and the service provider(Reshma and Balaji, 2012). When a user sends a service request to a broker, it is important that a matching service provider is sent back to the user by the broker. However, there are situations whereby a set of services meet the functional and non-functional request of the user, in such a situation the biggest challenge is finding the best service based on user preference. Presently, researchers have continued to use different approaches in trying to address the issue of service discovery. This approach can be presented in different categories as seen in figure 2.2. Furthermore, we make a survey of present service discovery approaches based on the classification in Fig 2.2.

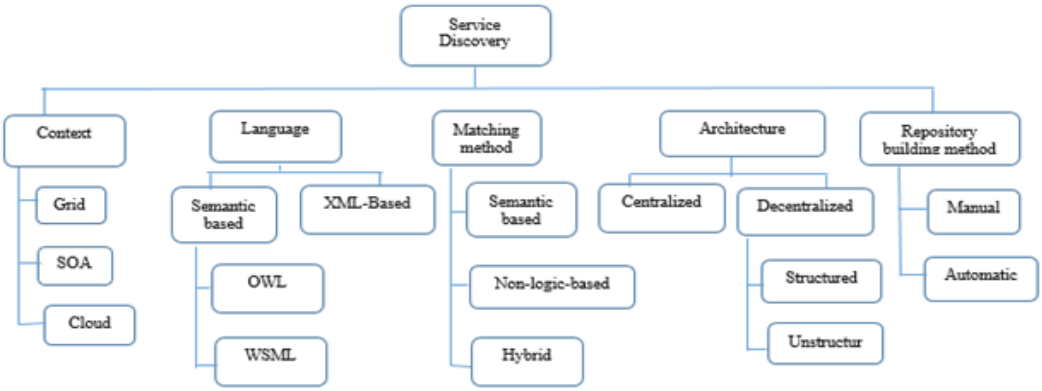


Figure 2.2 Discovery Approaches Taxonomy

2.3.1 Non-Logic Based Discovery

Approaches categorised under this type of service discovery apply symmetric attribute based matching between requirements and a request. An instance of this type of discovery is offered by Amazon EC2, Go Grid, Rackspace and IBM smart cloud whereby a syntactic matching discovery system is used to choose the suitable Cloud provider, service attribute and catalogue for deployment. Another approach is the Monitoring and Discovery Services (MDS) which uses Web Service Resource Framework (WSRF) standards with an indexed centralised information service which does not support complex queries(Schopf et al., 2006). Other applications of centralised attribute based matching of request to resources via inter-cloud(Buyya et al., 2010) Gridbus Toolkit(Buyya and Venugopal, 2004).

2.3.2 Semantic Based Discovery

The advancement in cloud service delivery steadily leaves users in an agony of choice. This makes cloud service identification and discovery a very complex problem due to non-standardization in naming convention, different service description and

heterogeneous types and futures of cloud services. Therefore, applying symmetric attribute based matching between a user requirement and a service offering is impossible. The use of semantics will only be possible when further levels of interoperability have been established, standards have been defined for a syntactic form of documents and their semantic contents. Building semantics of cloud services will require an inter-cloud language based on user requirement and service provider offerings which will enable both parties to share a common understanding concerning cloud service functional and non-functional properties, Quality of Service criteria and their measurement units. Furthermore, a semantic service can be described as a technique by which logic-based languages represented in well-defined ontologies can be used to define functional and non-functional properties of a service(Colucci et al., 2004, Sycara et al., 2003). Cloud service adoption discovery approaches can be categorised further based on the logic based language they support as below:

Web Service Modelling Ontology Matchmaking (WSMO)

Web Service Modelling Ontology(Roman et al., 2005) defines an explicit conceptual design model for semantic web services which is based on the Web Service Modelling Framework(WSMF)(Fensel and Bussler, 2002). The main objective of WSMO is to provide the necessary technology needed to attain flexibility and cost-effective integration within and across business boundaries. To achieve this, WSMO identifies four basic conceptual modelling elements needed to achieve flexible integration as illustrated in Figure 2.3:

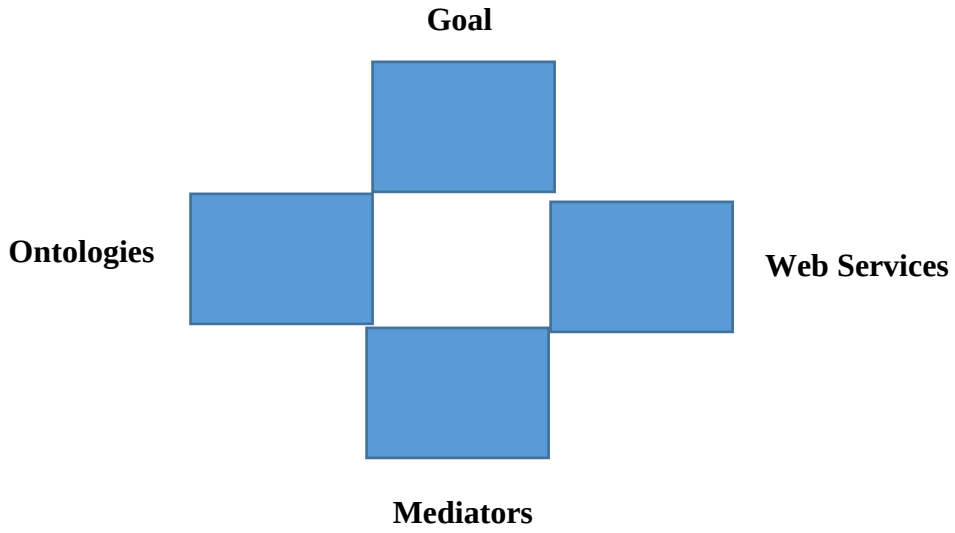


Figure 2.3 Elements of WSMO

As presented in Fig 2.3, Ontologies play a crucial role in enabling web-based knowledge processing, sharing and reuse between computer applications. They are generally defined as shared formal conceptualization of particular domains, ontologies offer a common understanding of topics that can be communicated between humans and application systems(Jasper and Uschold, 1999). Furthermore, ontologies provide formal and explicit specifications that enable automated processing of WSMO descriptions and also provide background knowledge for goals and web service descriptions(Fensel and Bussler, 2002). Goals describe aspects related to user desires in relation to the objective a business might have when searching web service.

Web services descriptions describe services provided by businesses, they help to describe the provision of value such business offer. They further identify the means of interacting with the provider in view of achieving the requested service. WSMO web service elements are defined as

- Capability: This element aids in describing the functionality offered by a given service.

- Interface: This element aids in describing exactly how the capability of a service can be satisfied. They generally aid in describing the activities of web services.

Mediators: The complexity associated with businesses dynamics brings a lot of heterogeneity. Goals and web services might be represented in different ontologies or vocabularies, also different businesses might use different interaction style or protocols as well as different business processes regulating such interactions. Mediators describe the elements to solve such differences. They resolve interoperability issues and allow endless integration of business partners, by overcoming heterogeneity in vocabularies, processes and protocols(Roman et al., 2005).

Furthermore, non-functional properties such as security, operating system support, scalability, reliability are also integrated into the definition of WSMO elements. In addition, Web Service Modelling Language (WSML) is the formal language used in the description of ontologies and Semantic web services. The implementation of WSMO is done in an execution environment for business application integration known as Web Service Modelling eXecution Environment (WSMX)(Haller et al., 2005).

OWL-S Based Service Matchmaking

The need for an automatic web service discovery was one of the major objectives of creating OWL-S. It is meant to support both simple and complex services. Generally, OWL-S helps in dealing with the following three tasks (Martin et al., 2004, Mcllraith et al., 2001).This is depicted in Figure 2.4.

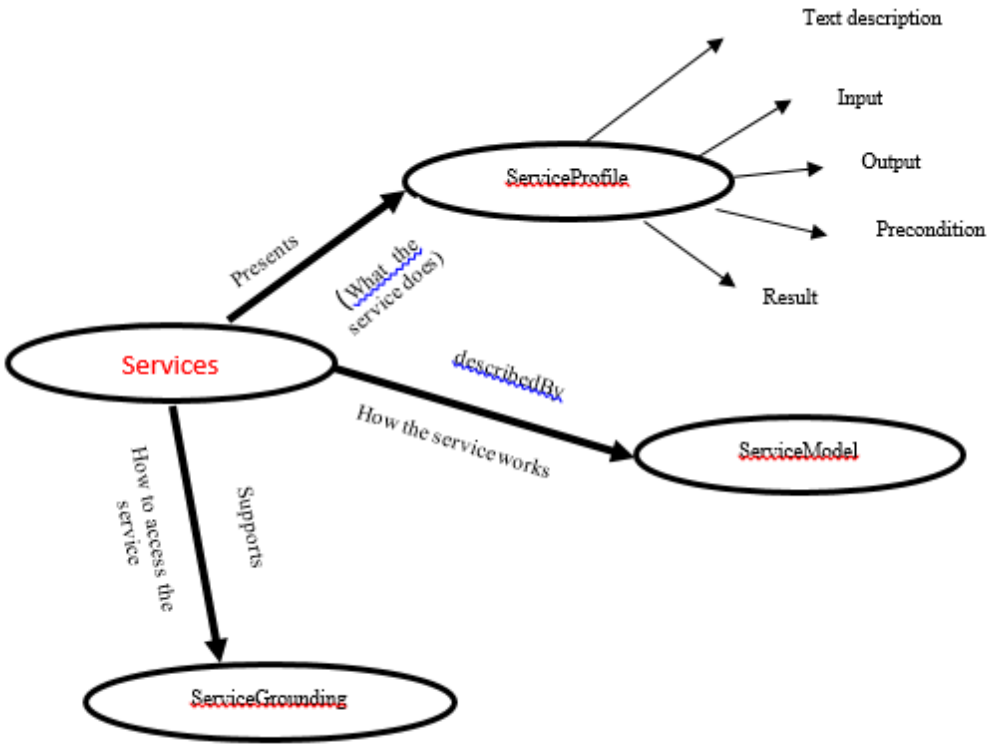


Figure2.4: OWL-S description of web-services

Automatic Web Service Discovery: This is an automated process that ensures the location of web services are able to provide a specific class of service capabilities while adhering to some client specified constraints. An example can be a user looking for a 3-star hotel in a particular city that accepts a certain credit card. Ideally, this task is performed by humans and they are required to use a search engine to look for a hotel, read the web page and execute the service manually. Using OWL-S mark-up services, the information needed for web service discovery could be specified as a computer interpretable semantic mark-up service Web sites. Whereby a service registry or ontology enhanced search engine can be used to locate such hotel automatically. In addition, a server could also proactively advertise itself in OWL-S with a service registry known as agents(Wong and Sycara, 2000) so that users can find it when the register is queried. OWL-S allows declarative advertisement of service properties and has the capability that allows for automatic service discovery.

Automatic Service Invocation: This is an automatic invocation of a web service by an agent or program, based on a declarative description of that service against a situation whereby the agent has been pre-programmed to be able to call that service. OWL-S mark-up of web services enables a declarative, computer-interpretable API which includes semantics of arguments to be specified when calls are being executed. OWL-S in combination with domain ontologies specified in OWL offer specific means declarative APIs for web services that allow this automated service implementation.

Automatic Web Service Composition and Interoperation: This is a task that deals with automatic selections, composition, and interoperation of web services to perform a complex assignment when a high-level description of an object is given. OWL-S provides declarative specifications of the pre-requisites and the consequences of applications of specific services, it also provides a language for defining service composition and dataflow interactions.

Although, OWL-S has shown that it has the capability to support complex tasks as described above. However,(Paolucci et al., 2004) proposed OWLSM which was among the efforts to retrieve ranked results based on different degrees of matching rather than returning only success or failure. While (Averbakh et al., 2009) further proposed service feedback as a method of improving the discovery results. Based on experimental evaluation and comparison with OWL-S results confirm that user feedback improves the quality of matchmaking.

2.3.3 Building Semantic-based Service Model

In computer science, there are two main approaches of building semantics: Procedural and declarative semantics. When using procedural semantics, an Expression X is given when there is a behaviour that some real or virtual procedure (program or machine) will exhibit on X. In most cases, to obtain an expression using procedural semantics, the user

will need to simply execute the procedure and observe the result. While in declarative semantics, an expression X is given an expression by mapping it to another known formalism or by declaring the conclusions or properties that associated with X. The expression does not need any specific computational procedure to be understood. Hence the approach is termed "declarative".

The difference between declarative and procedural semantics are not closely related to the difference between the XML and RDF approaches in relation to webpage semantics. An XML expression does not have inherent semantics and it is often determined by the action of one or more programs on it. While an RDF expression has a specific declarative semantics and all RDF processors must conform to the intended semantics. It is important to note that when comparing XML schema's "type –extension" mechanism with the *subclassOf* mechanism in RDF schema they may seem similar but their similarity is only superficial this is so because *subclassOf* can be used to model ontologies because a member of a subclass is also a member of a supper-class whereas in XML schema the elements of a Type Y are not really members of the original type Y(Decker et al., 2000). In addition,(Ferdinand et al., 2004) proposed an approach with 2 types of data transformation that maps XML schema with OWL ontologies and XML documents into RDF graphs.

2.3.4 Hybrid matchmaking

The notion of hybrid matchmakers was built by researchers' due to the computational expensive nature of logic-based reasoning vital for semantic based reasoning. The claim by hybrid matchmakers is that it enhances the quality of service discovery by merging both semantic and synthetic matching. OWL-MX(Klusch et al., 2009) and WSMO-MX(Klusch and Kaufer, 2009) are examples of hybrid matchmaking.

As mentioned above, WSMO-MX is a hybrid, while IOPE (input, output, precondition and effect) is a matchmaker built for services described in WSML. This is due that WSMO-MX applies variabilities in both logic and non-logic based techniques in searching for services which are close to a given goal semantically. They are further described in WSML-MX. The aim of WSML-MX is to improve WSML-RULE with more language elements that will allow users to execute relaxation constraints and set a preference for matchmaking. Hybrid matchmaker is determined based on precision, recall and computation time. Research findings show that hybrid approach out-performs both logic-based and syntactic-based approaches.

2.4 Service Selection Taxonomy

Service selection applications have been applied in different computing models such as Service Oriented Architecture and Grid computing. This is because web services have the capability to represent resources, while service selection methods help to allocate each request in a queue to the most appropriate resources based on its characteristics. Cloud computing has brought a radical change in web design and aesthetics. It has evolved to make the web not only a static information source for browser access but also a platform for web-based communities that facilitate user participation and collaboration. The works carried out in relation to System Oriented Architecture(SOA) and grid computing that can share their contributions in relation to selection challenges in the cloud are few(Dastjerdi and Buyya, 2011). Therefore, the aim of the service taxonomy presented in this section is to identify the state-of-the-art challenges in relation to web service selection as well as categorise works based on how they approach QoS attributes and how they tackle the issue of selection.

2.4.1 QoS Management

Many methods have been taken to tackle the issue of QoS management. Generally, quality of service management approach for QoS –aware Web service selection takes into account the following steps as represented in Fig 2.5 as follows:

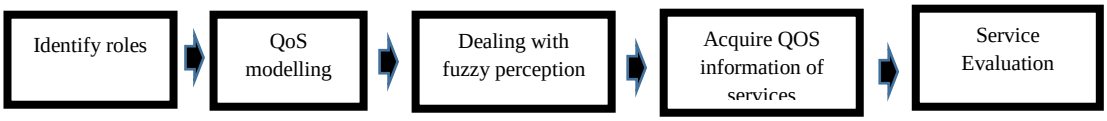


Figure 2.5: Quality of Service Management Process

- **Identify Roles:** The major role players in service selection problems are the Provider and the client (requester). The basis of selection is based on the defined roles of the problems. Selection solutions usually aim to help either the provider, the client or both to maximise profit.
- **Quality of Service Modelling:** In the existence of multiple web services with overlapping or similar functionality, users will judge each service acceptability based on their quality of service. QoS is a broad concept that encompasses both functional and complex non-functional properties such as price, availability, security reliability (O'Sullivan et al., 2002).It is important to note that a QoS involves multiple dimensions and quality of service composite services is measured by the QoS of its underlying component services. Furthermore, it is important that the QoS is determined based on the requestors perspective rather than the provider. In addition, the model should give the requestor the ability to identify which quality of service criteria is more significant to them and also it provides a method for defining the relationships between QoS criteria. For example, one user may prefer a service with similar storage allowance but lower price when considering two similar services or may even prefer a service with lower file size restriction. There

will be more understanding and transparency if the quality of service properties is placed in a hierarchical structure. Ontologies are commonly used to build such structures(Tsesmetzis et al., 2007).

- **Dealing with Fuzzy Perceptions**: This is another important aspect of quality of service management. This is because ranking systems are used by non-expects who find it challenging to express their preference using utility functions directly(Wang, 2009).
- **Gathering of QoS Information:** In this stage, an appropriate technique is required to acquire QoS information. Although different researchers have different perspectives in dealing with issues of QoS information gathering.(Toma et al., 2006)is in the view that users are responsible for the development of QoS information, while others are in the view that the providers of services are responsible for QoS information and they argue that providers are also supposed to provide QoS information together with the service description(Wang et al., 2004).
- **Aggregating the Evaluation findings into comparable Unit:** In this stage, it is important to aggregate QoS criteria and a sub-criteria scores/weight to obtain a final score for each service. It is important to select an appropriate aggregation method(Yu and Reiff-Marganiec, 2008).

2.4.2 Process of Service Selection

The process of service selection precedes QoS measurement. The degree of acceptability is determined by the superiority of one QoS over another when compared. The attained values of the QoS is inputted for selection approach. When selecting cloud services, the following steps are usually considered:

- The first step is usually accomplished by formulating and modelling of the problem to be tackled. This generally includes determining the objective for the selection problem and finding constraints.
- The next step is to adopt an adequate optimisation process or decision-making method that will suit the modelled problem in view of tackling the selection problem.

2.4.3 Service Selection framework

The use of different computer paradigms has enabled the investigation of service selection particularly for Grid and SOA. This section helps to demonstrate how the characteristics problem of each computer paradigm differs from others in a service selection process. The summary of each investigation is illustrated in Fig 2.6.

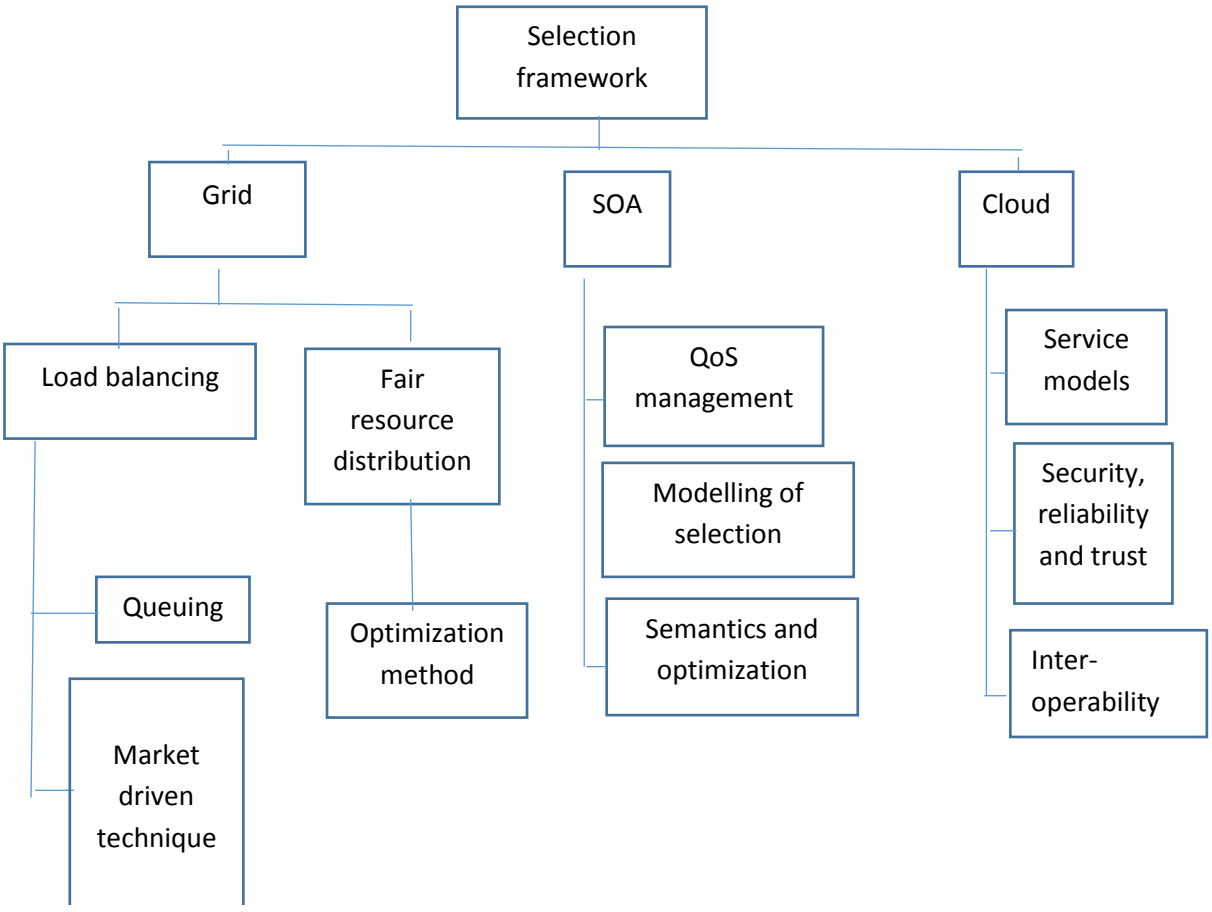


Figure 2.6 Service Selection Investigation Framework

Grid Computing

Grid Computing generally refers to the use of much-interconnected computing to resolve a problem through highly parallel computation in dynamic, multi-institutional virtual environment (Foster et al., 2003, Rhoton, 2013).These grids are often built on loosely coupled and heterogeneous systems, which control geographically distributed volunteer resources. They are mostly limited to scientific problems that require a large number of computer processing cycles or access to large volume of data. There may be some conceptual similarity between grid and cloud computing. This is based on the fact that they both involve large interconnected computer systems; their workload is also based on distribution and they also close the line between system usage and system ownership. Besides their similarity, they also have their distinctions. While a cloud services are generally opaque and cover a wide range of virtually every class of informational problems using models that decouple functionality from users, a grid may be transparent to its users and it mostly tackles a narrow problem domain. When considering QoS management and selection in Grid computing context, it majorly focuses on load balancing(Ackermann et al., 2011, Shan et al., 2002) and distribution of resources fairly among service requests(Zheng et al., 2010). Similarly, there may be situations whereby a service cannot satisfy user requirement independently, in such situations a composition service is required.

Service Oriented Architecture

A service-oriented architecture helps to decompose the information technology landscape of an enterprise into associated and sparsely coupled functional primitives called services. In disparity with monolithic nature of past applications, these services apply single actions which can be used by many different business applications. The business logic is then tasked with orchestrating the service objects by assembling them sequentially,

selectively or iteratively so that the business objective can be fulfilled. One of the major pros of this approach is that it maximises reusability of functionality and thereby reduces the effort needed in building new applications of modifying existing programs(Rhoton, 2013).Furthermore, some number of research literature has focused on describing QoS for services and user preference, developing QoS ontology and proposing various optimisation approaches that deal with multi-criteria web service selection.

Quality of Service Description: The work of (Toma et al., 2006) on QoS modelling analysed various approaches and their pros and cons. They identified the three main approaches when processing QoS in SOA as follows: direct negotiation, combined broker, separate QoS-broker. In the combined broker approach, which is an extension of UDDI the broker is extended to process QoS information. While the separate –QoS approach the devoted broker is responsible for processing QoS. Finally, the direct negotiation requires the provider and user to negotiate the terms and conditions on the service level agreement.

2.4.4 Quality of Service Modelling Taxonomy

Presently, QoS attributes can be defined in two ways which are Universal Discovery Description and Integration(UDDI) and semantic web services. Although UDDI and Web Service description Language fails to support the modelling of Quality of Service properties of web services.In fig 2.7, the summary of the classification of QoS management is illustrated and the preceding subsection presents the classification.

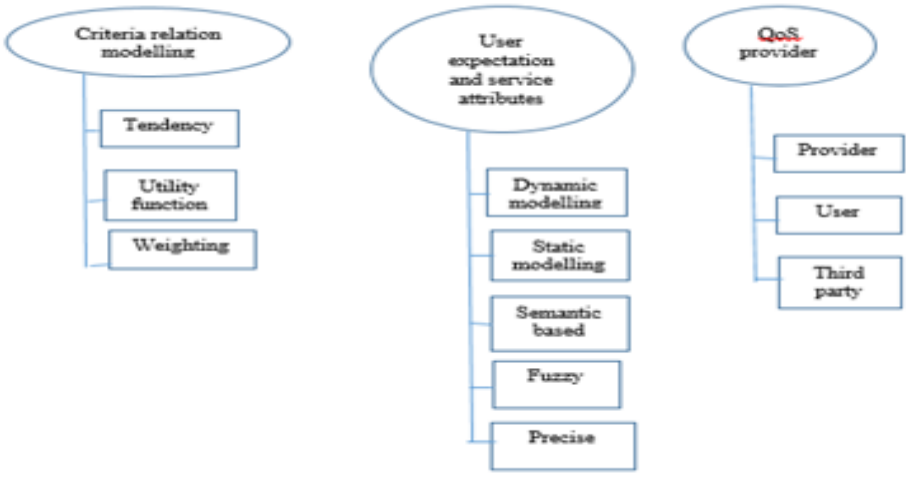


Figure 2.7: QoS Modelling Taxonomy of Web Services

User QoS determinants, Attribute relationship and Tendency Modelling

When users are considering adopting services, they express their expectation by considering the functional and non-functional characteristics of the available services. The business logic is then tasked with orchestrating the service objects by assembling them sequentially, selectively or iteratively so that the business objective can be fulfilled. They do this by identifying which of the QoS criteria are essential to their required needs compared to others. A simple method to achieve this is to ask users to assign a score to each criterion based on their satisfaction (user satisfaction). One of the most important and most generally accepted ways of achieving a decision matrix is by using weights in modelling the importance of service criteria based on user preferences. This approach has been applied in a lot of research works (Garg et al., 2013, Fensel and Bussler, 2002, Wang, 2009) as it is computationally efficient and easy to implement. Even though it is widely used, it still has its drawbacks which are the complexity in finding appropriate weighting coefficient when considering real world applications. Also, another complexity issue with the weighting method is the inability to determine whether a parameter value is more appreciated when it is smaller or greater, others issues of concern are “exact” and

“nearly”(Tran et al., 2009).Furthermore, one of the simplest forms of selecting user preference is by matching user preferred request with the properties of the available services. This can be done using a conditional programming language such as if-else constructs. These are generally applied when two values are compared to reach a decision((Pratt et al., 1984). The key issue with the selection of web services is that most of the web services have similar functionality, therefore it is important to rank the services to select the best for a particular request. In an effort to tackle these selection issues, Algorithms have been proposed with QoS parameters being put into perspective(Serhani et al., 2005).Euclidean distance algorithm which is a type of Multi-Criteria Decision Analysis(MCDA) algorithm, that involves the allocation of weights to each criterion and evaluating them thoroughly(Pandey et al., 2000).

In addition to the approaches mentioned above, (Garg et al., 2013, Tran et al., 2009) adopted the Analytical Hierarchical Process(AHP)(Saaty, 2008) for QoS ranking and attribute relationship modelling and service selection. AHP methodology is made up of three major phases, problem identification, evaluation and priority composition. In the problem identification phase: each problem is segregated into three elements which are the overall goal, its criteria and sub-criteria. In the second phase, the use of pairwise comparison is used to compare and judge the superiority of one criteria and sub criteria over another for decision making. In addition, all the solutions are ranked locally based on the sub- criteria. In the priority compositon stage, all the relative ranking solutions are combined to obtain the overall rank for the service.The major limitation of the AHP approach is the issue of rank reversal as suggested by (Belton and Gear, 1983, Dyer, 1990) that it cannot be used for very large comparisons since it makes use of pairwise comparison.

QoS Source:Service Provider, User and Third Party

Many researchers are in the belief that QoS information is advertised by service providers together with their service description. On the contrary(Wang, 2009) is in the view that some service providers do not release their QoS service information and in instances where they do, they overate their service functionality and this makes it difficult to compare with other services. This is the reason why the use of consumer feedback on web service delivery cannot be overemphasised as it is the most accurate means of QoS judgement. Although there are some non-functional values that cannot be measured by both users and providers such as trust, security, reliability and this is usually evaluated with the help of a third party who serves as a middleman monitoring services.

Context-Aware

There are instances whereby the QoS information of web services vary according to the user's contexts. The role of context-aware QoS information is to permit service providers or third parties to publish QoS values for web services based on the user context.(Badidi and Esmahi, 2011) in their approach for in context information provisioning proposed a framework which relies on deploying context services on the cloud by using context brokers to mediate between context services using a publish/subscribe model. The selection is based on multi-attribute decision algorithm of potential context services that are used to fulfil context consumer's requirement for context information. Furthermore, the approach of (Lamparter et al., 2007) adopts utility function policies in modelling context dependent user preference. This can be used in cases whereby a web service selected as the best service in a list of services is not available in the location. Therefore, it is unacceptable to select it for a user in that context. This is because context information of users aids in service coordination to improve the quality of users' experience. In addition, there are some law binding restrictions for deploying cloud services in specific

geographical locations. A good example is a law governing the transfer of data to clouds outside the European Union which is against the law for companies located in Europe.

2.4.5 Taxonomy of Web Service Selection Method

The taxonomy of web service selection is illustrated in Figure 2.8. Generally, research works related to service selection are categorised into two types of methods, which are decision making and optimisation. The decision making- method can be defined as the process of identifying and selecting alternatives based on set goals of the decision maker. When there is no measurement, the method of selection is generally defined as a Multiple Criteria Decision Method (MCMD)(Zeleny and Cochrane, 1973). The assumption is that there are many services to be chosen from and the aim is to select the one that best meets the defined goal. The process of decision making is illustrated in figure 2.9. Before setting the goals for the decision makers the attributes of the services are presented in a hierarchical structure figure 2.10 this is because, without a structured technique, the evaluation of the total quality of service will be difficult based on the number of attributes involved. The AHP approach is the most generally accepted MCMD as it helps users to assign the comparative importance of each criterion. Outranking approach is centred on the principle of the degree of one alternatives dominance over another rather than selecting a single best alternative. It compares the performance of alternative for each criterion and identifies the degree of a preference of one alternative over another without the use of a scale from the user. The problem with this approach is that it seldom reaches a decision and among all MCDM it is the most difficult to implement(Dyer et al., 2005). While Multiple Attribute Utility Theory (MAUT) is seen as the simplest approach for combining several preferences in the form of multiple attribute utility functions. In this approach, the utility function for each criterion is merged with weighting functions of

criteria(Dyer et al., 2005).When dealing with issues of multi-criteria with a small number of obvious alternatives, Analytical Hierarchical Process(AHP) and Multi-Attribute Utility Theory(MUAT) can be used to solve this problem

In situations where there are a large number of alternatives, multiple criteria optimisation technique can be applied. These techniques are classified into evolutionary-based and non-evolutionary based approach. The evolutionary based approach is based on Pareto solution, which adopts an economic concept whereby it is applied in conditions when a better value for an attribute is attained only when the value of at least one of the attribute gets worse(Wilson, 1972).In Figure 2.8 a taxonomy of service selection methods is illustrated.

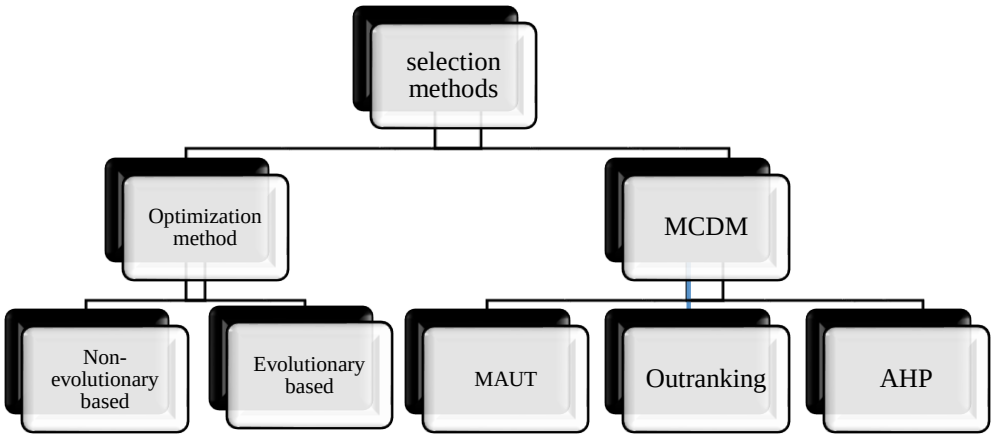


Figure 2.8: Taxonomy of Web Service Selection Method

In the following section, a detailed explanation of the Analytical Hierarchical Process (AHP) as a multi-Criteria Decision Method is explained. The steps involved in decision making is illustrated in Figure 2.9

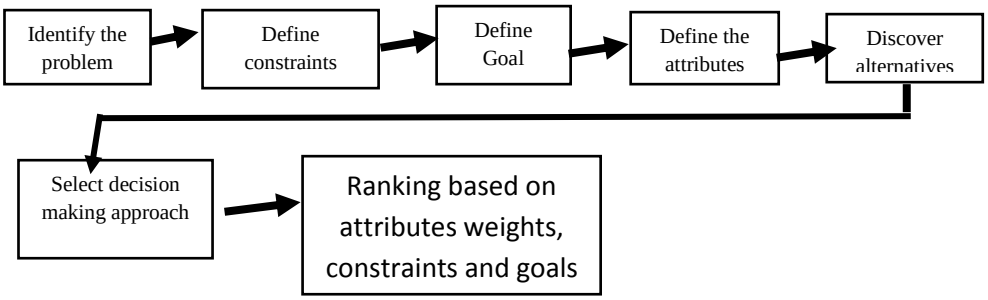


Figure 2.9: Decision Making Process

Analytical Hierarchical Process(AHP)

The AHP approach was proposed by (Wind and Saaty, 1980) as a type of MCDM algorithm. This approach is most widely used compared to other MCDM. It is generally based on three important phases which are: Problem decomposition, comparative judgement and priority synthesis. The first phase which is the problem decomposition stage consist of distributing the problems in a form of hierarchy as shown in fig 2.11. The next phase is the comparative judgement which is based on pairwise comparison as shown in Table 2.1 of each criterion by asking the decision makers to judge how important is criterion P1 compared to criterion P2. The answer to this question determines the weight assigned to each criterion. In the final phase, a sensitive analysis is carried out whereby each alternative solution is combined with the relative identified rank to generate the overall ranking. Furthermore, the important contribution of the AHP approach is the ability to convert subjective assessment of relative importance to measurable values or weights and the ability to perform consistency checks of an acceptable value of CR < 0.1.

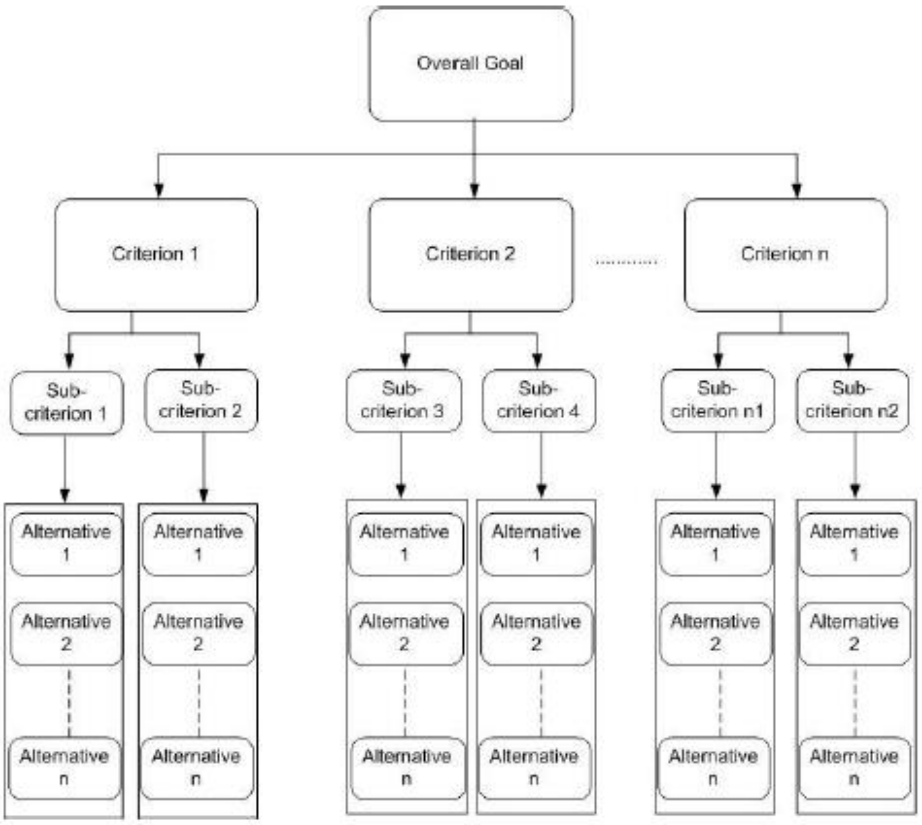


Figure 2.10 AHP Hierarchy Structure

Fig 2.10 depicts a representation of AHP hierarchy which is differentiated in four layers. The first layer represents the overall goal which describes the problem along with the objective. The second layer represents the description of the criterion which affects the decision process. It is important that there is no defined number of criterion to be used in the AHP process but the more the number of criteria the more complex it becomes to process. The third layer represents the sub criterion; this is optional depending on the type of comparison. The final layer describes the alternatives. Alternatives describe all possible solutions, such as when selecting a particular cloud service offering all service providers providing that product would be presented as alternatives(Saaty, 2008).

Table 2.2: Pairwise comparison

Scores	Relative importance value
1	Equal importance
3	Somewhat more important
5	Definitely more important
7	Much more important
9	Extremely more important

The pairwise comparison method as illustrated in Table 2.2. Each cloud service (or alternatives) is matched head-to –head (one-on-one) with each of the other services. A score of (1-9) is assigned based on the degree of importance of one service attribute over another. The service with the highest score is declared the best.

2.5 Ontology

Ontology can be defined as a formal representation of knowledge as a set of concepts and the relationships between one another within a certain domain. It also consists of hierarchical definitions of vital concepts within a domain and the description of the properties of each concept. They are used for effective knowledge sharing and its reuse. Suitable terminologies and semantic properties are usually expressed in the form of ontologies(Gruninger and Lee, 2002, Gruber, 2008). In addition, ontologies are used to address three major tasks which are: to accomplish interoperability, The facilitation of communication between software systems and to assist in communication between humans(Jasper and Uschold, 1999).

2.5.1 Ontology Components

To ensure interoperability between ontologies, a general structure is being adopted regardless of the language used in the ontology build-up. There are basic ontology components and concepts that make up an ontology as described below(Zeshan and Mohamad, 2012, Gruber, 2008)

1) **Individuals**: Individuals or instances represents the object associated with the domain. For example, in this research study, the individuals represent the cloud services offered by the cloud service providers.
2) **Classes**: Ontology concepts can be represented in classes and sub-classes.
3) **Properties**: There are two types of properties in an ontology which are object properties and data properties. Object properties describe the relationship between classes while the data properties describe the data relationship with the classes.
4) **Relationships**: This can be described as rich relations among concepts example is a child class and a parent class.
5) **Axioms**: They are used to provide a means of adding logical expression to ontology. This logical expression can further be used to refine the concepts and relationships in an ontology.
6) **Consistency check**: checking the consistency of an ontology is very vital as it helps detect inconsistencies such as duplication of individuals which may lead to reducing the importance of the ontology.
7) **Consistency**: This means that the ontology parts e.g. classes and concept and their relationships agree with each other.
8) **Restrictions**: These are associated with properties and they are used for verifying inputs
9) **Domain coverage**: This signifies the exact domain the ontology is covering such as cloud service discovery, recommendation and cloud resource management.

10) **Preciseness**: This means the axioms, relations and restrictions are involved in the built ontology.
11) **Events**: They spot the changing of attributes or relationships
12) **Automation**: This refers to a way of constructing an ontology. There are three ways which include manual, semi-automated and automated.

In the next section, the existing cloud service adoption techniques from previous research is explored.

2.6 Investigation of existing cloud service adoption techniques

In recent times, many researchers have proposed, designed, developed and implemented cloud frameworks and systems that allow users find suitable services that meet their requirement. While some have developed algorithms for resource management, others use ontology models to represent cloud services and to perform process matching between object and data properties of cloud service attributes in a bid to meet users' requirements (Chang et al., 2012, Ali et al., 2014). Ontologies can be defined as a "formal explicit specification of a shared conceptualization" (Gruber, 1993, Studer et al., 1998, Kang and Sim, 2011b). They are useful for information retrieval to deal with user queries as they contain a set of concepts on the domain and the relationships between these concepts (Reshma and Balaji, 2012). In addition, ontologies are known to have three important applications as follows: To enable the communication between software systems, to facilitate interoperability and to aid the communication among humans (Jasper and Uschold, 1999, Maedche, 2012).Furthermore, the challenges associated with traditional search tools as well as matching between user requirement and advertised services by providers can be eliminated through ontologies and semantic technologies(Lupiani-Ruiz et al., 2011). It is important in the area of information integration as seen in the work of (Wang et al., 2006), Knowledge management (Colomo-Palacios et al., 2010), Information

retrieval and question answering (Valencia-García et al., 2008) and Recommendation (García-Crespo et al., 2011).

Presently, most cloud service ontologies are general with little or no detailed work on each cloud services (Androcec et al., 2012).Although the work of (Youseff et al., 2008), presents a unified view of cloud computing representing its components and their relationships. Due to the rise in the number of service providers rendering similar services, there has been a continuous research towards distinctively understanding the different layers of this services, their attributes, and relationships, functional and non-functional properties. The work of (Rimal et al., 2009) presents a tabular representation of survey findings of cloud services, thereby comparing the offerings of services provided by major service providers in each service layer IaaS(Amazon web service, GoGrid, Flexiscale, Mosso) PaaS and SaaS (GoogleApp Engine, Azure, force.com, GigaSpaces). Also (Höfer and Karagiannis, 2011) propose a taxonomy of comparison of cloud services providing detailed characteristics in a hierarchical form using common terminologies associated with each layer as a baseline for information and communication. The authors (Weinhardt et al., 2009) classified cloud services based on pricing of complex services as well as security and reliability. While a framework for ranking cloud services by evaluating cloud offerings and ranking them based on their ability to meet users quality of service requirements is proposed by (Garg et al., 2013). Our work complements these previous works in the area of cloud service information gathering, classification and utilisation of service ranking tools toward meeting user requirements.

An ontology enhanced cloud service discovery system is proposed by (Han and Sim, 2010) the system enables users to select cloud services providers based on the provided ontology. The work of (Tahamtan et al., 2012) proposes an ontology based discovery of cloud providers with a range of querying possibilities on different cloud service layers. Cloud service provider resource management ontology is proposed by (Ma et al., 2011)

while the work of (Fortis et al., 2012) propose an ontology that relates to service lifecycle and cloud governance. The work of Han et al (2009) focuses on the ranking of available service providers using a statistical approach. The Authors, (Ali et al., 2014) claimed that their ontology is much better in the aspect of querying possibilities and more comprehensive with respect to other works where the three cloud service layers SaaS, PaaS, IaaS have been considered as it can be used in discovery of cloud services as well as resource management in more complex and comprehensive manner.

This study is complementary for existing cloud computing works as it proposes a framework that can be used for cloud service discovery, knowledge management and service ranking specifically for SME adoption of cloud services.

2.7 Conclusion

In this chapter, the concepts, background and methods of service adoption techniques have been discussed. Also, investigation of the importance of SMEs in different countries and classification of cloud service concepts have carried out. In addition, the classification of systems that enable each phase of service selection process in the context of Grid and SOA towards cloud service adoption was done. This has led to the understanding of the processes adopted in other cloud service adoption paradigm. Also, the literature reviewed have identified the possible methods that can be adopted in the architectural build-up of this research. Again, the literature reviewed further identified the limitation of existing approaches and research Gaps to be filled.

In the next chapter, the research methodology adopted to address the objectives of this research is discussed.

Chapter 3: Research Methodology

In the above sections, the main context in which this thesis is built upon and the background in terms of literature reviewed have been discussed. This chapter aims to identify and discuss the research methodology that is adopted to address the research objectives identified in chapter 1.

3.1 Research Methodology

This chapter details the research methodology adopted in this thesis, which is aimed towards adopting a framework to address the slow adoption of cloud services by SMEs in Nigeria. Furthermore, the research methodology helps to address the research objectives and research questions (described in section 1.4 & 1.6) respectively.

There are several research methods incorporated to achieve the research methodology in this thesis. First, was to determine the state-of-the –art in representing cloud service adoption techniques, evaluating the quality of work done and the nature of various approaches adopted. To achieve this, a Systematic Literature Review (SLR) was conducted. Consequently, this enabled the understanding of the research gap in cloud service adoption.

Second, was exploratory in nature as the objective was to understand the reason for slow adoption of cloud services by SMEs in Nigeria. This was done by investigating if the variables for slow adoption identified in the literature review stage of this research are similar to those in Nigeria and if there are any other identifiable variables specific to Nigeria's slow cloud service adoption (Carcary et al., 2014, Alshamaila et al., 2013). To achieve this, a mixed method data gathering approach was adopted at this stage which is the primary data gathering stage and in subsequent stages of this research (Rossman and

Wilson, 1985, Creswell and Clark, 2007, Jick, 1979).This includes quantitative (survey) and qualitative (Focus Group Discussion).These data gathering methods were carried out by adopting a stakeholder approach to establish the challenges leading to the slow adoption of cloud services by Nigerian SMEs. This is because the views expressed by stakeholders within the SMEs are quite vital. The stakeholders in this research context are either the SME owner or manager. The Focus Group participants brainstormed on elucidating, sorting, analysing and deliberating on the key challenges of cloud service adoption specific to Nigerian SMEs identified in the survey stage towards the framework design. Again, to tackle the issue of complex comparisons associated with cloud service selection which is a Multi-Criteria Decision Problems, a group interview(qualitative) was conducted using dyadic interview method (Morgan et al., 2013, Kendall et al., 2009). Present in the group interview was five SME managers who showed good knowledge of cloud services during the Focus Group Discussion stage of the research. They were randomly selected to prioritise service provider quality of service requirements identified in the primary data gathering stage using pairwise comparison scale. Also, to address the issue of rank reversal associated with the AHP ranking method, this research proposed the introduction of rational relationships for cloud service ranking.

Thirdly, the system development stage adopts a meth-ontology approach (Fernández-López et al., 1997, Corcho et al., 2005). This method is based on the idea of software engineering which defines a set of tasks to be performed for developing a consistent and complete conceptual model. It can be described as a comprehensive ontology method as it describes the building-up of ontologies either from scratch, reusing of other ontologies or by the process of re-engineering them. The method adopts a framework which consists of the identification of the main ontology development process activities such as conceptualization, integration and implementation. Furthermore, the method identifies the steps for performing activities, the techniques used for driving concepts, the outcome

and their evaluation(Cristani and Cuel, 2005). Also, this method does not focus on post development process. This method was adopted for the system development phase based on the aforementioned reasons.

Finally, the proposed framework is implemented using an ontology editor protégé(Knublauch et al., 2004, Gennari et al., 2003). The semantically developed cloud service ontology acts as a Decision Support System (DSS) within the proposed framework. The DSS can be used to address the dynamic needs of SMEs requirements when consulted. It promotes service ranking, cloud service knowledge management and cloud service recommendation towards cloud service adoption decision making by Nigerian SMEs. The evaluation of the proposed framework was performed using construct validity method by comparing the system output with the case study of service provider offerings as well as the assigned priority standards identified in the prioritisation phase of the framework in view of validating the completeness of the framework. Also, the stage 4 data gathering was quantitative as evaluation surveys were performed based on user opinion evaluation using a survey based on Technology Adoption Model, expert opinion evaluation(survey), comparison with internationally identified standards (ISO/IEC 25010:2011), researcher opinion evaluation by comparing cloud service ranking approach with other Multi-criteria Decision Ranking Methods using Technology Acceptance Model.

The following section 3.2 describes how the SLR was conducted. Section 3.3 presents the quantitative and qualitative data gathering methods 3.4 presents the data gathering stages. The summary of the research methods used to carry out this thesis is presented in section 3.5.

3.2 Systematic Literature Review (SLR)

To attain the objectives of this study, the research methodology was identified, an analysis and summary of all published approaches over the last two decades that have been proposed or used in addressing the issue of the slow adoption rate of cloud services by SMEs were performed. To achieve this, a systematic literature review (SLA) was conducted. A systematic review is a rigorous method and well-defined method to identify, examine, evaluate, synthesise and interpret the available evidence concerning a particular technology in view of understanding the current direction and status of research or to provide a background in order to identify research challenges (Kitchenham and Charters, 2007). This method was adopted because its approach gives the researcher an avenue to have a credible, repeatable and fair judgement of the available studies on identifying cloud service adoption techniques for SMEs. In this research study, the guidelines for SLRs as outlined in (Kitchenham and Charters, 2007) was followed. This comprises of three main phases: (1) Planning the review; (2) Conducting the review, and ;(3) Reporting the review. Figure 3.1 illustrates the stages of SLRs.

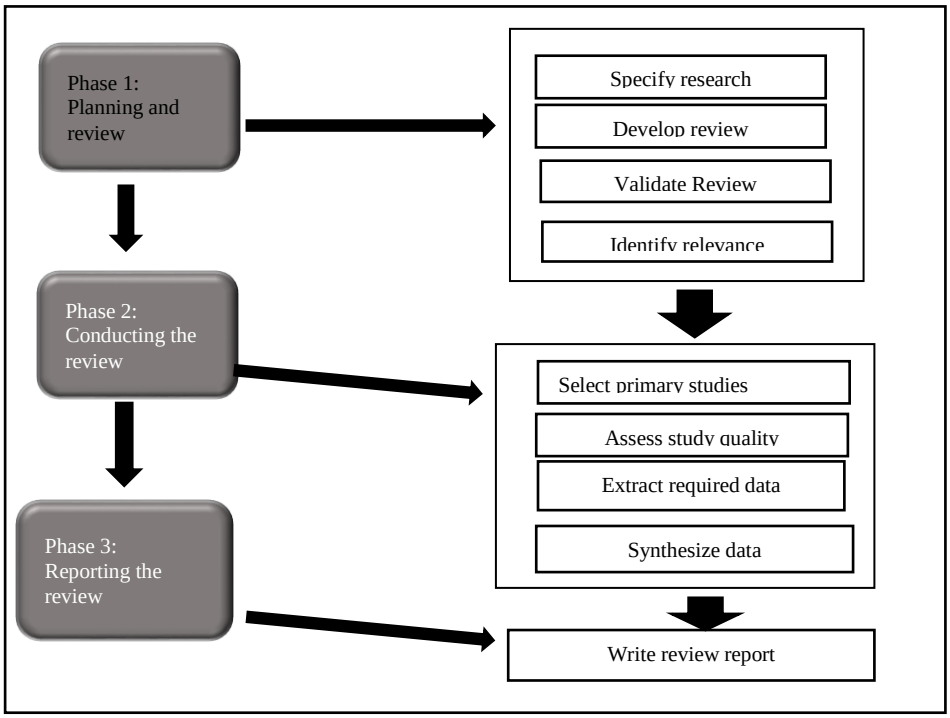


Figure 3 1 Systematic Literature Review Process

3.2.1 SLR Review Protocol

An important step of the systematic literature review process is the development of a protocol (Fig 3.2). This protocol presents all the background and procedures used by researchers to ensure that bias is neutralised, the threat to validity is minimised and rigour is achieved while conducting the review. The review protocol is one of the distinctive aspects that differentiates SLRs when compared to the traditional method of a literature review. The systematic review protocol begins by defining the research questions to be answered, followed by the search strategy process adopted in identifying the primary studies (Sections 3.2.3). This is followed by defining the inclusion and exclusion criteria

which were developed to determine a systematic approach for selecting among the identified reviewed literature (Section 3.2.4). The quality assessment criteria for primary studies are then defined (Section 3.2.5). Finally, data elements are extracted and synthesised to help answer the research question through an identified procedure (Section 3.2.6).

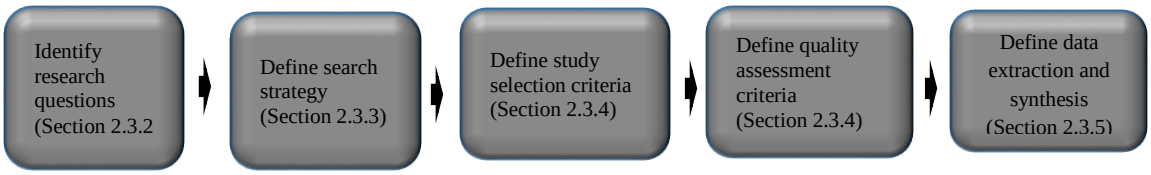


Figure 3 2 SLR Review Protocol

3.2.2 Research questions

SLR.RQ1: What techniques have been proposed to represent cloud service adoption?

SLR.RQ2: What is the quality of research conducted in the approaches reported?

SLR.RQ3: What is the context and areas of research of these identified studies employing cloud service adoption techniques?

SLR.RQ4: What is the limitation of existing techniques in relation to cloud service adoption?

SLR.RQ1 is motivated by the need to describe the state-of-the art on the existing techniques adopted by researchers to represent cloud service adoption. While SLR.RQ2 was designed to understand the general quality of research conducted towards cloud service adoption. SLR.RQ3 was formulated to help understand the application of each reported approach and to identify if there is any reoccurring procedure in different techniques while aiding researchers to navigate through the reported approaches. Again,

SLR.RQ4 is designed to provide a general overview of existing gaps in the area of service adoption techniques in order to provide a direction for further research.

3.2.3 Search Strategy

To answer the four SLR questions, a search string was constructed to help in identifying the relevant primary studies following the guidelines of (Kitchenham and Charters, 2007). The guidelines are as follows:

- To derive main terms from the topics being researched and research questions;
- Determine and include synonyms, related terms and alternative spellings for major terms;
- Check the keywords in all relevant papers researchers have already identified and those returned using initial searches from relevant databases;
- Include other relevant terms that increase the possibility of identifying further related material to the topic;

Incorporating the use of logical operators such as Boolean "OR" and "AND" to link alternative spellings and to join synonyms or phrases to create a search string.

Following the construction of various search strings using the guidelines listed above and conducting a series of test searches in diverse digital libraries and analysing the outcome, the following search string was conducted

<< Variability AND (Technology service OR Technology services OR Technology product Type OR Technology product types) AND (Variability OR Knowledge Management OR Variation Model or Future Modelling) AND (Tool OR Tools OR Approach OR Approaches, Method OR Methods)>>

The primary studies were conducted by searching 10 digital data sources (1.IEEExplore; 2.Citeseer; 3.SpringerLink; 4.Scopus; 5.Google Scholar; 6.ScienceDirect; 7.Scopus; 8. DBLP; 9. EBSCOhost E-journal Services; 10. ACM Digital Library.

In a view of establishing inclusiveness, the results were compared with related literature the researchers had established to be of high importance, all the papers compared were included in the identified primary studies. Papers that were inaccessible online were requested from the relevant authors via email.

As an additional measure, a manual search was conducted on different sources where cloud service adoption researchers were not able to publish their findings, the manual search process includes conferences and workshops. Papers published between 2005(i.e., when "cloud computing" in its modern sense was first mentioned in a Compaq international document and its popularisation in 2006 when Amazon.com introduced its Elastic compute cloud) up till Jan 2015 inclusive (when the research stage of this study was completed) were searched. Furthermore, besides the limited number of peered-reviewed publications for data analysis, the researcher attempted to acquire identified tools, in instances where tools weren't available for download or use online. The authors were contacted. The manual search covered but was not limited to the proceeding of the following conferences and workshops:

ICCC (International Conference on Cloud Computing)

ICOMP (International Conference on Internet Computing)

FICLOUD (International Conference on Future Internet of things and Cloud)

CLOSER (International Conference on Cloud Computing and Service Science)

MCS (International Workshop on Mobile Cloud Computing and Services)

DATACLOUD (International Workshop on Data-Intensive Computing in the Clouds)

MESOCA (International Workshop/Symposium on the Maintenance and Evolution of Service –Oriented and Cloud Based systems)

ESOCC (European Conference on Service-Oriented and Cloud Computing)

MDHPCL (International Workshop on Model-Driven Engineering for High Performance and Cloud Computing)

Finally, to complete the search strategy, forward and backwards reference checking ("Snowballing) was carried-out on the identified primary studies. Citations of the primary data identified that could be relevant to the review were found using search engines (forward reference checking). While the reference lists of the primary studies were checked for the likely relevant studies missed (backwards reference check).

3.2.4 Search Selection

This section explains the selection process and lists the criteria for inclusion and exclusion with their justifications.

- **Inclusion Criteria (IC)**

IC1: The primary study is peered-reviewed, scientific paper rather than a PowerPoint presentation or an extended abstract paper. This is because a paper that is not peer reviewed might be biased and this can mislead the researcher.

IC2: The primary study proposes a technique for cloud service adoption. This is to enable the researcher to identify the limitations, strength and research gap in cloud service adoption techniques.

IC3: When several reports of the same study existed in different sources, the most complete and recent version of the study was included in the review. This is

because focusing on earlier work will not be beneficial as the most recent published paper supersedes the previous ones.

IC4: The paper was written in English. This is to avoid issues of misinterpretation of intentions and facts. The researcher is not conversant with other languages and this might require the need of a third party.

- **Exclusion Criteria(EC)**

EC1: The primary study does not address a technique for cloud service adoption for SMEs. It is of no significant importance including papers that will not add any value to the research area because a research paper on large companies may not address the issue related to SMEs.

EC2: The primary study is short (less than 3000 words), a symposium paper, keynote, PowerPoint slides, poster presentation or a lecture note. This will not give adequate information on the methodology used, findings, strength and weaknesses and may lead to misinterpretation of keywords.

EC3: The paper was published before January 2005 and after February 2015.For the earlier date (January 2005) this was because cloud computing came into light around this period, although it was observed that publications on cloud services started around 2008. In essence, 2005 was picked because there might be earlier papers. The end date (2015) was chosen because the literature review phase of this research came to an end. However, other published peer reviewed papers after January 2015 were considered.

EC4: The primary study addresses cloud services but not cloud service adoption techniques. This was in view of limiting the primary study to address the research aim. Also, due to the generic nature of their findings.

The findings from different initial searches covering digital libraries, manual searches, and the works of known authors, produced 612 papers. After the initial screening of the papers abstracts, irrelevant papers (not addressing cloud service adoption technique) were excluded by one researcher, while 102 publications were selected. The full papers were then sorted and were subject to more detailed review whereby in each case a paper was thoroughly checked. 56 publications were selected through discussions based on the level of importance of the paper to the research topic. Finally, after considering the inclusion and exclusion criteria, a thorough discussion and voting in situations where there were disagreements, led to the exclusion of 59 papers and the inclusion 43 papers. The study selection process is summarised in Figure 3.3.

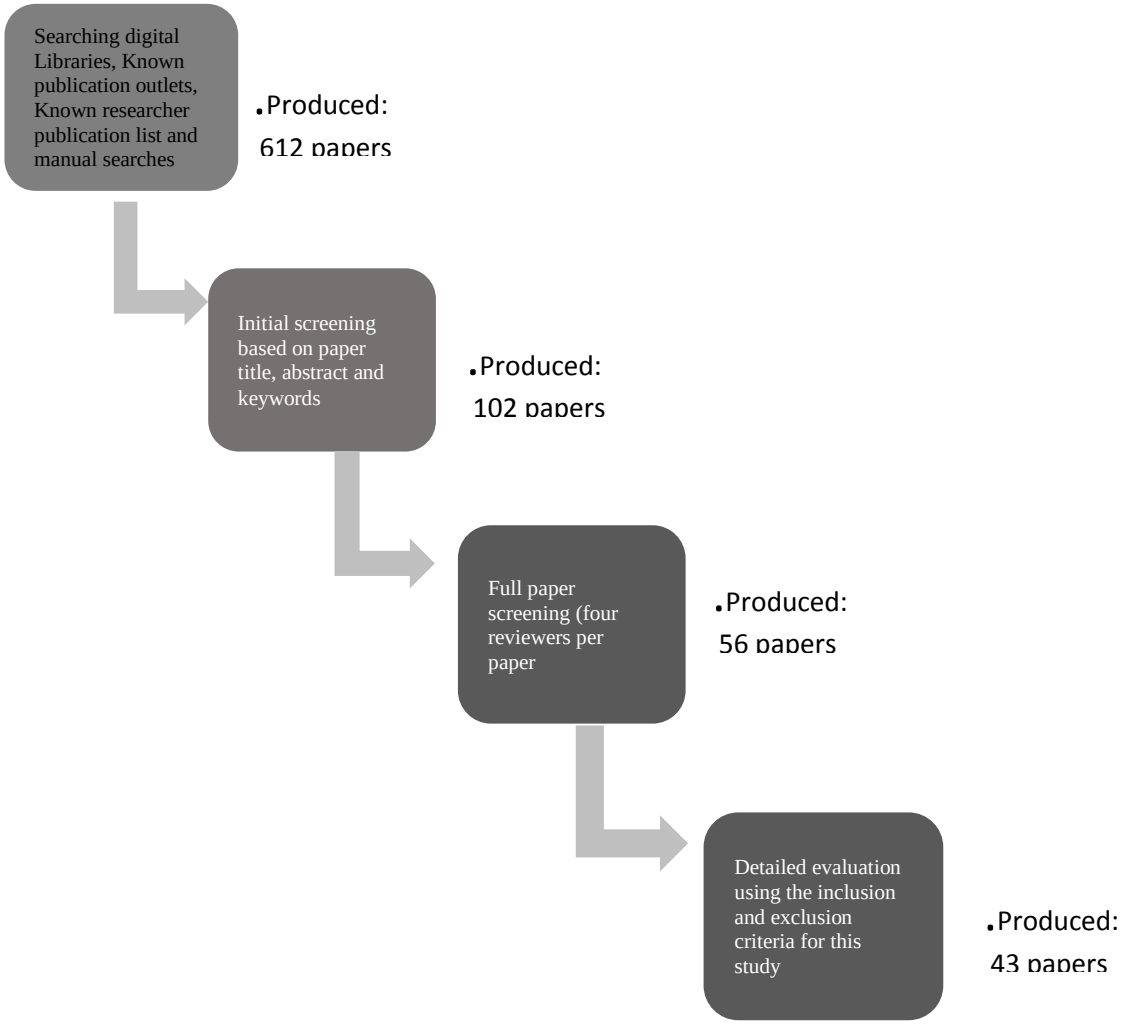


Figure 3.3 Search and Selection Process

3.2.5 Quality Assessment Criteria

The quality of the selected papers for this study was assessed based on the assessment strategy defined by (Kitchenham and Charters, 2007). A ternary scale was used to judge the reviewed studies on each element of the quality assessment criteria as presented in Table 3.1. The ternary scale consists of three-way judgement scale with each having a score of 1(Yes), 0.5(Partial) 0(No). This assessment method guided the researchers by providing a flexible approach to answer questions that were difficult to judge. Especially in situations where the author gave little information, the quality assessment questions were still considered. After the allocation of scores to questions, an aggregate score was assigned to each study. This data was also used to answer RQ3 discussed in chapter 4.

Table 3.1: Quality Assessment Criteria

QA(Quality Assessment)	Questions
QA.Q1	Is there a rational for why the study was undertaken?
QAQ2	Is there satisfactory description of the context (e.g. industry, laboratory settings, product used, etc.) in which the research was carried out?
QAQ3	Did the paper present enough details about the cloud service adoption technique to enable the researcher conduct the required analysis?
QAQ4	Did the paper present an evaluation of the tool? If yes, did it include feedback from the end users?
QAQ5	Are there substantive claims in the paper supported by reliable evidence?

QAQ6	Did the authors compare and evaluate their own results against related work?
QAQ7	Did the authors discuss the credibility of their findings?
QAQ8	Are limitations of the study discussed explicitly?

3.2.6 Data Extraction and Synthesis

The next step on completion of the search, selection and quality assessment step is the data extraction step. In this section, data extraction was carried out on the selected 43 primary studies using a data extraction form as shown in Table 3.2. The Table shows the mapping of the data extraction process in relation to the SLR questions they help to answer. Following the data extraction form information relating to the paper synopsis (DE.Q5). Also, to define the approaches identified elaborately, based on diverse techniques (DE.Q8) and the limitations of the identified approaches (DE.Q10). Information was gathered as much a possible at the same time data was kept as concise as possible in order to avoid the influence of a taxonomy or classification or adoption approach on this research work. The data extraction form is presented in table 3.2.

Table 3.2: Data extraction form

Data Fields	**Related Concerns/Research Questions**
DE.Q1 Paper title	Documentation
DE.Q2 Year of publication	Documentation
DE.Q3 Type of publication (e.g. Journal, conference Etc.)	Reliability of review
DE.Q4 Publication outlet (Conference name etc.)	Reliability of review
DE.Q5 Brief description (synopsis)	SLR RQ1
DE.Q6 Research context (e.g. Industry, academic, etc.)	
DE.Q7 Research Area (e.g. Cloud services adoption approach)	SLR RQ2,RQ4
DE.Q8 Proposed approach for representing variability in Cloud service adoption technique (Knowledge management, MCDM) and an example if possible)	SLR RQ2
DE.Q9 Relevance (Research/Practice/both)	SLR.RQ3,RQ4
DE,Q10 Research limitations as reported in the paper	SLR RQ4

3.3 Data Gathering Method

The primary data gathering for this research requires the assessment of different forms of data collection and analysis within a general methodological framework. There are two major methods available for researchers to use: quantitative and qualitative. However,

researchers often employ a third approach which is the mixed method design. In general, quantitative research method deals with numerical aspects of the phenomena under study, while a qualitative method is specific for producing narrative or textual descriptions of the phenomena under study (VanderStoep and Johnson, 2008). In a quantitative research method, different techniques are used for collecting and analysing data, while, in a qualitative method, the researcher is the primary instrument for collecting and analysing data (Creswell and Clark, 2007). The advantages and disadvantages of each method as well as the criteria for selection in an appropriate research design are shown in Table 3.3.

Table 3.3: Characteristics of Quantitative and Qualitative data gathering methods (Vanderstoep & Johnston, 2007).

Characteristics	Quantitative	Qualitative
Type of data	Describes the phenomena in numeric form	Describes the phenomena in narrative form
Analysis	Statistics are descriptive and inferential	Identifies major themes
Scope of inquiry	Specific questions or hypotheses	Broad, thematic concerns
Primary advantage	Large sample, statistical validity, accurately reflects the population	Rich, in-depth, narrative description of sample

Primary disadvantage	Superficial understanding of participants' thoughts and feelings	Small sample, not generalised to the population at large.

3.3.1 Mixed Methods Research Approach

Some researchers believe that quantitative and qualitative data gathering techniques are basically opposed in nature, while others are of the opinion that they represent different ends of the same continuum(Newman and Benz, 1998). Based on the second view, a mixed method can be perceived to comprise of the whole continuum because it integrates the elements of qualitative and quantitative methods (Creswell and Clark, 2007). A mixed method approach combines both quantitative and qualitative research methods to understand a research problem. The ability of the mixed method approach to associate with both qualitative and quantitative gives it several advantages. These advantages include the opportunity to confirm results from each method through triangulation of data and richer information can be extracted to enable the research analysis and outcomes. The mixed method approach is increasingly adopted by researchers as an approach that has the ability to broaden the range of any research as well as deliver stable results for the themes under investigation(Creswell and Clark, 2007). Factors that promote the adoption of a mixed methods approach are as follows:

- The use of mixed method approach increases the validity of the study based on triangulation of data. This increases the validity and data interpretation, showing different aspects of a phenomenon(Greene et al., 1989).

- A mixed method research permits the use of an exploratory inductive procedure that begins with empirical evidence of a particular phenomenon and is followed by a level of abstraction, theorization, generalisation and deductive information confirmation(Rocco et al., 2003).
- The utilisation of quantitative data may provide the researcher with numerical answers to the research question, however, there is need to understand the factors that are more relevant to the study.
- A two-way approach can increase the depth and breadth of result inquiry and interpretation, also reduce the effect of inconsistency in qualitative and quantitative findings(Rocco et al., 2003).

Based on these advantages, this research adopts a mixed method approach by integrating qualitative methods. The research design of this thesis involves the survey with Small and Medium Sized Enterprise (SMEs) managers as a tool for quantitative data collection and focus group discussions and group interviews with selected SME managers with knowledge of cloud services. The combination of the methods allows better support for the result and conclusions(Östlund et al., 2011) in understanding the challenges that cause the slow adoption of cloud service by Nigerian SMEs.

3.3.2 Quantitative Approach

Quantitative research method enables the measurement of the relationships between variables towards arriving at a valid and objective description of an issue(LeCompte and Goetz, 1982). It focuses on behaviours that can easily be measured, it enables researchers to collect data that using large samples to generate principles that can be used to reflect a larger population(Boynton and Greenhalgh, 2004). Objectivity is ascertained by minimising the interaction between participants, therefore the interpretation of the result does not promote the researchers personal bias(Newman and Benz, 1998). Data generated

from quantitative approach can be analysed based on descriptive or inferential statistics to test hypotheses in view of determining if significant responses or relationships exist(Teddlie and Tashakkori, 2009).In addition, based on the fact that quantitative questionnaire answers are usually pre-coded, they lack the gravity and vision of a qualitative study(Östlund et al., 2011). Developing standard questions by researchers can produce structural bias and false representation. Also, information gathered may not necessarily replicate how people feel about a subject. Again, the questions asked by the researcher needs to be carefully constructed and worded eliminating any redundancy. It needs to be very clear, should directly reflect the research objective and also address each point at a time(Dörnyei and Taguchi, 2009).

This research adopted survey as the quantitative approach because it can be used to determine quantitative data capable of statistical analysis through direct questions. The survey was widely distributed among the target population (SME managers). The aim of the survey was to investigate if the reason for slow adoption of cloud services in other parts of the globe, as identified in the literature review stage of the research is similar to that of Nigerian SMEs or there are other specific reasons for slow adoption of cloud services by Nigerian SMEs.

3.3.3 Qualitative Approach

Unlike a quantitative method, qualitative approach explores the views of respondents through a detailed description of their actions as well as the grounded knowledge of the richness of meaning associated with their observable behaviour(Teddlie and Tashakkori, 2009). Qualitative research allows researchers collect data through interviews or observations in form of written or spoken words, actions and visual images. The magnitude of the outcome of data retrieved from qualitative approach is perceived to have great strength in terms of richness, exploration and description(Östlund et al., 2011).

Again, qualitative research is concerned with words rather than numbers. The main characteristic features of a qualitative approach are:

- It is associated with constructivism, which implies that social properties are an outcome of the interactions between individuals(De Jaegher et al., 2010).
- It has an inductive perspective of the relationship between theory and research.
- It stresses on understanding the social world through examination of the interpretation of that world by study participants.
- It contributes ideas to the researcher (Newman and Benz, 1998).

This approach allows researchers to create new concepts as part of their data analysis and also derive conclusions based on interpretation. Some researchers are of the perspective that qualitative analysis has some shortcomings based on the fact that data are not tested to verify if the results are statistically significant or they occur by chance(Boynton and Greenhalgh, 2004).

This research uses focus group discussion and group interview as part of the qualitative approach in the data gathering stage and the prioritisation phase of the proposed ontological frame work. The focus group discussion aimed at investigating the perception of SME managers on the reason for slow adoption of cloud services for their business process. The group interview was carried out by those SMEs who showed good knowledge of cloud services in the assigning of weights to service provider offerings in the prioritisation phase (Phase 2) of the proposed framework design.

3.4 Data Gathering Stages

This thesis aims to develop a framework of cloud service adoption to meet the needs of Nigeria's SMEs. With this purpose in mind, it is important to first understand the

perception of Nigerian SMEs towards cloud service adoption. This is to understand if the reason for slow penetration of cloud services identified in the literature review section of this research is also experienced by Nigeria SMEs or if there are specific or additional issues causing the slow adoption of cloud services by Nigeria SMEs. Therefore, the empirical research in this study was conducted in four stages using appropriate research methods. In this part of the chapter, the various options used for data collection and analysis according to the needs and objectives of each stage of the study are discussed.

3.4.1 Procedure and Objective of each Data Gathering Stage

Stage 1 and 2 of the research data gathering were developed to understand the reason for slow adoption of cloud services by SMEs in Nigeria. The two stages are carried out with first a quantitative survey where SME owners are handed questionnaires based on closed ended questions (Appendix ii) and this is discussed in chapter 5(Section 5.4). The second stage of data gathering was qualitative, where SME managers brainstormed on the results confirming, analysing, expanding and reflecting on the findings from the first stage based on focus group discussion(Appendix iii) and discussed in chapter 5(Section 5.5). The third stage of data gathering was qualitative, using group interview of SME managers who showed vast knowledge of cloud service in the second stage of data gathering to assign weights to cloud service provider offering (Appendix iv) using pairwise comparison chapter 2 (Table 2.2) in the prioritisation phase of the framework development in chapter 6(Section 6.3). The fourth stage of data gathering was carried out based on a quantitative approach using survey methods (Appendix v, vi, vii) in the evaluation and validation of the proposed framework using SME managers, IT experts in information system and software application domain and PhD researchers respectively as respondents, this is discussed in chapter 8(Section 8.3).

After the finalisation of the research methodology, approval for carrying out the research on cloud service adoption by SME managers in Nigeria was obtained from the University of East London Ethics Committee. Details of the ethics approval are shown in Table 3.4.

Table 3.4: Ethical Approval

Application Date	Ethics approval purpose	Ethics approval Clearance Date
23/12/13	Data gathering from SMEs in Nigeria based on cloud service adoption	22/1/14

3.4.2 Research strategies for data gathering stages

There are numerous strategies within the qualitative, quantitative, and mixed method approaches that can be combined in various phases of a study(Bryman, 2006). However, every strategy has its advantages and disadvantages(Creswell and Clark, 2007) as shown in Table 3.5.

Table 3.5 Background of Research Strategies

Strategy	Approach	Main features
Experimental	Quantitative	Confirms if a specific action influences an outcome. Often used in laboratories and areas where measurements are recorded. It is also termed field experiment when dealing with groups or singles. **Advantage:** Variables are in small numbers which can isolated and intensively studied **Disadvantages:** May be limited in terms of generalisation.

Survey	Quantitative	Provides numeric description of trends or opinions of a population based on sampling. **Advantage:** The study result can be generalised from a small sample to large population. **Disadvantage:** Research bias may occur if respondents give correct responses.
Ethnographic	Qualitative	Focuses on the study of individuals' life based on stories. Uses conversation analysis and other techniques. **Advantage:** Provides in-depth knowledge of human life. **Disadvantage:** It is time consuming at data collection stage and difficult to generalise from one study.
Case Study	Qualitative	Study of events, activity or individuals. **Advantage:** Time –sensitivity for data collection, more realistic for qualitative research, can analyse more variables per study. **Disadvantage:** Focuses on one event therefore it limits the generating of a unified model.
Phenomenological	Qualitative	Focus on the phenomena described by study participants. Develops relationship patterns through understanding live experiences. **Advantage:** Helps to identify what and how questions to determine topic boundaries. **Disadvantage:** Understanding of phenomena due to variation in participants make analysis difficult.
Concurrent mixed method	Mixed method	Application of mixed method for comprehensive analysis of a research problem. Different forms of data are collected at the same time and then integrated into a general result. **Advantage:** Small forms of data can be integrated into larger one to provide different forms. **Disadvantage:** A form of data may not support others and there may be lack of relationships under analysis.
Sequential mixed method	Mixed method	Used to elaborate or expand the outcome of one method to another. Quantitative data can be collected and analysed followed by qualitative data (or vice versa) it is used to generalise result to a population. **Advantage:**

		Data can be generalised to a population and offers better understanding. **Disadvantage:** May be time consuming.
Transformative mixed method	Mixed method	This approach uses theoretical lens as central data. **Advantage:** Provides a framework for topics to be researched, methods of data collection or research changes anticipated by the study. **Disadvantage:** This approach needs to adopt theoretical framework as a basis for research process.

Source: (Creswell and Clark, 2007)

The *Sequential mixed* method listed under the mixed method approach in table 3.5, is adopted in the data gathering stages of this research. Stage 1 is focused on understanding the reason for slow adoption of cloud services by SMEs in Nigeria. In this stage, data is gathered quantitatively and it is analysed to understand if the reasons identified in the literature review section of this research are also the same reasons for slow adoption of cloud services by Nigeria's SMEs. In stage 2 a focused group discussion is conducted after the survey stage for the purpose of elaborating, triangulating and expanding the results of the quantitative data to qualitative observation that can aid in generalising the data to the population to provide an in-depth understanding of the result. The analysis chapter (Chapter 5) includes both quantitative and qualitative data analysis. In stage 3, a group interview is conducted following the focus group discussion. The participants of this group interview are those SME managers who showed in-depth knowledge of cloud services. This qualitative approach is performed for weighting cloud service provider offerings in the prioritisation phase of the framework design in chapter 6 (section 6.3). Again, in stage 4, a quantitative approach was followed for the framework evaluation in chapter 8, the proposed framework is evaluated by SME managers who did not adopt cloud service before using the proposed framework to determine if the framework can tackle the slow adoption of cloud services by SMEs in Nigeria.

3.4.3 Stage 1 Data Gathering

Generally, questionnaires and surveys are used by researchers to collect data from a sample population for thorough information on their beliefs, the past and future behaviour(Wright, 2005). The technique is used for identifying and examining patterns emerging from the analysis of variables under investigation. This method includes the development and assessment of variables and the analysis of these variables. A survey research which is done with the size of the target population in mind, a higher range of data collected enhances the generalisation of the study findings(Östlund et al., 2011).

In this stage (stage1), a quantitative survey including closed-ended questions is selected as the data collecting instrument. Questions designed for a pilot survey are proposed first before a pilot study is conducted. Furthermore, the results are analysed to increase the reliability of the survey and establish the main survey design(Bryman, 2006). The pilot survey was conducted with seven SMEs as a pilot study. Adjustments were made to ensure that that the questions are clear enough for valid response to be received.

The survey design (Appendix ii) was design based on the following success criteria and variables using:

SC1: This research adopts the SMEDAN definition of SMEs as defined in chapter 2 (section 2.1.6). Therefore, the following criteria are adopted:

Firms must have an annual turnover of less than 500,000,000 Naira. This is presented in chapter 5 (Fig 5.2). Also, firms must have less than 200 employees this is presented in chapter 5 (Fig 5.3).

SC2: SMEs are classified based on International Standard for Industrial Classification (ISIC) as shown in Table 5.2. Therefore, since SME operate in diverse services, they must

belong to one of the SME classifications as proposed by (ISIC) as presented in chapter 5 (Fig5.4).

SC3: For an SME to adopt cloud computing services, it must be ICT compliant. It must make use of computer hardware and internet services(Li et al., 2011, Kaufman, 2009). Therefore, SMEs must be ICT compliant in their mode of operation this is presented in Chapter 5 (Fig5.5 to Fig 5.7).

SC4: As shown in Table 3.5 mixed method approach helps to expand the findings in a quantitative research by a qualitative method and vice-versa. Therefore, it is important to identify those SME managers with knowledge of cloud service usage. This is presented in Chapter 5 (Fig 5.8 to Fig 5.11).

The final section of the survey was based on variables identified in the literature review section of this thesis as seen in the works of (Carcary et al., 2014, Alshamaila et al., 2013). Which are identifies as:

- V1-Security
- V2-Cost
- V3-Standard
- V4-Data lock-in
- V5-Broadband and bandwidth.

This section of the survey was designed to confirm if the variables listed above also play a role in the slow adoption of cloud services by Nigeria SMEs. This is presented in Chapter 5(Fig 5.12).

3.4.4 Stage 1 Data Analysis

The survey sample size was determined using fisher's formula. After the collection of the survey questionnaire, Data was manually transferred into SPSS (Statistical Package for Social Science) version 17. The analysis of the quantitative data uses descriptive statistics and frequency. It describes the background of the participating SMEs based on how they meet the research success criteria, the consequences of how each variable affects the adoption of cloud services based on the number of respondents. From the result analysis, it was important to have an in-depth understanding of the findings. Therefore, this informed for a qualitative approach (Focus Group Discussion) as it has the capability to elaborate and expand on quantitative data. Therefore, stage 2 data gathering was carried out.

3.4.5 Stage 2 Data Gathering

The focus of this stage is to confirm, expand and reflect on the result obtained in the stage 1 gathering of this research which was quantitative in its approach. Participants were chosen purposively from the SME managers who have knowledge of cloud service from stage 1, also other SME managers who did not participate in the survey were selected in view of having generalisability and validity of the study. Six focus group discussion session was carried out among 7 SME managers representing each category of SMEs in each session one session in each of the six geopolitical zones of Nigeria see (Appendix iii). The participants were asked general questions and specific questions about the survey findings during the focus group discussion. The section describes the method used and the key themes that emerged. The main findings based on the analysis of the themes are presented in chapter 5 (section 5.5).

A sequential explanatory strategy is known for mixed method approach which research with strong quantitative leanings adopt(Creswell and Clark, 2007). In this approach, a

quantitative data is first collected analysed, then the result is built on for a qualitative study. Creswell (2007) states that "*A sequential explanatory design is typically used to explain and interpret quantitative results by collecting and analysing follow-up qualitative data"*. Creswell's suggestion captures the main purpose of conducting this supplementary study using focus group discussion.

3.4.6 Stage 2 Data Analysis

The qualitative data collected from the focus group discussion sessions is analysed based on interpretative technique (Liamputtong, 2013). This technique allows the researcher to code themes investigated in previous stages, or discuss emerging themes from the comments made by the participants. As anticipated, the focus group discussions helped to identify new ideas and findings. From the focus group discussion, new variables emerged such as:

- V6-Interoperability
- V7-Reliability(Trust)

These are discussed in chapter 5. Also, there was the identification of general lack of knowledge in terms of

- Understanding cloud service provider offerings.
- Comparing and ranking cloud service provider offerings.

The issue of Understanding cloud service provider offering can is termed as lack of knowledge management. While the issue of comparing service provider offering is termed at a Multi-criteria decision Problem(Zeleny and Cochrane, 1973), which is a problem faced when making complex comparisons. This informed for 2 additional success criteria's as follows:

SC5 To tackle the issue of lack of knowledge identified in the focus group discussion, The variables identified in the data gathering stage 1 and data gathering stage 2 are compared with the three major types of cloud services to Identify which best tackles the adoption barriers. As knowledge is incremental, SaaS cloud service was seen as the cloud service that best addresses the slow adoption variables as it tackles the issue: cost, interoperability, security, bandwidth and reliability based on SLA. In addition, SaaS cloud service is the most adopted presently by SMEs in Nigeria among those who have adopted cloud service as shown in chapter 5 (fig 5.11). The focus group participant also showed a vast knowledge in SaaS cloud service. Based on these reasons this search is limited to SaaS storage cloud service offerings in view of not further complicating the issue of knowledge gathering as knowledge is incremental. The other cloud service types will be addressed in future works. Based on the above a case study of four major SaaS storage service is presented in chapter 6 (Table 6.1). The SaaS storage cloud service application forms the knowledge base for the proposed CLOUDSME service adoption framework.

SC6: In view of tackle the issue of complex comparison Analytical Hierarchical Process (AHP)(Saaty, 2008) was identified as the multi-criteria decision method that best addresses such problem as seen in the literature review section of this thesis. Adopting this method informs the need for stage 3 data gathering.

3.4.7 Stage 3 Data Gathering

As mentioned above, the AHP method is adopted for the solving the issue of complex comparison identified in stage 2(SC3) of the data gathering. This method requires the weighting of attributes using pairwise comparison table as seen in chapter 2 (Table2.2). To perform the task of assigning weights for the service provider requirement offerings this research adopts a qualitative method based on dyadic interviews. In dyadic

interviews, a small group of participants interact in response to open –ended questions in research(Morgan et al., 2013). This was done via skype with 5 SME managers selected from stage 2 data gathering and representing different categories of SMEs using pairwise comparison table to agree on assigning weights based a democratic approach. This weighting method was used to determine a) the superiority of one cloud service provider offering over another is seen in (Appendix IV) and b) The assigning of weight based on the degree of importance of one requirement over another as seen in chapter 6 (Fig 6.2).

3.4.8 Stage 3 Data Analysis

The service requirement comparison is synthesised using the AHP method to determine the relative service ranking matrix (RSRM) for each compared service provider requirements. This process is demonstrated for the cost variable as presented in chapter 6(section 6.4.2.1) the RSRV for the service attributes of the 4 compared SaaS cloud service storage application (Dropbox, Google Drive, iCloud and Dropbox) are presented in chapter 6(section 6.4.2). Also, to determine the standard benchmark that each individual service requirement must attain before it can be perceived acceptable for adoption recommendation, the weights assigned in chapter 6(Fig 6.2) are synthesised to determine the Relative service ranking vector(RSRV) which is presented in chapter 6 (Fig 6.4). The resultant RSRV for each attribute is set as the standard benchmark of the attribute. Again, according to (Belton and Gear, 1983, Dyer, 1990) in terms of ranking, The AHP method can suffer from rank reversal. To address this issue this research proposes an extended version of the AHP method introducing rational relationships as seen in the proposed ranking protocol in chapter 6(section 6.5).

The information from this stage 1 to stage 3 is implemented within a framework as discussed in chapter 8. From the SLR, the use of intelligent systems to address knowledge management as well as transforming human language to machine readable language using

ontology web language (OWL)which is supported by descriptive logic reasoning engine such as Pallet (Ali et al., 2014) was identified. Thus, in the proposed approach, a layered framework (CLOUDSME) which comprises of a DSS which holds an ontology of four major cloud storage application services is developed to realise the research contributions. The introduction of a set of concepts and associated semantic rules are used to tackle the challenge of specific tasking identified in previous works and also the implementation of the proposed cloud service ranking method in machine readable form as previous AHP rankings are presented in graphical views. To evaluate the proposed framework, stage 4 data gathering is performed.

3.4.9 Stage 4 Data Gathering

This is the framework evaluation stage which is discussed in Chapter 8 and it comprises of 4 evaluation processes performed concurrently as follows:

Construct validity: This evaluation method was conducted to determine whether all dynamic SME requirements can be covered in testing the research hypothesis that CLOUDSME can cover all required SME requirement based on it reasoning capability(Object property Similarity reasoning, Data Property Similarity Reasoning, Concept similarity reasoning). The system was queried to determine if the system feedback when consulted matched with the service provider offerings case study in chapter 6 (Table 6.1), if the cloud services that attain the proposed individual requirement standard benchmark (RSRV) as shown in chapter 6(Fig 6.4) are recommended by the framework DSS when consulted and finally if the proposed framework DSS ranking reflects the ranking protocol in chapter 6(section 6.5).

User opinion Evaluation: This evaluation approach was conducted based on a quantitative method using survey. 29 SMEs that participated in the data gathering phase of this research and willingly agreed to participate in this evaluation stage. The SMEs

selected had not adopted cloud services, the CLOUDSME system was installed for them to use for a 3 months period and they were monitored once in every two weeks during the period. A survey (Appendix V) was carried-out to determine if the proposed CLOUDSME could aid in tackling the issue of slow cloud service adoption by Nigeria SMEs. Also, to determine if the proposed system had enough knowledge to tackle the dynamic nature of user requirements as well as to determine the completeness of the proposed CLOUDSME.

Expert opinion evaluation: A quantitative survey (Appendix VI) was conducted to gather expert opinion to determine the validity and completeness of the dynamic context categories of the proposed CLOUDSME. The experts were selected from different IT companies around the globe as they were identified from LinkedIn. Sixty survey questions were distributed but only 17 responded.

Researcher opinion evaluation: A quantitative survey (Appendix VII) was carried out to compare the proposed CLOUDSME ranking approach against other multi-criteria decision methods. For this evaluation survey process, the researcher contacted 35 PhD students from different academic fields and universities, however, only 10PhD researchers were willing to participate. Therefore, this evaluation was carried by 10 PhD researchers identified from ResearchGate and academia and who had a vast knowledge of multi-criteria decision methods. The cloud SME approach was explained to them to determine if the proposed approach can outperform other MCDM methods.

3.4.10 Stage 4 Data gathering Analysis

The construct validity evaluation analysis was based on the validity and completeness of the context categories when the system was consulted as seen in chapter 8(section 8.2). The user opinion evaluation analysis was done based on Technology Adoption Model(TAM)(Dishaw and Strong, 1999) as presented in Chapter 8(section 8.3.2.1). The expert opinion evaluation analysis was analysed by comparing the system from with international standard for software and system quality ISO/IEC 25010:2011 in Chapter 8(section 8.3.3.2). The researcher opinion evaluation was performed based on Technology Acceptance Model (TAM), (Legris et al., 2003, Koufaris, 2002, Dishaw and Strong, 1999) as presented in Chapter 8(section 8.4.5).

3.5 Conclusion

In this chapter, the research methodology and the research methods adopted have been discussed. A systematic review approach that is used to identify the research gaps in cloud service adoption has been discussed. Similarly, the exploratory approach used to determine the challenges faced by SMEs in Nigeria in view of tackling the slow adoption of cloud services have been presented. Also, the dyadic interview approach used in the prioritisation phase for data gathering and the survey used for evaluation of the framework has been introduced in this chapter. In the next chapter, a comparative study using the SLR approach discussed in this chapter is presented.

Chapter 4: Comparative Review

This chapter presents a systematic review of the previous research works (43 papers) that has been carried out in the area of cloud service adoption. The systematic review process used in this section have been discussed in chapter 3.

4.1 Introduction

Over the last 10years, a lot of work has been done to address the issue of cloud service adoption using different technological techniques. Many researchers have related the slow adoption to the presence of various service providers offering diverse cloud services to users with different performance attributes and costs. These services include but not limited to virtual hosting services, operating systems, storage service, programming environment and web application services (Ali et al., 2014, Kang and Sim, 2011b, Yongbo and Ruili, 2011). Potential cloud service adopters have been faced with various challenges such as how to find the best service provider offerings that can satisfy their quality of service requirements such as security, reliability, cost and performance(Gupta et al., 2013, Garg et al., 2013). Another notable challenge is how to address the issue of comparing non-functional requirements because they are non-measurable attributes of cloud services (Saripalli and Pingali, 2011, Garg et al., 2013, Tran et al., 2009).

To tackle this issue of service adoption challenges, many researchers have proposed various techniques such as ontologies for service recommendation(Han et al., 2009) Service Ranking (Tran et al., 2009) Knowledge management(Ali et al., 2014)Service discovery (Kang and Sim, 2011b),Frameworks (Ebneter et al., 2010),Service brokerages(Bellamy, 2013). Although it is a general knowledge that finding a solution that can tackle the slow adoption rate of service adoption cannot be overemphasised, there seems to be no technique that addresses all the challenges.

In this chapter, a Systematic Literature Review (SLR) is presented. The comparative study summarises the state-of-the-art in representing cloud service adoption techniques. The analysis in this chapter is done based on the data collected from quality assessment and data extraction phase as described in Chapter 3 (Section 3.2.5 and 3.2.6) respectively, through Systematic Literature Review(SLR) review protocol in Chapter 3 (Section 3.2.1).

The findings from this chapter aim to identify the research gap in cloud service adoption both in academia and industry from a global perspective. In addition, it will serve as a reference for researchers trying to identify areas for further research.

The rest of this chapter is organised as follows: Section 4.2 presents the primary studies data and its analysis in relation to their publication type, trends and geographical distribution. Section 4.3 presents the analysis and discussion of data collected in order to answer the research questions for this SLR. Furthermore, section 4.4 presents threats and validity of the data and limitations of the proposed SLR method. Finally, findings of the analysed data for cloud service adoption techniques is concluded in section 4.5.

4.2 Data and Analysis (Primary studies)

After the data extraction phase was completed, data synthesis and analysis was performed on the collected information. This section provides analysis of 43 selected primary studies as presented in table 4.1 in relation to publication type (journal/conference), trends and their geographical distribution.

Table 4.1: Table of Primary studies

Study Identifier	Paper Title	Year of Publication	Source
S1	A new QoS ontology and its QoS-based ranking algorithm for Web services.	2009	(Tran et al., 2009)
S2	'Cloud computing–a classification, business models, and research directions	2009	(Weinhardt et al., 2009)
S3	An ontology-based system for cloud infrastructure services' discovery	2012	(Zhang et al., 2012a)
S4	Cloud-based semantic service-oriented content provisioning architecture for mobile learning	2011	(Yee et al., 2011)
S5	Ontology-based Cloud Services Representation	2014	(Ali et al., 2014)
S6	Madmac: Multiple attribute decision methodology for adoption of clouds'.	2011	(Saripalli and Pingali, 2011)
S7	'Cloudrise: exploring cloud computing adoption and governance with the TOE framework.	2013	(Borgman et al., 2013)
S8	Cloud Service Brokers: an emerging trend in cloud adoption and migration.	2013	(Wadhwa et al., 2013)
S9	Towards agents and ontology for cloud service discovery'.Cloud service adoption decision.	2011	(Kang and Sim, 2011b)
S10		2015	(Wease et al., 2015)

Study Identifier	Paper Title	Year of Publication	Source
S11	Cloud computing as an innovation: Percepetion, attitude, and adoption	2012	(Lin and Chen, 2012)
S12	Self-adaptive trade-off decision making for autoscaling cloud-based services	2015	(Chen and Bahsoon, 2015)
S13	Identification of a company's suitability for the adoption of cloud computing and modelling its corresponding Return on Investment.	2011	(Misra and Mondal, 2011)
S14	Enterprise architecture frameworks for enabling cloud computing	2010	(Ebneter et al., 2010)
S15	The development that leads to the Cloud Computing Business Framework	2013	(Chang et al., 2013)
S16	A research of critical factors in the the enterprise adoption of cloud service	2013	(Hsu and Wang, 2013)
S17	Cloudle: A multi-criteria cloud service search engine	2010	(Kang and Sim, 2010)
S18	Adoption of Cloud Computing services by public sector organisations.	2013	(Bellamy, 2013)
S19	Towards an ontology for cloud services.	2012	(Fortis et al., 2012)
S20	Ontology and search engine for cloud computing system	2011	(Kang and Sim, 2011a)

Study Identifier	Paper Title	Year of Publication	Source
S21	The usage and adoption of cloud computing by small and medium businesses	2013	(Gupta et al., 2013)
S22	Investigating decision support techniques for automating cloud service selection.	2012	(Zhang et al., 2012b)
S23	Scalable service-oriented replication with flexible consistency guarantee in the cloud	2014	(Chen et al., 2014)
S24	Automating cloud services life cycle through semantic technologies	2014	(Joshi et al., 2014)
S25	A cloud-based approach for context information provisioning	2011	(Badidi and Esmahi, 2011)
S26	Toward a unified ontology of cloud computing.	2008	(Youseff et al., 2008)
S27	An ontology-based semantic foundation for flexible manufacturing systems.	2011	(Uddin et al., 2011)
S28	Towards self-aware service composition.	2014	(Elhabbash et al., 2014)
S29	A comparative analysis on QoS-based web services selection and composition	2015	(Deepa and Sathiaseelan, 2015)
S30	An approach for selecting software-as-a-service (SaaS) product.	2009	(Godse and Mulik, 2009)

Study Identifier	Paper Title	Year of Publication	Source
S31	Cloud computing services: taxonomy and comparison	2011	(Höfer and Karagiannis, 2011)
S32	Cloudsourcing: managing cloud adoption	2011	(Géczy et al., 2011)
S33	Cloud computing: Today and tomorrow	2009	(Kim, 2009)
S34	Cloud computing security issues and challenges.	2011	(So, 2011)
S35	A taxonomy and survey of cloud computing systems.	2009	(Rimal et al., 2009)
S36	Cloud computing: adoption considerations for business and education.	2014	(Smith et al., 2014)
S37	The viability of cloud computing adoption in SMME's in Namibia	2013	(Tjikongo and Uys, 2013)
S38	Cloud computing: issues and challenges	2010	(Dillon et al., 2010)
S39	Cloud computing adoption by SMEs in the north east of England.	2013	(Alshamaila et al., 2013)
S40	Using Semantic Web Ontology for Intercloud Directories and Exchanges.	2010	(Bernstein and Vij, 2010)
S41	Understanding the determinants of cloud computing adoption.	2011	(Low et al., 2011)
S42	Reaching for the “cloud”: How SMEs can manage.	2011	(Sultan, 2011)
S43	A framework for ranking of cloud computing services.	2013	(Garg et al., 2013)

4.2.1 Demographic Data

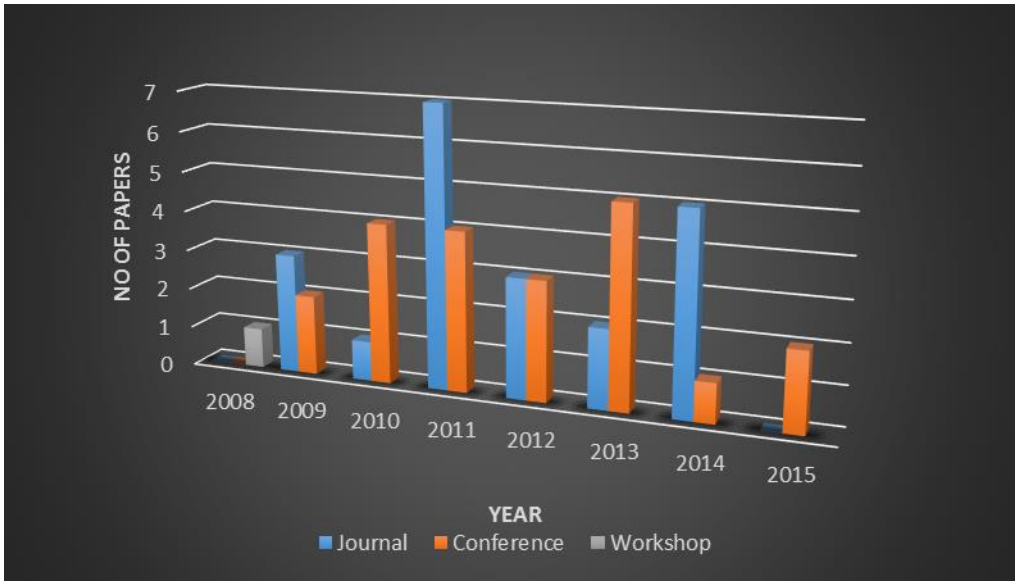


Figure 4. 1Publication by Year

In this research, the search period was set to start from 2000 but unfortunately, the earliest primary study was in 2008 and this could be because cloud computing is still in its infancy stage. Cloud computing is a new technology and its generally recognised and accepted definition by NIST "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" was only established by the U.S department of commerce in 2011(Mell and Grance, 2011). Fig 4.1 presents the number of primary studies identified along with the year in which they were published through different publication outlet type (Journal, conference or workshop). From the chart, there was an initial low publication on cloud computing adoption technique both in journal and conferences between the year 2008 and 2009. By 2010 there was an increase in the number of conference paper publications and it was also observed

that by 2011, a rise in the number of journal papers released on cloud service adoption was identified. Again, only one workshop was recorded in 2008 as seen in Fig 4.1. Although the primary study for data gathering was set until January 2015.However, primary studies include research works published before June 2015 when the search and selection process of this research study was completed (thus the first half of 2015 was partially included).

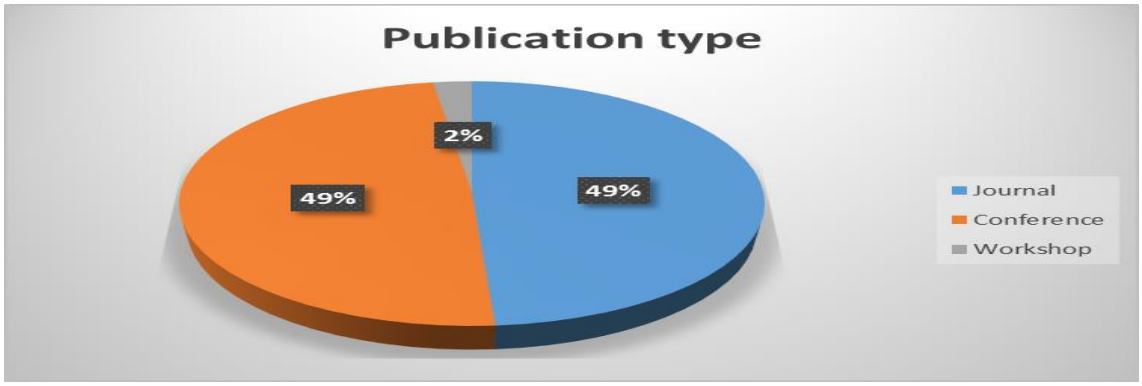


Figure 4. 2 Publication Type

Fig 4.2 shows a pie chart presentation of the publication type distribution of selected primary studies. As presented, it can be deduced that Journals were the most used publications with a total of 50%, followed by papers published in conference proceedings with 48% and 2% for workshop respectively.

4.2.2 Demographic Distribution

Fig 4.3 presents a chart showing the demographic distribution of publications by author's country. The distribution is based on the country where the author is located rather than where the paper was published. From the pictorial representation of the chart as seen in Fig4.3. The United Kingdom, Korea and the United States of America are the most popular in terms of research based on cloud service adoption techniques.

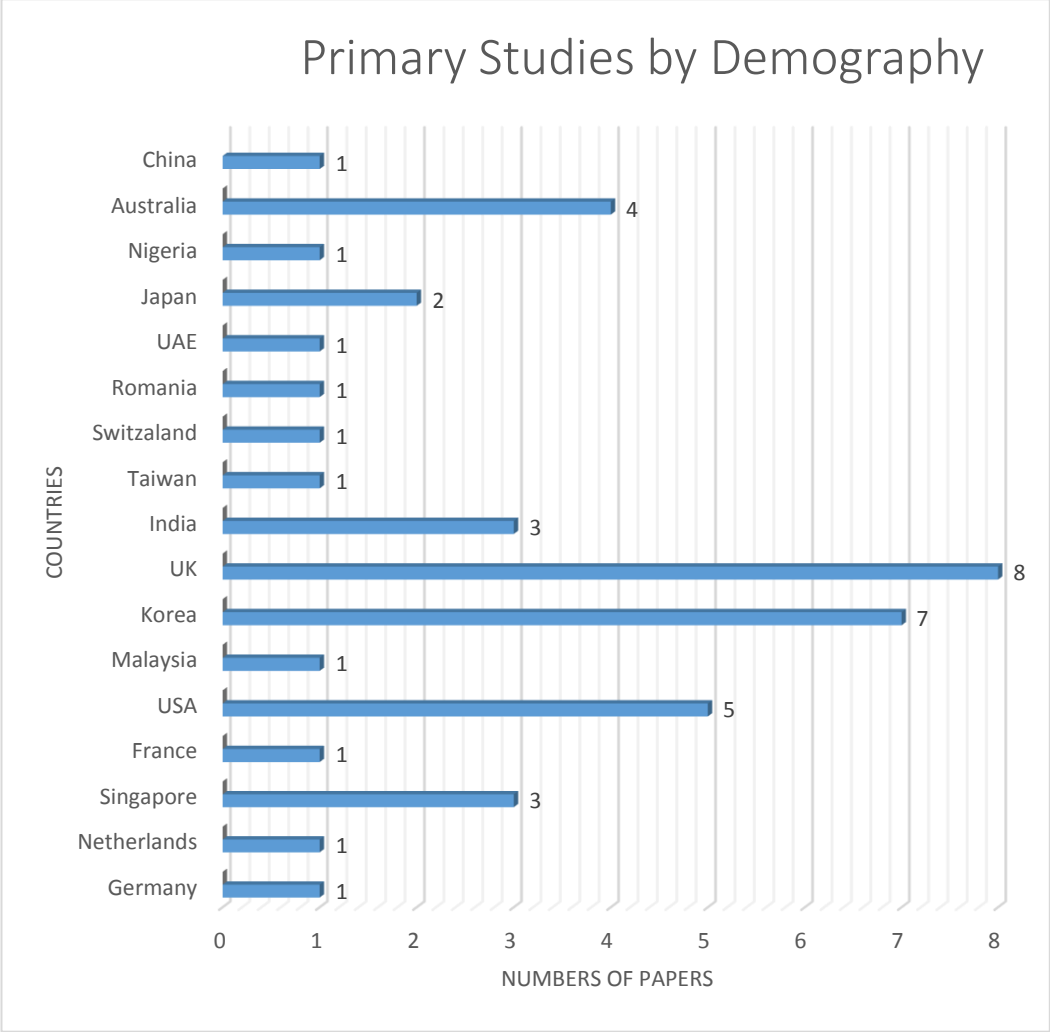


Figure 4. 3 Distribution of Primary Studies by country

4.3 Discussion of SLR Research Questions

This section aim to answer the SLR research questions (Please see chapter 3(Section 3.2.1 for SLR protocol) This is based on the synthesis and analysis of the data retrieved from the 43 primary studies captured in the data gathering stage and listed in Table 4.1.

4.3.1 SLR.RQ1: What approaches have been proposed to represent cloud service adoption techniques?

From the primary studies, it is observed that three major approaches represent cloud service adoption techniques.1) Tackling cloud service adoption technique with the use of ontologies 2) the use of service adoption frameworks 3) the use of Models which is further

differentiated into a) Unified Modelling Language b) Conceptual models. Please see Table 4.2 for a comprehensive classification.

Based on the selected 43 primary studies, 27% (12 papers) of the primary studies presented various frameworks in view of tackling cloud service adoption (e.g. S42, S37, S2, S7, and S11). Furthermore, 27% (12 papers) adopted the use of various service ontological representation such as ranking, Knowledge management, service recommendation, service discovery etc. (e.g. S1, S4, S26, S5 and S29). In addition, 27% (11 papers) of researchers from the primary studies adopted the use of Models which comprises of UML models (e.g. S22, S25) and conceptualised models (e.g. S10, S23, S41, S36). Finally, 19% (7 papers) adopted various methods such as analytical methods for ranking and recommendation (e.g. S21, S29) Taxonomy (e.g. S31, S35) Comparison (S29, S34).

Table 4.2: Cloud service adoption technique classification

Adoption Technique	No of papers	Percentage	Study Identifier
Frameworks	12	27%	S32,S37,S39,S43,S6,S7,S11, S14,S15,S28,S2,S42
Ontology	12	27%	S3,S4,S9,S17,S19,S20,S24, S26,S37,S1,S5,S40
Models (UML& Conceptual)	11	27%	S22,S25,S10,S18,S12, S23,S13,S8,S41,S36,S38
Others (Taxonomy, Analytical methods, comparisons)	8	19%	S21,S29,S30,S16,S34,S31,S35,S33

The ontology technique adopted to tackle cloud service adoption was based on various aspects of cloud services as below:

S26: These were the first to attempt establishing a detailed ontology of cloud services, .in their work they dissected the cloud into five main layers, and they further illustrated the relationship between the layers as well as their inter-dependency on preceding technologies. Their aim was to help the scientific community adopt cloud computing for

further research. The work of S26 is the building block of all cloud service techniques developed using ontologies.

S17: They propose Cloudle a multi-criteria cloud service search engine. In their approach, they devised a set of concepts that aid in determining the similarity among cloud services using a set of reasoning methods. In their findings, they concluded that a service search engine that uses an ontology as its search engine has a significantly better performance than a cloud service search engine without an ontology.

S19: In their research, they propose an ontology that relates to service life cycle and cloud governance taking a step further from SOA. Their ontology aims to deal with service management, security, monitoring and auditing issues of cloud services. Their objective is to develop an environment where collaboration between various enterprises can be established.

S40: In their work, they propose an inter-cloud directory and exchange ontology that acts as a mediator for enabling connectivity as well as collaboration among various cloud providers. To achieve this, they adopt a resource catalogue approach using a Semantic Web Resource Definition Framework (RDF) and ontology of cloud services across heterogeneous service providers.

S9: In their effort to contribute in cloud service recommendation through the use of a discovery agent, they proposed a four-stage, agent-based cloud service discovery protocol. Using an ontology, they develop a multi-agent system that has the capability to match customers request to resources. They also keep track of historical data by incorporating a database for making intelligent recommendations based on attribute value prediction.

S5: In their work, they propose a cloud service ontology for knowledge management and service discovery. Their developed ontology aims to explain the concepts, attributes of the concepts, axioms, individuals and the relationships among the cloud service concepts within a cloud service domain.

S1: In their work, propose an approach for designing and developing a quality of service ontology and its quality based ranking algorithm for evaluating web services. They adopt analytical Hierarchical Process (AHP) for their ranking algorithm. The QoS ontology aims to support QoS information in great details as well as facilitate various service providers in expressing their QoS offers and demand at different levels of expectation.

S24: In their approach propose an ontology of cloud service life cycle by dividing the cloud service into five phases with an ontology that helps describes the concept and relationship for each phase. The five phases are divided into requirement, discovery, negotiation composition and consumption. To show how their approach can automate the usage of cloud service they demonstrate their approach using cloud storage prototype that has been developed.

S4 In view of promoting cloud service adoption through Knowledge management, they propose the use of a generic semantic based service-oriented architecture in order to prove that semantic technology when implemented together with a cloud-based SOA, can provide learners with fresh experience. They achieve this by incorporating knowledge aggregation subsystem and a querying subsystem which are loosely coupled thus allowing rapid deployment across domains with suitable domain ontologies.

S27 In a bid to contribute to the growing research in cloud computing adoption, the authors propose an ontology based job allocation algorithm for cloud computing to perform inferences based on semantic meanings. As they aim to allocate requested jobs to cloud resources which are suitable for cloud service user requirement. The retrieve

resource candidates based on user requirements and a job is further allocated to the most suitable candidate for an agreed service level agreement (SLA). In their findings, they conclude that ontology-based resource management system helps to improve the efficiency of resource management in cloud computing.

S3 In their research, aim to promote cloud computing adoption by proposing an OWL-based ontology CoCoOn which defines the functional and non-functional concepts, attributes and relationships of infrastructure services. The objective is to develop a system that can recommend services by matching user request to the service description. The system matching is done based on regular expressions and SQL matching.

Other proposed cloud service adoption techniques are described using different methods such as frameworks as seen in the work of (S7 & S39) they proposed the use of Technology- Organization-Environment (TOE) framework to investigate the factors influencing cloud computing adoption. Also, how the use IT governance process and structure can be used to moderate those factors while S7 focuses on a set of hypothesis that is tested in a quantitative study of global enterprises, S39 Focuses on the use of semi-structured questions interviews and their research is targeted at SMEs in the north east of England. The work of S32 proposed a framework that is beneficial to both cloud service users and providers in a bid to offer a balanced approach in cloud service adoption and reduce the risk of service providers taking advantage of organisations data they do this by introducing a set of concepts. While the authors in S15 propose a cloud computing business framework (CCBF) their aim is to aid organisations to achieve good cloud design, migration and services they propose four key areas that work together to achieve their aim. They illustrate they illustrate the build-up to their framework using a case study and they conclude that their framework has added values and positive impacts to several organisations. Furthermore, the work of S28 proposes an intelligent framework for selecting and composing services which are grounded on computational self-awareness

to inform decisions of selecting and composing services in view of meeting both behavioural and functional requirements. Also, the work of S14 propose a framework that can aid a company analyse if its operations can be positively impacted by adopting cloud service. In addition, the work of S37 propose a framework using Technology Adoption Model (TAM) by targeting SMEs in Namibia that makes use of ICT infrastructure and in there finding they concluded that slow adoption was due to lack clarity in business models, privacy issues, the risk of vulnerability of data. The work of S43 proposes a framework for evaluating cloud service IaaS offerings and ranking them using Analytical Hierarchical Process (AHP) based on how they meet users' quality of service requirements. The work of S2 proposes a cloud service business framework that aid business in the adoption of a specific type of cloud service. The work of S6 proposes MADMAC framework for cloud adoption which is made up of three decision areas cloud switch, cloud type and vendor choice. They do this by assigning weights to attributes to arrive at relative ranking which is used identify the optimal alternatives.

In addition to frameworks, some researchers adopted models as a technique in view of tackling the issue of cloud service adoption such models are seen in the work of S8 in their approach, they propose Cloud Service Brokerages (CSB) which acts as an intermediary between consumers and providers. Their proposed CSB aims to categorise CSBs on the basis of services they provide and they devise a method for selecting CSB from a pool of CSBs. While the work of S13 propose a general return of investment model that aids SMEs in analysing their business and understand what part of the business should migrate to the cloud. The work of S41 focuses on cloud service adoption for high tech industries in Taiwan as a case study using 8 factors as determinants and relevant hypothesis was derived and tested using logistic regression analysis. The work of S10 proposes the use of Hierarchical Decision Model (HDM) to understand the decision-making process based on how an organisation evaluates its needs and chooses among

different cloud hosting environments. The work of S38 compares different computing methods and identify the challenges for cloud computing adoption. Furthermore, the work of S23 propose a Scalable Service Oriented Replication (SSOR) solution a middleware that has the capability to satisfy application requirements in cloud based service replication approaches. In addition, the work of S25 and S22 adopt UML to illustrate service entities and their relationships while S25 further uses multi-attributes decision algorithm for selection of potential context services that aim to satisfy context consumer request for context information. The work of S18 proposes a model that can aid cloud service brokerages develop new capabilities that can aid in accelerated cloud service adoption and benefit realisation. The work of S12 proposes a self- adaptive decision-making, an approach for auto-scaling in the cloud that has the capability to optimise trade-offs without much human intervention. Finally, other techniques include S31 and S35 taxonomy frameworks of cloud services, while S31 is presented in a tree like structure, S35 is presented in a table format. The work of S16 adopted critical index factor with AHP method with the study on external experts outside the company rather than inside the company and the research out focuses on the critical success factor and a new business model on cloud computing adoption. While the authors of S21 present five factors influencing cloud service adoption in the business community. The work of S29 proposes a QoS –based web selection and composition by linking and combining existing services to construct a newly composed web service that satisfies user requirements. Finally, the work of S30 presents a method that utilises Analytical Hierarchical Process (AHP) technique for prioritising SaaS salesforce automation products and also expert led scoring of the products.

4.3.2 SLR.RQ2: What is the quality of research conducted in the approaches reported?

Considering the SLR method discussed in chapter 3, each of the primary study was given a quality score between 0 and 8(based on the 8 questions established in chapter 3 with possible ratings of 0, 0.5, and 1 for each question). This list of study along with their allocated scores (for each question & combined score) can be found in appendix I. Fig 4.4 represents the number of studies with their quality score. The chart shows a normal Gaussian distribution curve with a mean of 5.5 and a variance of 1.1. The most common score was 5.5 (23% of the primary studies). The highest score was 7.5 (1 paper) while the lowest score was 3.5(2 papers).

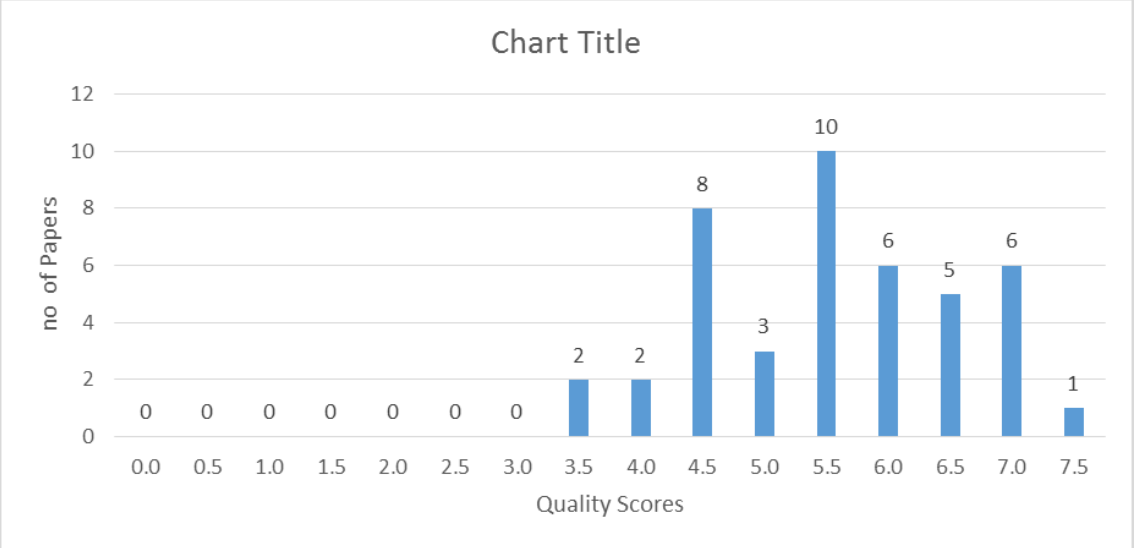


Figure 4. 4 Quality assessment rating of primary studies (overall)

Further analysis is done by identifying the quality assessment rating for each question as illustrated in Table 4.3. The first section of the table represents the quality assessment questions as discussed in section 2.3.5 (Table 3.1). The second section represents the number of paper that attained each of the rating scores (0, 0.5, and 1).

Table 4.3: Quality assessment rating for primary studies (each question)

RATING OF PAPERS USED FOR PRIMARY STUDIES BASED ON EACH ASSESMENT QUESTION	QUALITY SCORE		
	0	0.5	1
QAQ1 Is there a rational why the study was taken?	0	4	39
QAQ2 Is there adequate description of the context (Industry, laboratory used, etc.)in which the Research was carried out?	0	16	27
QAQ3 Did the paper present sufficient details about Cloud service adoption technique to be understood And used	0	12	31
QAQ4 Did the paper present an evaluation of the tool? If yes Did it include feedback from users?	10	21	12
QAQ5 Are there substantial claims in the paper supported by Reliable evidence?	0	15	22
QAQ6 Did the authors compare and evaluate their own results Against related works?	4	22	17
QAQ7 Did the authors describe the credibility of their findings?	1	21	12
QAQ8 Are limitations of the study discussed explicitly?	26	12	5

As seen from Table 4.3 most of the primary studies had a clear objective for carrying out the research, while fewer papers gave an adequate description of the research context. A majority of the researchers presented an evaluation of their tool as this may be due to the fact that most of them were specific in their approach towards cloud service adoption. While only 5 of the primary studies scored 1 point in terms of explaining the limitations of their work and 26 did not give any explanation in terms of limitation of their approach. Based on findings it can be concluded that most of the research work carried out in the area of cloud service adoption is justified as it is clear that cloud computing is still in its infancy stage and the enormous advantage it brings cannot be overemphasised. Therefore, researchers continue to propose different techniques to meet different user requirements in view of adopting cloud services. Another notable finding is that most of the researchers did not discuss the limitation if their work and this may be due to the fact that 67% of the primary studies are driven by academia while a very small number 5% is driven by industry (This is further discussed in section 4.3.3).

4.3.3 SLR.RQ3: What is the context and areas of research of these studies employing cloud service adoption techniques?

4.3.3.1 Research Context (Academia vs Industry)

The primary study research context was identified and classified as follows: Academia (A primary study that was conducted in an academic institution and by academics with no industry input) Industry (A primary study that was conducted by industrial based researchers or had direct industrial input) Industry & Academia (A primary study that was jointly researched by both academics and industrial researchers). From the research findings, the following was identified: Majority of the research was carried out in Academia 67% (29 papers) while research was based on industry 12% (5 papers) and the

research that had both Academic and industrial input had 21% (9papers). Table 4.4 represents a detailed classification of the primary studies research context.

Table 4.4: Research Context showing study identifiers (Academia vs Industry)

Research Context	Total Papers	Study Identifiers
Academia	29	S1,S2,S5,S8-S10,S12-S21,S23,S25-S27,S29,S32-S34,S36-S39,S41,S42
Industry	5	S7, S6, S40, S24, S31
Both	9	S11, S43, S32, S18, S26, S4, S3, S35, S30

From the findings, it can be observed that cloud service adoption technique was first proposed in 2008 based a joint research involving both the industry and academia. However, there are significant numbers of research works conducted between 2011- 2015 compared to 2005-2010(3 times the amount of research carried out). Also, a general increase is identified in the number of research carried out in all the research context areas compared. Figure 4.5 represents the research context findings.

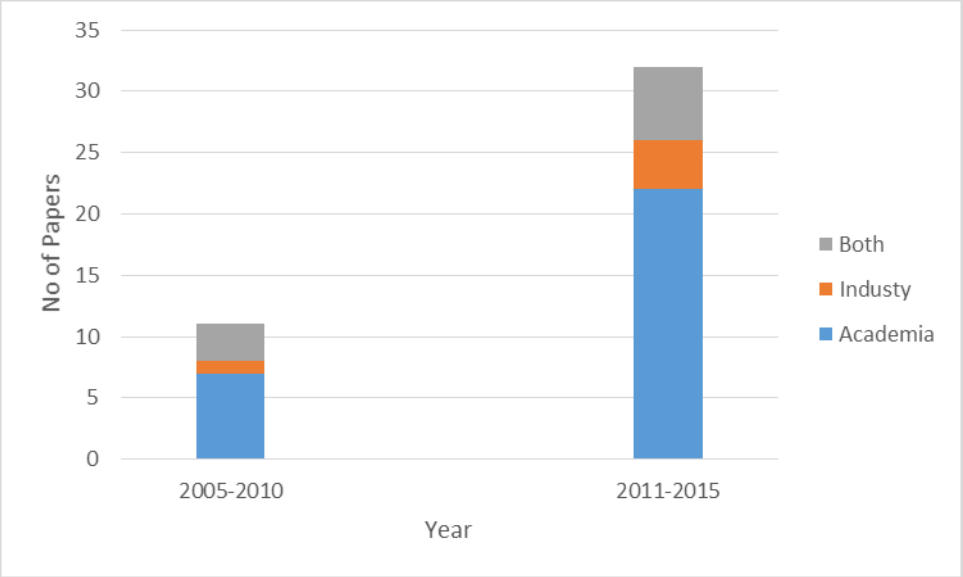


Figure 4. 5 Research context (Academia vs Industry)

4.3.3.2 Research Context (Theoretical Approach vs Practical Approach)

Based on the adoption techniques proposed in the research studies, it was important to further analyse if the proposed methods had a practical, theoretical focus or both. The analysis of the findings based on the comparison between (Theoretical vs Practical) in the last 10 years is depicted in Fig 4.6. It is observed that a majority of the primary research work was based on theoretical approach with no significant practical input. This may be related to the findings in Table 4.3 where majority of the researchers didn't discuss the limitation of their research as well as most of the primary studies drawn from academia. In general, 53% (23papers) of the primary studies were conducted based on theoretical approach while 26% (11papres) was practical based and the remainder of the primary studies had both practical and theoretical input 21% (9 papers). Table 4.5 shows a classification of the research context (Practical vs Theoretical).

Table 4.5: Research context showing study identifier (Theoretical vs Practical)

Research Context	Total Papers	Study Identifiers
Theoretical	23	S6,S7,S8,S11,S14,S16,S18,S19,S22,S26,S28S29,S30S36,S38,S41,S42,S43
Practical	11	S21, S2, S9, S40, S20, S3, S25, S12,S15, S37, S5
Both	9	S17, S27, S4, S24, S13,S10,S23,S39,S1

From the findings, it can conclude that there has been a significant increase in research (Theoretical vs Practical) from the years 2005-2010 compared to the years 2011 - 2015. The findings is further presented pictorially in Fig 4.6.

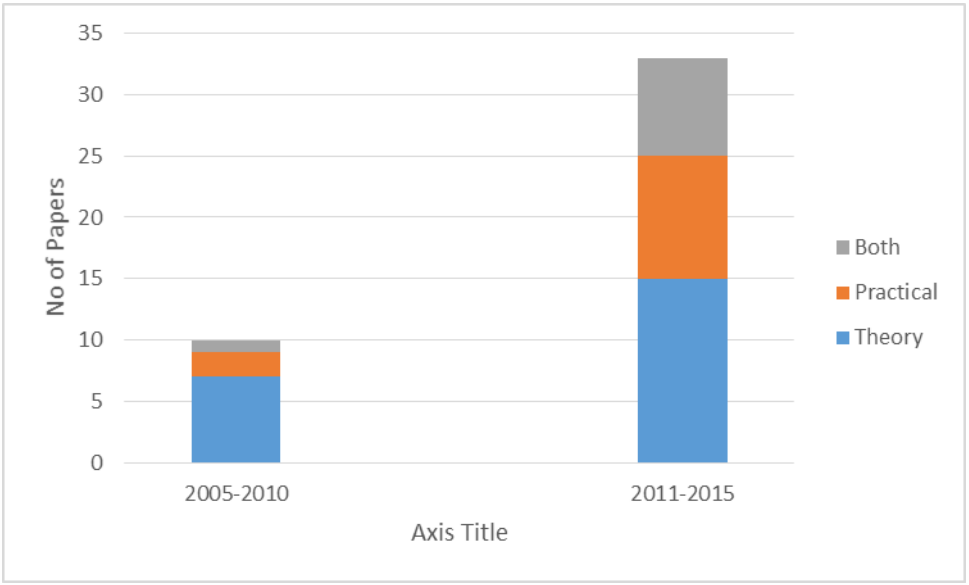


Figure 4. 6 Research context (Theoretical vs Practical)

4.3.4 SLR.RQ4: What is the limitation of existing techniques in relation to cloud service adoption?

Reporting the limitations of a research is as important as the objective and findings of that research because a research limitation not reported does not give other researchers a full understanding of its applicability. From the research findings, most of the primary studies that were reported were very clear with their objectives and their reason for performing the research as they try to propose a solution to the adoption of cloud services by proposing various techniques. However, a majority of the authors did not report the limitations of their proposed technique. From the reviewed papers, 60% (26 papers) did not report the limitations of their research, 28% (12 papers) partially reported their limitations.

The remaining 12%(5papers) reported their research limitations as this did not only help us to understand the research applicability but also understand the limitations that need to be addressed for further research. Some of the limitations identified were categorised as follows:

4.4 Limitations of existing cloud service adoption techniques

After a critical analysis of existing cloud service literature, with more emphasis on cloud service adoption techniques, it is evident that present techniques adopted have some limitations.

Below, a summary of some of the main limitations identified in the adoption of cloud services from academic research is identified and discussed.

L1: Limited support systems for aiding decision-making process:

Presently, a majority of the existing system focus on service discovery or knowledge management. There is a gap in the availability of decision support systems in terms of

cloud service comparison (MCDM) for SMEs in the decision-making process of cloud service adoption. Also, majority of the proposed methods are theoretical based (S30, S43).

L2: Limitation of user opinion in the system development life cycle:

Presently, most of the existing research on cloud service adoption for SMEs are based on literature. There is need for the SMEs managers (user) opinion at the inception and during the system development life cycle. As they will be able to determine if the system can tackle their adoption challenges.

L3: Limitation of research on SaaS cloud service adoption

Most researchers focus on IaaS and PaaS cloud service adoption because of the functional nature of the services provided. However, there is little research carried out regarding SaaS cloud service adoption due to its non-functional nature (S5, S17, S26, and S40).

L4: Limitation of cloud service adoption technique specific to SMEs

From the literature reviewed, most research work carried on cloud service adoption are either generic in nature or focus on other areas such as public-sector organisation(S18), education(S36) but there is little work done in regard to adoption techniques specific to SMEs.

L5 Limitation of cloud service adoption framework for Nigerian SMEs

From the research analysis conducted, there is no research framework presently on cloud service adoption for SMEs in Nigeria as well as most developing countries.

L6 Cloud service ranking approach

From research SLR findings, it is an obvious knowledge that ranking of non-functional properties of cloud services is a MCDM problem. Most research adopts the AHP method for addressing issues of complex comparison and present their finding with graphical representations (S43, S30, S16, and S10). However, there is the need to address the issue of rank reversal associated with the AHP method and represent the findings within a system.

4.5 Threats to validity & limitations of research

In this section, the limitations and threats to the validity of this research are discussed. Although we have adopted SLR as a research method, like other research methods SLR has some inherent limitations. The first limitation is the probability that the process adopted in the search and selection method may not have identified all the primary studies relevant to this research. This can be attributed to different reasons one of which is the terminologies used in the search process (considering that the SLR covers several domains and research communities). To tackle this limitation, the following measures were taken. Automated search was done on reputable databases of prominent publishers such as (e.g.IEEEXplore, DBLP) against known general indexing search engines such as (e.g. Google Scholar) This helped in guaranteeing extensiveness as different search engines use various algorithms. Furthermore, a manual search was carried out on various reputable publication outlets and publications of known authors in relation to cloud service adoption and the retrieved papers were compared to the result of those produced during the automated search. Finally, forward and backwards reference was conducted on the selected primary studies in view of ensuring that all the relevant papers were selected.

Another notable limitation associated with SLRs is the elimination of grey literature, which includes, thesis write-ups, technical reports and white papers. This could be

considered as a setback since most industrial led research is scarcely published in peer-reviewed outlets. Going by the SLR analysis as represented in SLR.RQ3 Fig 4.5, it is observed that majority of the primary research study is based on academic research with minimal studies attributed to Grey studies. In addition, another notable limitation is that of language barrier. In this research, primary studies search and analysis was limited to only those published in English. This could present a notion that research work related to cloud service adoption in other languages have been omitted. Addressing these limitations, the researcher is optimistic that most research work in this area appears to be published in English and so we do not consent that there is a significant work published in English which we haven't identified within the limits of the research period.

Besides the characteristic SLR methodology limitations, there are also threats to validity which are classified as follows; construct, internal, external and conclusion(Matt and Cook, 1994).

Some threats related to construct and internal validity has already been discussed in the above section. These threats occur based on flaws in the implementation of the research method adopted. A common construct validity issue in SLRs is author bias and this has been addressed by using multiple independent reviewers reviewing each primary study and an independent researcher reviewing the overall process. This has been discussed in the SLR method in chapter 3.

The threats to external validity focus on the application of the results of the study beyond the context of the research area. This research has tackled the issue of external validity as it is not limited to only one adoption technique, also multiple cloud service adoption techniques have been studied. In addition, all the raw data used in this study has been made available for other researchers to understand the research concept and analysis conducted.

Finally, conclusion validity limitation relates to the strength of the conclusions made based on the data available. Well -known threats are situations where researchers drive their conclusions to conform to their initial hypothesis. In this research, no initial hypothesis was set to address the SLR questions, however, they were tackled without any form of bias.

4.6 Conclusion

This chapter aimed at categorising the state-of the-art in representing cloud service adoption, This technique used was adopted from (Kitchenham and Charters, 2007) guidelines for a systematic literature review. Where 43 different journals and conference papers were critically analysed to identify and depict the works that have been carried out by different researchers. This technique assisted in identifying the trends and challenges in the cloud service adoption.

Furthermore, it can be stated that there is an upward trend since 2008 (see Fig 4.1) in the number of research done and techniques proposed to tackle the slow rate of adoption of cloud services. Furthermore, it was established that

- Service adoption frameworks and service ontologies are the most commonly proposed techniques in tackling cloud service adoption as presented in figure 4.1.
- In Table 4.2, most of the proposed ontologies from the 12 papers reviewed were specific in task. They focus on a particular adoption area e.g. knowledge management or ranking but not both. Thereby limiting the possibility of tackling various adoption challenges without putting the dynamic nature of user requirements into perspective.

- The primary studies also show that the researchers focused on proposing new techniques or improving existing methods to tackle cloud service adoption challenges.
- Majority of the primary studies were academically driven (67%) with a theoretical focus (53%).
- Overall, the research in this area was seen to have a clear rationale and objective but a majority of the proposed research lacked validation.

Finally, the leading countries in this research area are from United Kingdom, Korea, United States, Australia, India and Singapore. Again, as analysed in this chapter, frameworks and ontologies are the most popularly used techniques to address cloud service adoption (Table 4.2). Therefore, this research proposes a new cloud service adoption framework (CLOUDSME), which includes an ontologically developed Decision Support System that can aid in tackling the slow adoption of cloud services by Nigeria's SMEs.

Considering this, the next part of this thesis describes the rational that led to this research. The quantitative and qualitative primary data gathering conducted to identify the reason for slow adoption of cloud services by Nigerian SMEs (Chapter 5).

Chapter 5: Primary Data Gathering

In this chapter, the primary data gathering technique used for this research explained. To achieve this, the geographical distribution of Nigeria based on it geopolitical zones and where the data collection carried out discussed. The data gathering was conducted to determine the reason for slow adoption of cloud services by Nigerian SMEs. The research findings were analysed, and a comparison of cloud services adoption challenges in Nigeria compared to SME cloud service adoption in the England. The result in this chapter is the foundation of the proposed cloud service adoption Framework discussed in chapter 6

5.0 Introduction

This research aims to design a framework for aiding Small and Medium Scale Enterprise (SME) owners in Nigeria towards the adoption of cloud services for their businesses. In this research, the use of participatory design approach (Sears and Jacko, 2009) was adopted involving the key players in different sectors of the SMEs. This method enabled the various stakeholders to have a voice in the design of the framework with the view of a sustainable future development.

Against the above background, the data gathering was carried out in four stages as explained in the research methodology (Chapter 3). The research started by exploring the interdisciplinary literature review in cloud services adoption, given the research gap till date as discussed in chapter 4.

Similarly, this chapter aims to discuss the first and second stage of data gathering, which is on primary data collection. The approach involves triangulating different data gathering

methods to enhance the validity of the research. The data collection method that is adopted is a mixed method approach which combines quantitative and qualitative data gathering methods (Creswell and Clark, 2007).For the quantitative method, a questionnaire based survey was carried out. Questionnaires were distributed to 300 SMEs managers with a response rate of above 50%. Again, for the qualitative method, six participatory focus group discussions were held with one in each of the six geopolitical zones of Nigeria.

There were seven SMEs managers present in each focus group session each representing the different categories of SMEs in Nigeria and chosen based on the International Standard for Industrial Classification (ISIC). The focus group participants brainstormed on elucidating, sorting, analysing and deliberating on the key challenges of cloud services adoption in Nigeria identified in the survey stage towards the framework design. The remaining sections of the chapter are as follows 5.1 Data gathering method, 5.2 Justification of method, 5.3 Data collection, 5.4 Survey findings and analysis,5.5 Focus group & survey combined analysis, 5.6 Research requirement, 5.7 Cloud service adoption challenges England vs. Nigeria and 5.8 Conclusion.

5.1 Data Gathering Approach

The research design adopted has its basis in the social constructionism philosophy. This epistemology assumes the view that knowledge is established based on understanding derived from how participants understand the meanings attached to occurrences based on their experiences. Because this research adopts a stakeholders' approach to building knowledge, the views as expressed by stakeholder within the SMEs are quite vital. The relevance of the critical design ethnography and social constructionism as the research philosophy is therefore apposite.

A participatory approach was used where data have been obtained inductively. This method utilises an interactive design system that allows for continued refinement and analysis. Therefore, it can be linked to the grounded theory where the researcher begins with an entirely open mind without any preconceived idea of what will be found aiming to generate a new knowledge based on data.

5.2 Justification of the Method

This research adopted a mixed method approach that combines both qualitative and quantitative research methods. Data was collected through the use of questionnaires and focus group discussions. The advantages of adopting a mixed method approach were discussed in the research methodology chapter 3(Section 3.3.1). A quantitative research approach was adopted where questionnaires were utilised to help provide quantified data for decision-making. The data collected were used to understand the challenges faced by SMEs in Nigeria and the findings are essential to the proposed semantic framework (CLOUDSME) discussed in (Chapter 6). It also provides a transparent set of research methods and supports the presentation of complex data in a succinct format. According to (Gilson, 2012), Quantitative methods provide the opportunity to apply a comparable method across cross-sectional studies. This quantitative study is conceptualised from a theoretical basis to ensure that the instruments employed in this process have prior validity, reliability and will be appropriately designed to address and answer the research questions.

Also, this study adopted a qualitative research approach which is based on focus groups discussions. The FGD enabled the stakeholders in the SMEs from varying range of businesses to explore and expand on the result obtained in the quantitative data gathering stage. Therefore, having a say in the design of the framework thus giving it an

inclusive approach in the design and development. Therefore, minimising the level of bias (Van Selm and Jankowski, 2006).

5.3 Data Collection

In developing the questionnaire, a detailed review of existing literature which focuses on reasons for technology adoption/non-adoption, as well as readiness for new technology acceptance considered. The questionnaire (Appendix ii) was designed using closed ended questions as the use of closed end questions aids researchers in generating and gathering information quickly (Boynton and Greenhalgh, 2004).In developing the focus group agenda, open ended questions are mostly used in focus group discussions as they invite free comments where it's hard to predict the range of responses to a particular issue(Frary, 1996).

In selecting the SMEs for this research, for the quantitative method, a stratified sampling technique was adopted as discussed in research methodology chapter 3(section 3.5) success criteria 1-4. The sampling frame was stratified according to the Small and Medium Sized Development Agency of Nigeria (SMEDAN) definition. It defines SMEs based on the following criteria: A micro enterprise refers to a business with less than 10 people with an annual turnover of below five million Naira; a small enterprise as a business with 10 – 49 people with an annual turnover of N5, 000,000.00 - 49,999,000.00 and a medium enterprise as a business with 50 – 199 people with an annual turnover of N50, 000,000.00 to N499, 000,000.00. For this research SMEDAN definition is being adopted:

1 Firms must have less than 200 employees

2 Firms must be located in Nigeria.

3 They must have an annual turnover of less than 500,000,000.00 Naira (1usd is equivalent to 160Naira at the time of this research).

The owners or manager within each SME selected by contacting them either via phone calls or emails or in person. This is because he/she is regarded to be in the best position to answer questions pertinent to the research problem. The survey variables which are security, cost, standards, data lock-in, broadband and bandwidth were identified in the works of (Carcary et al., 2014, Alshamaila et al., 2013, Godse and Mulik, 2009) in the literature review stage of this research. The researcher distributed 300 questionnaires to SMEs managers across the six geopolitical zones of Nigeria (See Table 5.1).

In the qualitative method, A purposive strategy employed in developing the sampling frame (Saunders, 2011), This sampling strategy unit chosen because they have specific characteristics that enable a core theme understood in greater detail. Purposive sampling ensures that critical research issues addressed, and that diversity in each category explored (Crabtree and Miller, 1999, Silverman, 2013).

The focus group discussions consisted of 42 SMEs stakeholders spread across the six geo-political zones of Nigeria (7 present in each session) and cut across different aspects of businesses. These seven SMEs were chosen based on the International Standard for Industrial Classification (ISIC) so that everyone will have a say and bias eliminated towards giving the research an inclusive approach.

The researcher distributed 300 questionnaires to SMEs managers across the six geo-political zones of Nigeria.

Table 5.1: The six geopolitical zones of Nigeria

SOUTH EAST	• Anambra, Enugu, Ebonyi, Imo and Abia states.
SOUTH SOUTH	• Edo, Delta, Rivers, Bayelsa, Cross-River and Akwa-Ibom states
SOUTH WEST	• Lagos, Ogun, Oyo, Osun, Ondo and Ekiti states
NORTH CENTRAL	• Kwara, Kogi, Plateau, Nassarawa, Benue, Niger and F.C.T
NORTH EAST	• Taraba, Adamawa, Borno, Yobe, Bauchi and Gombe states
NORTH WEST	• Sokoto, Zamfara, Kebbi, Kaduna, Katsina, Kano and Jigawa states

Furthermore, Fig 5.2 shows the Map of Nigeria with the various states spread across different geopolitical zones where this research was carried out. Table 5.2 illustrates the classification of SMEs based on International Standard for Industrial Classification (ISIC)

and each category of SME represented. Thereby showing a varying range of SME owners from different sectors who participated in the survey and focus group sessions.

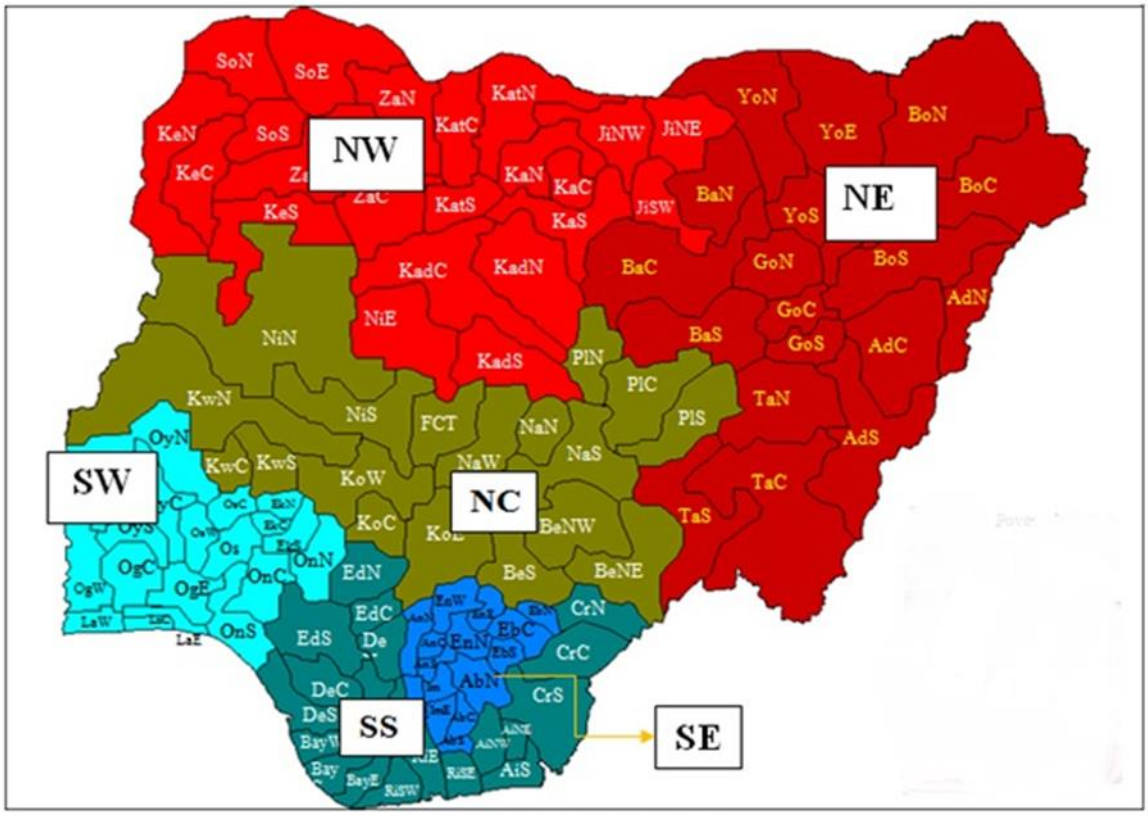


Figure 5. 1 The six geopolitical zones in Nigeria where the research was carried out

Furthermore, as mentioned above the 7 SME that participated in each focus group session were selected randomly based on the ISIC classification of SMEs as represented in Table 5.3 as long as they met the sampling criteria.

Table 5.2: International Standard for Industrial Classification (ISIC)

D	Manufacturing
F	**Construction**
G	Whole and retail trade, repair of motor vehicle, motorcycle and personal household goods.
H	Hotel and Restaurants
I	Transport, Storage and Communication
J & K	Financial intermediation, Real estate, Renting& Business activity
M,N&O	Education, Health and social work

5.4 Quantitative Survey Approach (Data gathering stage 1)

300 questionnaires distributed to SME managers across the six geopolitical zones of Nigeria with 50 questionnaires circulated in each of the six geopolitical zones (please see attached Appendix 2, for questionnaire sample and survey results) with a response rate of above 50%.

From the questionnaire, the researcher tried to determine if the SME met the success criteria for this research by asking the following questions:

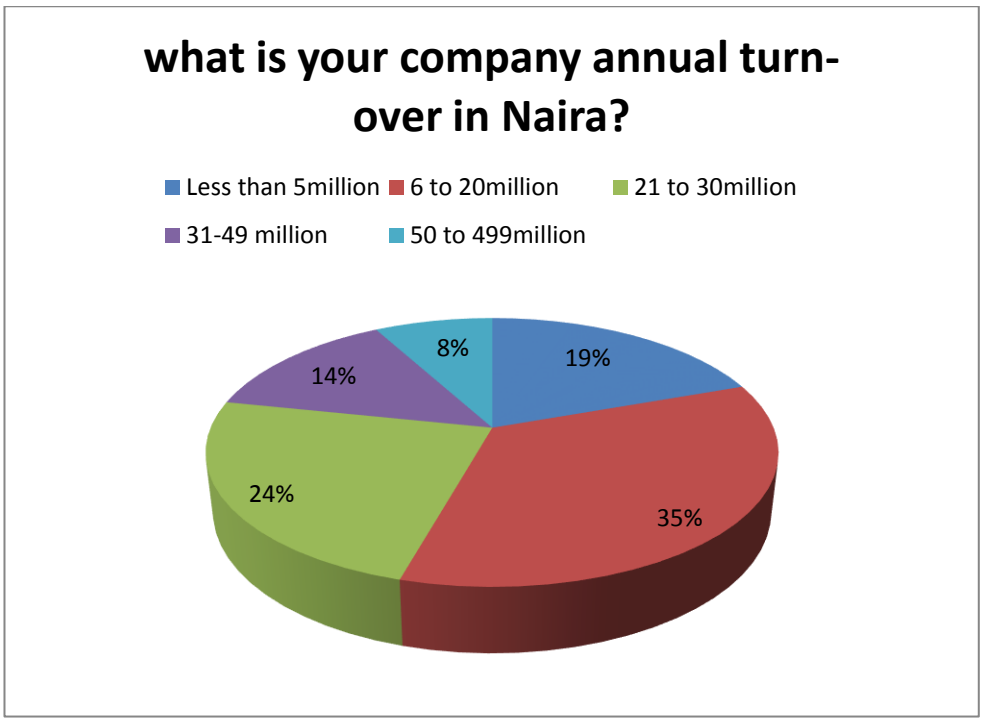


Figure 5. 2 Shows SMEs annual turnover

From Fig 5.2 it can be seen that all the 276 respondents were within the category of companies with an annual turn-over between 5million to 499million naira. With the majority of the SMEs seen within the range of 6 to 20million (35%) and also the SMEs with the lowest income range based on the respondents as represented in 5.3 is seen between 50 to 499million (8%).

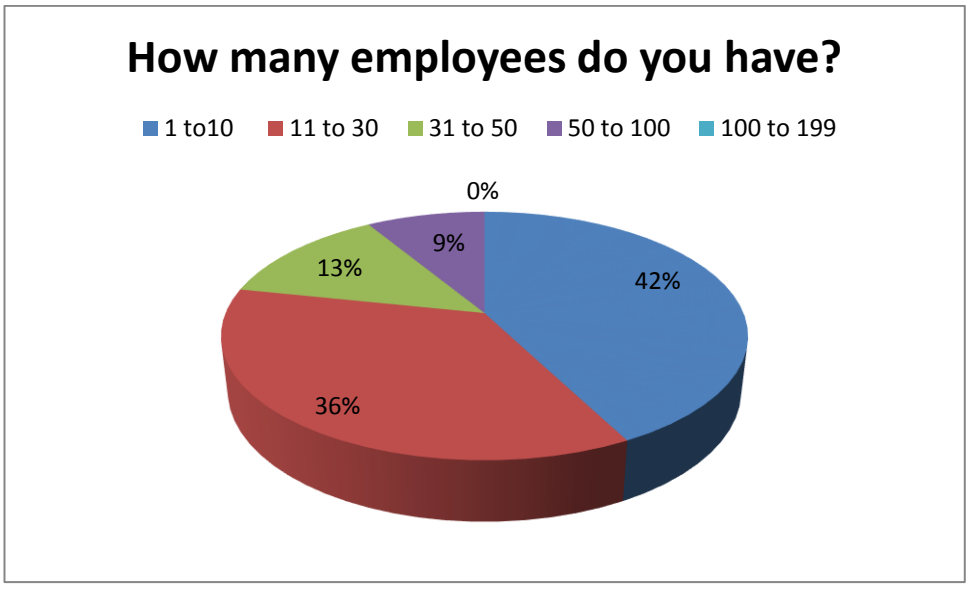


Figure 5. 3 Shows no of SME employees

From Fig 5.3 analysis, it can be seen that the number of employees of the businesses that took part in this survey lie within the SMEDEN classification (Section 5.3) of SMEs. The majority of the SMEs have a staff strength of between1 to 10 (42%) while none of the SMEs that participated in the survey have a staff strength from 100 to 199 (0%). Fig 5.2 and Fig 5.3 shows that all the SMEs that participated in the survey meet the research success criteria 1 as outlined in Chapter 3(section 3.4.3)

Figure 5. 4 Shows different sectors of SME represented bases on ISIC

As seen in figure 5.4, all the SMEs that took part in this survey are within the ISIC classification with the highest represented being SME in Education (18%) and the lowest being manufacturing (11%). Therefore, gives the research a diversified sample size. These findings conform to the success criteria two as identified in chapter 3(section 3.4.3).

The next set of questions (fig 5.5 to fig 5.7) was to determine if the SMEs make use of ICT as proposed in success criteria 3 as identified in chapter 3 (section 3.4.3)

Figure 5. 5 Shows SME ICT usage

Fig 5.5 shows that 100% of the respondent use ICT for their businesses and this indicates that most of the Nigeria SMEs have adopted ICT as part of their company business process.

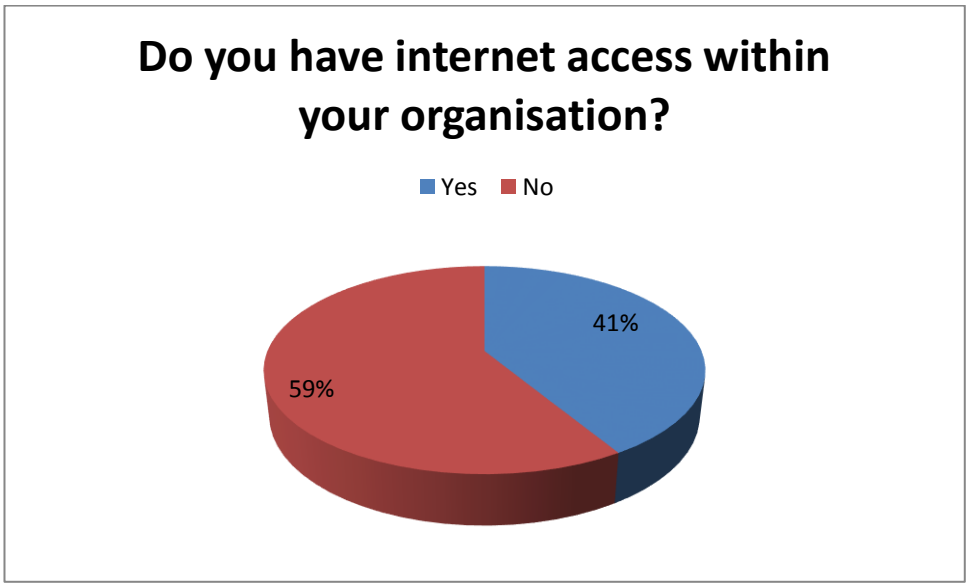


Figure 5. 6 Shows SMEs with internet access

Fig 5.6 shows that 59% of the respondents don't have Internet connection within their organisation while 41% have internet connection within their organisation. The result indicates that more businesses need to subscribe to the web if they are to adopt cloud

services. With many internet providers springing up in the country, it can forecast that in the near future, a majority of the SMEs will have access to the web for their business.

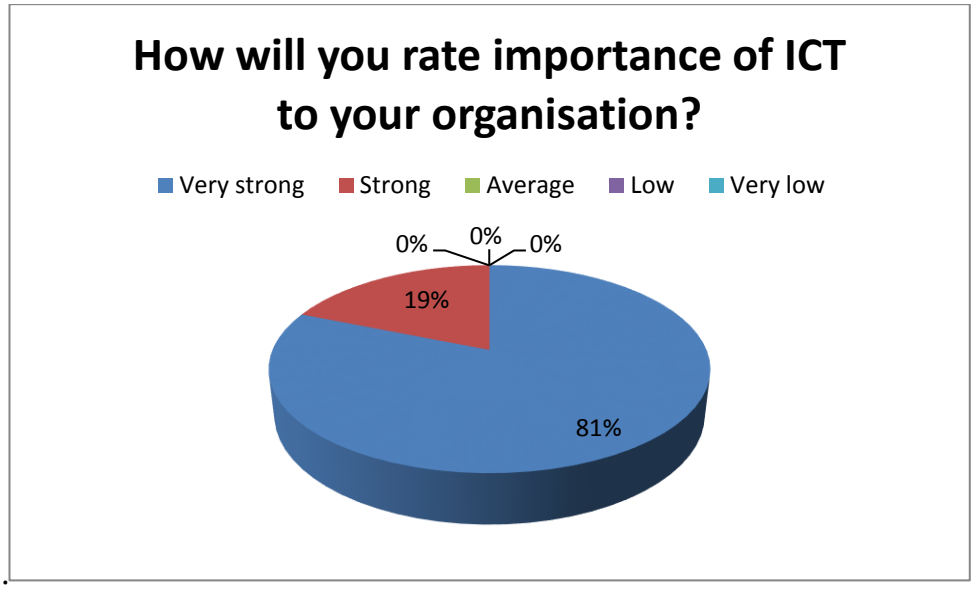


Figure 5. 7 Determine the importance of ICT for SME business process

From Fig 5.7, illustrates that the use of ICT is essential to Nigerian SMEs as 81% of the respondents' rate ICT as a powerful instrument for their organisation.

The next set of questions Fig 5.8 to 5.11) is to determine cloud computing awareness and usage as proposed in success criteria 4 chapter 3 (section 3.4.3).

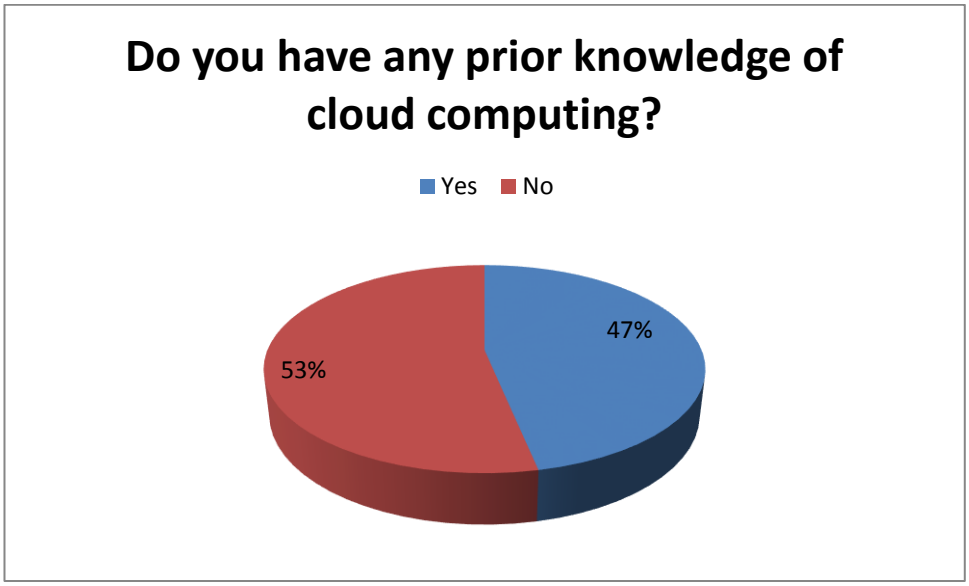


Figure 5. 8 Determine the cloud service knowledge of SME managers

Fig 5.8 shows that 53% of the respondents do not have any prior knowledge of cloud computing while 47% of the respondent have prior knowledge of cloud computing. The results indicate that majority of SME managers do not have knowledge of cloud computing and this might attribute to the fact that the technology is still new to the country. There is need for more advertisement from service providers as well as government to create more awareness about cloud services.

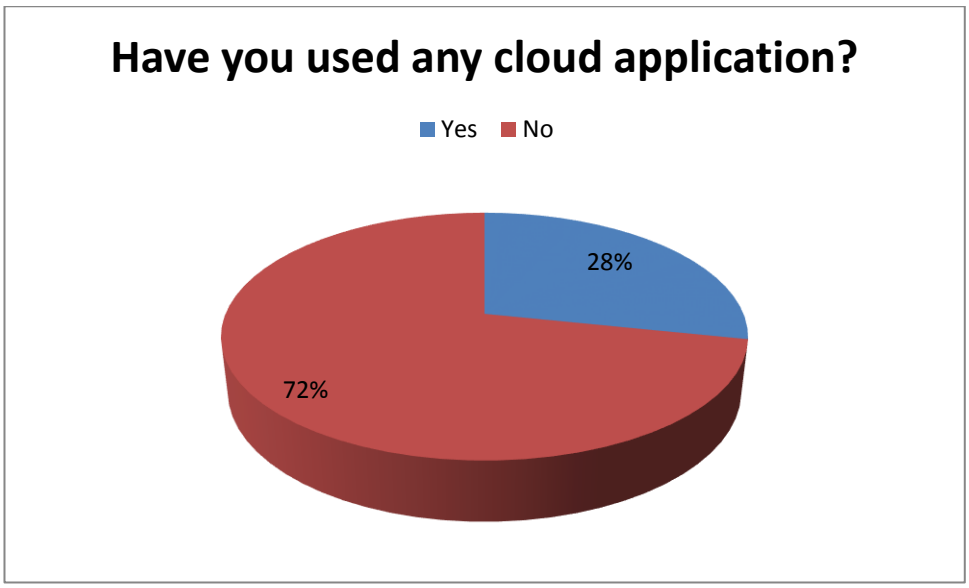


Figure 5. 9 To determine cloud service usage by SME managers

As illustrated in Fig 5.9, the result informs that 72% of the respondents have not used any cloud application and only 28% of the population have used cloud services.

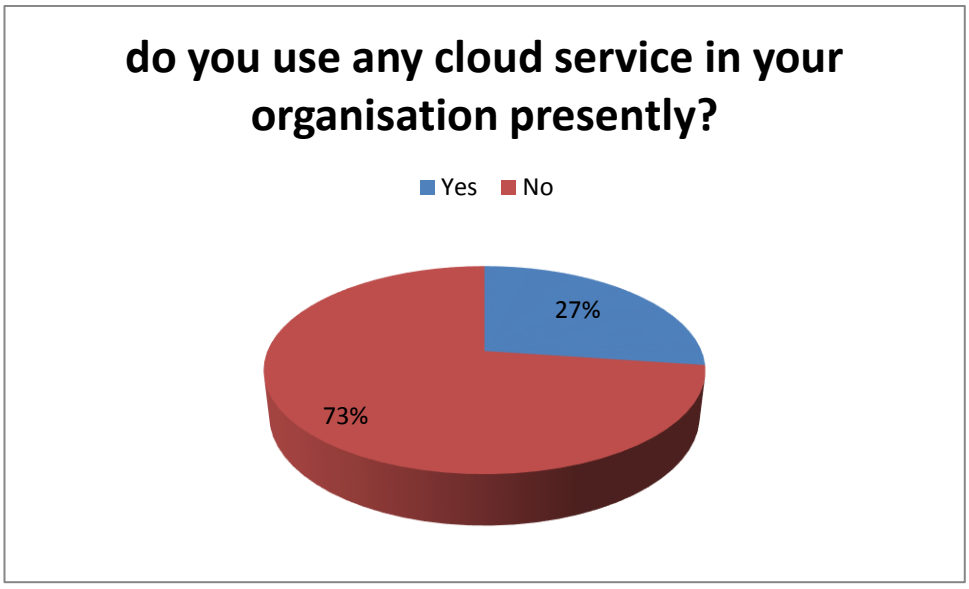


Figure 5. 10 To determine cloud service usage within SMEs Environment

Fig 5.10 shows that 27% of the respondents use cloud services in their organisation while 73% of the respondents do not use cloud services in their organisation. The findings indicate that some SMEs in Nigeria have started using cloud computing services for their businesses thereby taking advantage of the new technology.

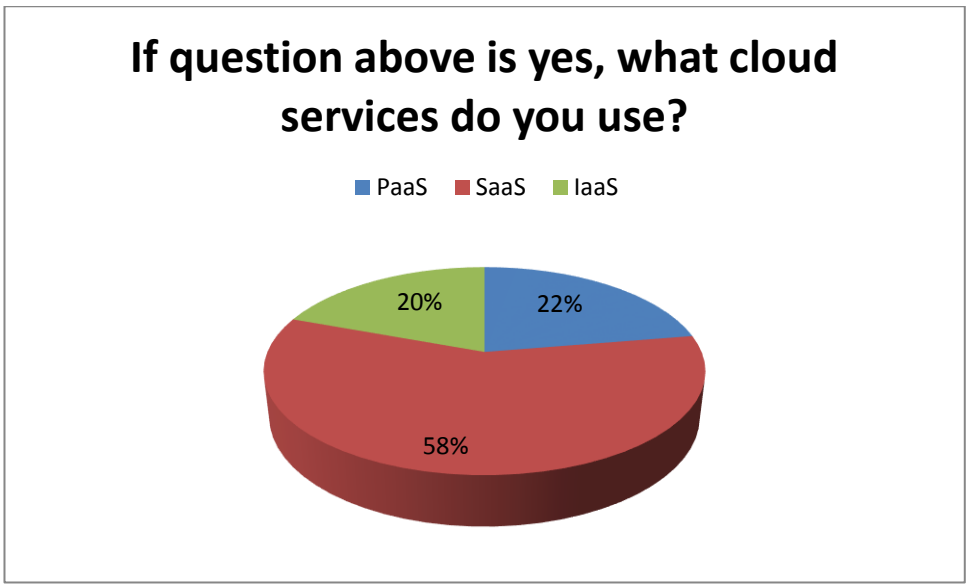


Figure 5. 11 Showing the type of cloud service most adopted by SMEs

Fig 5.11 shows that SaaS is the most adopted type of cloud service presently used by SMEs with 58% of the respondents, next is PaaS with 22% of the respondents, the least services used is IaaS with 20% based on the research findings. The results inform that although there is few SMEs using cloud services, however, SaaS cloud service is more adopted by SMEs compared to other cloud services.

The final section of the survey was to understand how Nigerian SMEs view the slow adoption variables(1-5) identified in the literature review stage of this research as seen in

the works of (Carcary et al., 2014, Alshamaila et al., 2013, Godse and Mulik, 2009) towards cloud service adoption.

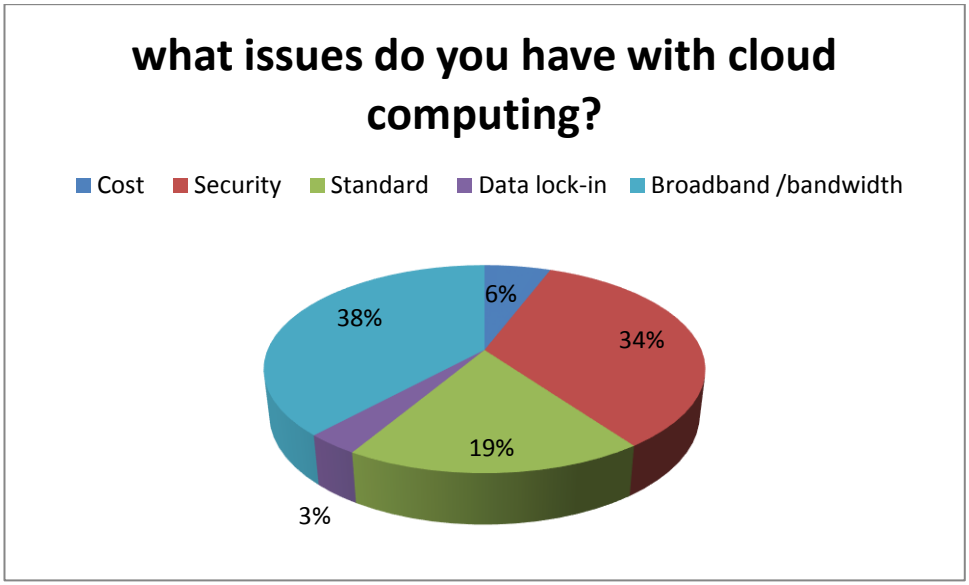


Figure 5. 12 Showing the type cloud service adoption challenges faced by SMEs

From Fig 5.12, it can be seen that majority of the respondents see broadband and bandwidth (38%) as the biggest challenge of adopting cloud computing services as there is not enough internet coverage around the country. For the adoption of cloud service, there is a need for internet availability. Therefore, since majority of the respondents selected broadband and bandwidth as their biggest barrier to cloud service adoption, the availability of internet coverage across the country has the capability to increase cloud service adoption by SMEs in Nigeria. The challenge with the second highest respondent is security with 34% of the interviewees. Security has been a challenge for most internet based technologies. Cloud service providers have continued to find solutions to security issues related to not only cloud computing but also other web based technologies. Finding a solution that can minimise the security risk attached to cloud services as well as making users aware of the type of security a service provider uses can help tackle the slow

adoption of cloud services by SMEs not only in Nigeria but globally. Lack of standard is third with 19% of the respondents; this implies that standards also play a role in cloud service adoption in Nigeria. Therefore, the implementation of standards governing cloud services in Nigeria can help tackle the slow adoption of cloud service by Nigerian SMEs. The challenge with the fourth highest respondents cost with 6% of the total respondents. One of the primary aims of adopting cloud services is to reduce the cost of services. The low rate of respondents selecting cost shows that, although cost identified as a barrier but the SME do not see it as a primary reason for slow cloud service adoption. The variable with the least number of variables was the issue of data lock-in 3%. The results imply that data lock-in identified as one of the reasons for slow cloud service adoption in Nigeria, However, only a small number of SMEs consider it as a reason for the slow adoption of cloud services. An important conclusion of this findings is that cost is not the most important factor for SME adoption of cloud services. 'Broadband &bandwidth' and security are considered the top two priorities for SMEs to adopt cloud services in Nigeria.

In section 5.4, the quantitative survey findings (Stage 1 data gathering) analysed. However, it is important to elaborate and expand on the above findings given generalising the data to the population to get an in-depth understanding of the result as well as triangulate the results of the research. The mixed method approach allows researchers mix quantitative and qualitative methods. Therefore, a qualitative method in this study was conducted using focus group discussions due to the reason discussed in chapter 3(section 3.3.3).

5.5 Qualitative research Approach

The qualitative data gathering (Data gathering stage 2) based on Focus group discussion sessions carried out in the six geopolitical zones of Nigeria, one session in each zone with 7 SME owners or managers present in each focus group discussion. Each participant was carefully recruited based on their prior knowledge of cloud services. In each zone, the environment was comfortable and the participants sat in a circle seating arrangement. The researcher acted as the moderator. An assistant moderato employed to take care of logistics, welcome participants as they arrived, allocate participants designated seats, monitor recording equipment and take notes. However, the assistant moderator did not participate in the discussions. Please see (Appendix iv) for focus group agenda. The researcher (Moderator) started the focus group discussion by:

- Welcoming participants
- Introducing the moderator and Assistant
- Introducing the topics of discussion
- Asking participants to introduce themselves and their business sector
- Also ground rules for the sessions was highlighted as follows:
  - No right or wrong answers
  - Participants were told that the session will be recorded and were informed of their confidentiality
  - Only one person can speak at a time
  - First name basis should be used when referring to a co-participant
  - Participant have the right to agree or disagree with the opinion of a co-participant but their views must be listened to and respected.
  - Cell phones need to be turned off or silent mode activated.

Analysis of cloud services adoption challenges identified by participants during the focus group sessions was done by the researcher systematically as follows:

During the focus group discussion

- Inconsistent comments were identified and probed for understanding.
- Each participant was asked a final preference question.

Immediately after the focus group discussion

- Conducted moderator and assistant debriefing.
- Each focus group discussion was compared with the previous.
- Ideas were noted.

Days after the focus group discussions

- Findings were described and quotes were identified.
- Individual focus groups results were compared.
- Identification of emerging themes by question and overall.

Finally, report preparation

- Narrative style of report was adopted.
- Sequence of themes was employed.
- Report was shared for verification with other researchers.
- Report was revised and finalized.

Themes were identified and discussed descriptively as follows:

5.5.1 Theme 1: Security

The participant identified security as one of the major barriers that might still be a threat to cloud service adoption even if every other challenge is overcome. In the survey,

security identified as the challenge with the 2nd highest number of respondents (34%) this shows that security is a threat to cloud service adoption by SMEs in Nigeria. A majority of the participants are of the view that storing their data in the cloud is a significant risk as hackers may have easy access to their data. They also argue that it is challenging for businesses to allow a third party control their data usage with them having minimal or no control. They believe that storing their data in-house is more secure than in the cloud. One of the managers, Mr Malik from a reputable company in the North Central zone said:

"*I do not know if I can go to sleep knowing that someone else has full access to my business information and not knowing where exactly it is stored*".

The concerns of the participants are synonymous with that of other cloud service adopters around the world. Security of data has been a challenge that cloud service providers keep tackling. It is important that both service providers and government agencies propose necessary measures that will build the confidence of prospective SME adopters of cloud services. There is the need for the guarantee of data security and privacy well stated in the Service Level Agreement (SLA) so that the consequences for breach of data privacy is well understood and agreed by all parties. Also, the need for a decision-making system that can aid SMEs in choosing cloud services based on how best they tackle security is critical.

5.5.2 Theme 2: Broadband & Bandwidth

The participants identified broadband and bandwidth as their major challenge at the moment because cloud services need an internet connection. This can also be understood to be in agreement with the survey findings as a majority of the respondents 38% (highest) chose broadband and bandwidth as their major challenge towards cloud service adoption. They argued that internet services do not cover every part of the country and in some areas, the connectivity is very slow, and this will not enable them to enjoy the full benefits

of cloud services if they adopt it. The participants from the North East and South East stressed that the service is not stable even when it is available. Other from the North Central and Southwest agreed on the availability of broadband, but the issue was different service providers offering similar internet services at various rates. Another concern was the effect of some services being very stable and fast in some parts of the zone while in other regions it may not be available or too slow. A majority of the participants agree that with the number of internet service providers increasing in the country, the competition among them will be very high shortly. Therefore, they anticipated that within short time the challenge of broadband and bandwidth would solve. From the findings of the survey and focus group sessions, it agreed that broadband and bandwidth is a significant barrier to cloud service adoption in Nigeria. It is important that internet services are available and efficient for SMEs in Nigeria to adopt cloud services. The lack of internet services is a common issue with developing countries as identified in similar studies, where broadband & bandwidth services are identified as a barrier to cloud service adoption(Godse and Mulik, 2009). Although, most of the focus group participants are confident that the number of internet service providers spreading around the country is on the rise. On this basis, they are optimistic that within few months the competition among service providers will be high and this will help tackle the broadband and bandwidth issues for efficient cloud service usage. This leads to a belief that many SMEs in Nigeria share the same view as those that participated in the focus group and survey. Going by the access of the SME owners on internet broadband and bandwidth, it be can be concluded that many SMEs will be willing to adopt cloud services if the issue of broadband and bandwidth addressed. Therefore, it is critical to identify the cloud services that allow bandwidth increment and include them in a knowledge management framework for aiding SMEs in clod service adoption decision making.

5.5.3 Theme 3: Standard Framework:

Majority of the participants argued that for the effective adoption of cloud services, there needs to be a standard framework that will act as a decision support tool to guide them in the cloud service adoption process. Although they agreed that there is information on cloud services on various blogs and service provider websites but as this is new to them they will not know what service provider offering is best for their business. They also argue that it will be a complex task for them to search the internet looking for service providers with no method of comparing which service provider offering is reliable, secure and compatible at the best affordable price. They also suggested that a framework that is user friendly and can compare and recommend cloud services in view of meeting their requirements in cloud service adoption decision process cannot be overemphasised. In addition, they require a framework that can give them a basic knowledge of cloud services especially for those who do not have any prior knowledge of cloud services. The participants also suggested that it is important that the framework is available as soon as possible so that they can have a dedicated framework for SMEs. From the focus group discussions, it can be deduced that the SME managers whom are decision makers for their business are in the view that a framework which can be consulted for their decision making process towards cloud services adoption is important. Those participants who are conversant with cloud services agree that there are cloud service adoption frameworks available but there is none for SMEs especially those in developing countries. Finally, we can conclude that the implementation of a cloud service framework that can act as a knowledge management, cloud service recommendation and service ranking specific to SMEs in developing countries is needed to boost cloud service adoption rate by SMEs.

5.5.4 Theme 4: Standards:

The issue of standards identified by some SME managers who have prior knowledge of cloud services but they did not view it as a high priority, unlike the survey where 19% of the respondents recognised standards as their concern towards cloud service adoption. In their argument, they raised the awareness of the regulation of cloud service storage in Europe and they are not aware of any of such law in Nigeria. If such laws exist it should be made known to them either by the government or service providers as it will boost the confidence of prospective adopters. Another issue of standard raised was the case of different service providers offering similar services but using different naming conventions. They believe that this makes it harder to compare cloud service offered by service providers. It is important that a platform that has all the similar cloud services provided by various providers are identified with the same naming convention, so that issue of naming complexity eliminated. The argument of the participant about the regulation of cloud service storage within the European Union identified in the literature review stage of this thesis. Is widely known that European Union Data protection law regulates data storage within the European Union and this varies with other countries across the globe as data storage is not restricted. Some of the organisations associated with cloud service standards are as follows:

- Distributed Management Task Force (DMTF): They focus on interoperability management of enterprise computing and cloud computing.
- Object Management Group (OMG): This group focuses on modelling deployment of applications and services on cloud for interoperability, portability and reuse.
- Open Group Cloud Work Group: This group is collaborating on standard models and frameworks at eliminating vendor lock-in for enterprises.

Another issue raised which is still a challenge in cloud technology worldwide is the ambiguity in the naming of cloud service offerings by service providers.

5.5.5 Theme 5: Reliability

The participants argued that reliability of service providers is essential for cloud service adoption by SMEs in Nigeria to be successful. One of the participant Mr Femi from the South-West zone said:

"*If the cloud service providers act like other service providers in other sectors of the economy who act like politicians, promising everything beautiful to encourage customers and then when adopted you realise the services promised are not rendered then cloud service adoption will drop drastically".*

They also identified the issue of service providers rendering efficient services only for a short period and in the long run start disappointing customers. This is where knowledge of the cloud service comes in place as cloud service providers may not locate in Nigeria. Comparing cloud service providers with other service providers in other sectors of the economy can be overlooked. Cloud services providers only require a user to have internet access wherever they are located to access their service offerings. It is important that a well-documented Service Level Agreement (SLA) is signed and acknowledged by both the user and the cloud service provider because of tackling the issue of reliability.

5.5.6 Theme 6: Data/Customer Lock-in

The focus group participants were concerned about what happens to their data in the cloud if they decide to opt out of the service. The issue of data lock-in was not a priority in the survey as only 3% of the respondents (lowest) identified data lock-in as an adoption barrier in the study. They mentioned some uncertainties as follows:

- Will the service providers keep their data confidential after they have opted out?
- How long will their data be in possession of the service provider after they have opted out?

- What happens to their data if they decide to change cloud service provider, will they have to delete or opt out before transferring their data to another cloud service?
- How long does a new cloud service adopter have to be bound to a particular service provider if they decide to opt out due to dissatisfaction of services?

The concerns of the participants can be addressed with well detailed SLA.

5.5.7 Theme 7: COST

The focus group participants agreed that the cost of adopting cloud services was fair due to the enormous benefits they stand to gain when the technology is adopted. They made references to the initial cost of purchasing a mobile call line in the country. They argued that it was costly at the initial stage but with the introduction of more mobile service providers joining the industry, the price was slashed drastically due to a high level of competition among vendors. They are confident that this will also happen in the cloud service adoption even if the cost is high at an initial stage. The major concerns raised was that internet providers might increase the price of internet services if they realise that so many SMEs are adopting cloud services and this will reduce the cost benefit of cloud service adoption. Although they consider cost as an important factor when considering cloud service adoption however they do not believe it is a big challenge considering that there are many service providers and the competition between both cloud service providers and internet providers will help reduce the cost of cloud service adoption. The low importance associated with this challenge (cost) reflected in the survey session as a small percentage of the respondents (6%) selected price as their cloud service adoption challenge. Consumers of any kind are inspired by both the importance of a particular product and the cost of purchasing that product. It is important for service providers to

note that if the cost of adoption is high, the SMEs may reject the product and look for other alternatives.

5.5.8 Theme 8: Interoperability/Compatibility:

The issue of interoperability raised by the participants present in the focus group discussions. In their argument, they fear that service providers may restrict the way clients/applications/users interact with the cloud environment. They believe that this will force them to be locked-in to a service provider offering, thereby hindering them from switching to another service provider as well as the inability to simultaneously optimise resources at different levels within the business organisation. Another concern identified was the issue of their customers either adopting a different service provider offering from theirs. They believe this is a likely issue that may affect their business when they eventually adopt cloud services. They further argued that some service provider offerings especially priority cloud APIs make it extremely challenging to integrate cloud services with organisations existing legacy systems.

Going by their argument, it is evident that the interoperability and compatibility issues raised refers to both the inter-relationship among different cloud platforms and the connection between a cloud service platform and an organisation's local systems. It is the primary requirement of cloud service users to see a seamless fluid data across clouds and between clouds and other local organisations applications. This can only be addressed when the issue of interoperability is resolved. A typical example of such interoperability and compatibility issue is a situation whereby an SME adopts Gmail for their email services and Salesforce.com for their HR services. In this kind of situation, for the SME to achieve optimisation, the features of the email services (e.g. calendar, address book, etc.) must connect to the Human Resources (HR) employee directory located within the HR system.

There were several other adoption issues identified such as what to migrate and when to migrate as well as matters of inadequate power supply and Government policies.

5.5.9 Theme 9: Lack of knowledge of the service

One of the biggest challenges identified by the SME managers is the lack of awareness of cloud services. This was also identified in the survey as 53% of the respondents had no prior knowledge of the service, and 47% had prior awareness of the service. The majority of the participants were of the view that either the service providers are focusing on the developed countries before reaching out to SMEs in developing countries or they are not advertising the presence of the service well enough so that they can take advantage of this new technology. Another group of participants especially those from the North central and south west zone were aware of the services but have issues on how to compare service provider offerings because of selecting the best. This can attribute to a multi-criteria decision problem. While some of them have started adopting the services, others are hoping to adopt cloud services in future. As they keep monitoring the usage in other parts of the world. Based on the perspective of the participants, it is important that service providers do more to advertise their products so that the knowledge of the services will not be confined to only SMEs in developed countries but in developing countries as well. Furthermore, those participants who already have knowledge of the services but are monitoring its usage before the adoption can be categorised under prospective users with fear of adoption of new technology. Finally, most of the participants were willing to adopt cloud services for their business as such it is important for service providers to target SMEs for their service advertisement.

In above sections, the data gathering technique discussed as well as the analysis of cloud service adoption challenges particularly with SMEs in Nigeria. The findings have given

the researcher more depth over requirements that need to be considered bearing a framework in mind. Further requirements are identified in section 5.6.

5.6 Envisioned Requirements

The requirements for the envisioned system framework identified through literature, focus group discussion, survey and interviews with experts. Furthermore, they are divided into research and system requirements as both should be achieved by the envisioned system.

5.6.1 Research Requirements

1) The research requirements identified by experts and from literature reviews. They are identified as part of the vision of the envisioned service.

2) Reduction in cost is the chief attraction to cloud services. This is important for SMEs because it helps to maximise profit. Reduction in cost includes upfront and operational cost.

3) A method for measuring QOS associated with cloud service providers. To address the issue of complicated comparison caused by services providers offering similar services at various prices.

4) A process for ranking cloud services based on the ability to meet user requirements.

5) A platform for promoting cloud service knowledge management to aid SMEs in the cloud service adoption process.

6) A framework to promote cloud service awareness for Nigeria SMEs

5.6.2 System Requirements

1) The proposed system should provide a mechanism for cloud service information management and it should include requirement parameters information.

2) The proposed system should ensure a standard means of describing cloud service providers service offerings. This is because at the moment there is no standard vocabulary for representing cloud service offerings and this can be confusing to users.

3) The selection process should be able to interrelate with different sections of the system to retrieve user requirements. Also, the system should be able to answer user queries simultaneously, without affecting the accuracy of the search process.

4) The proposed system should be able to multitask. It should not be specific e.g. limited to only Knowledge management. It should be able to tackle more than one adoption challenge.

5) The system should be able to track cloud service provider offerings automatically, and if a service is not available within the system, it should not allow the process searched.

6) The proposed system should be accurate and efficient in handling user queries for cloud service requirements. The search interface should be user-friendly, and the search carried out automatically. The recommendation process should retrieve information that best meets users' requirement while addressing difficult comparisons.

In the next section, a comparison between cloud service adoption in Nigeria as a developing country and England as a developed country discussed. The comparison is based on the findings from this research and that of similar research carried out on cloud service adoption among SMEs in England(Alshamaila et al., 2013).

5.7 Cloud Service Adoption Challenges England VS Nigeria SMEs

Small and Medium Sized Enterprises (SMEs) are vital components to every country; they are the bedrock of the EU economy, representing about 99% of all businesses. They are projected to account for 67 percent of total employment and 58% of gross value added (Wymenga et al., 2011). SMEs make a significant addition to the socio-economic and political infrastructure of developing and developed countries as well as nations categorised as being in transition from command to market economies(Matlay and Westhead, 2005). Also, a healthy and growing SME sector is alleged to be crucial for sustainable competitive advantage and economic development at national, regional and local levels(Snowdon and Stonehouse, 2006). In chapter 2, the classification of SMEs in various countries around the world especially in England and Nigeria have been identified. Given the nature of importance of SMEs in the economy of most countries and the unending benefits of cloud services to SMEs; it is important to understand the cloud service adoption challenges between England (developed country) and Nigeria (developing country) SMEs. This is done to determine the cloud service adoption gap between developing and developed countries for further research purposes.

To achieve this, a similar research study on cloud service adoption in the north east of England (Alshamaila et al., 2013) compared with the cloud service adoption findings in this research as illustrated in table 5.3.

Table 5.3 Similarity and differences in cloud service adoption challenges England VS Nigeria

Challenge	**England**	**Nigeria**
Security	x	x

Trust	✓	x
Geo-restriction	x	✓
Broadband &bandwidth	✓	x
Trial ability	x	✓
Cost	✓	x
Knowledge	x	x
External support for decision making process	✓	✓
Interoperability	✓	✓
Customer lock-in	x	✓

In Table 5.3, the similarity and differences in cloud service adoption challenges among SMEs in the England and Nigeria have been identified. In the next section, the findings in Table 5.3 discussed further.

5.7.1 Security & Trust

The challenge of security and trust identified as a cloud service adoption problem by both SMEs in Nigeria and England. From table 5.3, security continues to be a threat to cloud technology in both developing and developed countries as observed. The SMEs from both countries agree that privacy of data and third-party interference is a challenge to cloud service adoption. Both service providers and researchers need to continue finding ways to tackle the issue of security by discovering new methods that can be used to address security issues in cloud computing to boost the confidence of likely adopters. However,

the issue of Trust was perceived differently by the SMEs in England compared to those from Nigeria. While the SMEs in Nigeria identify lack of trust for service providers as a challenge to cloud service adoption, the reverse is the case for SMEs in England. The early adopter and possible cloud service adopters in England have trust for the service providers as long as a Service Level Agreement (SLA) applies to both parties. They are more concerned with the uncertainty associated with the adoption of new technology.

5.7.2 Geo-restriction & Trial-ability:

The issue of Geo-restriction and trial-ability is more synonymous with the SMEs in England as depicted in table 5.3. Nigeria SMEs did not identify such challenge as an adoption problem. SMEs in England argued that they sign confidentiality agreements with their customers. Therefore, it is important they know exactly where their data is stored and who has access to their data. Many of the SME participants in England prefer their data to be stored and guided by the UK/EU laws. Also, England SMEs identified the issue of lack of trial versions by service providers. The further argue that if cloud service providers introduce trial version, it will enable them to have a better understanding, knowledge and how best it can be in cooperated in their business process. The argument regarding trial-ability by England SMEs if applied by the service provider can be considered as a means of aiding cloud service adoption by SMEs in both developing and developed countries.

5.7.3 Knowledge, external support & Interoperability:

From table 5.3, SMEs in England and Nigeria identify lack of knowledge of cloud services as a challenge towards its adoption. This problem can be termed a global challenge since countries recognise it in both developing and developed countries. It is important that cloud service providers spend more energy on promoting and advertising

their services. Also, SMEs from both divide identified the importance of cloud service decision-support tool to help in the cloud service adoption process. They also identified the issue of interoperability as a challenge that needs addressing so that cloud services can be compatible with their existing technology as well as sharing of data between them and their customers. SMEs in both countries may continue to be slow in cloud services adoption if the issue of interoperability is not addressed.

5.8 Conclusion

In this chapter, the technique used to gather primary data discussed. The distribution and location of SMEs that participated in the quantitative (survey) and qualitative (focus group discussions) explained. The cloud service adoption challenges faced by SMEs in Nigeria was identified. Also, a comparison of cloud service adoption challenges between England and Nigeria SMEs discussed. In the next chapter, a solution framework CLOUDSME that has the capability to address the adoption challenges identified in the primary data gathering stage presented.

Chapter 6: CLOUDSME Framework

So far, some tools and techniques for tackling slow adoption of cloud services have been identified. Also, a well-detailed analysis of the state- of- the-art of the research area has been carried out in chapter 4. The reason for slow adoption of cloud services in Nigeria identified in chapter 5. Within the techniques, Framework and ontologies widely used towards tackling the issue of slow adoption of cloud services globally. While AHP seen as the most adopted method for addressing MCDM problems, it is often used by researchers for comparing and ranking cloud service offerings of service providers, however, AHP has the issue of rank reversal as suggested by (Belton and Gear, 1983, Dyer, 1990).

Again, a critical analysis and discussion of cloud service adoption techniques as well as modelling tools and the approaches adopted in tackling the slow adoption rate of cloud services have been carried out. Furthermore, the characteristics, reasons and area of implementation discussed. Also, the limitations of these approaches as well as the challenges faced in the research area reviewed.

In chapter 5, the reason for slow adoption of cloud services by SMEs in Nigeria identified and analysed. This was done using a mixed method approach which include quantitative (survey) and qualitative (Focus group discussion). The findings from the data gathering phase informed the researcher with an in-depth knowledge of the major cloud service adoption challenges peculiar with Nigerian SMEs as (security, broadband &bandwidth, data lock-in, cost, interoperability, reliability, knowledge) as discussed in chapter 5.

This chapter describes the architecture of the proposed decision support framework (CLOUDSME). The framework is equipped with a semantic model to aid SME

owners/managers in the decision-making process of cloud service adoption. This section is divided into four parts 6.1 Overview of CLOUDSME, Section 6.2 CLOUDSME Phase 1 (This is based on SME stakeholder requirements (variables) identified during the data gathering stage 1 and 2 of this thesis (chapter 5) compared against cloud service provider requirement offerings). Section 6.3 CLOUDSME prioritisation phase 2(Formalism), Section 6.4 Adopting the AHP approach for the prioritisation phase. Section 6.5 Proposed CLOUSME ranking protocol Section 6.6 Decision Support System Architecture, 6.7 Conclusion.

6.1 Overview of CLOUDSME

An overview of the service framework shown in Figure 6.1. The proposed framework comprises of four different phases. The first phase comprises of information gathering of cloud service catalogues advertised by service providers to meet user requirements. The information gathered consists of requirements and their parameters of cloud service provider offerings. The second phase comprises of the prioritisation phase whereby a set of formalism is used to compare two similar requirement parameters of different cloud service provider offerings using pairwise comparison table (see Chapter 2, Table 2.2) to judge the superiority of one cloud service offerings over another in quantifiable values. The assigning of weight is done by 5 SME managers using a qualitative approach based on group interview (data gathering stage 3) to weight cloud service requirement parameters in applying AHP as a Multi-Criteria Decision-Making method. A set benchmark is determined by the priority value for each Key Performance Indicator (KPI) after comparing and normalising the importance of one KPI over another based-on SME manager's perspective. In the third phase, the research introduces a set of protocols for ranking each cloud services by proposing the use of rational relationships to tackle the issue of rank reversal associated with the AHP approach. The fourth phase is the design

and development of an ontology of cloud service which is designed as a Decision Support System (DSS) using an ontology editor Protégé. The ontology editor has the capability to translate human language to machine readable language to achieve the system goals. The implementation of the framework uses a set of concepts and associated semantic rules to retrieve user requirements and the ranking of cloud services towards tackling the slow adoption of cloud service by SMEs. The decision making which comprises of knowledge management, service recommendation, service ranking, service discovery and adoption decision. This chapter discusses the phases 1, 2, 3 and 4 while the implementation and decision making is discussed in chapter 7.

Before introducing the framework, it is important to address that cloud services that best meet the requirements identified in the data gathering stage 1&2 of this thesis. SaaS designated as the cloud service that best suits these requirements as it tackles most of the identified variables. Also, it is the cloud interface layer that requires users to have services access using a web browser and thin computer terminals. Furthermore, from the data gathering stage 1 of this thesis, majority 58% of the respondent who has already adopted cloud services selected SaaS as the service chosen as seen in (Chapter 5, Fig 5.11). Therefore, this implies that SaaS services have a high acceptance rate among Nigeria SMES that have adopted cloud services. Based on the above and knowing that knowledge is incremental, this thesis is limited to SaaS storage application services. A case study of SaaS storage application as shown in Table 6.1 forms the basis of the proposed framework. Fig 6.1, represents the proposed CLOUDSME framework showing the different phases.

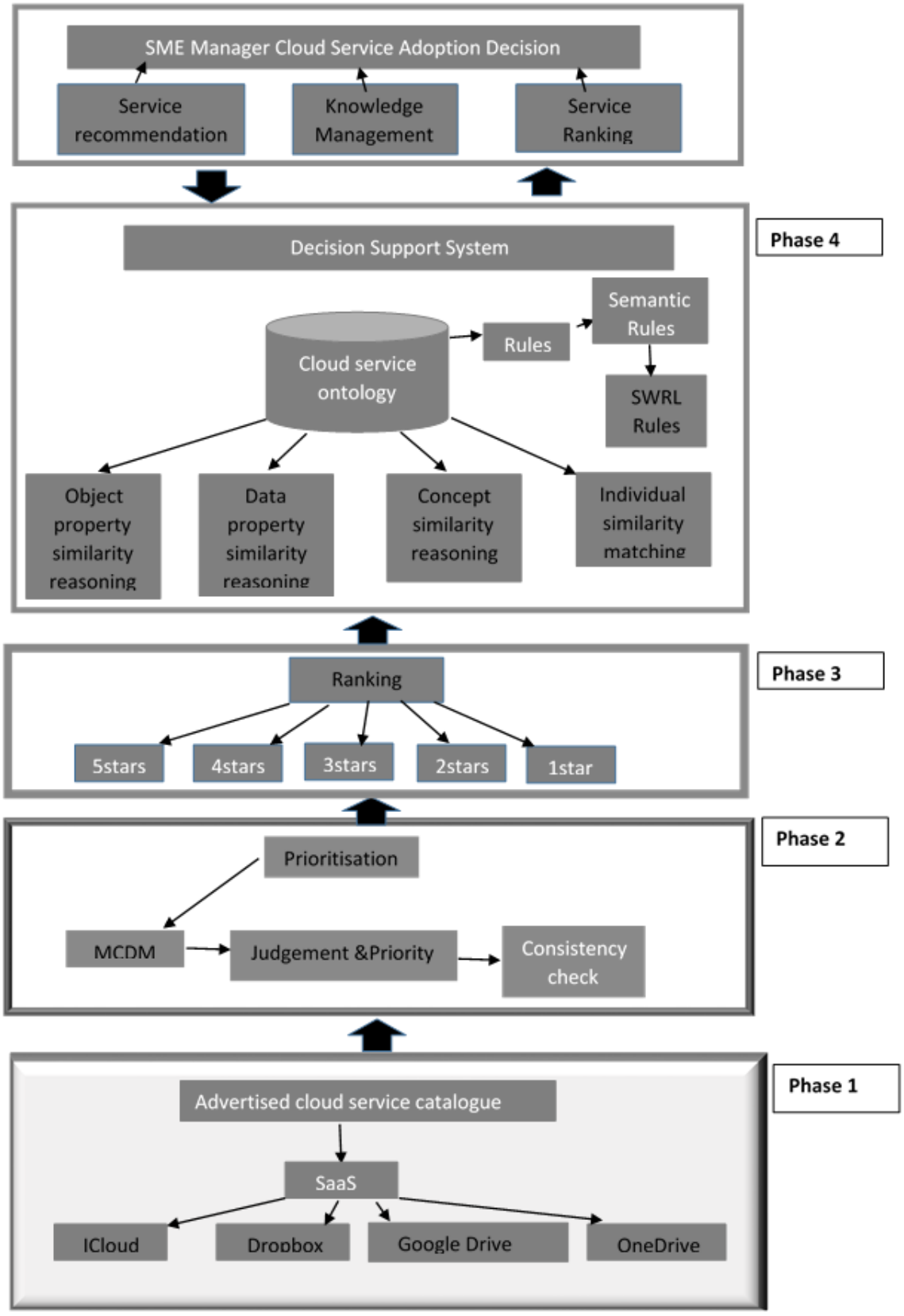


Figure 6. 1 CLOUDSME Framework

6.2 CLOUDSME PHASE 1

This CLOUDSME phase based on a case study of four major SaaS cloud service storage applications and their requirement offerings. The offering refers to the physical resources advertised on the cloud service provider websites. The SaaS storage application case study seen in table 6.1. The four top SaaS storage applications and their service providers are represented in this thesis as follows: Service B-Dropbox (Dropbox Inc.), Service A-One Drive (Microsoft), Service C- Google Drive (Google) and Service D- ICloud (Apple). These provide a knowledge base in addressing success criteria five as seen in chapter 3(Section 3.4.6). In the data gathering stage 1(survey) in chapter 5(section 5.4), 34% of respondents mentioned security, 34% bandwidth, 19% trust, 6% as their significant challenges in cloud service adoption. While in the focus group session Trust (reliability, Data lock-in) interoperability (Operating system supported) and lack of knowledge were identified in the focus group discussion. Therefore, the core of this phase is to initiate a knowledge base for the proposed framework base on the case study of four major SaaS storage application services and how they meet user requirements as presented in table 6.1. The parameters managed by CLOUDSME include Trust, security, Operating System supported, Cost, Bandwidth and other service requirements advertised by service providers such as Office via the web, File size restriction and free storage.

Table 6.1: A Case Study of 4 major SaaS cloud service storage application provider requirement offerings as advertised on their website.

Service provider offerings	**Service_A (SaaS)**	**Service_B (SaaS)**	**Service_C (SaaS)**	**Service_D (SaaS)**
File size Restriction	2GB	-	10GB	15GB
(Trialability) Free Storage	5GB	2GB	15GB	2GB
(Cost) On-Going Payment plan	$83.88/1TB/1 Year $2/month/100GB	$99/1TB/1 Year $10/month/1TB	$99/1TB/1 Year $2/month/100GB	$99.99/1TB/ Year $20/month/1 TB
(Interoperability) Operating system supported	Windows, Mac, Android and iOS	Windows, Mac, Linux, Android, iOS	Windows, Mac, Android and iOS	Windows, Mac, Android and iOS
Trust Access rights	SLA	SLA	SLA	SLA
Security	Encrypt per file basis/no on rest encryption	AES 256- bit Encryption	128- bits AES and HTTP	128-bits AES
Office via web	Yes	Yes	Yes	Yes
Bandwidth adjustment	No	Unlimited	User restriction	No

6.2.1 Standardization of service provider offerings

In an attempt to have a unified vocabulary for the service attributes represented in CLOUDSME, the following are proposed: Gigabyte (GB) is used as the measurement for storage in the cloud. This is to have a uniform measuring standard all data are converted to Gigabyte and represented as GB. Furthermore, Cost (PA) are presented in United States Dollars (USD) as this is the most generally accepted currency in the world. Two types of payment plans advertised by service providers which are monthly payment and the yearly payment and presented as payment plan 1 and Payment plan 2 in CLOUDSME. As mentioned above, to maintain uniform vocabulary within the system the annual payment plans are converted to months for better understanding and user friendliness. Also, the

software resource associated with the service is the operating system (OPS). The alternatives for OPS includes Windows, Linux, Mac, iOS and Android. The remaining requirements represented as follows: Security (SE), Trust (TS), Free Storage (FS), Office via web(OVW), Bandwidth Adjustment(BA), File Size Restriction (FSR).

6.2.2 Cloud service properties Vs User requirements

The four cloud services and how they tackle user requirements discussed as follows:

- **Security(SE)**

Security is considered as one of the biggest fears among cloud service adoption challenges. This is because cloud computing represents a relatively new technological model and hence a lot of uncertainty on security issues at all levels. Possible security issues that may occur in a SaaS environment are application security which is due to services delivered over the internet. Therefore, some web flaws (e.g. hacking) may occur leading to SaaS applications being vulnerable. Another security issue that may result in multi-Tenancy issue whereby users share the same database and this may lead to high risk of data leakage.

In a bid to address these problems most service providers have adopted different security measures. Dropbox uses AES-256- bit encryption to protect customer files at rest, Google Drive uses128-bits AES and HTTP, One Drive users, can encrypt on per file basis although they do not get at rest encryption on default, while iCloud uses a minimum of 128-bits-AES. Furthermore, the most insecure cloud storage is one that shares its login details with other products and services. Google Drive users are most likely to be vulnerable since all its offerings use the same login details, next is One Drive and the iCloud. The users of Dropbox are least vulnerable due to Dropbox having very few services.

- **Accessibility and Trust(TS)**

Cloud service applications easily accessed over the internet via a web browser and this makes accessibility via any computer device easy. This leads to easy access to information stealing through mobile malware, insecure market place as well as unauthorised hacking. Amongst the four compared cloud services, Dropbox is least likely to be accessed without authorization because compared to other SaaS services it has only on point access except in situations where a user decides to reuse the same password across different platforms. Also, all four services backed by SLAs that guarantee a 99% uptime per month. However, there is still a little possibility of outage sometimes.

- **Interoperability (OPS)**

All four compared cloud services are compatible via multi platforms. Google Drive is compatible with Windows, Mac, Android and iOS although it does not support Windows mobile. One Drive which is a natural Windows product is compatible with Windows mobile as well as the Mac, Android and iOS. Dropbox is compatible with windows mobile, Android, Mac, iOS and Linux while iCloud is compatible with windows, Mac, iOS and Android.

- **Free Storage(FS)**

The four SaaS cloud services compared, offer free storage to its users although it is limited. The free storage allowance varies among the service providers. Google Drive offers the highest free storage allowance with a space of as much as 15GB; One Drive offers a free allowance of 5GB while Dropbox and iCloud offer 2GB each. Free storage is included in this comparison as it can address the issue of trial-ability if the need arises.

- **Office via The Web (OVW)**

The ability for cloud services to access Office applications is vital to some SMEs. OneDrive which is part of Microsoft products automatically links with Office 365, and this gives its users the opportunity to edit their office documents directly within the web

app. Likewise, users of Dropbox can also edit their office documents on office apps and save directly to Dropbox if using the Office app online. Furthermore, Google Drive users can also edit, save and share documents via office apps.

- **Bandwidth Adjustment(BA)**

Among the four SaaS services compared, only Dropbox and Google Drive allows bandwidth adjustment. Dropbox and Google Drive lets users to upload data from smartphones and a web client. While Google Drive uses 100% of the bandwidth by default, Dropbox uses only 75%, but they can both be increased or decreased depending on the user's choice. While Google controls the amount of bandwidth that should be used while uploading or downloading on desktops and smartphones, Dropbox offers unlimited upload without any form of restrictions.

- **Payment (PA)**

Payment is one the factors considered when considering adoption of cloud services. The cost of cloud services varies among service providers at different subscription rate and price packages. One Drive offers $83.88/1TB/Year, Dropbox and Google Drive offers $ 99/1TB/Year, while ICloud offers $99.9/1TB/Year. However, each of the service providers still provides monthly subscriptions in other accommodate users who prefer to pay on a monthly subscription. OneDrive costs $2/month/100GB, Dropbox costs $10/month/1TB, GoogleDrive costs $2/month/100GB and $10/month/1TB, while ICloud offers $20/month/1TB.

- **File Size Restriction(FSR)**

SaaS cloud services regulate the number of files shared at any given time. This restriction varies among the service providers. One Drive allows for 2GB; Google Drive allows 10GB and ICloud allow 15GB. Dropbox is the only cloud service that does not restrict the amount of file shared.

After the phase 1 which was based on identifying Major SaaS cloud services storage applications and how they address the user requirements (Variables) established in 1&2 data gathering stages of this thesis, the next section which is the prioritization phase aims to tackle the issue of complex comparison using the AHP approach to address the research success criteria six as identified in stage 2 data gathering (Focus group discussion) and seen in chapter 3(Section 3.4.6).

6.3 CLOUDSME Phase 2 Prioritisation

This phase of the proposed framework tends to deal with the issue of multiple comparisons using the AHP approach to tackle the research success criteria 6. The cloud service requirement offering prioritisation is vital to the framework development and it is bases on how they meet user requirements. The task of comparing of cloud services requirements and their parameters is very complex. This challenge is described as a multi-criteria decision making (MCDM) problem (Zeleny and Cochrane, 1973). To address the problem, the research proposes the use of Analytical Hierarchical Process (AHP) which is one of the most widely used methods for tackling problems related to MCDM. This approach utilised in this research based on its ability to check consistencies of judgement lacking in other MCDM methods.

6.3.1 Major Steps in AHP process

There are three significant steps within the AHP mechanism which are: problem decomposition, Judgement of priorities and aggregation of priorities.

1. Problem decomposition

In this step, a hierarchy structural representation of cloud services that shows the interrelationship among the overall goal, the attributes and the alternative services shown. This layer tends to analyse the goals and how each cloud service quality tends to satisfy the essential requirement of the user.

2. Judgement

This step deals with the assigning of weights to each attribute which is essential in comparing two cloud services to ascertain their relative importance. To address this issue, the user assigned weighting method which is a standard for using AHP considered. In this regard, weights are assigned using pairwise comparison scale of [1-9] as shown in Chapter 2 (Table 2.2) as recommended in the AHP method to judge the importance of one attribute over another. This allows the quantifying of cloud service provider offerings regarding preference of a specified service requirement over another. By using the AHP method, the sum of all weights must be equal to 1(Saaty, 2005).

3. Aggregation of priority

The task of assigning weights is not as easy as it seems because some of the attributes are not quantifiable. To tackle this issue, the following formalism is considered:

Let's assume A_q be the weight assigned by the user for the attribute q. let P_i and P_j be the values of attribute q for cloud services i and j. If b_i and b_j are the cloud services, then b_i / b_j represents the relative comparison of b_i and b_j. Then the value required by the user is presented as t_1. To compare the values P_i and P_j for cloud services b_i and b_j, it is important to confirm that the conventional unit for both values are the same. In an instance where the cost of two advertised cloud service data storage is compared, they must have the same currency notation (USD) as well as price per GB. This enables a perfect comparison. To contain the versatility of cloud service attribute especially the non-

measurable characteristics of some attributes, a different nature of comparison is proposed for each type. Furthermore, for 2 types of cloud services b_i and b_j with numeric attributes can be compared using two different criteria either higher is better therefore a higher intensity of importance is assigned or higher is lower therefore a lower intensity of importance is assigned to it. If higher is better, then $\frac{p_i}{p_j}$ is the value of b_i/b_j and if lower is better then $\frac{p_j}{p_i}$ is the value of b_i/b_j. In addition, two attributes that maybe defined based on the number of platforms supported are considered. To assign weights to cloud services for such attributes, the following declaration is considered. Let size P_i and P_j to be the number of platforms supported buy services i and j respectively. Let t_1 be the size of the user requirement value for quantity of service attribute q. In such scenario, the cloud service with the largest number of elements is declared better and higher weights are assigned to it. Furthermore, in a scenario where A_q is the weight assigned by the user for the attribute q, let P_i and P_j be the values of attribute q for cloud services *i* and *j*. If P_i and P_j values are equal, then their intensity of importance is equal to 1.

The above comparison matrices enable a one -on- one comparison of each cloud service for an attribute. This will further translate into a one –to-one matrix for a size N × N if there are a total of N services. The relative ranking of an attribute for all the cloud services is given by the eigenvector (ƛ) of the matrix.

Finally, each attribute is aggregated with their relative weights assigned in phase 2. The process of aggregation is repeated for all attributes in the service hierarchy.

6.3.2 Consistency Check

When the pairwise comparison is performed, some inconsistencies may arise. Such as in situations where three of the following criteria are considered. The first criterion is judged

to be slightly more important than the second criterion while the second criterion is also judged somewhat more important than the third. It is evident that inconsistency will arise if the third criterion is judged to be equal or greater than the first criterion. Also, inconsistency will result if the first criterion is judged to be slightly more important than the third criterion. This is because from the above scenario a consistency evaluation should judge the first criterion more important than the third.

As mentioned above, one distinct advantage of the AHP above other MCMD is its incorporation of an effective technique that aids in checking the consistency of the judgements made when building each of the pairwise comparison matrices involved in the process. This technique depends on the computation of suitable consistency index. To determine the consistency index (CI), the scalar *x* is first computed as the average of the elements of the vector whose *j*th element is a ratio of the *j*th element of the vector *A.w* to a corresponding element of the vector *w (* where A is a matrix and w is a weight vector*).*Then:

$$CI = \frac{X-M}{M-1} \tag{6.1}$$

A perfect judgement should always obtain *CI=0,* but small inconsistency values are accepted when:

$$\frac{CI}{RI} < 0.1 \tag{6.2}$$

From the equation above, *RI* is the random index which is the consistency index when the entries of the matrix of A are completely random. The values of *RI* ranges from ($m \leq 10$) as shown in Table 6.2.

Table 6.2: Average random consistency (RI)

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

6.4 Adopting the AHP process for CLOUDSME prioritisation phase

In adopting the major steps of the AHP approach as discussed in section 6.3.1 for the prioritisation phase of this thesis, the first phase is mentioned in section 6.2.2. To proceed with the remaining steps of the AHP approach, it is important to conduct data gathering stage 3 which is a qualitative data collection method. This is important because the AHP approach requires the weighting of service attributes. In this research, the weighting of service provider offering based on how they meet user requirements is carried by 5 SME managers(Godse and Mulik, 2009). Identified and selected to have vast knowledge of cloud services during the Focus group discussion sessions of this research partaking in an online dyadic group interview session via skype

6.4.1 Dyadic group interview (Stage 3 data gathering)

In dyadic interviews, a small group of participants interact in response to open –ended questions in research(Morgan et al., 2013). This qualitative approach was done via skype with 5 SME managers selected from stage 2 data gathering (Focus group) and representing different categories of SMEs using pairwise comparison table as presented in chapter 2 (Table 2.2) to agree on assigning weights using a democratic approach to cloud services requirements parameters as presented in the case study in Table 6.1. This

weighting method was used to determine a) The superiority of one cloud service provider offering based on how they meet each user requirements identified in this research as seen in Table 6.1 and discussed in section 6.2.2 over another, (please see Appendix 4) for user requirement weight results. Again, the assigning of weight based on the superiority of one attribute over another as seen in Fig 6.2.

$$\begin{bmatrix} \therefore & PA & OPS & SE & FSR & BA & FS & OVW & TS \\ PA & 1 & 2 & 1/3 & 4 & 6 & 7 & 5 & 1/2 \\ OPS & 1/2 & 1 & 1/4 & 3 & 5 & 6 & 4 & 1/3 \\ SE & 3 & 4 & 1 & 5 & 8 & 9 & 7 & 2 \\ FSR & 1/4 & 1/3 & 1/6 & 1 & 4 & 5 & 3 & 1/5 \\ BA & 1/6 & 1/5 & 1/8 & 1/4 & 1 & 2 & 1/3 & 1/7 \\ FS & 1/7 & 1/6 & 1/9 & 1/5 & 1/2 & 1 & 1/4 & 1/8 \\ OVW & 1/5 & 1/4 & 1/7 & 1/3 & 3 & 4 & 1 & 1/6 \\ TS & 2 & 3 & 1/2 & 4 & 7 & 8 & 6 & 1 \end{bmatrix}$$

Figure 6. 2 The Relative Matrix (RSRM) for the combined KPI

6.4.2 CLOUDSME Aggregation & Prioritisation

The aggregation of CLOUDSME follows the formalism discussed in section 6.3.1. The first set of data as seen in appendix 4 is aggregated and a Relative Service Ranking Matrix (RSRM) is constructed for each requirement. This is done to determine the priority weight Relative Service Ranking Vector (RSRV) for each requirement. The matrix for Payment (Pa) has been shown (for illustration), while RSRV for the other requirements based on appendix 4 are outlined.

Based on the Dyadic group discussion result as shown in appendix 4, the relative service ranking matrix (RSRM) for payment (Pa) is as follows:

. Payment (Pa)

Step 1: To determine the RSRM for payment, based on the payment judgement as shown in appendix 4 by applying Pair wise comparison and using the aggregate priority formalization as discussed in section 6.3.1. The following steps are presented. Fig 6.3a presents the payment matrix.

Service_B , Service_C, Service_A, Service_D

$$\begin{matrix} \mathbf{B} \\ \mathbf{C} \\ \mathbf{A} \\ \mathbf{D} \end{matrix}\begin{bmatrix} 1 & 1 & \frac{1}{3} & 2 \\ 1 & 1 & \frac{1}{3} & 2 \\ 3 & 3 & 1 & 4 \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{4} & 1 \end{bmatrix}$$

Figure 6. 3a RSRM Payment

Step 2: Synthesize Matrix for Payment to determine the Relative Service Ranking Vector (RSRV). The relative RSRV which is the priority weight determined for the payment requirement for each cloud Service B, Service C, service A and Service D respectively is highlighted in bold in fig 6.3b.

$$\begin{bmatrix} 0.1818 & 0.1820 & 0.1740 & 0.2222 & \mathbf{0.1899} \\ 0.1818 & 0.1820 & 0.1740 & 0.2222 & \mathbf{0.1899} \\ 0.5454 & 0.5454 & 0.5220 & 0.4444 & \mathbf{0.5142} \\ 0.091 & 0.0910 & 0.1300 & 0.1111 & \mathbf{0.1080} \end{bmatrix}$$

Figure 6. 3b RSRV of payment for each cloud service B, C, A, D respectively

Step 3: The next step as explained in section 6.3.3 is the consistency check. The ability to perform consistency check gives the AHP method an advantage over other MCDM as discussed in chapter 2(section 2.3.5). Therefore, the following steps are carried out to determine if the judgement for payment is consistent.

$$0.1899\begin{bmatrix}1\\1\\3\\\frac{1}{3}\end{bmatrix}+0.1899\begin{bmatrix}1\\1\\3\\\frac{1}{2}\end{bmatrix}+0.5142\begin{bmatrix}\frac{1}{3}\\\frac{1}{3}\\1\\\frac{1}{4}\end{bmatrix}+0.1080\begin{bmatrix}2\\2\\4\\1\end{bmatrix}=\begin{bmatrix}0.7672\\0.7672\\2.0856\\0.4265\end{bmatrix}$$

Step 4: Next we divide the elements of the weighted sum matrices by their priority vector value as below:

$\frac{0.7672}{0.1899} = 4.040$, $\frac{0.7672}{0.1899}$=4.040, $\frac{2.0856}{0.5142}$=4.056, $\frac{0.4265}{0.1080}$=4.0

Step5: The next step is to determine *λmax*, this is derived by finding the average of the values derived in step 4 as follows:

$\lambda max = \frac{4.040+4.040+4.056+4.0}{4}$= 4.034

Step 6: Determine the consistency index CI as follows:

$$CI = \frac{\lambda max - n}{n-1} \qquad (6.1)$$

$\frac{4.034-4}{4-1}$= 0.01133

CI= 0.01133

Finally, we select the appropriate value of the random consistency ratio RI for a four size matrix as shown in Table 6.2 which is a universally accepted value. The RI value for a four-sized matrix is 0.9. The RI value is used to determine the consistency ratio CR as follows:

CR=$\frac{CI}{RI}$ (6.2)

$CR = \frac{0.0133}{0.9}$ = 0.0125

CR=0.0125 <0.1

The above CR value for payment is less than 0.1. This implies that the judgement for payment regarding comparison among the different services is correct. Similarly, the same procedure is performed for all the other requirements based on the findings in (Appendix 4) for the selected SaaS storage services applications to determine their respective RSRV. The resultant RSRV values for each requirement is presented below representing Service B, Service C, Service A and Service D respectively:

The Relative ranking vector for Operating System supported (OPS) is

$\boldsymbol{RSRV_{ops}}$= $(\mathbf{0.5717\ \ 0.2090\ \ 0.1093\ \ 0.1093})$

Next, the relative ranking vector for file size restriction (FSR) is determined as

$\boldsymbol{RSRV_{FSR}}$=$(\mathbf{0.5542\ 0.1462\ 0.058\ 0.234})$

Next, the relative ranking vector for free storage (FS) is determined as:

$\boldsymbol{RSRV_{FS}}$=$(\mathbf{0.0967\ 0.5551\ 0.2517\ 0.0967})$

Next, the relative ranking vector for security (SE) is determined as

$\boldsymbol{RSRV_{SE}}$= $(\mathbf{0.4708\ \ 0.0732\ \ 0.1714\ \ 0.2839})$

Next, the relative ranking vector for Trust (TS) is determined as

$\boldsymbol{RSRV_{TS}}$=(**0.625 0.125 0.125 0.125**)

Next the relative ranking vector for Bandwidth Adjustment (BA) is determined as

$\boldsymbol{RSRV_{BA}}$=(**0.5750 0.2867 0.069 0.069**)

Finally, the relative ranking vector for Office via Web (OVW) is determined as

$\boldsymbol{RSRV_{OVW}}$= (**0.5542 0.1462 0.058 0.234**)

The relative ranking vector for each of the service requirements based on how the SME managers that participated in the dyadic group interview judged their ability to meet SME demand has been represented. In the next section, the second set of data retrieved from the dyadic interview session as shown in figure 6.2 which was judged based on pairwise comparison table in chapter 2 (Table 2.2) to determine the superiority of one requirement over another is being aggregated to determine the priority benchmark for each requirement.

6.4.3 Service Requirement Benchmark

In this section, the combined RSRM for all the proposed requirements in the case study as obtained from the dyadic group discussion and shown in Fig 6.2 is synthesised to determine the RSRV for each requirement. The synthetisation matrix is presented in Fig 6.4. The resultant RSRV for each attribute is set as an acceptable benchmark for each service requirement. The resultant RSRV for each requirement is proposed as the benchmark that must be attained for a cloud service recommendation to an SME for adoption. Also, the resultant RSRV is used in the CLOUDSME ranking protocol which will be discussed in the next section. The resultant RSRV presented in bold in Fig 6.4.

	PA	OPS	SE	FSR	BA	FS	OVW	TS	RSRV
PA	0.1377	0.1828	0.1267	0.2249	0.1739	0.1666	0.1880	0.1121	**0.1640**

OPS	0.0688	0.0914	0.0951	0.1687	0.1449	0.1428	0.1504	0.0746 **0.1170**
SE	0.4132	0.3656	0.3805	0.2811	0.2318	0.2142	0.2633	0.4484 **0.3247**
FSR	0.0344	0.0304	0.0633	0.0562	0.1159	0.1190	0.1128	0.0448 **0.0721**
BA	0.0229	0.0182	0.0475	0.0140	0.0289	0.0476	0.0125	0.0324 **0.028**
FS	0.0196	0.0152	0.0761	0.0112	0.0144	0.0238	0.0094	0.0280 **0.0247**
OVW	0.0275	0.0130	0.0543	0.0187	0.0869	0.0952	0.0376	0.0373 **0.0463**
TS	0.2755	0.2742	0.1902	0.2249	0.2028	0.1904	0.2257	0.2242 **0.2259**

Figure 6. 4 Benchmark (RSRV) for each service requirement

The RSRV in Fig 6.4 represents the acceptable benchmark for each requirement described in the study. The next step is to determine the ranking of the SaaS storage service. For the ranking section, two different ranking protocols are shown. The first ranking protocol represents the traditional AHP method of ranking. The traditional AHP ranking method has the issue of rank reversal. To address the issue, this research proposes CLOUDSME ranking protocol by introducing rational relationships to tackle the issue of rank reversal. The next section 6.4.4 presents the traditional AHP ranking approach. Section 6.5 presents the proposed CLOUDSME ranking protocol.

6.4.4 Tradition AHP Ranking

The traditional AHP ranking method requires that a combined matrix of the SaaS storage cloud services and their resultant SaaS KPIs is synthesized as shown in figure 6.5a to determine the highest ranked service as follows:

	PA	OPS	SE	FSR	BA	FS	OVW	TS

Service B	0.1899	0.5717	0.4708	0.5542	0.5750	0.0967	0.2519	0.6250
Service C	0.1899	0.2090	0.0734	0.1462	0.2867	0.5551	0.1553	0.1250
Service A	0.5142	0.1093	0.1714	0.058	0.069	0.2517	0.5502	0.1250
Service D	0.1080	0.1093	0.2839	0.2340	0.069	0.0967	0.0423	0.1250

Figure 6. 5a Combined cloud service and requirement matrix

The next step is to determine the ranking of the cloud services and this is done by multiplying the RSRV of each KPI with the resultant RSRV of each service KPI.

Service B

0.1640(0.1899) + 0.1170(0.5717) + 0.3247(0.4708) + 0.0721(0.5542) + 0.028(0.5750) + 0.0247(0.0967) + 0.0463(0.2519) + 0.2259(0.6250) = **0.4672**

Service C

0.1640(0.1899) + 0.1170(0.2090) + 0.3247(0.0734) + 0.0721(0.1462) + 0.028(0.2867) +0.0247(0.5551) + 0.0463(0.1553) + 0.2259(0.1250) = **0.1469**

Service A

0.1640(0.5142) + 0.1170(0.1093) + 0.3247(0.1714) + 0.0721(0.0580) + 0.028(0.069) + 0.0247(0.2517) + 0.0463 (0.5502) + 0.2259(0.1250) = **0.2185**

Service D

0.1640(0.0108) + 0.1170(0.1093) + 0.3247(0.2839) + 0.0721(0.2340) + 0.028(0.069) + 0.0247(0.0967) + 0.0463(0.0423) + 0.2259(0.125) = **0.1737**

From the above AHP ranking procedure, it can be seen that provider A has the best acceptable payment that meets user requirement, while Service C has the best free storage allowance. But Service B with a ranking value of 0.4672 is the highest ranked of the four SaaS storage services compared as presented above. Next, a pictorial representation of

the compared cloud services and their resultant requirement priority value is presented in figure 6.5b.

Figure 6. 5b: A visual cloud service storage comparison based on traditional AHP Approach

The traditional AHP approach which is widely used for research purposes in tackling MCDM problems has been presented in section 6.4.4. However, this approach has been criticised to suffer from rank reversal(Belton and Gear, 1983, Dyer et al., 2005). In view of tackling the issue of rank reversal associated with the AHP approach, this research introduces the use rational relationships in the ranking process.

6.5 Proposed CLOUDSME Ranking Protocol

For the cloud service ranking, this research deviates from the traditional summing up of weight used in the AHP method by proposing a protocol for ranking the cloud services as using rational relationships to tackle the issue of rank reversal as follows:

- Declare the acceptable standard benchmark for each service requirement as presented in section 6.4.3(Fig 6.4). Also, the priority weight for each requirement which must meet the assigned benchmark is obtained as presented in section 6.4.2(RSRV for each service requirement).
- Obtain the acceptable KPI standards from the highest to lowest
- The service ranking proposed is graded from 5 stars to 1 star where five stars are the services with the highest ranking and 1 star are services with the lowest rank(Wong and Mui, 2009, Young and Welford, 2003, Baccianella et al., 2009).

For the service ranking the following declarations is made

Let M- Be the cloud service

p_1- The weight value of the attribute with the highest KPI priority

p_1x_1 - The acceptable standard for the attribute p_1

q_2 - The weight value of the attribute with the 2nd KPI priority weight

q_2x_2 - The acceptable standard for attribute q_2

r_3 - The weight value of the attribute with the 3rd priority weight

r_3x_3 - The acceptable standard for attribute r_3

k_4 - The weight value of the≥ attribute of any of the remaining KPI priority

k_4x_4 - The acceptable standard for any of the attribute of k_4

a) 5 stars service ranking is characterized based on the following formation

When

$$M \rightarrow (p_1 \geq p_1x_1) \wedge ((q_2 \geq q_2x_2) \vee (r_3 \geq r_3x_3)) \wedge (k_4 \geq k_4x_4) \quad (6.3)$$

b) 4 stars service ranking is characterized by the following formation

When

$$M \rightarrow (p_1 \leq p_1x_1) \wedge ((q_2 \geq q_2x_2) \vee (r_3 \geq r_3x_3)) \wedge (k_4 \geq k_4x_4) \quad (6.4)$$

c) 3 stars service ranking is characterized by the following formation

When

$$M \rightarrow (p_1 \leq p_1x_1) \wedge (q_2 \leq q_2x_2) \wedge (r_3 \geq r_3x_3) \wedge (k_4 \geq k_4x_4) \quad (6.5)$$

d) 2 stars service ranking is characterized by the following formation

When

$$M \rightarrow (p_1 \leq p_1x_1) \wedge (q_2 \leq q_2x_2) \wedge (r_3 \leq r_3x_3) \wedge (k_4 \geq k_4x_4) \quad (6.6)$$

e) 1 star ranking is characterized by the following formation

When

$$M \rightarrow (p_1 \leq p_1x_1) \wedge (q_2 \leq q_2x_2) \wedge (r_3 \leq r_3x_3) \wedge (k_4 \leq k_4x_4) \quad (6.7)$$

In the above sections, the sequence of activities that take place towards the build-up of the framework as well as the phase 1, 2 and 3 of the framework has been discussed. The first phase deals with the gathering of information from service providers websites based on how they address the user requirements identified in the survey stage of this research as presented in section 6.2(Table 6.1). The information gathered forms the knowledge base which the phase 1 of the proposed framework is built. The second phase of the framework which is the prioritisation phase tackles the issue of complex comparison using the AHP approach as discussed in section 6.3. The third phase introduces the formalism that is proposed in CLOUDSME service ranking as presented in section 6.5. This approach deviates from the traditional AHP approach by introducing rational relationship. The reason for introducing this approach is to tackle the issue of rank reversal associated with the AHP method. The implementation of the ranking approach is shown in chapter 7(section 7.2.3).

In the next section, the phase 4 of the framework which holds the information from phase 1-3 is being discussed. This phase introduces the Decision Support System (DSS) which acts a knowledge management system for aiding SME managers in making decisions towards cloud service adoption. The DSS is developed using an ontology of cloud services. The ontology which is constructed using a set of concepts and associated semantic rules is used to retrieve information based on SME manager requirements. Furthermore, the design of the cloud service ontology which has been developed and tested on protégé software (an ontology editor) to check inconsistencies is discussed in the next section.

6.6 CLOUDSME Decision Support System Architecture

The decision support system architecture shows the sequence of activities that take place within the DSS when a user requirement is queried. To complete this framework, an ontology of SaaS cloud storage Application is developed. This service ontology holds information gathered from phase 1, 2 and 3 of the framework. The developed cloud service ontology has been tested using protégé software which is an ontology editor to check consistencies as explained below.

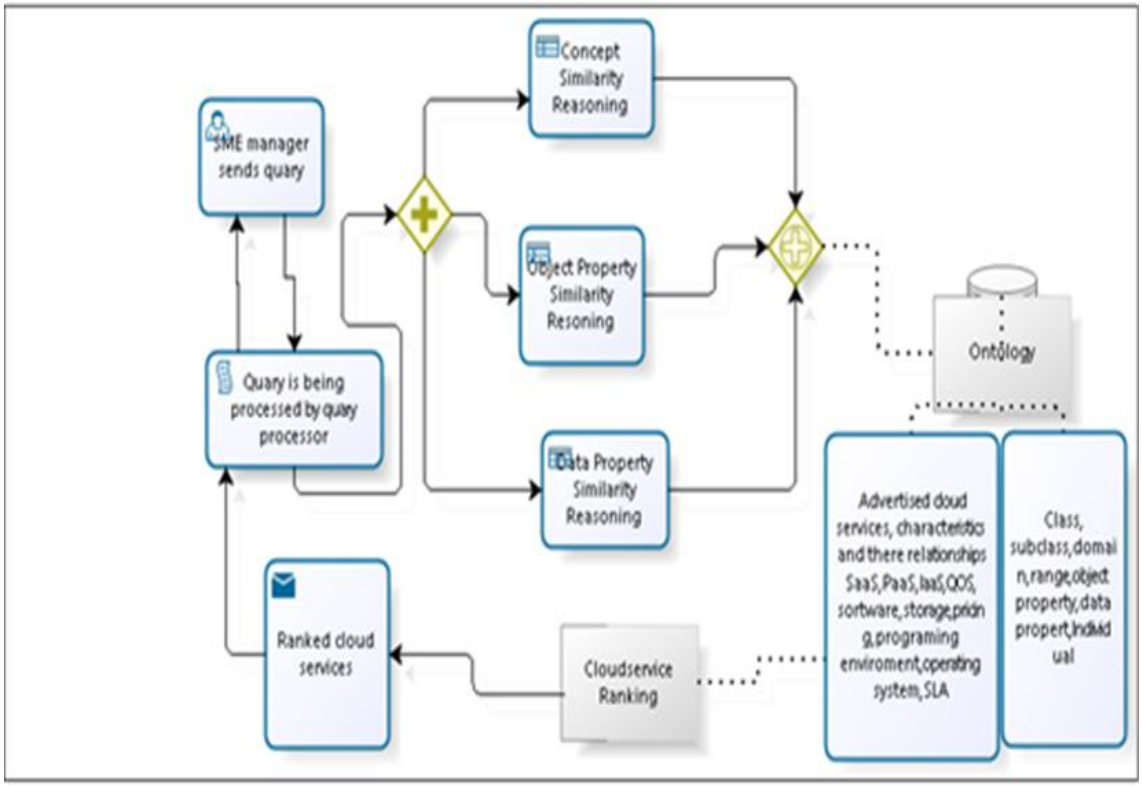


Figure 6. 6 Showing CLOUDSME DSS Architecture

6.6.1 Characteristics of each component of cloud service DSS Architecture

The CLOUDSME DSS architecture in Fig 6.6, consists of the following component: Graphical User Interface, query processor, Similarity reasoning, cloud service knowledge

management (ontology) and service ranking. Firstly, The SME owner/ manager sends their requirements to CLOUDSME from the user interface. The interface has the capability to interact with the ontology to transform human language (English) to machine readable language with support of Pellet a description logic reasoning engine which has reasoning capabilities to infer knowledge based on concepts and relationships in view of retrieving accurate and timely information to aid decision making. The decision support system carries out the following functions depending on user requirement: 1) Query processing 2) Similarity reasoning 3) Similarity matching 4) Cloud service ranking.

6.6.1.1 Query Processing

When a user requirement is sent by the SME owner/manager via the graphical user interface, the query processor initiates query processing and converts the query to machine readable format. Then the processor sends the processed query to the similarity reasoning component for further processing based on the required information (demonstrated in Chapter 7).

6.6.1.2 Similarity Reasoning

The processed query initiates the similarity reasoning process by consulting the cloud service ontology. Similarity reasoning decision is based on the type of information the query processed seeks to fetch. As mentioned above the above section, the main similarity reasoning types as shown in the CLOUDSME system architecture are as follows:

- **Concept Similarity Reasoning**: This is based on the conceptual modelling of our ontology to meet user requirements. The presence of pellet reasoner within the ontology editor (protégé) aids the DSS to undergo conceptual reasoning by consulting the ontology to retrieve accurate information using system algorithms to meet user requirements.

- **Object Property Similarity Reasoning**: This is the type of reasoning that occurs when an SME owner requirement is and there are two or more cloud services having similar object property of the required instance.
- **Data Property Similarity Reasoning:** This is a type of reasoning that occurs within the ontology when a user queries the DSS CLOUDSME for two or more cloud services with same datatype properties for a range of data.

6.6.1.3 Individual Similarity Matching

This is a condition within the DSS whereby cloud services are recommended based on the ability of the service requirement parameter weight to attain the acceptable standards for the service required before it can be recommended by the system to the user. Furthermore, it is the minimum standard a service requirement parameter weight must attain when compared to other cloud services with similar requirement type. The service matching is centred on semantic rules built within the system ontology.

6.6.1.4 Service ranking

The cloud service ranking algorithm has already been discussed in section 6.5 and implemented in chapter 7 (section 7.2.3). CLOUDSME service classification achieved is categorised as 5 Stars, 4 Stars, 3 Stars, 2 Stars, and 1 Star (from the Highest to lowest as discussed above). The use of semantic rules and numeric reasoning makes it possible for cloud service ranking to take place within the system.

6.6.2 Service Ontology

The service ontology is a formal representation of the cloud service information as advertised by cloud service providers. The concepts that make up the ontology are described under the superclass CLOUDSME. The service ontology (CLOUDSME) is made up of three major sub- ontology which inter-relate to answer user queries. Presented

as follows and implemented in Chapter 7: Fig 6.7a represents the service requirement parameters from the service provider websites as shown in phase 1 section 6.2, Fig 6.7b represents the prioritisation of the service requirements using the AHP approach to tackle complex comparisons as shown in Phase 2 of the framework section 6.3.While fig 6.7c represents the cloud service ranking phase discussed in section 6.5.

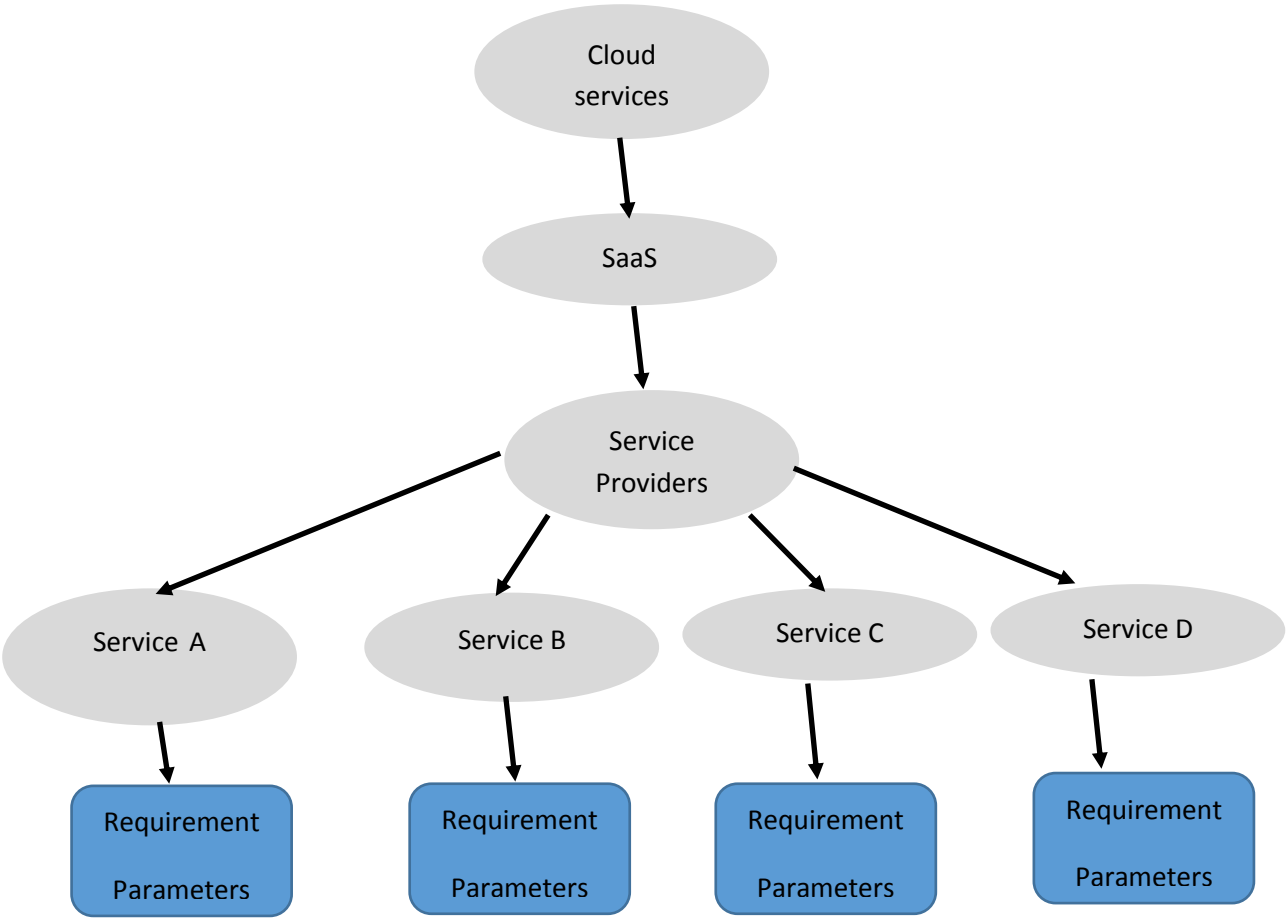


Figure 6.7a Requirement parameters

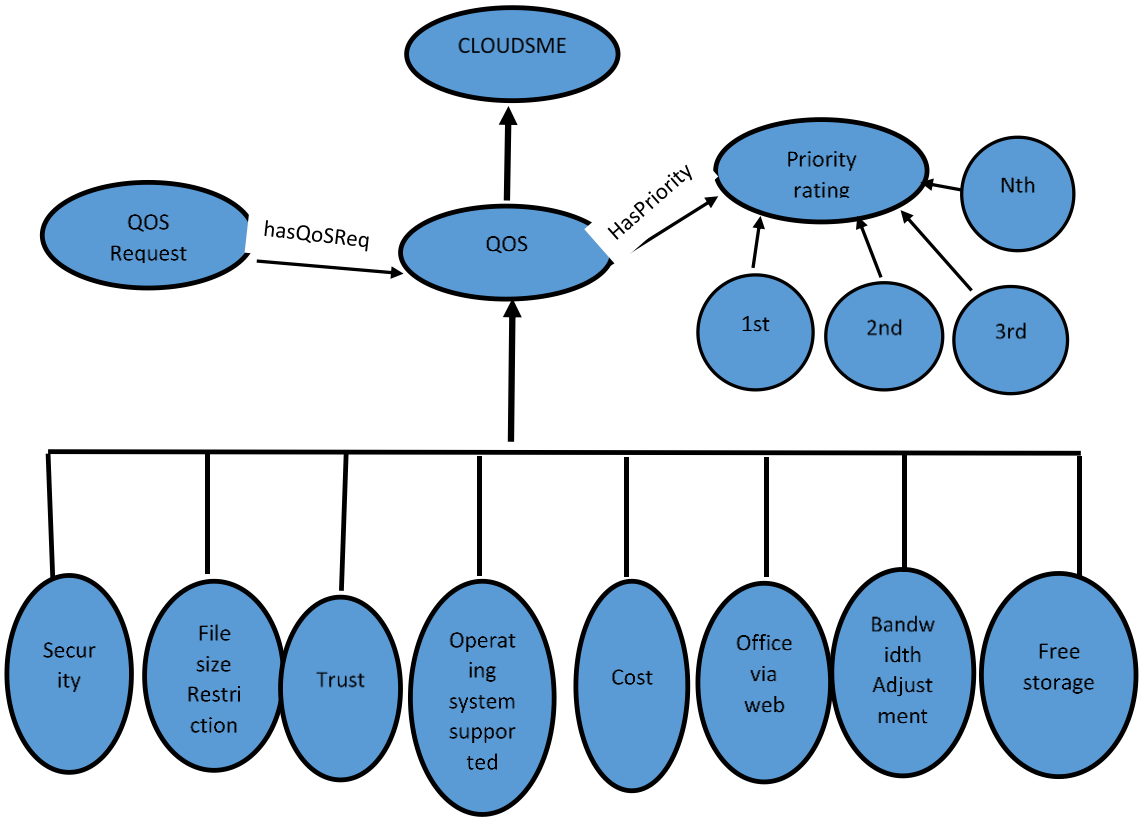
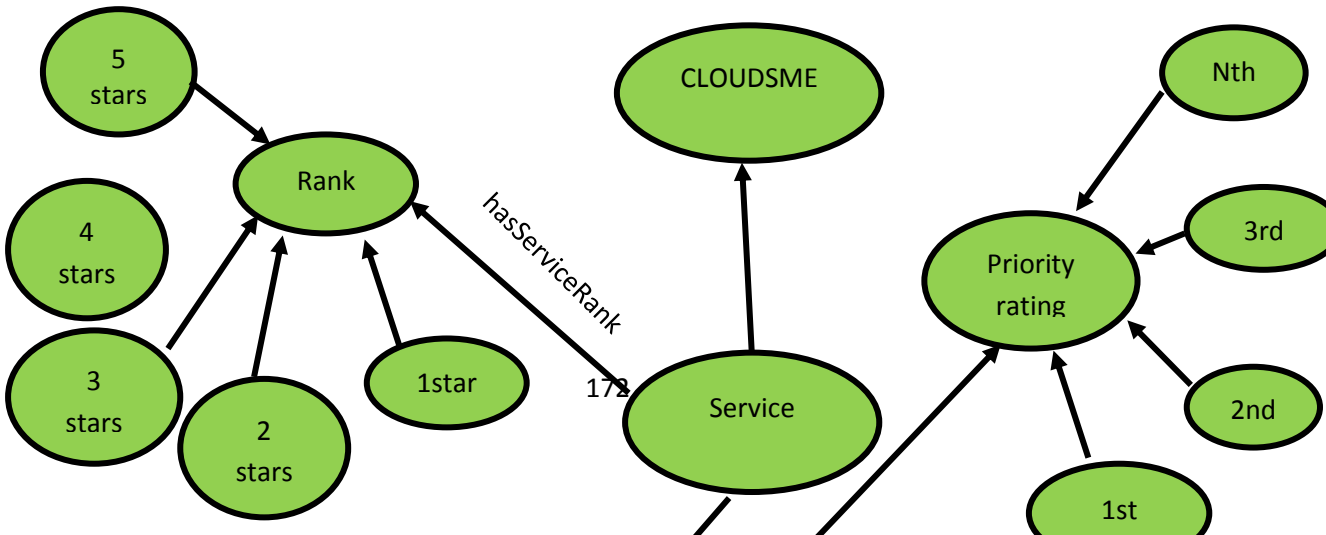


Figure 6. 7b Prioritisation of requirements



As shown in Fig 6.7a, the superclass is CLOUDSME which is the building block of all the ontological concepts. The top class is the cloud service class which represents the three types of cloud services, which are IaaS, PaaS and SaaS. This research is only concerned with the SaaS service type. Therefore, the subclass of the SaaS type is the SaaS providers of the top four SaaS storage application service discussed in this research. E.g., Google is the service provider for the service Google Drive. While the requirements are

the identified Nigeria's SMEs cloud service adoption challenges (variables) from the survey. Also, the requirement parameters are the smallest unit of the class which are referred to as instances e.g., the requirement parameter for security offered by Service B is AES 256-bit encryption. The OWL property restriction makes it possible for each service instance to be identified when the ontology is queried.

The Prioritisation ontology is based on the weighting of the requirements as presented in section 6.4.2. The requirements are (Security, cost, trust (reliability), bandwidth adjustment, operating system supported (interoperability& compatibility).Some other requirement offered by the services include (Office via web, free storage, File size Restriction), Each service requirement is assigned a priority score(see section 6.4.3) from the highest to lowest (1^{st} to Nth respectively) as shown in Fig 6.7b which a cloud service provision must attain before it can be recommended by the DSS when a particular requirement needed by an SME.

The last part of the ontology is associated with the service ranking as presented in Fig 6.7c. The owl rank enumeration makes the ranking possible and the services are ranked as 5 stars, 4 stars, 3 stars, 2 stars and 1 star respectively.

The interesting part of the ontology is the inter relationship between two classes the prioritisation class and the ranking class. This is made possible using semantic rules interacting with the owl rank enumeration within the ontology. Which allows semantic matching between the requirement priority weights and the assigned benchmarks for service ranking. Further discussion is done in the implementation stage chapter 7. The ranking formalism can be seen in section 6.5. Also, figure 6.7c some semantic web statements are presented.

6.6.3 Storing CLOUDSME Semantic Information

CLOUDSME information is stored using RDF format. This format allows service entries to map service requirements offerings and their parameters within the ontology. Furthermore, the mapping makes sure that all similar service requirements adopt a single vocabulary for better comparison and user friendliness by reduce complexity as cloud service provider makes use of different vocabulary when advertising.

The use of RDF format enables acceptable naming conventions that aids in query processing. The RDF comprises of a triple (prefix, predicate and suffix). In an English Language statement *GoogleDrive has storage of 100GB.* This translated to RDF format as shown in Figure 6.8. The prefix will be the name of the service e.g. GoogleDrive, the predicate will be the relationship *has Storage* and the suffix will be *100GB.*

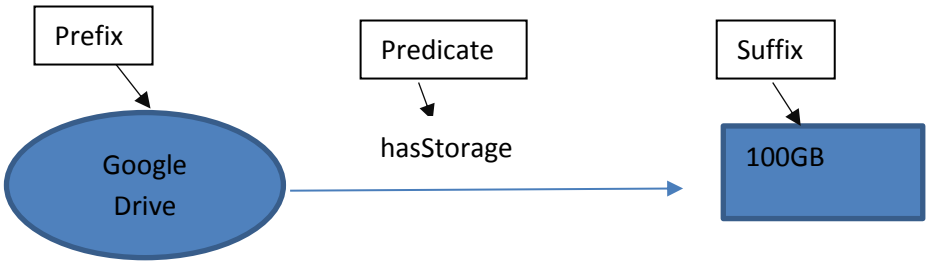


Figure 6. 8 RDF format

6.6.4 CLOUDSME Services Selection

The cloud service user requirements as obtained in the survey stage of this research (Chapter 5) together with the service provider requirement parameters as presented in the case study (Table 6.1) and their requirement priority weight as presented in section 6.4.2(RSRV for each service requirement) as well as the obtained standard benchmark for each service requirement as presented in section 6.4.3(Fig 6.4) are semantically modelled within the DSS ontology of CLOUDSME. The descriptive logical reasoning engine (Pallet reasoner) triggers the inter-relationships between concepts to improve the

efficiency of the service selection process by eliminating provider services that do not meet the criteria of the user requirements.

The pallet reasoner is mainly concerned with two parts of the selection process. The first and major part is the matching of user requirements with cloud service provider requirement offerings. The second part is the matching of user requirement with service provider's individual requirement benchmarks to retrieve and recommends services that best meet the requirement for decision making. An instance of the first selection process is described as follows: in a scenario, whereby an SME owner needs a cloud service for his business which is compatible with the android operating system. This is an interoperability issue based on the user requirement. The pallet reasoner will filter the ontology to determine which cloud services are Android compatible in view of meeting the user requirement. The reasoner eliminates all other operating systems returning exactly those services that are compatible with android. The operation query is shown in Fig 6.9, and its implementation chapter 7(section 7.2.1.2, Fig 7.6).

The CLOUDSME filter queries the service properties with the help of the naming vocabulary adopted in this research. Example of such query is represented in Figure 6.9.

SELECT***FROM** SERVICES **WHERE** SERVICE **HAS** OPERTING SYSTEM NAME '**Android'**

Figure 6. 9 Query for extracting services that are compatible with Android

The query for fetching all SaaS cloud services that are compatible with Android operating system is shown in figure 6.9. The word 'Android' enable the query to fetch the exact cloud service compatible with android.

For the second aspect of service selection, which is the matching of user requirement with service provider's individual requirement benchmarks to retrieve and recommends

services that best meet the requirement for decision making. An instance of this aspect is when an SME owner requires a particular service e.g. File size restriction(FSR), but is confused on which service to choose from the various service (MCDM problem). When CLOUDSME is consulted, the pallet reason matches the user requirement (FSR) priority weight as presented in section 6.4.2(RSRV for FSR) of each cloud service with the standard benchmark for FSR (0.0721) as presented in section 6.4.3(Fig 6.4) and implemented in the ontology as 721 in chapter 7. The logical reasoner now filters out all the services that did not meet the acceptable minimum benchmark and returns all cloud services that meet the standard benchmark for FSR. This is presented in Fig 6.10 as FSRacceptability and implemented in chapter 7(section 7.2.2, Fig7.9). The same process is repeated when other requirements are sorted for a recommendation.

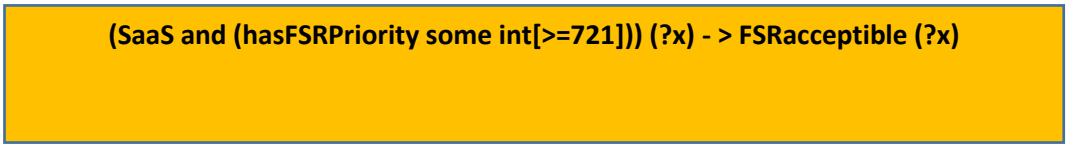


Figure 6. 10 The semantic rule for service recommendation of FSR

Figure 6.10, presents how the ontology uses Semantic rules to retrieve user requirement when tackling issues of complex comparison. The semantic rule helps identify the cloud services that match the SME owner's service requirement. It initiates an interaction between the three sub ontology classes described in Fig 6.3 to perform the task of matching user requirements with service requirement parameter offerings. Depending on the user requirements, the pallet reasoner logically filters the cloud service offerings of the four cloud services. It matches the user requirement with the cloud services based on the ability of the cloud service requirement to meet the (>=) accepted standard benchmark of the requested requirement. The cloud services that meet the required benchmark for the user requirement(s) are then retrieved and recommended by the DSS for decision making as Xacceptible. In the implementation phase, all priority values identified in the

prioritisation phase are multiplied by 10000. Therefore 0.0721 which was identified as the benchmark for FSR in section 6.4.3(Fig 6.4) is presented as 721 in the ontology implementation chapter 7 (section 7.2.2, Fig7.9). In addition, a set of semantic rules is being used to implement the proposed service ranking as presented in chapter 7(section 7.2.3, Fig 7.10).

6.6.5 SAWSDL for automatic service discovery within CLOUDSME

The SAWSDL provides the mechanism that enables intercommunication between semantic and non-semantic descriptions for automatic service discovery. It also supports the sharing of service descriptions and the transfer of information between semantic and non-semantic sources for service discovery without specifying a language for representing semantic models. Again, the mechanism uses concepts from semantic models that have been defined either within or outside the WSDL document which can be referenced from within WSDL components as annotations.

6.6.5.1 SAWSDL References for Description Sharing

Entity level descriptions of information between cloud services is shared using SAWSDL "Model Reference" An example of Model reference represented in CLOUDSME is shown as follows:

<XS: element name= "Security"

Sawsdl:

ModelReference=http://www.semanticweb.org/richard/ontologies/2015/3/untitled-ontology-142#security>

The example shown above represents the SAWSDL annotation for the description of the Security class. The security class is part of the requirement for CLOUDSME and it is available in the given URI. The technology upon which SAWSDL annotation is written

is XML. The information can be adopted by both semantic and non-semantic web services based on the fact that they are written in WSDL; which adopts XML based description of services.

6.6.5.2. LiftingSchemaMapping / LoweringSchemaMapping for service retrieval

The lifting and lowering schema mapping used by SAWSDL annotation are extension services which are added to XML Schema element declarations and type definitions for specifying mappings between semantic data and XML. This allows the transfer of information between semantic and non-semantic information as well as service retrieval. The lifting schema mapping is done based on XQuery (Boag et al., 2002) which is a query language adopted for querying XML sources. The lowering schema mapping uses SPARQL and Semantic Rules for querying semantic sources.

The lifting schema mapping was adopted in CLOUDSME by retrieving non-semantic information sources an example of which is declaration of the value for security priority as integer. Lowering Schema was adopted by using semantic rules to communicate between semantic and non-semantic sources for service ranking retrieval.

6.6.6 CLOUDSME Information Update

The CLOUDSME information update will be done manually as an automatic update is beyond the scope of this research. Depending on the availability of information, updates will be performed when there is a change in cloud service provider offerings. Manual update will be performed by the CLOUDSME developer.

However, it is possible to implement automation of functional requirements using crawlers or the use of intelligent agents to update service provider information. Both mentioned methods are beyond the scope of this research. The services information would be received through user's reviews of the services and through cloud service provider

requirement offerings especially in terms of physical cost which is a service provider's responsibility.

Regarding updating information, it is important first to verify that the information is reliable from the service provider website or other sources of information advertisement. The next step is to determine whether the information meets the ontology descriptions for cloud services, service requirement parameters offerings. Then the RDF information for the information is updated. Finally, the system maintains a separate RDF for each of the cloud service requirement parameters.

6.7 Conclusion

In this chapter, a Novel CLOUDSME framework has been presented. The framework consists of 4 major phases: The first phase deals with gathering of information of cloud services as advertised by four major SaaS storage cloud service application providers. The information was gathered based on their ability to tackle the slow adoption challenges identified in the survey stage (Chapter 5) of this thesis. The information collected is presented in a case study in table 6.1 forms the knowledge base of the proposed framework.

The second phase of the framework holds the prioritisation phase. In this phase, a cloud service selection and recommendation formalism that tackles the issue of multiple comparison (MCDM problem) presented. The CLOUDSME prioritisation is based on the AHP method for solving MCDM problems. The selection and recommendation are performed based on the ability of a cloud service requirement to attain a set benchmark for each user requirement and a service is recommended if its attribute meets the benchmark for a particular user requirement.

The third phase is the service ranking process is based on a set of protocol that adopts rational relationships by extending the AHP ranking method to tackle the issue of rank reversal associated with AHP. The ranking is categorised using 5stars to 1 star from highest to lowest ranked respectively as shown in section 6.5.

The fourth phase is the Decision support system (DSS). In this phase, the information from phase 1, 2 and 3 are modelled within an ontology of cloud services built using protégé software, an ontology editor for aiding knowledge engineering. The architecture of this phase (Fig 6.6) and the mechanism on how it operates has been presented in presented in section 6.6.

In the next chapter, the implementation of the DSS architecture as presented in Fig 6.6 is discussed.

Chapter 7: CLOUDSME Implementation

This chapter describes the implementation phase of CLOUDSME. The semantically developed system consists of knowledge management, service selection/recommendation and service ranking. The implementation phase is based on the three different phases as described in chapter 6. The first implementation phase is specific to information management of cloud services as advertised by service providers as they try to meet user requirement. The second phase of implementation was concerned with CLOUDSME knowledge management, service recommendation and service selection in view of dealing with the issue of complex comparisons. The third implementation phase deals with the implementation of CLOUDSME ranking. Also, semantic rules were also implemented to enable intercommunication between concepts and their relationships to meet user requirements.

This chapter is made up of three subsections; in the first section, the implementation of the service knowledge management is discussed. While section 7.2 describes the implementation of service selection by using different possible SME user scenarios to demonstrate that the proposed framework can aid in decision making towards cloud service adoption. Section 7.3 concludes this chapter.

7.1 CLOUDSME Knowledge Management Service Implementation

The CLOUDSME knowledge management was implemented in three phases. The first phase was the information gathering which have been discussed in chapter 5 of this thesis. Furthermore, the SaaS storage application services was chosen because it was seen to best address the challenges identified by Nigerian SMEs as the cause for slow cloud service adoption. Also, the survey also shows that majority of the Nigerian SMEs who have

adopted cloud services (58%) adopted SaaS services. The second step was the implementation of the service ontology. The final step was the implementation of the RDF manager and storage of the RDF information within the ontology.

7.1.1 Implementation of CLOUDSME service ontology

The CLOUDSME service ontology was developed using protégé **(Somasundaram et al., 2006).** Protégé is an ontology editor used for developing knowledge-based applications supported by description logic reasoning engines (Pellet). The reasoner has the capability to infer knowledge based on concepts and relationships in view of retrieving accurate and timely information to aid decision making. The ontology editor acts as a foundation for building concepts in OWL such as classes, subclasses, their properties and relationships.

7.1.2 Classes

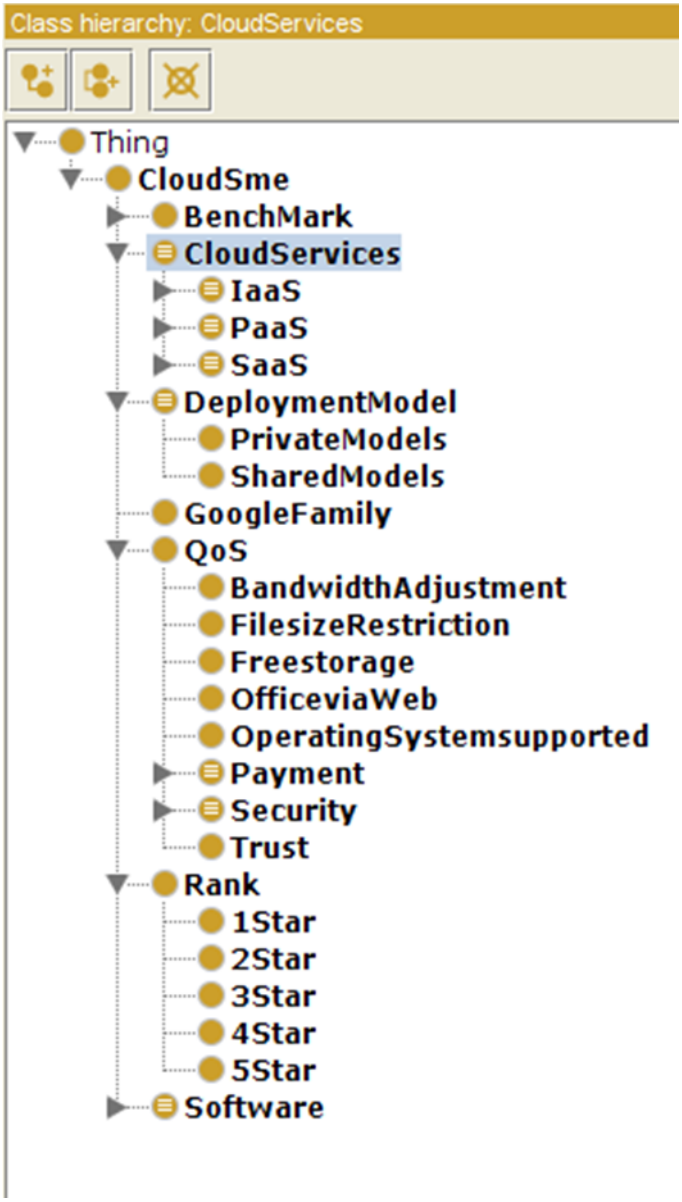


Figure 7. 1 CLOUDSME Ontology Classes

The CLOUDSME ontology has six major high-level classes, these classes are independent of each other but are all under the super class CLOUDSME. The classes as shown in Fig 7 have relationships with each other through their object type property. Furthermore, they cannot be parents or subclass of each other. For example, going by the ontology build-up as shown in Fig 7.1, prioritisation and Rank classes are inter-related although neither is prioritisation a type of Rank nor is a Rank a type of prioritisation. A subclass is a subtype of a parent class, for example, 5star is a type of rank. Therefore,

5star is a subclass of the parent class Rank. Figure 7.1 shows a high level of classes and subclasses within CLOUDSME.

The Cloud Service class describes the different cloud services (IaaS, PaaS and SaaS), although the research focuses on SaaS cloud services. The Service Class describes the various services offered by the cloud service, The Rank class describes the ranking of each cloud service such as 5star, 4 star, 3star, 2star or 1star respectively while the Benchmark class describe the value of the acceptable benchmark (e.g. FSR acceptability) that must be met or surpassed by each quality of service value before it is being recommended to a user.

7.1.3 Object and Data Properties

There are two types of property relationships between concepts in an ontology build-up. These are object properties and data properties respectively.

The object properties are used to describe the relationships between different individual classes. An example of such relationship can be described as ***Cloudservice*** *hasQos* ***QoS.*** In the given example, the cloud service class is the domain, QOS is the range, and the object property hasQoS describes the relationship between the domain and the range. Some of the object properties implemented in CLOUDSME are shown in table 7.1. These relationships enable CLOUDSME to adopt a uniform vocabulary for the different cloud service offerings.

Table 7.1: Object property relationship as presented in CLOUDSME ontology

Domain	Object Property	Range
Cloud Service	hasPayment	Payment
Cloud Service	hasRank	Rank
Cloud Service	hasSecurity	Security
QOS	hasbenchmark	benchmark
FSR	hasBenchmark	FSRacceptablity

Unlike object properties, Data properties are used to describe the relationship between Individual and XML Schema data type and RDF literal. For example, "Cloud service *hasOperatingSystemName* Name". From this instance, the cloud service is the domain and *hasOperatingSystemName* is the data property and Name is the Range. The difference between object property and data property in this instance is that in Object property, Name will be identified as another Class but in data property, the range (Name) is a datatype with a sting value. Datatype property can be a string (character values), Integer (numbers), literal (Alphanumeric values), Double (Number values with decimal). Table 7.2 shows some data properties as presented in CLOUDSME.

Table 7.2 Data property relationship presented as presented in CLOUDSME.

Domain	**Data Property**	**Range**
Cloud Service	hasOperating SystemName	String
Cloud Service	hasProviderName	String
QOS	hasPriority	Integer
Cloud Service	hasFilesizeRestriction	Integer
Cloud service	hasSecurityType	string

Figure 7.2 shows snap shot of the representation of the object and data property as depicted in CLOUDSME ontology.

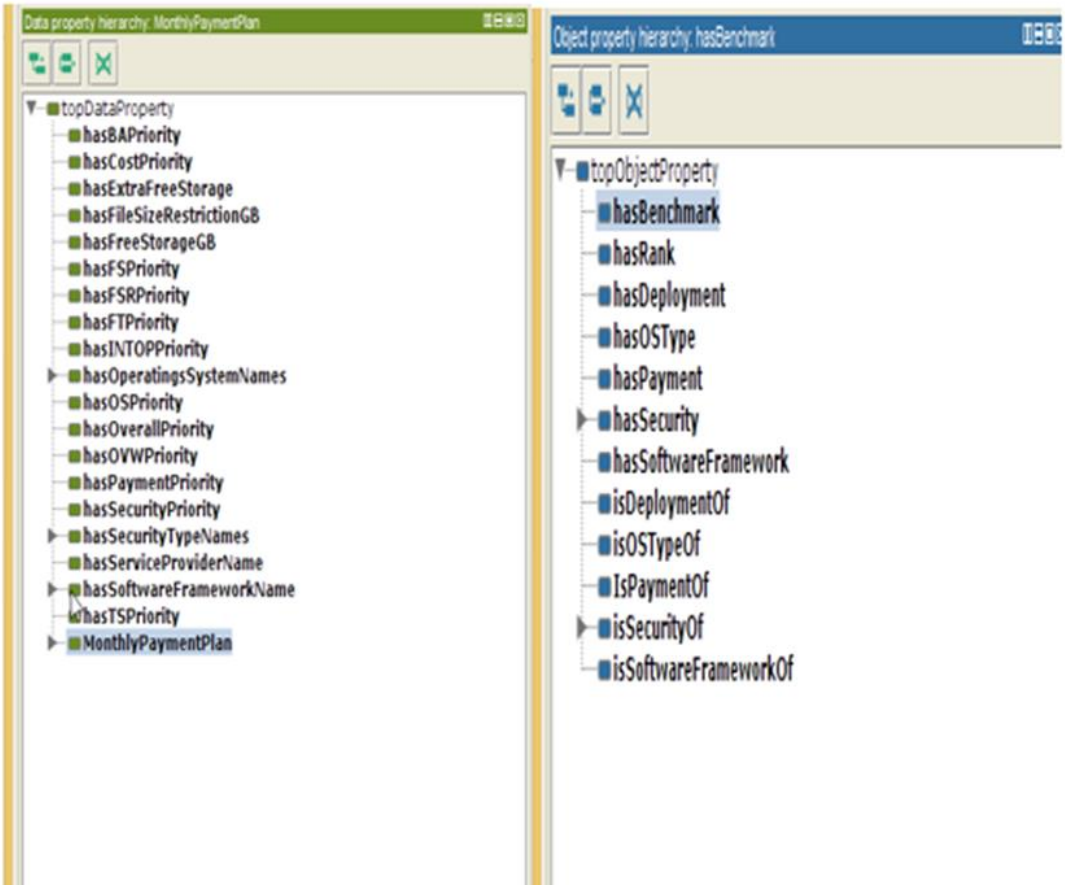


Figure 7. 2 CLOUDSME object and Data properties

In figure 7.3, a snapshot of the data type properties with their values as built is CLOUDSME is presented.

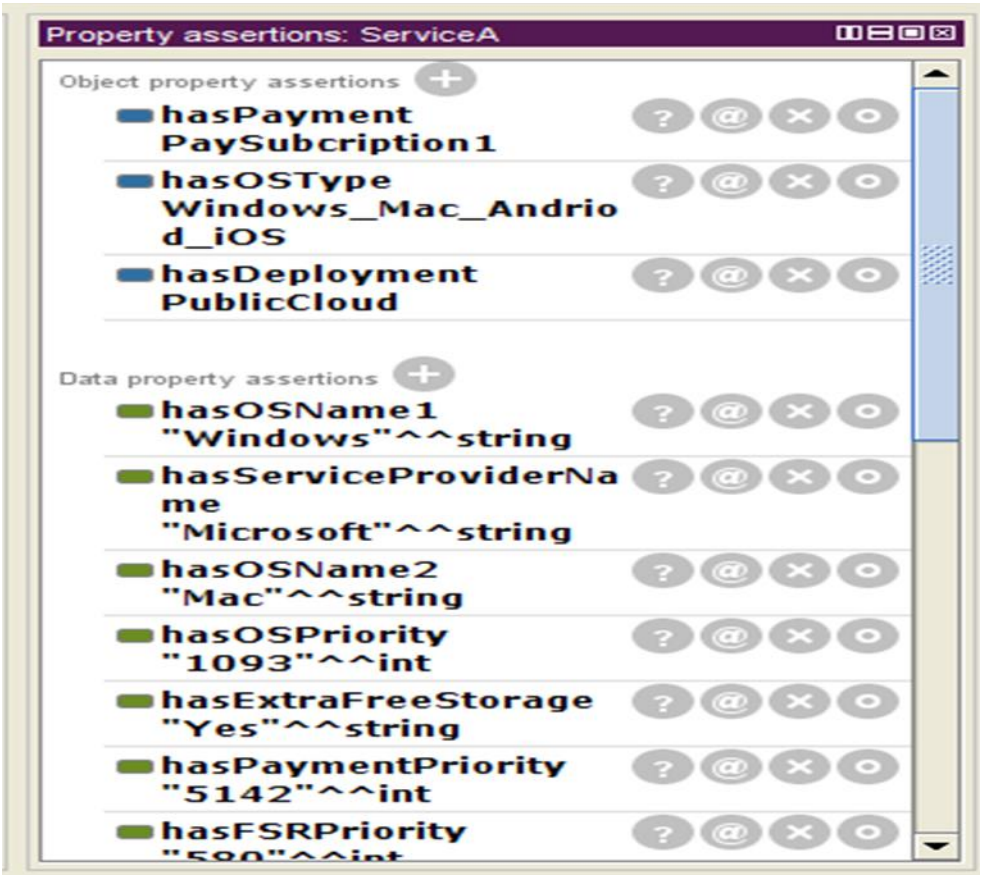


Figure 7. 3 Example of CLOUDSME data property (Snap shot)

7.1.4 Individual/Instances

In an ontology build-up, individuals or instances represents the objects of a particular domain that cannot be further broken down. In this research, the individuals are represented as indivisible values of each class within CLOUDSME. Figure 7.4 shows an example of SaaS cloud service instance as built in CLOUDSME.

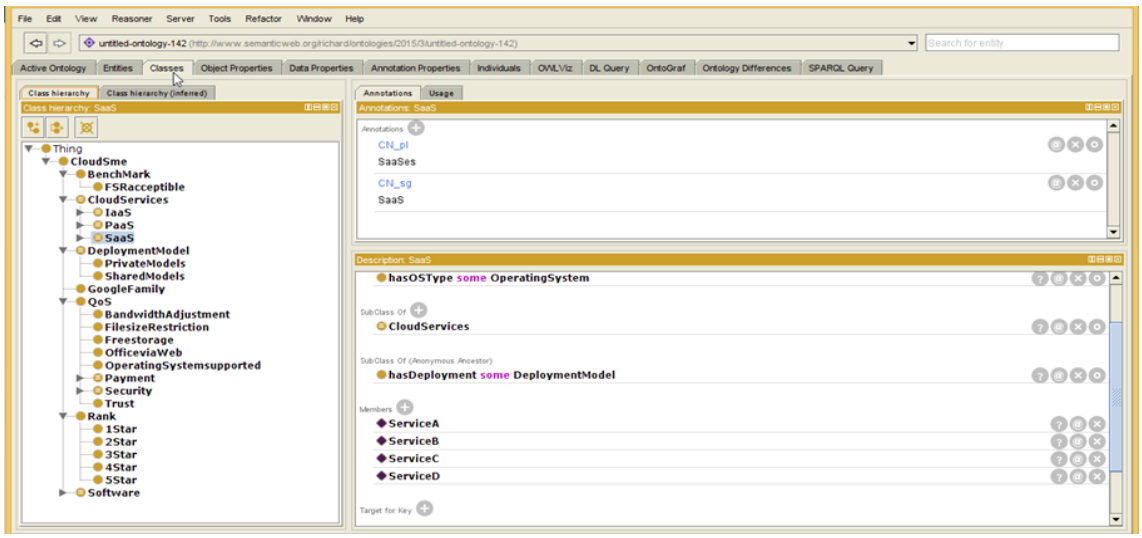


Figure 7. 4 Presents the instances of SaaS as designed in CLOUDSME

The naming convention shown in Fig 7.4 represents the four cloud services: A, B. C and D respectively as members of the SaaS cloud service type. Each of the services accounts for a major SaaS storage Application cloud service as described in the previous chapters.

7.2 Implementation of CLOUDSME Selection

The CLOUDSME selection service is based on the conceptualization of the service ontology. It consists of three major phases which are the knowledge management phase, the service recommendation phase and the service ranking phase. The knowledge management phase is based on the modelling of the cloud service provider offerings as presented in Table 6.1. The service recommendation phase is based on the ability of a provider offering to meet the minimal benchmark set for each QOS type. The process proposed for attaining the benchmark for each attribute has been discussed in chapter 6. The cloud service ranking is the final phase of the CLOUDSME selection service. Both the recommendation and ranking are based on sematic rules. The information retrieved by CLOUDSME depends on the user requirements. At this stage, SME scenarios are used to determine if the system can answer user requirements. A minimal user input is required by the system.

7.2.1 Knowledge management Implementation

As mentioned in the CLOUDSME architecture, the knowledge management implementation is designed based on three major similarity reasoning types within the DSS of the proposed framework as follows:

7.2.1.1 Concept Similarity Reasoning

This is based on the conceptual modelling of the proposed CLOUDSME to meet user requirements. The presence of pellet reasoner within the ontology editor (protégé) aids the proposed DSS to undergo conceptual reasoning by consulting the ontology to retrieve accurate information using system algorithms to meet user requirements. To demonstrate that the proposed DSS equipped with a semantically designed ontology of cloud services can undergo conceptual similarity reasoning to answer user requirements. A user scenario is described as follows: In a scenario, whereby an SME owner intends to adopt a cloud service for his data storage with a budget of 2 Dollars per month for 100GBs of storage and consults CLOUDSME for decision making. Based on the SME user requirements, the query sent by the user will trigger the system to use the ontology to do concept similarity reasoning. This is based on the conceptual modelling of advertised cloud services from service providers websites as shown in Table 6.1. The user requirement can be summarised as follows. The cloud service required by the user is a SaaS cloud service with a storage of 100GB and a price value of 2 Dollars. The conceptual modelling is designed within the system following the RDF format of Subject, Predicate and Object statements with Subject and Object representing the domain and range of the predicate. The system translates the user requirement into machine language as follows :**(** **DOMAIN:** SaaS**, Data Property:** hasPaymentplan1price**, Range**: Integer**)**. To retrieve the user requirement from CLOUDSME, the following query is processed in machine readable format as (**CloudServices and hasPaymentplan1price value 2 and**

haspaymentPlan1GB value of 100) as represented in Figure 7.5. The query is translated to lay terms as follows (**Cloud service with a payment plan of 2USD for 100Gigabyte of data per month)** Please note that the price value is in USD/Month and the GB (Gigabyte).

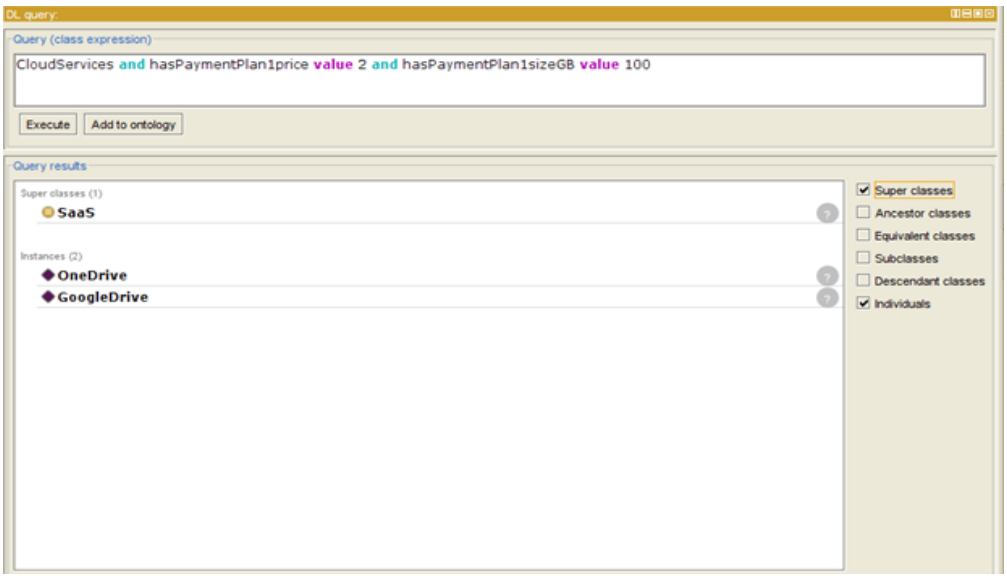


Figure 7. 5 Example of conceptual similarity reasoning

Based on the requirement by the SME user and the conceptual modelling of cloud services requirement offerings as advertised by service providers and presented in the case study in Table 6.1, the conceptual reasoning was able to retrieve the cloud service required as SaaS and the service that best meets the requirements in the above scenario are *Service C* and *Service A*. The SME owner can now narrow his decision on these two SaaS storage application services.

7.2.1.2 Object Property Similarity Reasoning

This can be referred to as a condition where two or more cloud services have a common object property relating to the same instance. To demonstrate that the decision support system equipped with an ontology of cloud services when queried can undergo object property similarity reasoning, the following user scenario is used to demonstrate this as follows: In a scenario whereby an SME owner requires a cloud service for his business, which is compatible with android operating system. Based on the user requirement, the ontology will determine which cloud services meets the following RDF condition (**Subject** :(CloudServices) **Predicate** (hasOSname3) **Object** (Android)) with the subject and object representing the domain and range respectively. For the ontology to understand the user requirement in machine readable language the following query is sent (**Cloudservices and hasOS name3 value "Android")** as represented in Figure 7.6**.** The query can be translated in lay terms as follows (**Cloud service that is compatible with Android operating system)**. Please note that OS stands for operating system.

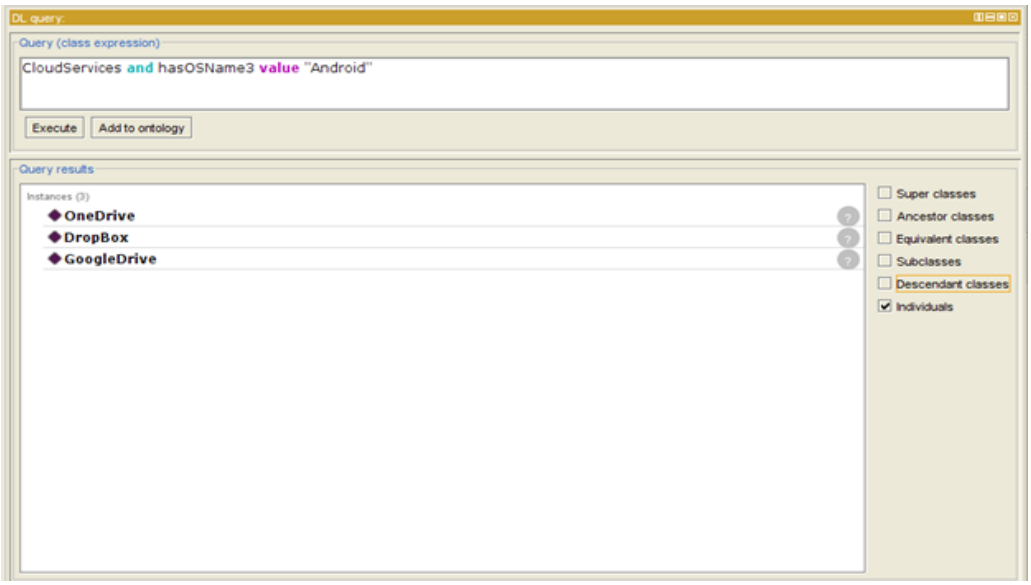


Figure 7. 6 Example of Object property similarity reasoning

Based on the modelled ontology of advertised cloud services by service providers as represented in the DSS, *ServiceC, ServiceB* and *ServiceA* are the cloud services that are android compatible and retrieved from CLOUDSME as shown in Figure 7.6.

7.2.1.3 Data Property Similarity Reasoning

This type of reasoning occurs within the ontology when a user queries the DSS for two or more cloud services with same datatype properties for a range of data. To further demonstrate that the DSS which includes a semantically designed ontology of cloud services can perform datatype similarity reasoning. In a scenario, whereby an SME owner request a cloud service with a file size restriction of data between 2 and 14 Gigabytes (GB), the RDF format of the requirement within the ontology is as follows (**Subject**: (Cloud Service) **Predicate**:(hasFilesizeRestrictionGB) **Object**: Int [>X<]). The system, when queried undergoes data property similarity reasoning to meet the user requirement by translating the user request to a machine-readable language. The following query is inputted to meet the user requirement (**CloudService and hasFileSizeRestrictonGB some int [>1, <15].** The query in lay terms is presented as follows: **(Cloud service with a file size restriction between 2 and 14gigabytes)**

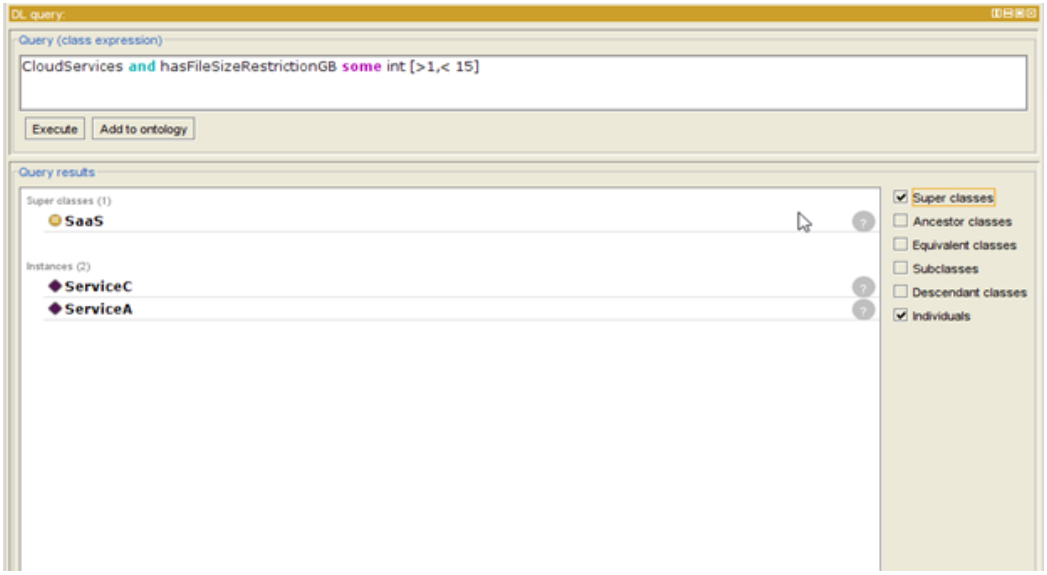


Figure 7. 7 Data Property similarity reasoning

As presented in in Figure 7.7, going by the datatype property similarity reasoning, the system retrieved SaaS service as the cloud service type and *ServiceC* and *ServiceA* as the cloud services that met the user requirement.

At this stage, the research has demonstrated that the proposed system can undergo conceptual similarity reasoning, Object property similarity reasoning and Data property similarity reasoning. The reasoning capability enables the system promote knowledge management for SME owners during their cloud service adoption process. The next section will demonstrate the implementation of CLOUDSME recommendation process by undergoing individual matching within system to meet user requirements.

7.2.2 Service Recommendation Implementation:

This concept is enabled by Individual similarity matching within the DSS. Cloud services are recommended based on the ability of each of their attributes to meet certain acceptable standards as discussed in chapter 6 and this is achieved with the use of semantic rules as shown in Figure7.8. In the above sections, the system has demonstrated that it has the

capability to inter-relate between domains to aid SME owners adopt cloud services for their businesses. In addition, the system has also demonstrated that different cloud service offerings from various service providers can be presented in a similar vocabulary for better user understanding when consulted during service adoption processes. Furthermore, the system has implemented the minimum acceptable standard for each criterion as represented in Table 7.3 and as discussed in chapter 6. To demonstrate that the system can perform individual similarity matching, the system is queried to recommend the cloud services the meet the acceptable standard for File Size Restriction (FSR) which has an acceptable standard value of (0.0721=>721). To achieve this requirement, Semantic rules have been established within CLOUDSME DSS with the service benchmarks as shown in Table 7.3.

Table 7.3 Benchmark for each service requirement criteria

Service Attribute	**RSRV Standard**	**CLOUDSME Benchmark**
Payment	0.1640	**1640**
Operating system supported	0.1170	**1170**
Security	0.3247	**3247**
File size Restriction	0.0721	**721**
Bandwidth Adjustment	0.0280	**280**
Free Storage	0.0247	**247**
Office via Web	0.0463	**463**
Trust	0.02259	**2259**

In other for CLOUDSME to recommend the best cloud services that would meet a user requirement, we present an example of a semantic rule within the DSS to demonstrate how it recommends cloud services to SME users for adoption based on individual similarity concept. In a scenario, whereby an SME manager (user) requires cloud services that best meets his file size restriction issues and consults CLOUDSME for recommendations. The following semantic rules has been implemented within the DSS as follows (Any cloud service that has a priority value either equal to or above 721 which is the minimum acceptable benchmark for file size restriction should be recommended to such a user with FSR requirement). The semantic rule is shown in figure 7.8, while the implantation of the semantic rule is shown in figure 7.9.

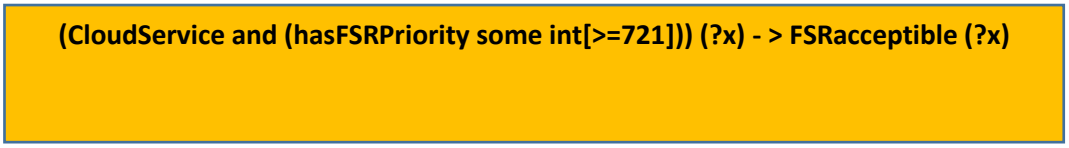


Figure 7. 8 Semantic rule for FSR benchmark for cloud service

The semantic rule implementation is shown in figure 7.9 to show the cloud services recommended by CLOUDSME to meet the user requirement.

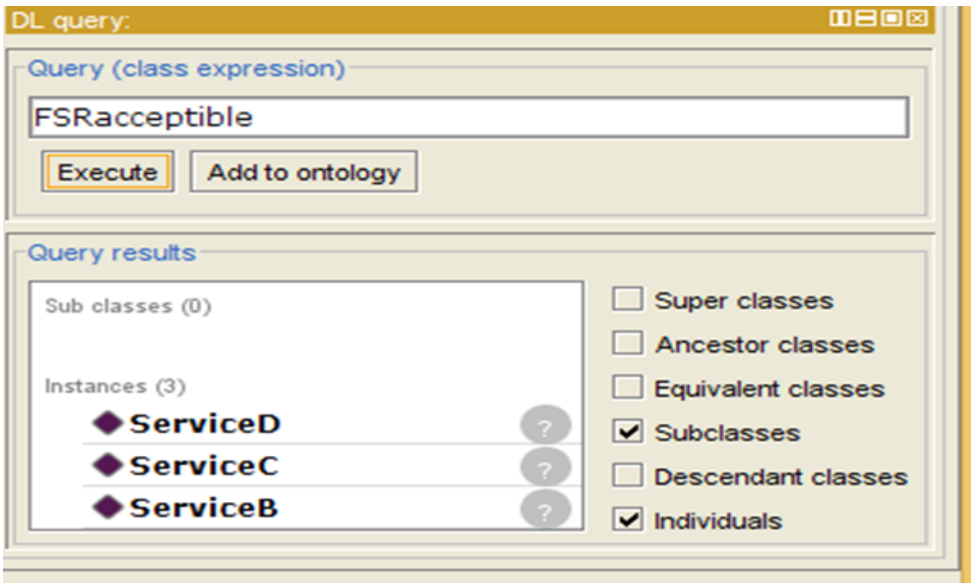


Figure 7. 9 Individual Similarity Matching showing CLOUDSME Recommendation

From the Fig 7.9, Individual similarity matching, the system recommends, *ServiceD, ServiceC* and *ServiceB* as the cloud services that meet the acceptable standard for File Size Restriction. The above system recommendation will enable the user to narrow his choice to either of the recommended cloud services in his decision making. Thereby tackling the issue of complex comparison. The next section discusses the implementation of the proposed cloud service ranking approach.

7.2.3 Service Ranking Implementation

The CLOUDSME ranking protocol has been discussed in chapter 6 of this thesis write-up. The cloud service ranking was achieved by the extending the AHP approach with the introduction of rational relationships. The ranking mechanism adopts 5stars, 4stars, 3stars, 2 stars and 1star from highest ranked to lowest ranked. In figure 7.11, the implementation of the ranking criteria is implemented using semantic rules. The 5stars ranking criteria as shown in equation 6.3 is as follows:

5 stars service ranking is characterized based on the following formation

When

$$\mathbf{M} \rightarrow (p_1 \geq p_1 x_1) \wedge ((q_2 \geq q_2 x_2) \vee (r_3 \geq r_3 x_3)) \wedge (k_4 \geq k_4 x_4) \quad \textbf{(6.3)}$$

The above equation 6.3 which represents 5 stars ranking is implemented using semantic rules within CLOUDSME as shown in figure 7.10.

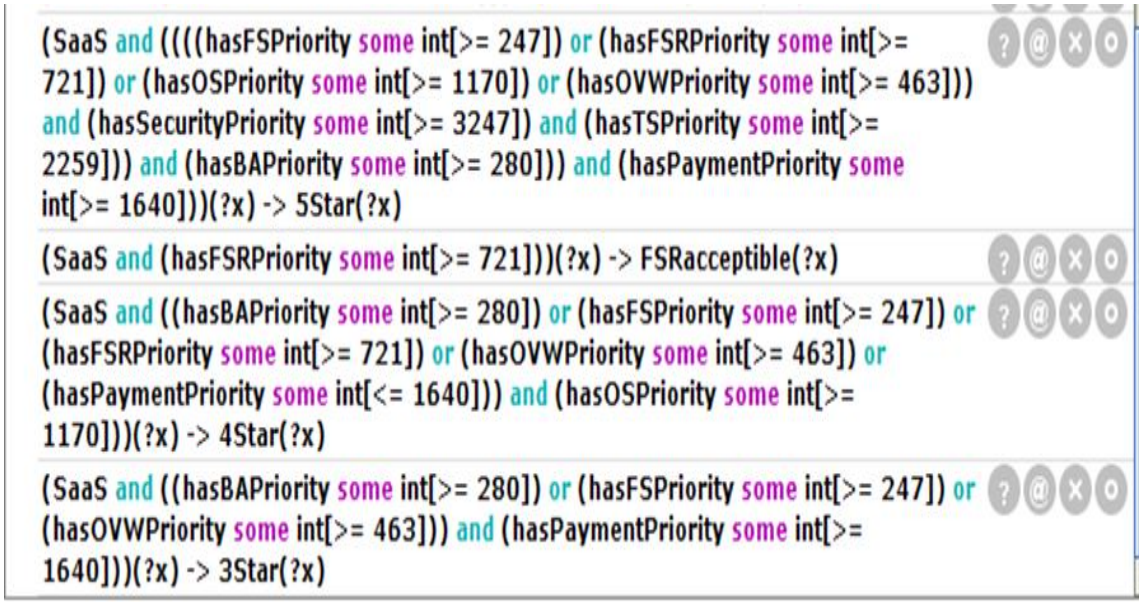


Figure 7. 10 Sematic Rules within CLOUDSME for 5star ranking

In Figure 7.11, a system query is executed to determine the cloud services that meets the 5stars ranking criteria.

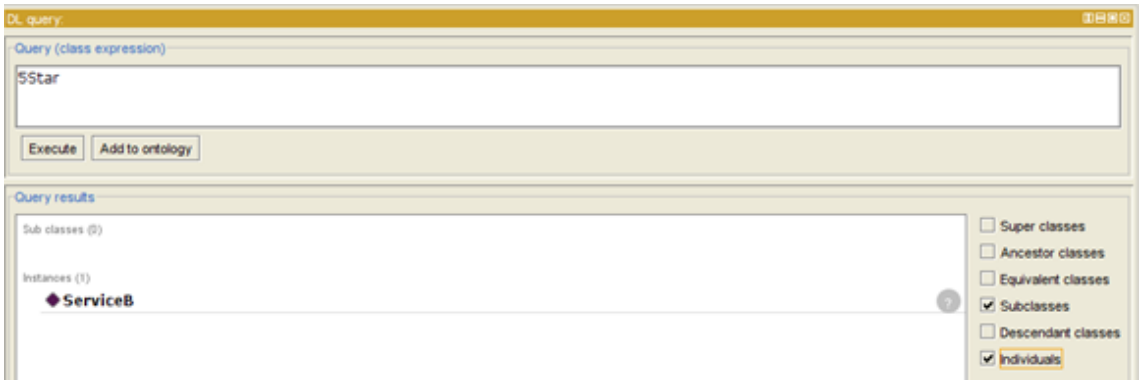


Figure 7. 11 Service B as the only SaaS storage application service that meets the 5 Star ranking.

From the above query, it can be seen that only service B attained the 5stars rank. This shows that although a different approach was used in this thesis for service ranking, The result of the ranking is similar to that of the AHP ranking as shown in chapter 6(Section 6.4.4) where Service ranked highest. Figure 7.12a shows the high level classes while figure 7.12b shows some sections of the Cloud service concept relationships within CLOUSME.

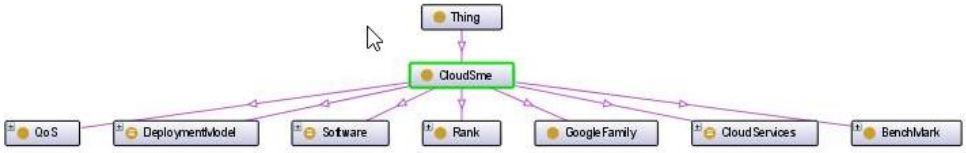


Figure 7. 12a CLOUDSME high level classes

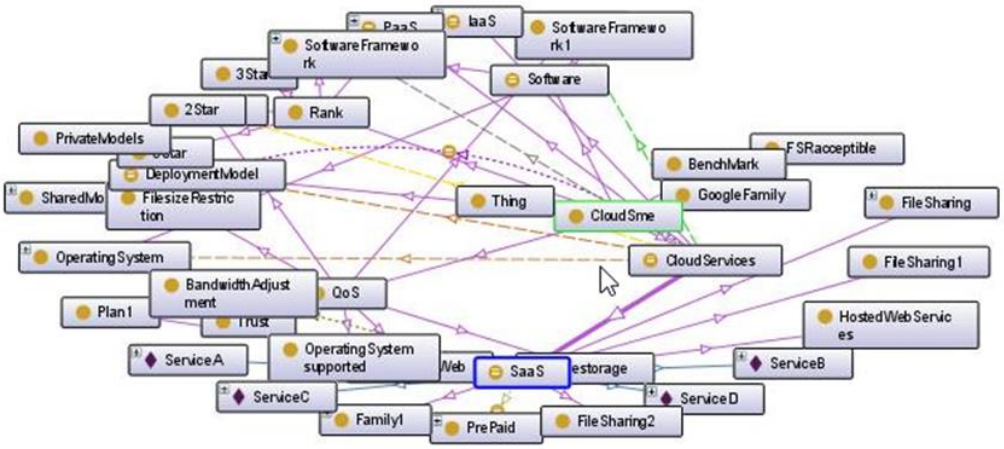


Figure 7. 12b Relationships between concepts within CLOUDSME DSS

7.3 Conclusion

In this chapter, the CLOUDSME decision support system has been implemented. This includes the cloud service Knowledge management, recommendation and Ranking. SME user scenarios were used to demonstrate the capability of the system to meet different user requirements. Different reasoning techniques were also exhibited in this chapter in view of meeting user requirements, The RDF format was used to present different cloud service requirements in a uniform vocabulary.

The proposed framework implementation has shown that it can aid SMEs in cloud service adoption by promoting knowledge management, service recommendation and ranking. The RDF format was used to unify the service provider requirement parameters within the DSS thereby presenting the requirements in a unified vocabulary for easy knowledge presentation. This will help increase the awareness of cloud services when consulted by SMEs in view of cloud service adoption. Furthermore, based on the implementation of prioritisation phase of the framework the issue of complex comparison which has been viewed as an uphill task in cloud service adoption by SMEs in Nigeria has been addressed. Finally, the implementation of the proposed CLOUDSME ranking formalism has shown that the issue of rank reversal associated with the AHP ranking approach which has made other researchers present their ranking findings using graphical presentations can be implemented using semantic rules.

Chapter 8: Evaluation

The previous chapter described the implementation of CLOUDSME. In this chapter, the evaluation strategies used to validate the proposed contribution is described. The use of experiments and empirical studies can be used to validate or reject the effectiveness of some methods, techniques or tools(Easterbrook et al., 2008). The stage 4 data gathering as discussed in chapter 3(Section 3.8.1) of the mixed method approach adopted in the research as explained in chapter 3 was performed based on the three of the four evaluation strategies.

- Construct validity (system output vs case study)
- User opinion evaluation (experimental survey)
- Expert opinion evaluation(survey)
- Researcher opinion evaluation (experimental survey)

The following methods were applied in this section in view of evaluating the contributions in this thesis. In section 8.2, the use of a confirmatory construct validity evaluation is performed to confirm if the framework DSS output when consulted matches with the service provider requirement parameters as presented in Chapter 6 (Table 6.1) case study of service provider requirement offerings and the prioritisation phase findings of this research. This evaluation method aims to demonstrate the validity and completeness of context categories. Section 8.3, this section discusses two evaluation methods; the first was based on User opinion evaluation which was performed based on an experimental survey. The survey questions were centred on Technology Adoption Model (TAM) as shown in (Appendix V). The second evaluation was based on expert opinion evaluation.

This survey was performed to validate the completeness of the framework in terms of dynamic system requirements. The survey questions as presented in (Appendix VI) was centred on ISO/IEC25010:2011 which is a standard for evaluating systems and software. In section 8.4, an experimental survey was performed to evaluate if the proposed CLOUDSME ranking approach can outperform other MCDM such as AHP and Outranking methods.

8.1 Overview

In this section, a detailed description of the evaluation of the proposed CLOUDSME decision support system is performed. Firstly, in section 8.2 the validity of the context aspect completeness, accuracy and efficiency is done using construction validity evaluation method by comparing the system output against the case study of cloud service provider parameters as presented in chapter 6 (Table 6.1) and the ability for the system to recommend a service that attains the requirement benchmark presented in chapter in chapter 6(Fig 6.4) and implemented as shown in chapter 7 (Table 7.3) in view of meeting user requirements when the framework is consulted .Secondly, in section 8.3 the validity of the context aspects and completeness evaluation of CLOUDSME was performed based on SME (user opinion). In this section, an experimental survey was conducted, which was centred around TAM (Appendix 5) to collect user opinion on CLOUDSME from 29 SME managers/owners who took part in the data gathering (stage 2) of this research and had not adopted cloud services for their businesses. The CLOUDSME DSS ontology was installed on their computers for three months and were followed up every 2 weeks. This evaluation was performed to determine if the system had enough knowledge to answer their cloud service adoption needs, has information to address their adoption challenges as well as to determine if CLOUDSME has any influence in their cloud service adoption decision. The SMEs that participated in this survey ranged from different aspects of SMEs

such as Real estate, hospitality, transport, entertainment, communication, Education, wholesale and retail based on International Standard for Industrial Classification (ISIC) due to the dynamic nature of SMEs and their requirements. Again, the evaluation and validity of the context aspects and completeness of CLOUDSME were conducted based on expert opinion evaluation. A survey was conducted which was centred on ISO/IEC25010:2011 to gather expert opinion as presented in (Appendix VI). The experts were chosen from different IT companies around the globe as they were identified from LinkedIn. Sixty survey questionnaires were distributed, but only 17 responses were obtained. In section 8.4, an evaluation experiment survey (Appendix VII) of the proposed CLOUDSME ranking approach compared to AHP and outranking methods was performed. For this evaluation process, 35 researchers were contacted, only 10 PhD researchers responded and were selected from different UK universities identified from Research gate and Academia covering different research areas and conversant with Multi-criteria Decision Methods. Finally, in section 8.4 concludes this chapter.

8.2. Construct Validity Evaluation

Construct validity method is the degree to which a test measures what it claims or proposes to be measuring(Cashin and Elmore, 2005). In this research, a confirmatory case study as presented in chapter 6(Table 6.1) as well as the proposed evaluation benchmarks as presented in chapter 6 Fig 6.4) in view of assessing the proposed CLOUDSME context model ontology with specific emphasis on its validity and completeness(Mann, 2001, Cook, 1978, Suwa et al., 1982). An exploratory case study scenario of four major SaaS storage cloud services was adopted at the development phase of CLOUDSME. As the research framework proposes a knowledge management domain, service recommendation domain and service ranking for cloud service adoption by SMEs. The empirical evaluation was followed by confirmatory case study (presented in Chapter 6,

Table 6.1) from content oriented domain service provider offerings and the SME cloud service adoption requirement findings (Chapter 5). These two complements each other. The evaluation was done manually, and user requirements were captured and implemented based on how services were judged to meet user requirements. A construct validity method adopted has two defined objectives which are (a) to evaluate the validity of context categories and (b) completeness of context categories.

8.2.1 Validity of context categories

Analysis of application scenarios for knowledge management and service recommendation from different SME categories as being performed for validity for context categories in CLOUDSME is the concern. Two scenarios were analysed from the knowledge management domain and the service recommendation domain to check whether context categories meet the dynamic needs of SMEs when CLOUDSME is being consulted by users. This was performed to test the hypothesis that CLOUDSME has the reasoning capability to meet changing needs of SMEs when consulted.

A scenario from the cloud service knowledge management domain:

Serviced-based applications are widely used in CLOUDSME knowledge management domain. A knowledge management generation sample scenario is explored and analysed in view of defining dynamic requirements of SMEs in the cloud service adoption process.

In the case study as presented in Chapter 6, table 6.1, Service A and Service C offers a payment plan (Cost) of $2/month/100GB. Also, they are both compatible with Android operating system. In the assumption that an SME needs to adopt a cloud service with the above requirement parameters and consults CLOUDSME.

The above information is required from CLOUDSME and compared to the case study table to confirm if CLOUDSME has enough knowledge to give an accurate feedback. To

address such requirement, CLOUDSME will need to perform both object property similarity reasoning and data property similarity reason at the same time to retrieve the services that meet the requirements. This is illustrated in Fig 8.1.

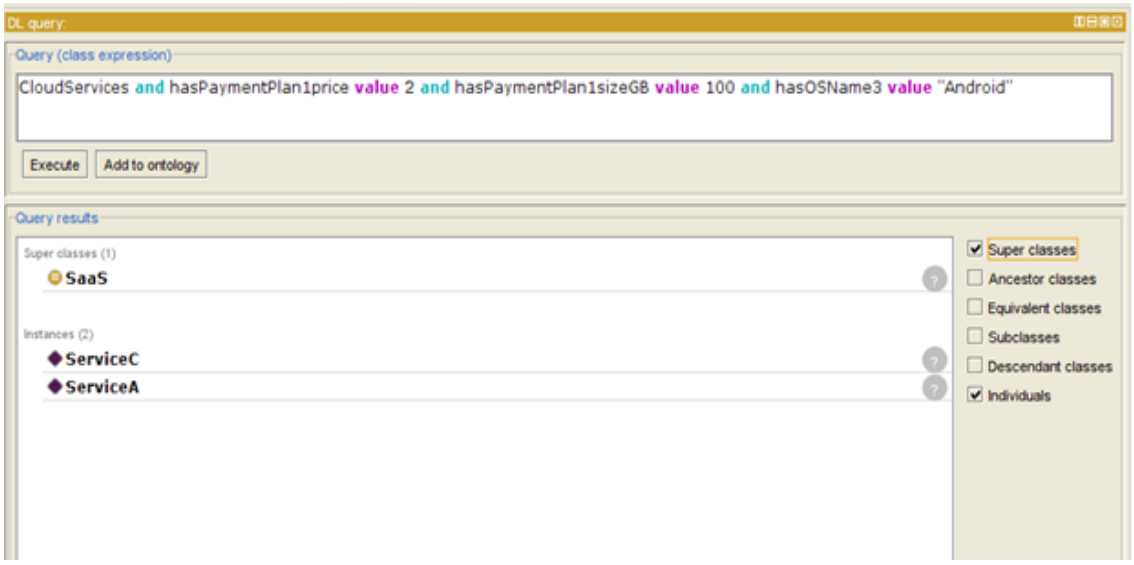


Figure 8. 1 Cloud service requirement and CLOUDSME process at consultation (Knowledge management domain) process.

A scenario from the cloud service recommendation domain

The importance and accuracy of service recommendation is vital to cloud service adoption by SMEs. A cloud service adoption scenario is explored to determine the service recommendation aspect for a different confirmatory requirement in view of defining the dynamic capability of CLOUDSME.

In view of determining that the proposed CLOUDSME can tackle the issue of complex comparisons in recommending a cloud service in decision making toward cloud service adoption. In phase 2 of the proposed framework, the benchmark for all the service provider parameters was determined as shown in chapter 6(Fig 6.4) where benchmark for security was declared as 0.3247 and implemented as presented in Chapter 7 (Table 7.3)

as 3247.Therefore, CLOUDSME when consulted for decision making in terms of cloud service that best meets SME security requirement based on service provider offerings. The DSS will interpret the user requirements as a cloud service that both meets/surpasses the benchmark for security and recommend it to the user. The ability to identify dynamic requirement of SMEs and the recommendation capability of CLOUDSME in decision making is relevant to this scenario as illustrated in figure 8.2.

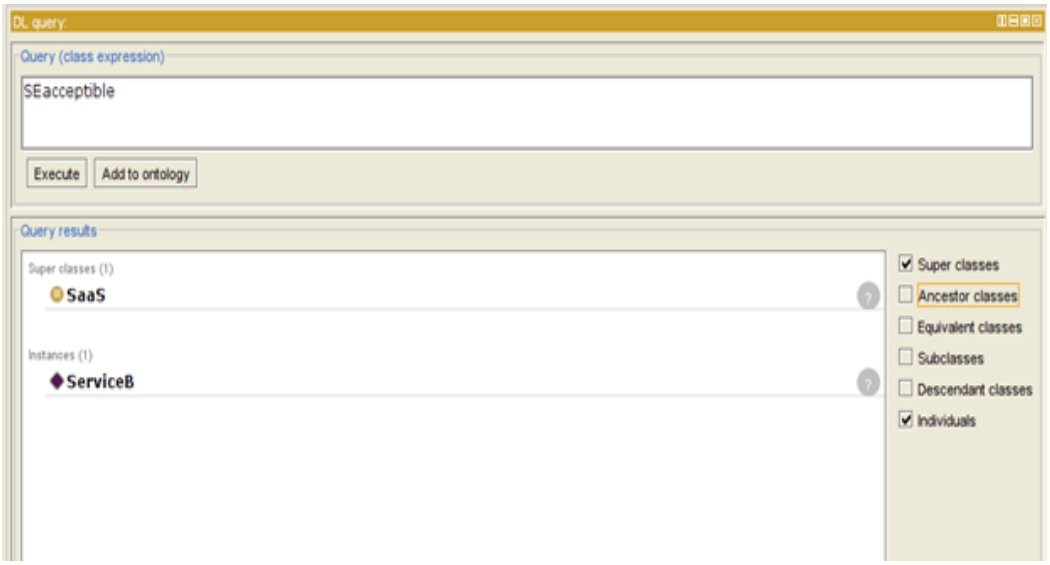


Figure 8. 2 CLOUDSME recommendation for security

From fig 8.2, CLOUDSME recommends Service B as the only cloud service that meets the benchmark for security. This is evident from chapter 6(section 6.4.2) as only service B with a security priority weight of (0.4708-> 4708) was the only cloud service to meet the security variable benchmark.

8.2.2. Completeness of context categories

The analysis of the application scenarios from two complementary domains justifying the completeness and accuracy of context categories compared to the proposed CLOUDSME DSS is the concern. Observation is done to determine whether all dynamic SME

requirements can be covered to test the hypothesis that CLOUDSME can cover all required SME requirement based on reasoning capability (Object property Similarity reasoning, Data Property Similarity Reasoning and concept similarity reasoning) as explained in Chapter 6 and implemented in Chapter 7. This complements the validity, which has been evaluated in Figure 8.2. The relative property of a data model is described as its completeness(Böhlen et al., 1995, Snodgrass, 2012). In the aspect of accuracy, the response to the knowledge management scenario and the recommendation scenario was compared with the advertised service provider's offerings case study in chapter 6(Table 6.1) and the service benchmark for recommendation in Chapter 6(Fig 6.4) and as implemented in chapter 7(Table 7.3). In terms of validity, the knowledge management generation scenario was explored in Figure 8.1, and the service recommendation scenario was explored in Figure 8.2 and compared their dynamic requirements with context features of the proposed CLOUDSME DSS in Chapter 6 to evaluate its completeness. The results enable the understanding that the dynamic nature of SME requirements can be defined in context categories and context categories can be attached to the quality of service context, domain context and platform context of CLOUDSME Model. The dynamic requirement of the different categories of SMEs as discussed in Chapter 5 can be defined in context categories of the proposed CLOUDSME model. Based on the evaluation, it can be concluded that the proposed CLOUDSME model is complete.

To further validate the proposed CLOUDSME a survey based User and expert opinion evaluation is performed in the next section.

8.3 Survey based evaluation: User and Expert Opinion

The majority of social surveys use a form of questionnaire to achieve reliable and valid information. When carrying out survey research, one of the vital elements is the construction of well -written and manageable questionnaires (Nardi, 2015). For the user

opinion analysis, The CLOUDSME model was installed for 29 SME managers who participated in the stage 2 data gathering stage of this research (Chapter 5) and did not adopt cloud services for their business prior to the use of CLOUDSME. They were chosen randomly from different categories of SMEs (ISIC) (Chapter 5, Table 5.2). They made use of CLOUDSME model for three months and were monitored once in two weeks throughout the study period. The questionnaire designed was based on Technology Adoption Model(TAM) and was analysed to determine if CLOUDSME has enough knowledge to meet their cloud service adoption requirements, the system has enough information to help tackle their cloud service adoption challenges and to determine the trend of cloud service adoption before and after using CLOUDSME. For the expert opinion analysis, system analytic experts from around the world were identified via LinkedIn and contacted through email. Questionnaire was designed to validate the completeness of CLOUDSME model framework using criteria for International Standards for System and Software Engineering (ISO/IEC 25010:2011). Experts' opinion was analysed regarging dynamic requirements for system acceptance from composition to execution stage. The experts were chosen randomly based on their experience, knowledge on various system application domains, business analytic skills and willingness to participate.

8.3.1 Questionnaire design

When constructing questionnaires it is important to consider the impact of own bias at all stages (Kitchenham and Charters, 2007). In view of eliminating bias in the questionnaire construction for both the user and expert opinion analysis, some techniques were adopted from (Kitchenham and Charters, 2007)

- Questions were developed from each section to adequately cover the scope of the thesis

- Simple questions were asked in order to limit the factors that may influence respondents' opinion
- Clear and unbiased instructions were outlined
- Questions were arranged in such a way that the answer to one does not influence the next
- Provided mutually exclusive and unbiased response categories.

8.3.2. User Opinion Evaluation

The user opinion questionnaire (Appendix V) was designed to focus on context categories and cloud service adoption in view of determining the validity and completeness in terms of meeting dynamic SME owner/manager requirement towards cloud service adoption for their business. The validity scale was defined as (1) - Strongly Agree. (2) -Agree (3) -Uncertain (4) –Disagree (5) Strongly Disagree.

The survey was designed for two main reasons: (a) To determine the level at which context categories of CLOUDSME meet the dynamic requirements of different categories of SMEs (ISIC) and (b) To determine the adoption trends of SME towards cloud service after using CLOUDSME for three months. The questions can be viewed in (Appendix 5). In the survey design, it was important to determine that the questions asked were easy to understand and were based on Technology Adoption Model (TAM)(Dishaw and Strong, 1999, Koufaris, 2002). Also, difficulties using the system were detected as well as other issues that were not anticipated were solved. On this basis, a pilot survey was carried out. To ascertain that all SME categories are involved in the pilot survey, 7 SMEs (one from each category) were selected. The pilot survey led to some changes in the questionnaire. Such as simplifying the terminologies and reduction of the number of questions in the questionnaire. In completion of the pilot survey, it was agreed that the questionnaire was stable. Therefore, the survey was made available to SMEs that willingly agreed to

participate. The 29 SMEs that participated in this survey were from different categories of SMEs as well as various locations in Nigeria. It is assumed that this variation in partaking SME groups, from different places can help achieve an unbiased, practical result.

8.3.2.1 Analysis of User Opinions: Results and Discussions

The survey starts with an introduction page, which describes the aim and objective of the survey regarding cloud service adoption. The researchers' email address and phone number were made available so that participants could easily contact the researcher if they needed additional information or had any other unforeseen issues. Participants were also contacted (followed-up) once in two weeks within the three months in view of tackling unforeseen challenges. A total of 100 SMEs who participated in the data gathering of this research and who hadn't adopted cloud services were individually contacted to participate in the survey. However, only 29 were willing and agreed to take part. The 29 SME managers completed the survey. Results from the user opinion survey were analysed to evaluate the validity and completeness of context categories in meeting dynamic SME user requirements. Also, to determine cloud service adoption trend of SME owners after using CLOUDSME.

Validity – definition of dynamic service context and user categories

The validity of CLOUDSME completeness based on its context categories in meeting dynamic SME user categories was surveyed through user opinion using closed end questions. The user opinions were analysed and illustrated to check the validity of CLOUDSME dynamic service context, context categories and ability to aid in SME adoption of cloud services.

The validity of the use of context categories to answer dynamic service requirement by SME managers was analysed from the answer given in Q1 and illustrated in Figure 8.3.

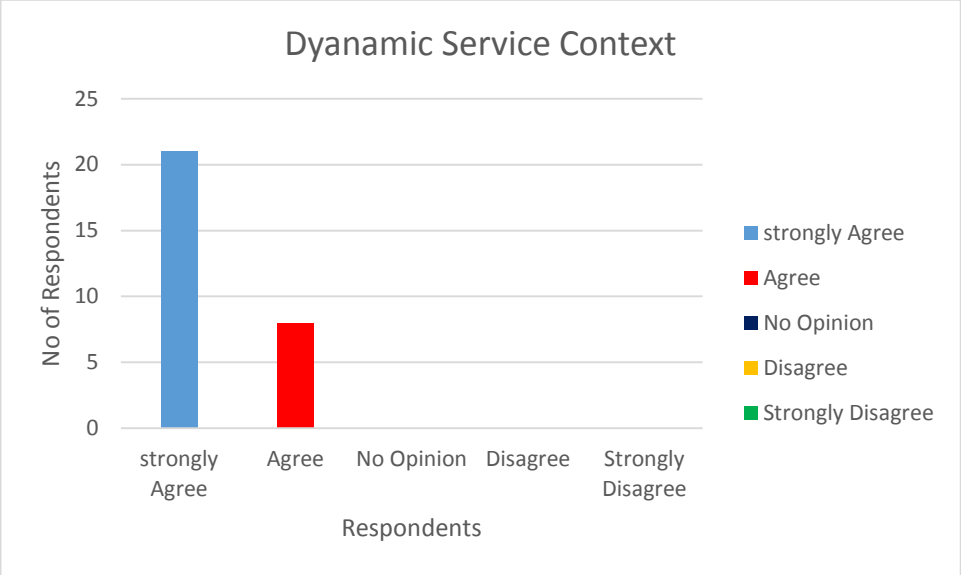


Figure 8. 3 Validity – Response to dynamic use requirements

The result shows that most of the respondents agree that the context categories of CLOUDSME can be used to answer dynamic SME requirements. Based on this response, we can clarify that system's ability to tackle dynamic SME cloud service requirements is valid.

From Q2, the user opinion in terms of functionality, the ability to multitask, answer user requirements, execute queries and make recommendations when CLOUDSME is consulted was surveyed. The result of the survey has been illustrated in Fig 8.4 to check the functionality of the inter-relationship between the different domains of CLOUDSME in view of answering user queries.

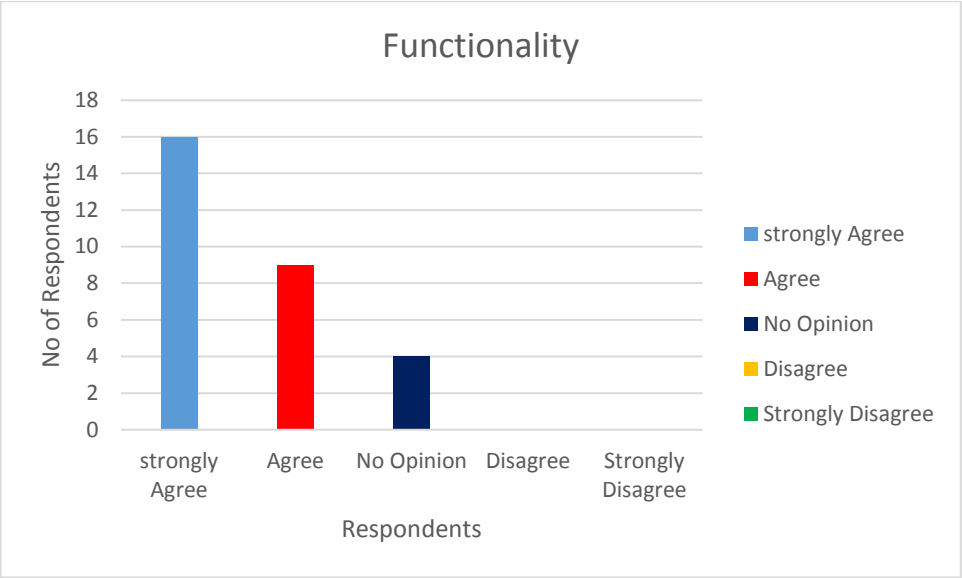


Figure 8. 4 Validity of inter-relationship between context domains

The result shows that majority of the respondents either strongly agree or agree with the functionality of CLOUDSME which is based on the inter-relationship/interaction between context domains of the system to answer user requirements. In line with the observation it can be concluded that the inter-relationship/interaction between domains when a user requirement is sorted, which is determined by Similarity reasoning types as discussed in Chapter 6 is valid.

From Q3 the SME manager's opinion regarding time taken for a user requirement to be answered when CLOUDSME is consulted was surveyed. The survey results illustrated in Figure 8.5 to validate the response in time taken for CLOUDSME to respond to user requirement.

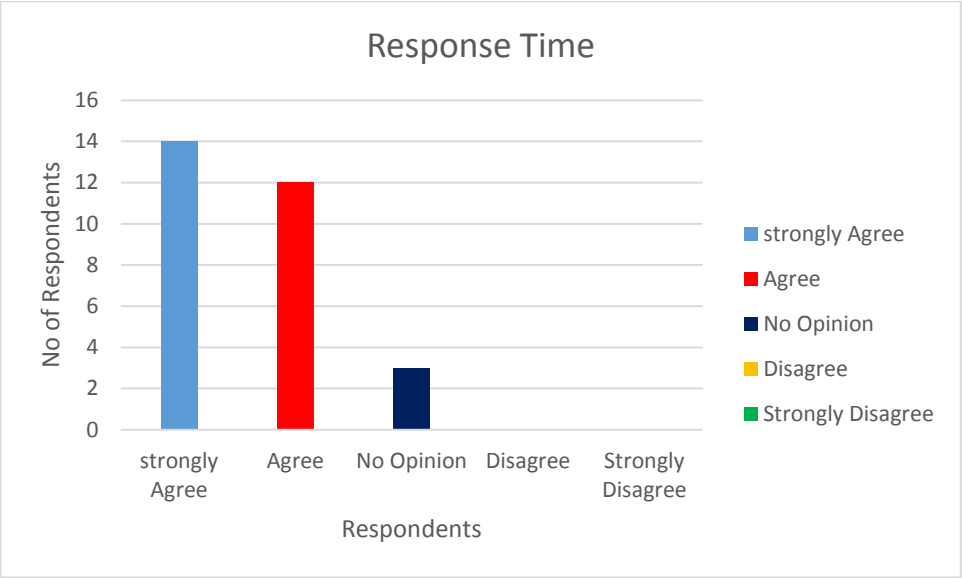


Figure 8. 5 Validity of response time to user requirement

In line with the user response as illustrated in Figure 8.5, it can be observed that majority of the respondents strongly agree or agree with the time it takes for a user requirement to be answered. In view of the user's opinion, we can conclude that the response time to user requirement execution is valid.

From question 4, the ease of use of CLOUDSME was surveyed in view of determining the simplicity and user friendliness of the model. The survey result has been analysed and illustrated in Figure 8.6 to observe the validity of the simplicity (user friendliness) of CLOUDSME.

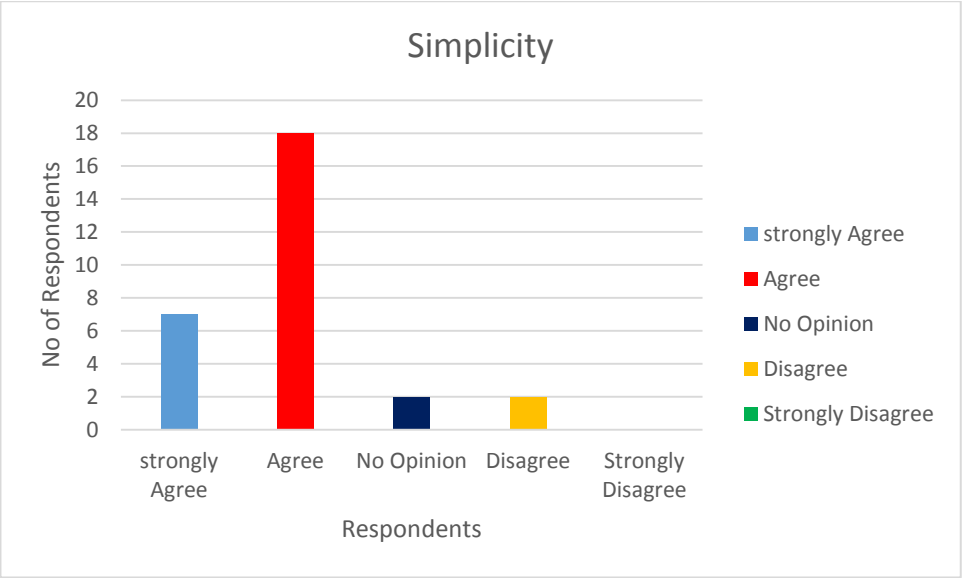


Figure 8. 6 User Friendliness Validity

From the analysis as illustrated in Figure 8.6, it can be deduced that the majority of the users agree with the claim that CLOUDSME model is easy to use, while a small fraction of the user disagree this may be due to the use of the protégé interface for query execution. However, it can be concluded that the majority of participants agree that the system is user friendly. Based on the analysis of the user response, it can be concluded that the claim for user friendliness of CLOUDSME is valid.

From Q5, the user opinion on the efficiency of the system was surveyed. The survey result has been analysed and illustrated in Figure 8.7 (to determine the efficiency of the system when consulted).

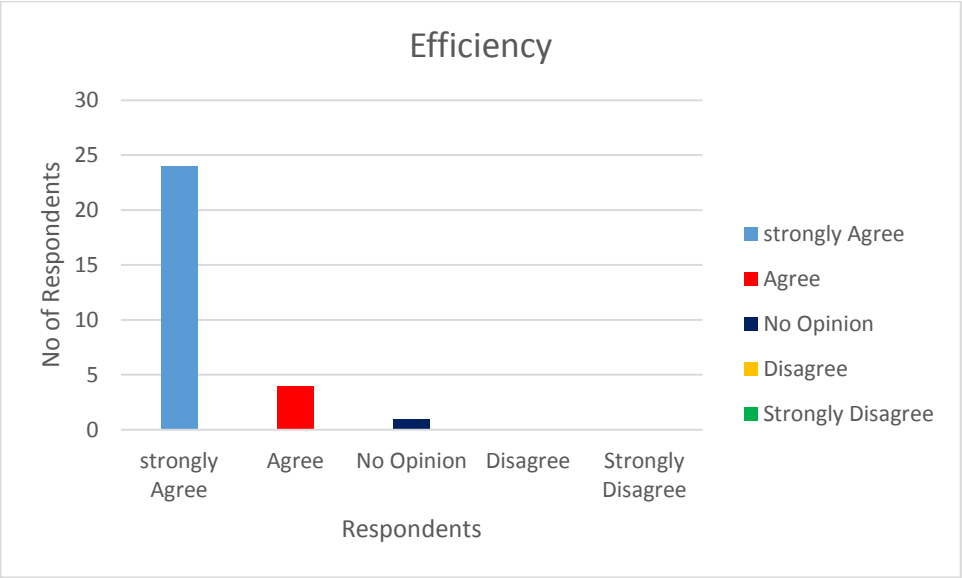


Figure 8. 7 Validity of system efficiency

The analysis of user opinion with respect to efficiency of the system shows that majority of the SME managers strongly agree that the system is efficient. This user opinion is based on the system response to user requirement when consulted. Such as: (1) it does not give a different response when the same user requirement is sorted (2) the system does not respond with numbers where it is supposed to respond with letters etc. Based on the user response it can be concluded that the system is valid in terms of efficiency.

From Q6 the user opinion on the acceptability of the proposed DSS with regard to it context categories is explored. This includes whether the system has enough information to tackle the SME manager cloud service adoption challenges. The survey result has been illustrated in Figure 8.8 to observe the validity of the context categories in terms of completeness of the system.

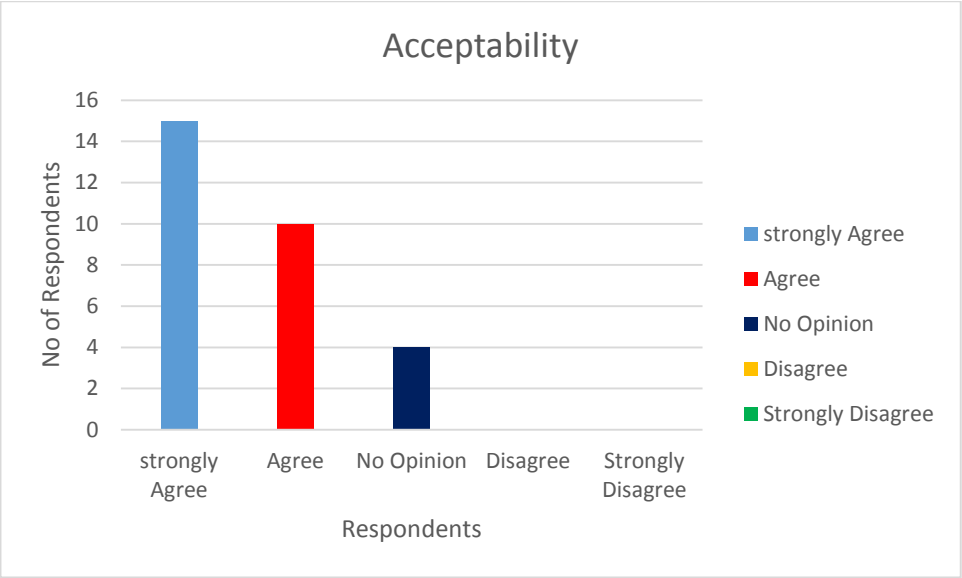


Figure 8. 8 CLOUDSME validity in terms of completeness of context categories

In line with the observation of the user response in regards to tackling user challenges towards cloud service adoption, majority of the participants strongly agree or agree with very few undecided. Based on the analysis and findings it can be concluded that CLOUDSME domain context are valid.

Furthermore, a combined analysis to determine the completeness of cloud SME based on user opinion was carried out. The result is illustrated in Figure 8.9.

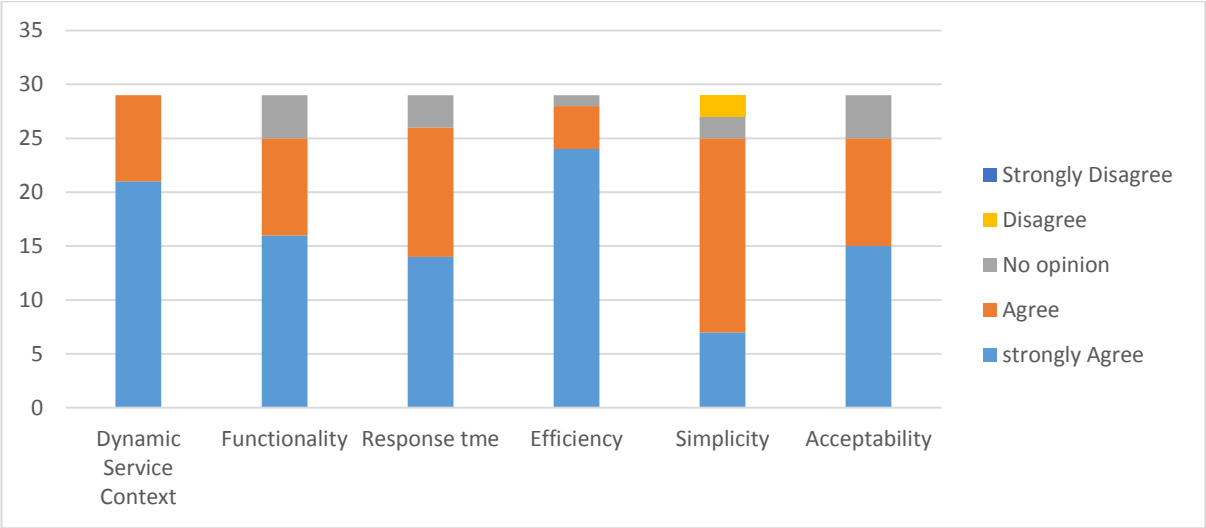


Figure 8. 9 CLOUDSME completeness validation

Based on the combined user opinion as illustrated in figure 8.9, we observe that majority of the participant either strongly agree or agree on the different validation requirements of CLOUDSME. Therefore, it can be concluded that the system is complete.

Finally, in view of determining if the aim of the system which is to aid in cloud service adoption by SMEs towards tackling the slow adoption of cloud services is valid, the participants cloud service adoption status after using CLOUDSME system for 3 months was surveyed. The survey result has been illustrated in Figure 8.10 to determine whether the use of the system can aid tackling the slow adoption rate of cloud services by SMEs.

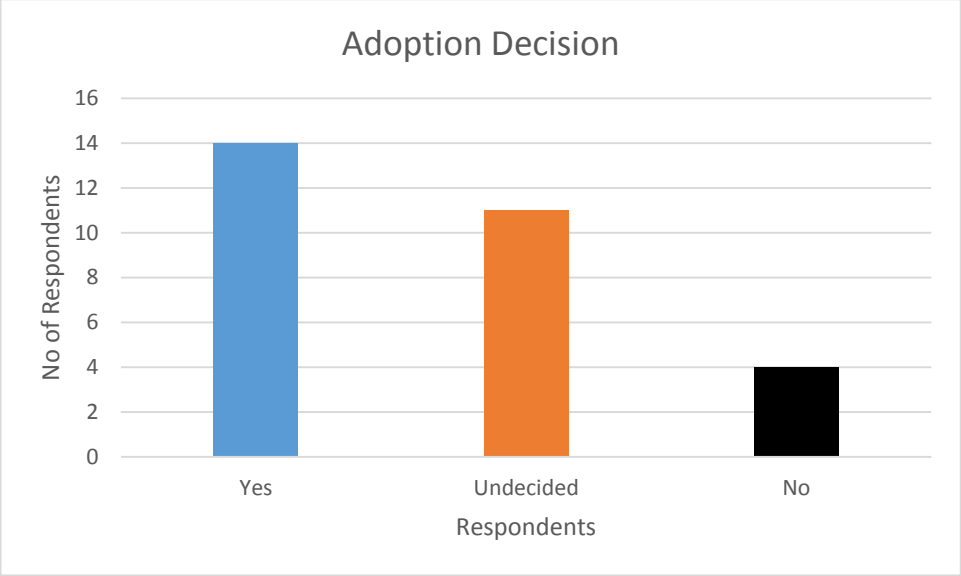


Figure 8. 10a Validity of CLOUDSME to aid in cloud service adoption

Before the experiment, none of the participating SMEs had adopted cloud services for their business. However, after using CLOUDSME for 3 months, most of the participants (14respondents) have adopted cloud service, while (10respondents) were undecided on whether to adopt or not and only a small fraction of the participants (5resondents) had not accepted. The reason why some of the participant are either undecided or have not adopted cloud services can be related to the Roger Bell curve of technology adoption life cycle as shown in Figure 8.10b.

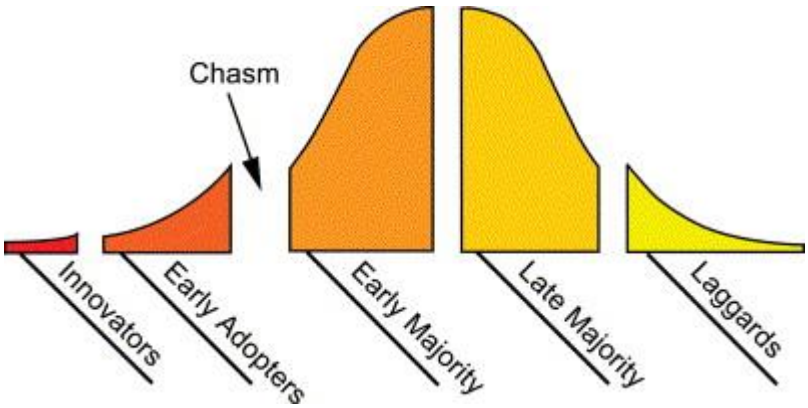


Figure 8. 10b Validity – definition of dynamic service context requirement

According to Technology Adoption Lifecycle there are the early adopters (those who are quick to adopt innovation). Those who adopted cloud service while using CLOUDSME Model and immediately after the experimental period are categorized as early Adopters. More so, there are the early majority (those who do not accept the technology immediately) or late majority (those who adopt it on the long run) and the laggards (those who are sceptical). From the survey, those who were undecided and those who hadn't adopted cloud services can be categorized either as either the late majority or the laggards. However, based on the results, we can conclude that CLOUDSME can aid in tackling the slow adoption rate of cloud services by SMEs. Therefore, the aim of the research based on user opinion is valid.

8.3.3 Expert Opinion Evaluation

In the expert opinion validation stage of this research, domain experts were used. Questions and answer based analysis method was adopted to determine the validity and completeness of CLOUDSME. Expert opinion was evaluated based on dynamic requirements applicable to the composition and execution stages of service based models. Experts were chosen based on their knowledge and experience on various information system and software application domains.

8.3.3.1 Expert Opinion Questionnaire Design

The expert opinion questionnaire (Appendix VI) design was constructed bases on the criteria for International Standard for System and Software engineering (ISO/IEC 25010:2011). To eliminate bias, some techniques were adopted from (Kitchenham and Charters, 2007) as described in section 8.3.1. The questionnaire was designed with specific emphasis on context categories, the validity of these categories as well as

completeness in terms of dynamic system requirements attached to execution stage of service applications. The validity scale was defined as (1) - Strongly Agree. (2) -Agree (3) -Uncertain (4) –Disagree (5) Strongly Disagree.

In addition, separate questions were provided to evaluate the completeness of CLOUDSME model, as follow Q1 (b), Q2 (b), Q3 (b), Q4 (b) and Q5 (b). The questionnaires were designed with support of experienced professionals in Service Oriented Architecture (SOA) applications and intelligent system domains. Please see (Appendix VI) for questionnaire.

The survey deals with dynamic requirements in relation to dynamically developed service applications. To achieve the aim of this survey, firstly, a pilot survey was conducted to identify the flaws in the survey proposal phase. Especially the view of industrial experts in understanding the questionnaire. For the pilot survey, 5 experts were chosen (System analysts, senior project manager (SAPBI), software architect, project manager) for the pilot survey. The outcome of the pilot survey led to some changes in the proposed questionnaire. This included reduction in the number of questions and terminology used in the questionnaire design. In completion of the pilot survey, the questionnaire was assumed to be stable and was distributed to 60 experts in different software companies at different locations around the world. However, only 17 responded. The respondents were from various countries such as America, United Kingdom, Malaysia, Ghana, Nigeria and Canada, Australia, Germany. The participants were from such companies as APIT (Malaysia), Quest Diagnostics (USA), WIZCORE SAP (UK), NHS (UK), Tecnovation (Ghana), TIT Psychic (UK), IITT (Nigeria). It is assumed that the variation in the location of participants as well as their expertise in various areas of computing will result to an un-biased practical result.

8.3.3.2 Expert Opinion analysis: Result and discussions

The expert opinion survey began with an introduction page, the page defined the dynamic service context in respects to SMEs towards the adoption of cloud services as well as the information required throughout the survey. Both open and closed end questions were asked to determine the completeness and validity of dynamic service context requirements and context categories. The results were analysed to validate the dynamic context requirements and context categories.

Validity- definition of dynamic service context requirement and categories

The validity of service context categories was surveyed based on expert opinion using closed-ended questions. The expert's opinion was collected and analysed and illustrated to determine the validity of the definition of dynamic service context requirement and service categories.

The validity of the definition of dynamic service context requirement was analysed based on the respondents' opinion to the answer in Q5 and illustrated in Figure 8.11.

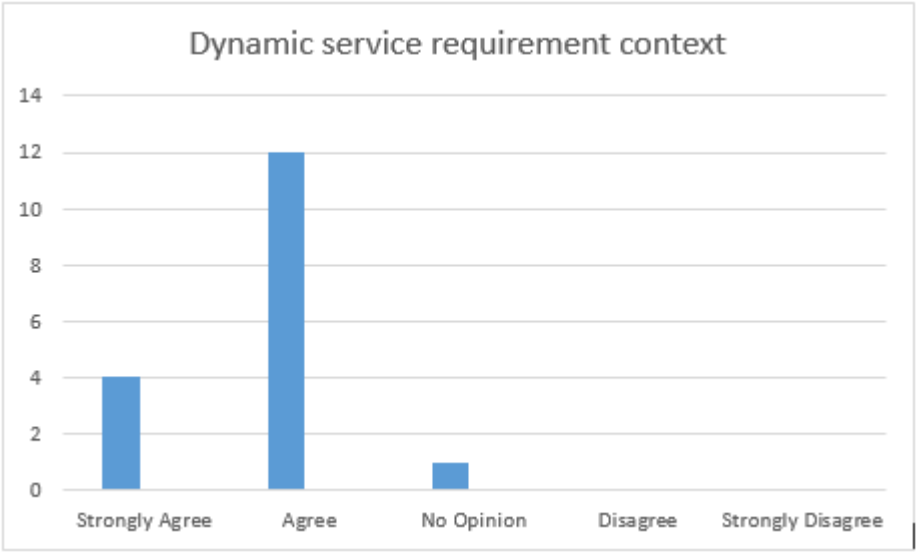


Figure 8. 11 Validity – definition of dynamic service context requirement

From the result, it is observed that the majority of the respondents agree with the definition of dynamic context requirement and its contents. Based on the experts' opinion it can be clarified that that the definition of dynamic content requirement is valid.

Q1 was designed to determine the expert opinion validation on QoS context categories, the expert opinion on the quality of service content categories was surveyed. The survey result is illustrated in Figure 8.12 to determine the validity of QoS context categories. The context categories can also be referred to as possible user requirement when CLOUDSME is consulted.

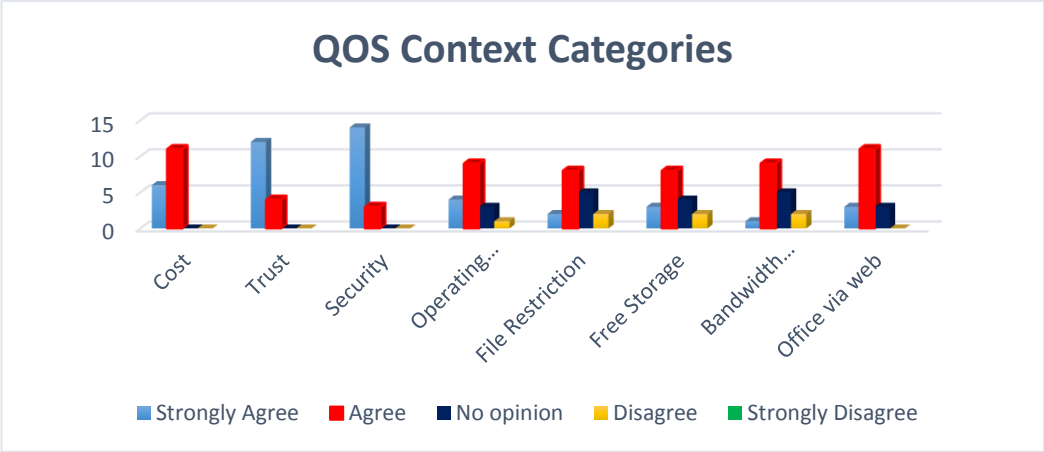


Figure 8. 12 Quality of service context category and their validity

Furthermore, the quality of service context categories together with their expert opinion was analysed and illustrated in Figure 8.13. From the illustration, it can be observed that the majority of the experts either strongly agree or agree to the claim.

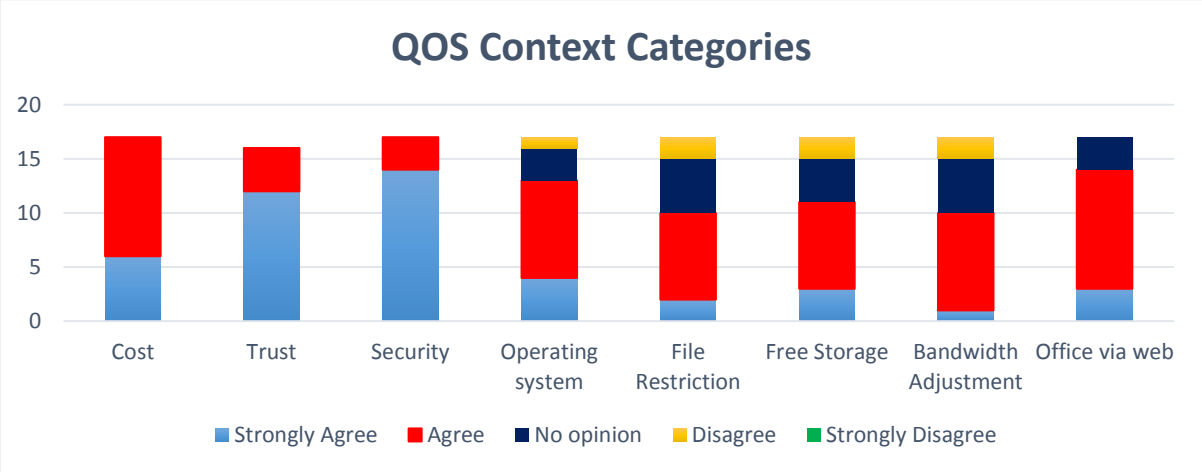


Figure 8. 13 Quality of service context category with analysis of expert opinion

Based on the observations, it can be confirmed that the quality of context categories is valid and they can be required when CLOUDSME is consulted.

From Q2 the expert opinion on domain context categories was surveyed. The survey resulted is illustrated in Figure 8.14 in view of obtaining the validity of domain context categories.

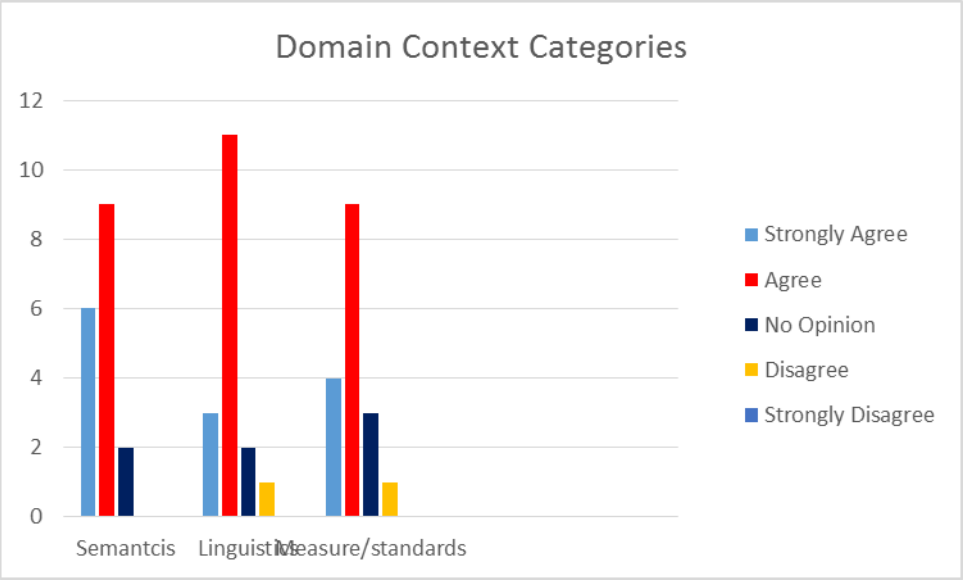


Figure 8. 14 Domain context category with their validity

The domain context categories along with their expert opinion were analysed and illustrated in Figure 8.15. It can be observed that majority of the respondents either strongly agree or agree with the claim.

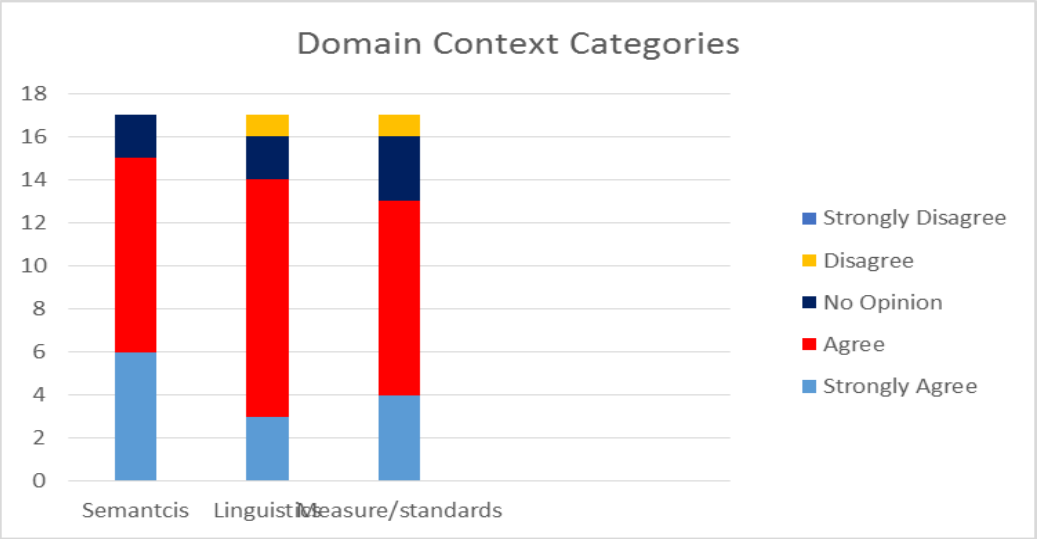


Figure 8. 15 Domain context category with expert opinion analysis

Based on the observation we can conclude that the domain context categories is valid. The domain content categories can be a user requirement when CLOUDSME is consulted.

From Q3, the expert opinion based on platform context categories was surveyed. The survey findings are illustrated in Figure 8.16. Considering the observation on expert's opinion on platform context categories, it is observed that majority of the expert strongly agree or agree with the claim. However, some of them were indifferent.

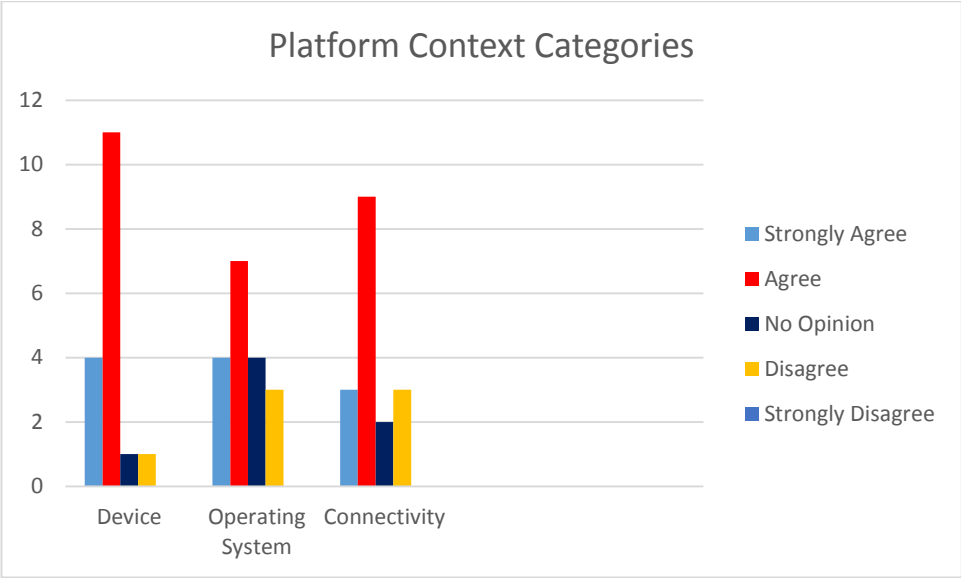


Figure 8. 16 Platform context category validity

Each platform context category together with its expert opinion is illustrated in Figure 8.17.It can be observed that the majority of the respondents either strongly agree or agree with the claim. Based on the observation, platform context categories are valid and can be a requirement in service process when CLOUDSME is consulted.

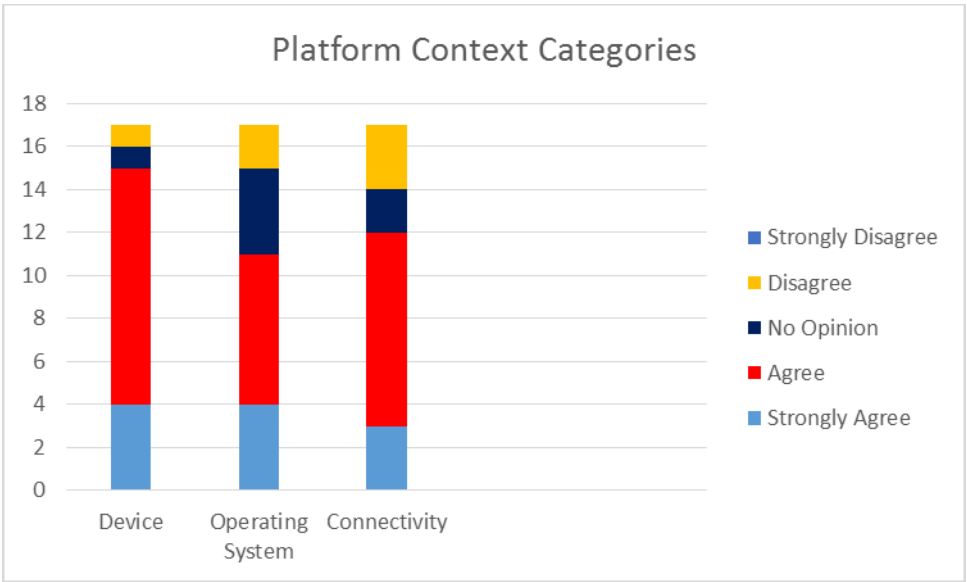


Figure 8. 17 Platform context category with expert opinion analysis

From Q4, the expert opinion with regards to functional context category was surveyed. The survey findings are illustrated in Figure 8.18.

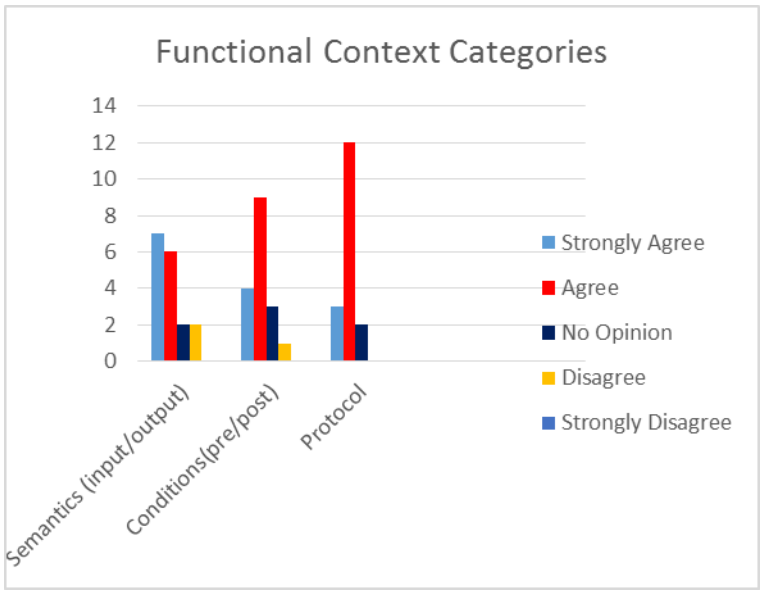


Figure 8. 18 Functional context category with their validity

The functional context category together with their expert opinion have been analysed and illustrated in Figure 8.19. It can be observed that majority of the respondent either strongly agree or agree with the claim.

Based on the findings, it can be concluded that the functional context category is valid. This implies that the functional context category can be a requirement in service process when CLOUDSME is consulted.

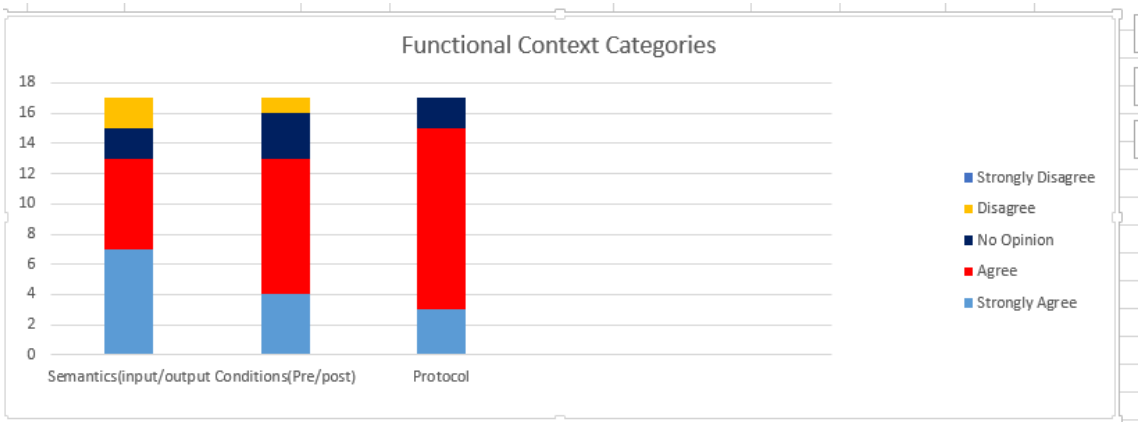


Figure 8. 19 Functional context categories with expert opinion analysis

Completeness of CLOUDSME- Dynamic service context requirement and taxonomy

Open survey questions were also designed to evaluate the completeness of service context categories and description of context categories from an expert perspective.

Completeness of Quality of Service Context: As a follow-up to Q1, an open-ended question Q1b was designed to determine the completeness of CLOUDSME in relation to QoS context categories. Majority of the experts approve the QoS context categories completeness. However, some of them propose the addition of some features which are beyond the scope of CLOUDSME as it is specific for aiding SMEs in making decisions towards cloud service adoption. Such features include government policy, maintainability and Timing. These identified adoption challenges, does not fit into the context categories of CLOUDSME.

The completeness of quality of service context compared to ISO/IEC 25010:2011:

To determine if CLOUDSME QoS, which is based on dynamic context is complete in relation to ISO/IEC 25010:2011 (which deals with system and software quality standards)

Q6 was designed. Majority of the participants agree with the claim that the quality of service context is dynamic as explained in ISO/IEC 25010:2010. The expert opinion is illustrated in figure 8.20.

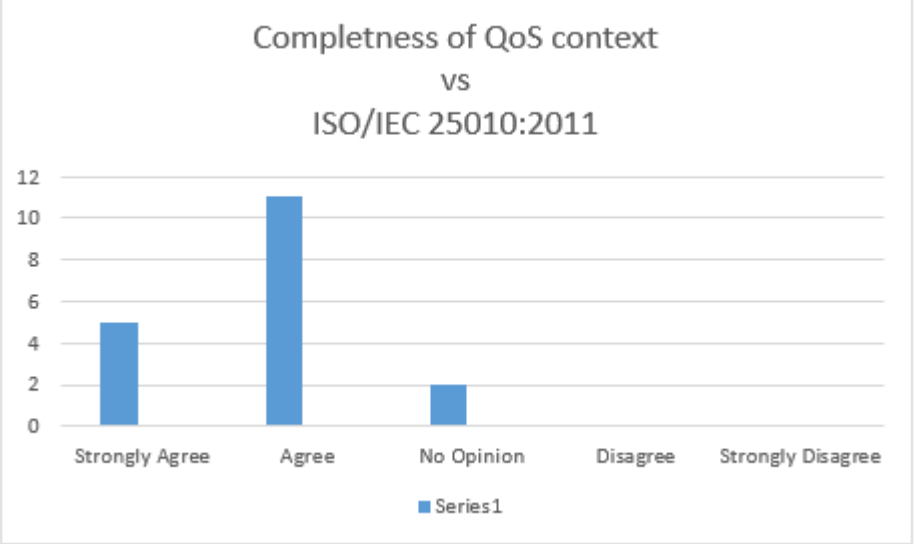


Figure 8. 20 completeness of QoS context VS ISO/IEC 25010:2011

Completeness of service domain context: As a follow-up to the expert opinion on Q2, an open- end question was designed to determine the completeness of the domain context categories. Majority of the respondent either strongly agree or agree with the completeness of the domain context. Although two participants propose that a user guide should be integrated. Based on the understanding of the researcher, a user guide could also be added as a manual document.

Completeness of platform context: As a follow-up to Q3, an open-ended question Q3b was designed to determine the expert's opinion in relation to completeness of platform context. Majority of the experts agree with the claim that platform context is complete. Although one of the respondent raised the issue of compatibility of CLOUDSME with mobile devices. Although CLOUDSME just like other smart services are tightly

integrated with hardware devices, the inability to install cloud SME on some mobile devices (e.g. Android) might be one of the limitations of the model.

Completeness of functional Context: As a follow-up to Q4, an open-ended question Q4b was designed to determine the completeness of functional context based on expert opinion. Majority of the experts agree that the functional context is complete. However, one participant raised the issue of interrelationship between different aspects functioning together at process time. This type of issue has been addressed under protocol context with the implementation of semantic rules.

Completeness of dynamic context requirement definition: To determine the expert opinion on the definition of dynamic context requirement, an outlined description of ISO/IEC 25010:2011 was given to the experts to compare with CLOUDSME. Their opinion was summarized as illustrated in Figure 8.11. Majority of the experts confirm that the definition is complete and knowledgeable.

8.3.4 Discussion and Summary

In this section, CLOUDSME service context requirement and context categories were evaluated for validity and completeness. Firstly, case study scenarios from two different context domain which are Knowledge management and service recommendation domains were evaluated for validity and completeness. The two case study scenarios were explored to determine the completeness of context categories in relation to CLOUDSME. Based on the results obtained in this thesis, it can be concluded that context categories of CLOUDSME are valid and context domain are complete.

Secondly, a survey based on User opinion and Expert opinion was conducted to determine the validity of the definition of dynamic service requirements and context categories. For the User opinion evaluation, 29 users (SME managers) from different categories of SMEs

who participated in the data gathering stage of this research and had not adopted cloud services prior to this evaluation stage were selected. CLOUDSME DSS was installed in their computers for 3months for them to consult towards cloud service adoption decision making. The survey result after the 3months of using CLOUDSME clarified the validity and completeness of dynamic service context requirement and context categories of CLOUDSME. After the 3 months experimental period, Majority of the Users adopted cloud services (Figure 8.10). This leads to the conclusion that CLOUDSME a semantically developed framework can aid in tackling the slow adoption of cloud services by SMEs.

Furthermore, Expert opinion was obtained to determine the validity of definition of service context requirement and completeness of context categories. This was done to gather expert opinion on the validity of the proposed CLOUDSME. Experts were chosen from different IT companies located around the world. Based on the result obtained, majority of the experts agree with the claim, although some of the experts recommended additional features such as Government policy for service adoption, maintainability and time for executing user requirement which are beyond the scope of this research.

Finally, one of the experts identified the inability of the CLOUDSME to be installed in some mobile devices such as Android platforms as protégé software is compatible with Linux and Windows operating systems. This is considered as one of the limitations of the DSS. Although with the growing technological advancement, it is believed that in the near future the installation of CLOUDSME on all mobile devices will be possible. In the next section, researcher opinion evaluation is performed to validate the proposed CLOUDSME ranking approach.

8.4 Evaluation of CLOUDSME Ranking Approach

The CLOUDSME ranking approach introduced in phase 3 of the proposed frame work and discussed in Chapter 6 (Section 6.5) and implemented in Chapter 7(Section 7.2.3) is evaluated to determine if it outperforms the traditional AHP method and Outranking method for ranking MCDM problems.

Experiment Aim:

To Compare CLOUDSME ranking against AHP and outranking Approach.

8.4.2 Objective:

The objective of this early user experiment was to determine whether CLOUDSME ranking approach can outperform AHP and outranking approach based on Technology Acceptance Model (TAM)

8.4.3 Setup:

Ten PhD researchers from different research areas some of whom agreed to be identified in this study as follows Olajide Jolugbo-Information systems(Lancaster University), Seun Alele- Business Management(University of East London) , Alice Mukaka- Humanitarian Studies(University of East London), Joseph Ikhalia- Software Engineering(Brunel University) Oluchukwu Nwosu Geology (Cardiff University) who are very conversant with data analysis especially when using Multi-Criteria Decision Methods (MCDM) for data analysis. They were selected based on their understanding and willingness to participate in this experiment. The CLOUDSME approach was well explained to them as they were already conversant with the AHP and outranking approach. They were asked to analyse a small data set from their research area using the three methods. At the end of this experiment, a survey(see Appendix VII for survey questions) was conducted taking into consideration the elimination of bias (Kitchenham and Charters, 2007). The survey

was given to them in view of comparing the three ranking methods to determine if the proposed method can outperform AHP and Outranking methods

8.4.4 Results:

In Figure 8.21 the researchers opinions is illustrated based on Technology Acceptance Model (TAM) (Legris et al., 2003, Koufaris, 2002, Dishaw and Strong, 1999). In view of adopting the model for this comparison, the model has been extended to include accuracy as part of the judgement criteria.

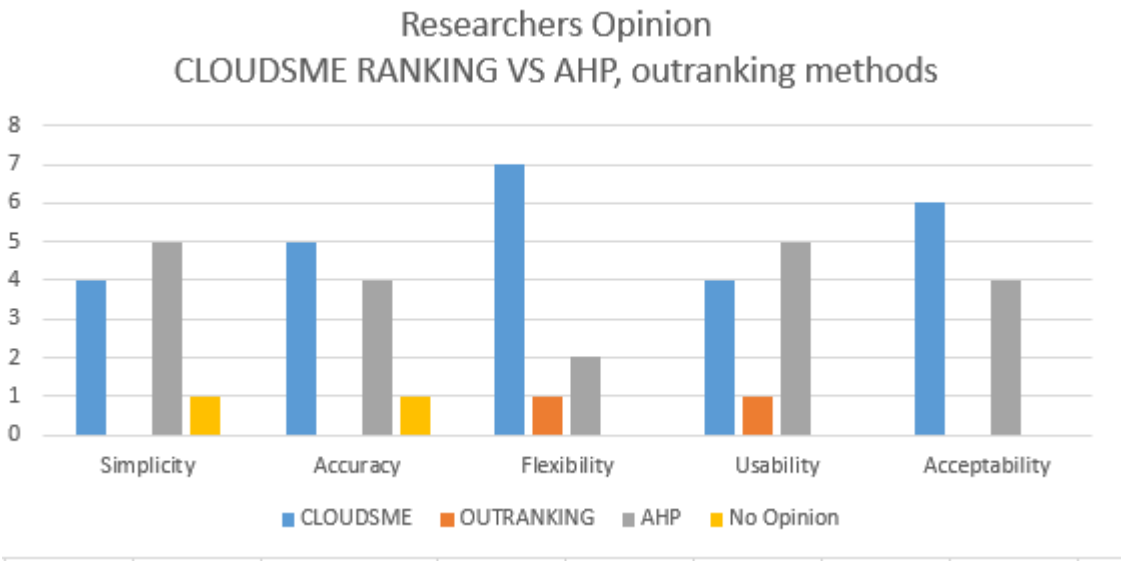


Figure 8. 21 Researchers Opinion CLOUDSME Ranking VS AHP and Outranking

8.4.5 Analysis of Result

Based on the result obtained from the opinion of different researchers, by adopting an extended version of the Technology Acceptance Model (TAM)(Legris et al., 2003, Koufaris, 2002, Dishaw and Strong, 1999).Although the sample size is small due to the fact that the researchers involved in this study needed to have prior knowledge of outranking and AHP ranking methods. The CLOUDSME ranking method was explicitly explained to the participating researchers for adequate understanding. Another reason for the small sample size was due to the willingness to participate bearing in mind that

researchers are very busy. From the result as depicted in Fig 8.22, majority of the respondents view both AHP and CLOUDSME approach as simple to use even though CLOUDSME is one respondent lower than AHP in terms of simplicity of usage. This could be because the researchers are still not conversant with the CLOUSME ranking approach as it is still new. Based on the researchers' opinion we can conclude that CLOUDSME approach is simple to use. From Fig 8.22, the result shows that the majority of the researchers are in the opinion that both CLOUDSME and AHP ranking approach are both accurate. Although in this judgement criteria CLOUDSME is perceived to be more accurate as the number of respondents for AHP is one less than those of CLOUDSME this could be based on the use of pairwise, comparison, consistency checks, benchmark and introduction of rational relationships in dealing with rank reversal which is lacking in AHP but adopted in CLOUDSME. The AHP method does not include rational relationships and benchmarks are not clearly defined. Regarding outranking, none of the respondents selected it, this could be based on the fact that it does not really have a structure for decision problems. Also, Outranking method has no formal guide for weighting attributes. Therefore, it can be concluded that CLOUDSME approach is more accurate based on researcher's opinion. Furthermore, researches opinion was sorted on Flexibility, from the result as shown in figure 8.22 of researcher's opinion result, majority of the researchers are of the opinion that CLOUDSME ranking Approach is more flexible than AHP and Outranking. This maybe because it gives the researcher the ability to rank based on set benchmarks as well as the ability to select which attributes to be included in the final ranking rather than summing up the total weights as compared to AHP. While outranking preference process is complicated and difficult to explain to non-experts. Based on the researcher's opinion, it can be concluded that CLOUDSME is more flexible than AHP and outranking methods. Again, the researchers' opinion was sorted on the

comparison of AHP, CLOUDSME ranking and outranking based on usability, that is the ability to guide users from the beginning to the end of the ranking process.

Based on the researcher's opinion findings, as illustrated in figure 8.22, Most of the researchers are of the opinion that both AHP and CLOUDSME are user friendly although AHP has one respondent more than CLOUDSME. However, outranking method has only one respondent. This shows that even though AHP is perceived to be slightly more user friendly than the CLOUDSME, this could be due to the sample size or the newness of the proposed method. Based on the Researchers opinion, it can be concluded that CLOUDSME ranking approach is user friendly. Finally, the researcher's opinion was sorted in terms acceptability of the three compared methods for research purposes. Six of the respondents are in the opinion that CLOUDSME is more acceptable to AHP with four respondents and outranking no respondent. From the findings of the researcher's opinion on the comparison of the proposed CLOUDSME ranking method, AHP ranking method and outranking method. The researchers sampled in the study are of the opinion that CLOUDSME ranking is more acceptable than AHP and Outranking methods. Therefore, it can be concluded that judging by researcher's opinion using a survey designed based on an extension of Technology Adoption Model (TAM) the proposed CLOUDSME ranking method outperformed both the AHP and Outranking methods. Therefore, CLOUDSME Ranking method is valid for research purposes.

8.5 Conclusion

In the Chapter, the evaluation of CLOUDSME an SME cloud service adoption framework has been presented for validation purposes. The use of case study of service provider requirement offering as presented in Chapter 6(Table 6.1) was adopted to evaluate and validate the completeness of dynamic context categories and domain categories of the proposed CLOUDSME. In addition to this, evaluation surveys were carried out to evaluate both the user and expert opinions views on dynamic user requirements, acceptability and validation of the completeness of CLOUDSME. Again, experiment on researcher opinion was performed and evaluated to validate the proposed CLOUDSME ranking protocol by comparing it with other widely used MCDM techniques.

The evaluation findings show that CLOUDSME framework is complete, it has enough knowledge and context categories to answer dynamic SME requirements. Also, based on the user opinion evaluation, CLOUDSME usage has the capability to tackle the slow adoption of cloud services by Nigerian SMEs as majority of the respondents adopted cloud services after using CLOUDSME for 3 months. Additionally, the proposed CLOUDSME ranking protocol outperforms AHP and Outranking methods when dealing Multi- criteria decision problems. Based on the above findings, the proposed CLOUDSME framework is valid.

Chapter 9: Conclusion and future work

This PhD research presented a study to develop a framework (CLOUDSME) which includes an ontologically developed decision support system to tackle the slow adoption of cloud service by Nigerian SMEs.

The research was introduced by discussing the motivation, aim and objective in chapter 1. The literature background of similar works carried out in the area of cloud service adoption was discussed in chapter 2. The research methodology adopted comprises of both qualitative (focus group discussions) and quantitative (survey) approaches as it allows for multiple data collection methods. This research adopted a stakeholder holder approach by involving managers of SMEs. This was because they are known to be the decision makers in an SME environment. They were selected using a stratified sampling method based on International Standard for Industrial Classification (ISIC) to partake in the research survey and focus group discussion sessions. The aim was to understand the possible challenges faced by SMEs in Nigeria towards cloud service adoption. Also, a comparative study of the state-of-the arts was analysed using well defined method known as Systematic-Literature-Review. The findings of the SLR was well presented so that other researchers working on cloud service adoption can choose the best technique that meets their research needs. Furthermore, Men-ontology method was adopted in the development of CLOUDSME. The research methodology was discussed in chapter 3. The analysis of data gathered from the survey and focus group sessions was used to identify the cloud service adoption challenges which are specific to Nigerian SMEs. Also, the type of cloud services (IaaS, PaaS and SaaS) that will best tackle the SME challenges towards cloud service adoption was identified. In addition, the findings of the data analysis was compared with a similar research for cloud service adoption for SMEs in the

United Kingdom. This comparison was carried out to understand if the cloud service adoption challenges are similar or different for both developing (Nigeria) and developed countries (UK). This was carried out in chapter 5.

Based on the finds from above the chapters, this thesis has proposed a novel cloud service adoption framework which includes a semantically developed cloud service ontology as decision support system. The framework design and development was discussed in chapter 6. The proposed semantic approach promotes knowledge management by proposing an ontology of advertised SaaS cloud storage application services as advertised by service providers. At the moment, various cloud service providers present their services using different vocabulary, thereby making it difficult for possible SME cloud service adopters to understand the differences and similarities of the services provided by numerous service providers. However, the ontology description language helps to formalize a uniform vocabulary to represent the cloud service provider offerings.

Another challenge identified was how to compare the various QOS offered by various service providers as well as ranking the services based on how best they meet user requirements. This type of comparison is known as a Multi-Criteria Decision problem and it is associated with complex comparisons. To tackle such complex comparison, a Multi-Criteria Decision Method (MCDM) is needed. This thesis proposed an extension of the commonly used AHP approach for tackling Multi-criteria decision problems by introducing benchmarks and rational relationships thereby giving researchers more flexibility in the final ranking stage.

In addition, this thesis also proposed a set of semantic rules within the ontology to implement the proposed benchmark for each QOS offering. A service provider offering must be equal or greater than its proposed benchmark before it can be recommended to a possible SME manager who requires the particular service for adoption. Again, a set of

algorithms was introduced using semantic rules to implement the cloud service ranking protocol. Services are ranked 5stars, 4 stars, 3 stars, 2 stars, 1 star, from highest to lowest depending on how they best meet user requirements. The system implementation was discussed in chapter 7. In chapter 8 different evaluation methods were adopted in view of validating the proposed framework. The evaluation techniques include user opinion evaluation, expert opinion evaluation comparison with international standards of systems and software.

This thesis is concluded in this chapter. It is divided into two sections where: Section 9.1 describes the research findings based on the research questions while section 9.2 describes the likely future research work.

9.1 Research Findings

The summary of the research findings is given below:

RQ2: What approaches have been proposed to represent cloud service adoption techniques?

From the primary studies, It was observed that presently there are three major techniques used cloud service adoption; (a) Tackling cloud service adoption with the use of ontologies (b) The use of service adoption frameworks (c)The uses of Models which are further differentiated into 1) Unified Modelling Language 2) Conceptual models.

RQ1: What is the current state, impact and challenges of cloud service adoption in Nigeria (developing country) compared to United Kingdom (Developed country)?

The challenge of security and trust was identified as a cloud service challenge by both SMEs in Nigeria and UK. However, the issue of Trust was perceived differently by the SMEs in the UK compared to those from Nigeria. While the SMEs in Nigeria identify

lack of trust for service providers as a challenge to cloud service adoption, the reverse is the case for SMEs in the UK. The early adopter and possible cloud service adopters in the UK have trust for the service providers as long as they are binding by a service Level Agreement (SLA). They are more concerned with the uncertainty associated with the adoption of new technology. Also,

It is observed that the SMEs in UK and Nigeria identify lack of knowledge of cloud services as a challenge towards its adoption. This challenge can be termed a global challenge since it is identified by countries in both developing and developed countries. In addition, SMEs from both divide identified the importance of cloud service decision support tool to aid in the cloud service adoption process. The issue of Geo-restriction and trial-ability is more synonymous with the SMEs in the United Kingdom as such challenge was not identified by Nigerian SMEs.

RQ3: What uniqueness does CLOUDSME have over other cloud service adoption techniques presently used?

The proposed CLOUDSME has the capability to promote knowledge management by proposing an ontology of advertised SaaS cloud storage services as advertised by service providers. The ontology description language helps to formalize a uniform vocabulary to represent the cloud service provider offerings. Also, it proposes an extension of the commonly used AHP approach for tackling Multi-criteria decision problems by introducing benchmarks and rational relationships thereby giving researchers more flexibility in the final ranking stage. In addition, it recommends accurate information by introducing a set of semantic rules within the ontology to implement the proposed benchmark for each QOS offering. A service provider offering must be equal or greater than its proposed benchmark before it can be recommended to a possible SME manager who requires a particular cloud service offering for adoption. Again, it uses semantic rules

to introduce a set of algorithms within the DSS to implement the cloud service ranking protocol. Services are ranked 5stars, 4 stars, 3 stars, 2 stars, 1 star, from highest to lowest depending on how they best meet user requirements. CLOUDSME has the capability to address the dynamic requirement of SMEs based its conceptual reasoning capability (Object property Similarity reasoning, Data Property Similarity Reasoning, concept similarity reasoning) and inter-relationships between context domains. It is user friendly, timely and efficient.

RQ4 What advantage does the use of semantic technology have towards decision making against a generic web search and service provider website with specific emphasis on the adoption of cloud services by SMEs?

Generic search engine (Keyword search)

The generic search engine does not deliver any method for evaluating and ranking the quality or reliability of the retrieved web information. The format of retrieved information is also not standardised, thereby complicating issues such as readability and clarity of heterogeneous service information. Considering the unreliability of some web service information. The search engine design is not specifically meant for service retrieval. Therefore, there is no means to determine the heterogeneous nature of services. Hence, such result may be irrelevant when emphasising on cloud services. In addition, the search engine approach does not consider the dynamic request nature of users. This can be also considered as a poor performance of search engine technique in terms of accuracy.

Service provider website

Entering the website of various SaaS storage cloud service providers does not give the SME manager any method of evaluating the service offerings and then make a direct decision on service selection based on however he perceives one service QoS to be better

than the rest. This method might be good for generic knowledge on cloud storage services. However, just like the search engine approach, this method can also be ascertained to be poor.

Semantic web

Semantic web has the capability to evaluate and rank the quality or reliability of the retrieved web information. The format of retrieved information is standardised, thereby promoting readability, clarity and knowledge service information. The semantic web can be modelled specifically meant for service retrieval. Therefore, there is no means to determine the heterogeneous nature of services. Also, the semantic web can be used to address the dynamic nature of user requirements. Based on the research implementation in chapter 7, the advantage of semantic technology against generic search and visiting service provider website for aiding cloud service adoption by SMEs are numerous.

9.2 Future work for CLOUDSME

The future work for the CLOUDSME framework includes extending the DSS, integration of an automation of service provider offerings.

9.2.1 Extending the DSS

In this research, the emphasis was based on 4 major cloud service providers for illustration purposes. However, in future, CLOUDSME can be extended to integrate other SaaS storage cloud services by other service providers such as Amazon cloud, Box.com etc.

The context of cloud service providers QOS information has been identified in relation to SMEs adoption of cloud services. The number of parameters used to compare the cloud services can be extended. Extending the number of parameters may enhance the decision-making capability of CLOUDSME.

Also, this research focused more on the non-functional properties of cloud services. It can be extended to include the functional properties offered by PaaS and IaaS cloud services.

9.2.2 Improving CLOUDSME service Automation

In the current version of the proposed framework the cloud service providers and their offerings are manually searched and updated with the DSS of CLOUDSME.

The process of searching for new service providers and updating their information can be automated using web crawlers. A web crawler has the capability to search the web in support of other services; it is generally used by search engines to update information. The inclusion of SAWDL annotations can allow semantic software agents to automatically invoke themselves to perform a set of tasks. This can potentially update cloud service provider information automatically with the CLOUDSME DSS.

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List of Appendix

Appendix i: list primary data with allocated score

Study Identifier	QAQ1	QAQ2	QAQ3	QAQ4	QAQ5	QAQ6	QAQ7	QAQ8	TOTAL
S1	1	1	1	0.5	1	1	1	0.5	7
S2	1	0.5	1	0.5	1	0.5	0.5	0	5
S3	1	1	1	0.5	1	0.5	0.5	0	5.5
S4	1	1	1	0	1	1	0.5	0	5.5
S5	1	1	1	0.5	1	1	1	0	6.5
S6	1	0.5	1	1	1	0.5	0.5	1	6.5
S7	1	1	1	0.5	1	0.5	0.5	0	5.5
S8	1	0.5	0.5	1	1	1	1	0	6
S9	1	1	1	1	0.5	0.5	1	0	5
S10	1	0.5	1	1	1	0.5	1	0	5.5
S11	1	1	0.5	1	0.5	1	1	0	6
S12	1	1	1	1	1	0.5	1	0.5	6
S13	1	0.5	1	0.5	1	1	0.5	0	4.5
S14	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	4.5
S15	1	1	1	1	0.5	1	1	0.5	7
S16	0.5	0.5	0.5	0.5	1	0.5	0.5	0.5	4.5
S17	1	1	1	0.5	1	0.5	0.5	0	5.5
S18	1	0.5	0.5	0	1	0.5	1	0	4.5
S19	1	1	1	0	1	1	0.5	0	5.5
S20	1	1	1	0.5	1	1	0.5	0	6
S21	1	1	1	0	1	1	1	1	7
S22	0.5	0.5	1	0.5	1	1	0.5	0	5
S23	1	1	1	1	1	1	1	0.5	7.5
S24	1	1	1	0.5	1	0.5	1	0.5	6.5
S25	1	1	1	0	1	0.5	0.5	1	6
S26	1	0.5	1	0	1	0	0.5	0.5	4.5
S27	1	1	1	0.5	0.5	0	0	0	4
S28	1	1	0.5	0.5	0.5	0.5	0.5	0	4.5
S29	1	0.5	0.5	1	1	0.5	1	1	6.5

S30	1	0.5	1	0.5	0.5	1	1	0.5	6
S31	0.5	0.5	1	1	1	0.5	1	0	5.5
S32	1	1	0.5	1	0.5	0.5	0.5	0.5	5.5
S33	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	3.5
S34	1	0.5	0.5	0	0.5	0.5	0.5	0	3.5
S35	1	1	1	0	0.5	0.5	0.5	0	4.5
S36	1	1	1	0.5	0.5	0.5	1	0	5.5
S37	1	1	1	0.5	1	0.5	1	1	7
S38	1	0.5	0.5	0	0.5	1	0.5	0	4
S39	1	1	1	0.5	1	1	0.5	0.5	6.5
S40	1	1	0.5	0	0.5	0.5	1	0	4.5
S41	1	1	1	0.5	1	1	1	0.5	7
S42	1	1	1	0.5	0.5	0.5	1	0	5.5
S43	1	1	1	1	1	1	1	0	7
TOTAL									
AVERAGE	41	35	37	22.5	35.5	29	31.5	11	

1.07392	5.55814	1.0363
Variance	Average	STD

Appendix ii

Survey Findings

From the questionnaire, the researcher tried to determine if the Business met the criteria for the research by asking the following questions:

No of Employees		
1 to 10	117	42%
11 to 30	99	36%
31 to 50	36	13%
51 to 100	24	9%
101 to 199	0	0%
Annual Revenue (Turn- over in Naira (1usd=160Naira))		
Less than 5 million	54	19%
6million - 20 million	96	35%
21 million - 30 million	66	24%
31 million – 49 million	38	14%
50 million – 499 million	22	8%
SME sector		
Transportation	35	13%
Wholesale/Retail	42	16%
Construction	38	14%
Finance	34	13%
Hospitality	42	15%
Education	49	18%
Manufacturing	31	11%

The next set of question was to determine if the Businesses make use of ICT

Do you use any form of ICT in your Organisation?		
Yes	276	100%
No	0	0%
What kind of ICT device do you use?		
Desktop	83	30%
Mobile	74	27%
Laptop	96	35%
Tablet	17	6%
Others	6	2%
What do you use technology infrastructure for?		
Communication	276	100%
Data storage	157	56%
Business transaction	124	44%
Email	212	76%
Other	105	38%
Do you have a company website?		
Yes	106	36%
No	176	64%

How do you save your organisation data?

Hard drive	101	37%
Email	59	21%
Database	82	30%
Manual file	31	11%
Other	3	1%

Do you have broadband (internet) connection within your organisation?

Yes	114	41%
No	162	59%

Do you have issues using the web?

Yes	196	71%
No	80	29%

What kind of issues do you have?

Slow	81	29%
Security	0	0%
Connectivity	36	13%
Cost	106	39%
Other	53	19%

How much do you invest on technology purchase annually?

Less than 10,000	0	0%
11,000 – 50,000	25	9%
51,000 – 100,000	72	26%
101,000 – 500,000	106	39%
Above 500,000	73	26%

How much do you invest on technology maintenance annually?

Less than 10,000	37	13%
11,000 – 50,000	54	20%
51,000 – 100,000	92	33%
101,000 – 500,000	77	28%
Above 500,000	16	6%

How will you rate the importance of ICT in your organisations operation?

Very strong	224	81%
Strong	52	19%
Average	0	0%
Low	0	0%
Very Low	0	0%

Do your staffs undergo training before using ICT infrastructure?

Yes	193	70%
No	83	30%

The next set of questions is to determine cloud computing awareness usage, adoption and challenges.

Do you have prior knowledge of cloud computing?

Yes	129	47%
No	147	53%

Have you ever used a cloud application?

Yes	78	28%
No	198	72%

Do you use any cloud service in your organisation presently?		
Yes	`75	27%
No	201	73%
What cloud service do you use?		
PaaS	15	6%
SaaS	39	58%
IaaS	13	20%
What issues do you have with cloud computing?		
Cost	21	6%
Security	124	34%
Standards	67	19%
Data lock –in	12	3%
Broadband/bandwidth	138	38%

Appendix iii

Focus group Agenda & sessions findings

Table 1, 2, 3, 3, 5 & 6 shows the summary of the various focus group session

Table 1: The Focus Group session North West Zone

Date	21st April 2014
State held	Kano State
No of participants	7 SME managers
Sectors of SMEs present	Manufacturing Hotel and Restaurant Banking Transport Automobile Education Construction
Cloud service adoption challenges identified	Broadband Bandwidth Standard framework Security Knowledge of the services Acceptability of new methods Reliability

Table 2: The Focus Group session North Central Zone

Date	5th May 2014
State held	Abuja
No of participants	7 SME managers
Sectors of SMEs present	Communication Health and social worker Wholesaler Transport Hotel and Restaurant Education

	Construction
Cloud service adoption challenges identified	Broadband Bandwidth Standard framework Knowledge of services Security of data Data confidentiality Acceptability of new methods Reliability/Accountability of providers migration

Table 3: The Focus Group session North East Zone

Date	16th May 2014
State held	Adamawa
No of participants	7 SME managers
Sectors of SMEs present	Telecommunication Education Retailer Transport Manufacturing Micro Finance Automobile repairs
Cloud service adoption challenges identified	Broadband Standard framework Security of data Data confidentiality Customer lock-in

	Knowledge of services Migration Lack of awareness of services Issue of power supply

Table 4: The Focus Group session South East Zone

Date	28th May 2014
State held	Enugu
No of participants	7 SME managers
Sectors of SMEs present	Oil and Gas Real estate Communication Transport Manufacturing Banking Education
Cloud service adoption challenges identified	Broadband Standard framework Security of data Data compatibility Knowledge of services Customer lock-in Migration Reliability of new technology Issue of power supply

Table 5: The Focus Group session South South Zone

Date	16th August 2014

State held	Rivers
No of participants	7 SME managers
Sectors of SMEs present	Oil and gas Real estate Communication Retail Automobile Banking Restaurant
Cloud service adoption challenges identified	Broadband Standard framework Security of data Data compatibility Knowledge of services Customer lock-in Migration Reliability of new technology Issue of power supply

Table 6: The Focus Group session South West Zone

Date	16th August 2014
State held	Lagos
No of participants	7 SME managers
Sectors of SMEs present	Oil and gas Real estate Communication Retail Health care Banking Hotel and Restaurant
Cloud service adoption challenges identified	Broadband Standard framework Security of data Government policies Knowledge of services Customer lock-in Migration Issue of power supply

Appendix iv

Weighting of service provider offerings with Pairwise comparison

Payment

	Dropbox	Google Drive	One Drive	iCloud
Dropbox	1	1	1/3	2
Google Drive	1	1	1/3	2
One Drive	3	3	1	4
iCloud	1/2	1/2	1/4	1

Operating System Supported

	Dropbox	Google Drive	One Drive	iCloud
Dropbox	1	3	5	5
Google Drive	1/3	1	2	2
One Drive	1/5	1/2	1	1
iCloud	1/5	1/2	1	1

Free Storage

	Dropbox	Google Drive	One Drive	iCloud
Dropbox	1	1/5	1/3	1
Google Drive	5	1	3	5
One Drive	3	1/3	1	3
iCloud	1	1/5	1/3	1

Trust (Accessibility)

	Dropbox	Google Drive	One Drive	iCloud
Dropbox	1	5	5	5
Google Drive	1/5	1	1	1
One Drive	1/5	1	1	1
iCloud	1/5	1	1	1

Security

	Dropbox	Google Drive	One Drive	iCloud
Dropbox	1	5	3	2
Google Drive	1/5	1	1/3	1/4
One Drive	1/3	3	1	1/2

iCloud	1/2	4	2	1

Bandwidth Adjustment

	Dropbox	Google Drive	One Drive	iCloud
Dropbox	1	3	7	7
Google Drive	1/3	1	5	5
One Drive	1/7	1/5	1	1
iCloud	1/7	1/5	1	1

Office via Web

	Dropbox	Google Drive	One Drive	iCloud
Dropbox	1	2	1/3	7
Google Drive	1/2	1	1/4	5
One Drive	3	4	1	9
iCloud	1/7	1/5	1/9	1

File Size Restriction

	Dropbox	Google Drive	One Drive	iCloud
Dropbox	1	4	7	3
Google Drive	1/4	1	3	1/2
One Drive	1/7	1/3	1	1/4
iCloud	1/3	2	4	1

Appendix v

USER OPINION

Questionnaire

This questionnaire is designed to determine the opinion of CLOUDSME users based on their experience of using the system in an experiment to determine if the system has enough knowledge to tackle the dynamic SME requirements in view of adopting cloud services. The result of this experimental survey is used to evaluate the proposed system framework, which is one of my contributions in my PhD thesis.

Please select one option for each question.

Q1. Do you think the system has enough knowledge to tackle more than one of your business requirements when consulted?

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree

Q2. Does the system respond adequately to your requirements in terms of Multitasking (responding to more than one requirement at time)?

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree

Q3. Are you satisfied with the system response time, in terms of responding timely to a requirement when consulted?

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree

Q4. Do you think the system is user friendly, easy to use when consulted?

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree

Q5. Do you think the system is efficient, i.e. does it respond adequately by retrieving the required information when consulted without causing further complications?

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree

Q6. Does the system have enough information to tackle your cloud service adoption challenges especially in terms of Knowledge of cloud services, Quality of services, cloud service recommendation and cloud service ranking?

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree

Q7 Have you adopted cloud services after using CLOUDSME decision support system for three months?

Yes ☐ **Undecided**  **No** 

Appendix vi

Expert Opinion

Questionnaire

This questionnaire is designed to determine the opinions of experts about the requirements of expert system applications at time of consultation. The experts are chosen from various computing fields around the world (USA, Malaysia, UK, Ghana, Nigeria, Canada, Australia etc.) The feedback is used to evaluate CLOUDSME an ontologically designed cloud service adoption middleware for small businesses, which is one of the contributions of my PhD thesis. As a quid pro quo, I am happy to recognise you and/or your organisation in my thesis.

Name (optional): Organisation (optional): Computing field (optional):

Are you happy to be recognised? [Yes/No]

Please select one of the following options from each question and your opinion were necessary:

Q1 Do you think the following service attributes can be requirements in SaaS cloud service storage adoption process at when a decision support system is consulted?

	Strongly Agree	**Agree**	**No Opinion**	**Disagree**	**Strongly Disagree**
[Cost- The price of services in a particular currency]					
[Trust- The confidence in relationship between cloud service providers and users]					
[Security-The confidentiality, authentication, integrity of cloud service offerings by service providers.]					
[Operating system- The platforms which the cloud service operates and the platforms which					

it is compatible with.]					
[File size restriction- The size of data that can be transferred at a particular time via cloud services]					
[Free Storage- Ability to have some storage space either at the initial stage of adoption or as a form of customer loyalty]					
[Bandwidth Adjustment- The ability to adjust the network speed in terms of connectivity]					
Office Via web- Ability to use al office packages form one service					

Q1b Can you recommend any other cloud service attribute that could be a user requirement at system consultation time for SaaS storage service?

Q2 Do you think the following application domain aspects can generate requirements of services at system consultation time?

	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
[Linguistics-Tis refers to languages used to present queries, functionalities, domain relationships and responses.]					
[Semantics-This refers to semantic framework such as ontologies, taxonomies and vocabularies]					
[Measures/standards-This refers to measuring standards such as benchmarks, service ranks, etc.]					

Q2b Can you recommend any other domain application concept that can generate requirement of services at system consultation time?

Q3 Do you think the following technical operation environment can generate requirement of services at system consultation time?

	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
[Device-refers to computer hardware platform environment for execution of service requirements]					
[Operating System-Computer software					

environment for service execution]					
[Connectivity-Service communication network]					

Q3b. Can you suggest other platform dependant properties, which can be used to generate requirement in service consultation time?

Q4. Do you think the following operational service features can generate requirements at consultation time?

	Strongly Agree	**Agree**	**No Opinion**	**Disagree**	**Strongly Disagree**
[Protocol Information-Sequence of information retrieval]					
[Semantics relevant to input and output service parameters e.g. >< conditions.					
Pre-conditions and post-conditions of services.					

Q4b. What other operational service features do you think can generate requirements at system consultation time?

Q5. The context conception is widely used in mobile computing applications to define dynamic aspects. In this research, this concept is extended and dynamic service context is defined as those service user requirements or service related information that binds the service provider to the service users. The dy**namic service requirements of SaaS cloud storage services was modelled in a cloud service ontology to aid SMEs in decision making towards cloud service adoption for their businesses. Putting the dynamism of SME categories into perspective.**

Do you think the definition of dynamic service context requirement based on the view of dynamic aspects of services is well represented?

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree

Q5b. Do you have any comments?

Q6. Do you think the properties defined in Q1-Q4 meets the internationally recognised standards for evaluation of software quality ISO/IEC25010:2011?

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree

Q6b. Do you have any comments?

Appendix vii

Researcher Opinion

Questionnaire

This experimental survey is carried out by researchers to evaluate the comparison of the proposed CLOUDSME ranking protocol against Analytical Hierarchical Process (AHP) and outranking multi-criteria decision methods. This comparison is carried out using the technology Adoption method guidelines. The researchers are chosen from various UK Universities. The proposed CLOUDSME ranking protocol is explained explicitly to the participants. They apply this approach using data's from their research area to evaluate which of the Multi-Criteria Decision Methods (MCDM) best solve their complex ranking problems. The proposed CLOUDSME ranking protocol is one of the contributions of my PhD thesis. As a quid pro quo, I am happy to recognise you and/or your university in my thesis.

Name (optional): Organisation (optional): Computing field (optional):

Are you happy to be recognised? [Yes/No]

Please select one of the following options from each question.

Q1.Which of the ranking methods do you think is Simple to apply when dealing with complex multi-criteria decision problems?

AHP ☐ CLOUDSME ☐ Outranking ☐

Q2. Based on your experience of solving MCDM problems using the three methods. Which of these methods do you think gives a highest degree of accuracy putting into consideration the complexity associated with MCDM problems?

AHP ☐ CLOUDSME ☐ Outranking ☐

Q3. When tackling MCDM problems, it is important for the researcher to have a degree of flexibility to help reduce the complexity in making judgements. Which of the methods is most flexible?

AHP ☐ CLOUDSME ☐ Outranking ☐

Q4. Which of the methods gives a step by step guide from the inception to the end of the ranking processes thereby giving the researcher enough confidence in the final ranking outcome?

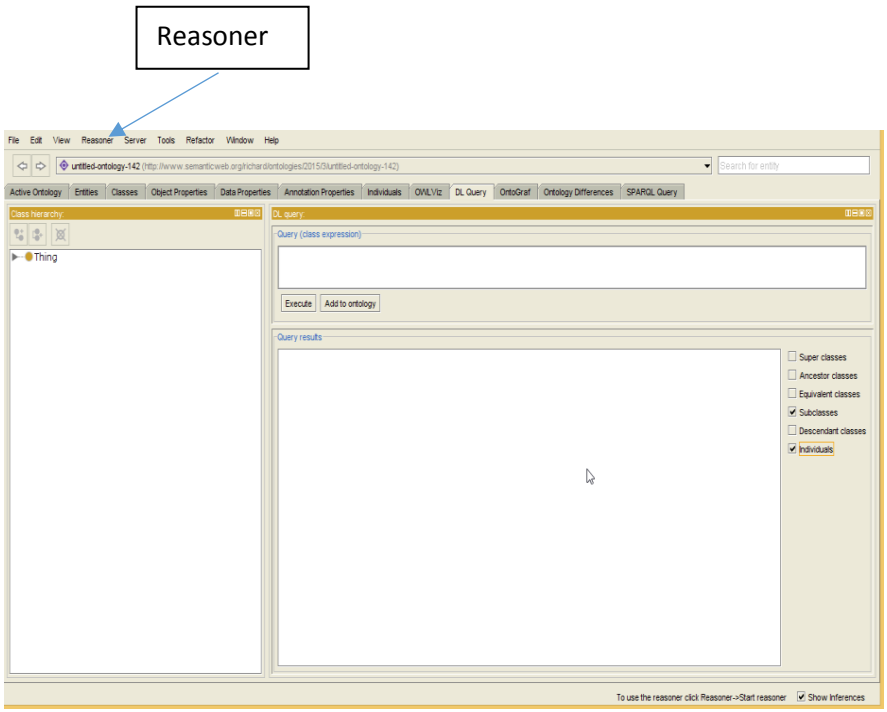
AHP ☐ CLOUDSME ☐ Outranking ☐

Q5. Based on your experience in using the three compared MCDM approaches. Which do you think is most acceptable putting into consideration Q1 to Q4?

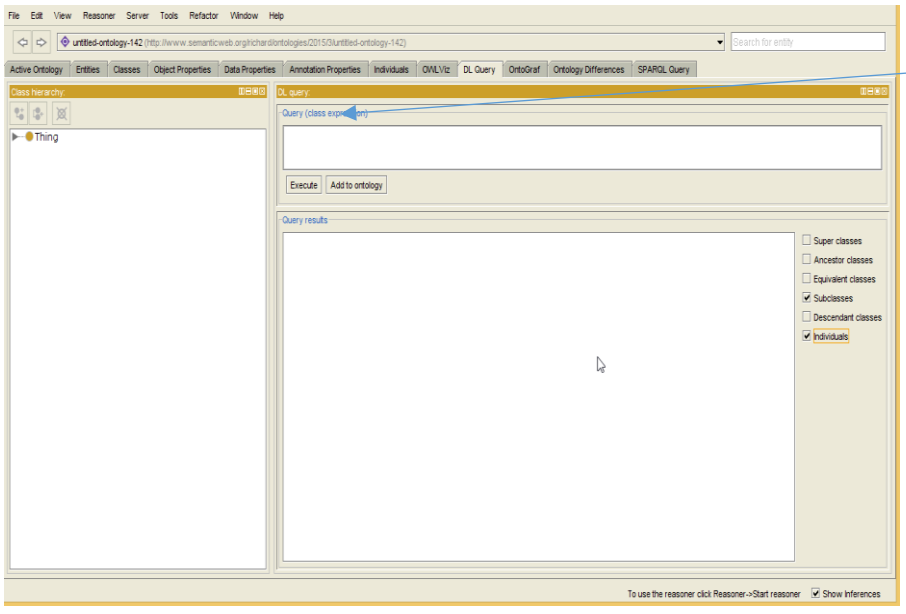
AHP ☐ CLOUDSME ☐ Outranking ☐

Appendix viii

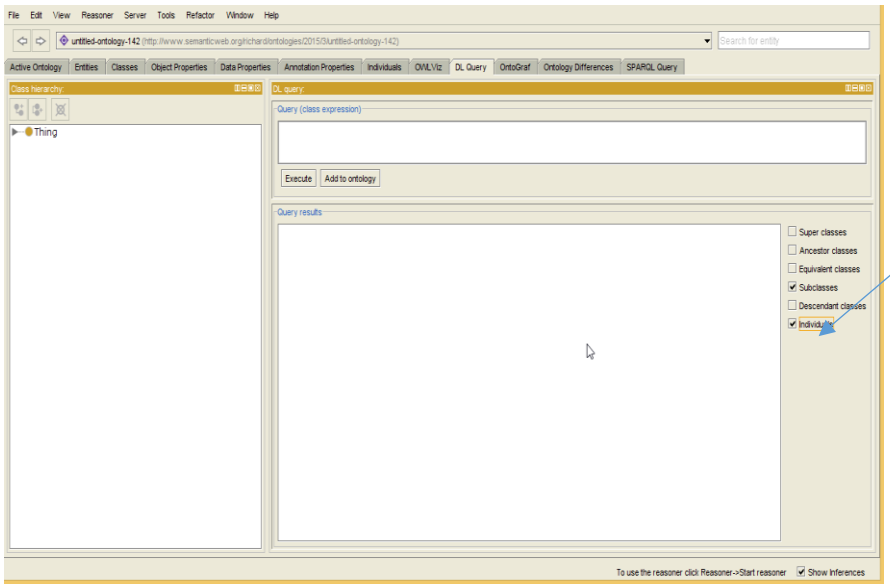
CLOUDSME Simple user guide for SME Managers (Experiment purpose)



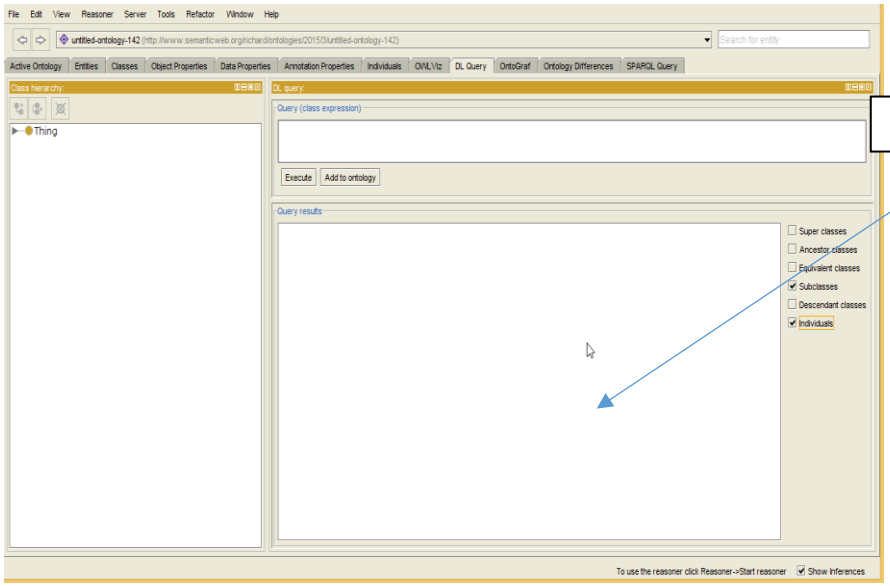
Step 1-Reasoner: is to activate the reason by clicking on it.



Step 2- Query class expression: This is where the query is inputted.



Step 3- Individual: Click on the check box before the individual to get a feedback for the query sent.



Step 4- Query result: view query result