A Model to Support the Decision Process for Migration to Cloud Computing

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A thesis submitted in partial fulfilment of the

requirements for the degree of

Doctor of Philosophy

Bournemouth University

Faculty of Science and Technology

January, 2016

Abstract

Cloud computing is an emerging paradigm for provisioning computing and IT services. Migration from traditional systems setting up to cloud computing is a strategic organisational decision that can affect organisations' performance, productivity, and growth as well as competitiveness. Organisations wishing to migrate their legacy systems to the cloud often need to go through a difficult and complicated decision-making process. This can be due to multiple factors including restructuring IT resources, the still evolving nature of the cloud environment, and the continuous expansion of the cloud services, configurations and providers. This research explores the factors that would influence decision making for migration to the cloud, its impact on IT management, and the main tasks that organisations should consider to ensure successful migration projects. The sequential exploratory strategy is followed for the exploration. This strategy is implemented through the utilisation of a two-stage survey for collecting the primary data. The analysis of the two-stage survey as well as the literature identified eleven determinants that increase the complexity in the decisions to migrate to the cloud. In the literature some of those determinants were realised, accordingly, there have been many proposed methods for supporting migration to the cloud. However, no systematic decision making process exists that clearly identifies the main steps and explicitly describes the tasks to be performed within each step. This research aims to fill this need by proposing a model to support the decision process for migrating to cloud. The model provides a structure which covers the whole process of migration decisions. It guides decision makers through a step-by-step approach aiding organisations with their decision making. The model was evaluated by exploring the views of a group of the cloud practitioners on it. The analysis of the views demonstrated a high level of acceptance by the practitioners with regard to the structure, tasks, and issues addressed by the model. The model offers an encouraging preliminary structure for developing a cloud Knowledge-Based Decision Support System.

List of publications

Journal papers

Sahandi, R., Alkhalil, A. and Opara-Martins, J., 2013. Cloud Computing from SMEs perspective: a Survey based Investigation. *Journal of Information Technology Management*, *24,* (1), 1-12.

Alkhalil, A., Sahandi, R. and John, D., 2015. A Decision Process Model to Support Migration Cloud Computing. *The International Journal of Business Information Systems* in press. (Accepted)

Conference papers

Sahandi, R., Alkhalil, A. and Opara-Martins, J., 2012. SMEs' Perception of Cloud Computing: Potential and Security. In Collaborative Networks in the Internet of Services, Springer: Berlin Heidelberg, 186-195, October 2012.

Alkhalil, A., Sahandi, R. and John, D., 2013. Migration to Cloud Computing-The Impact on IT Management and Security. In 1st International Workshop on Cloud Computing and Information Security, Atlantis Press, in Shanghai, China 196-200, November 2013

Alkhalil, A., Sahandi, R. and John, D., 2014. Migration to Cloud Computing: A Decision Process Model. In: Central European Conference on Information and Intelligent Systems, CECIIS-2014, In Varazdin, Croatia, 17-19, September 2014.

Alkhalil, A., Sahandi, R. and John, D., 2016. A Review of the Current Level of Support to Aid Decisions for Migrating to Cloud Computing. In the International Conference on Internet of things and Cloud Computing (ICC 2016) (The Møller Centre-CHURCHILL COLLEGE University of CAMBRIDGE) Cambridge, United Kingdom.

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Alkhalil, A. and Sahandi, R., 2012. Migrating to Cloud Computing: Security, Methodology, and Culture. 4th Annual Postgraduate Conference, Bournemouth University, 28th June 2012.

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Acknowledgement

I would like to express my sincerest appreciation and gratitude to my supervisor **Dr Reza Sahandi**. He has been a remarkable mentor for me. I would like to thank him for encouraging my research and for allowing me to grow as a researcher. I would not make it this far without his guidance.

I would also like to thank my second supervisor **Dr David John** for his excellent comments and suggestions.

I would like to thank all the participants in this research especially the interviewees who shared with me their valuable insights into various aspects of migrating to cloud computing.

A special thanks to my family and friends for supporting and encouraging me. Words cannot express how grateful I am to my mother. Her prayer for me was what sustained me thus far. I would also like to extend a special thanks to my beloved wife Ala and to my brother Nasser.

Author's declaration

I declare that the work in this thesis was carried out in accordance with the regulation of Bournemouth University. The work contained in this thesis is the result of my own investigations and has not been accepted nor concurrently submitted in candidature for any other award.

I declare that while registered as a candidate for the research degree, I have not been a registered candidate or enrolled student for another award of the university other academic or professional institution.

Signature of Candidate: Adel Alkhalil

Data: January 2016

Type of Award: Doctor of Philosophy

School: Science and Technology

Chapter 1 Introduction

1.1 Overview

The usage of internet applications to run business processes is increasing and information technology has become a necessary infrastructure that organisations must have to be able run their business processes smoothly (Chou 2010). Nowadays, the Web is not only a communication medium, but also a platform for businesses and societies that increases their accessibility to a wider range of users. This substantial advance as well as the developments of Information and Communication Technology (ICT) infrastructures have increasingly led to the vision that computing will be the 5th utility, similar to existing ones (water, electricity, gas, and telephone) (Carr 2003 ; Buyya et al. 2009).

> "As a business resource, information technology today looks a lot like electric power did at the start of the last century when it was routinely produced by individual businesses rather than utility providers" (Kepes 2011,p.5).

In fact, as early as 1960 John McCarthy pointed out "computing may someday be organised as a public utility" (cited by Dikaiakos 2009). This vision has led to computing being transformed to a model comprising services that are commoditised and delivered in a manner similar to traditional public utilities which stimulates a new paradigm – Cloud Computing (Buyya 2009). The emergence of this phenomenon fundamentally changed the way information systems are developed, deployed, scaled, updated, maintained and paid for (Marston et al. 2011). An extreme scenario of this advancement is that the only software an organisation needs is a web-browser and the only necessary hardware is a machine to run the browser and to connect it with the internet.

The concept of cloud computing is based on a set of many pre-existing and well examined concepts such as distributed and grid computing, and Virtualisation (Sahandi et al. 2013). Although many of them do not seem to be new, the actual innovation of cloud computing lies in the way IT services provided to customers (Leimeister et al. 2010). The National Institute of Standards and Technology (NIST) has provided the most commonly used definition of cloud computing that is:

> “Cloud computing is a model for enabling 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. This cloud model promotes availability and is composed of five essential characteristics, three delivery models, and four deployment models” (Mell and Grance 2011, p.2).

From business perspective, cloud computing can be defined as:

> "Cloud computing is on-demand access to virtualised IT resources that are housed outside of your own data centre, shared by others, simple to use, paid for via subscription, and accessed over the Web" (Fu and Gondi 2010, p.194).

This rapid evolution of the ICT within the contemporary business market has caused competition to be at the highest level, thereby resulting in many products and skills becoming obsolete (Pauly 2011). Therefore, in order to thrive, an organisation has to be aware of the changes and take advantage of new opportunities. This puts many organisations under pressure to find and implement new strategic ideas at an even faster pace to gain the competitive edge over their rivals within the global market. “The need to quickly respond to business demands is imperative in this new age” (Primus 2011). In order to increase competitiveness, organisations need to rationalise output to reduce costs, enhance process innovation and incorporate new technologies. A new strategy should enable enterprises to incorporate new technologies, reduce costs, develop process innovation, and enhance speed of implementation (Sahandi et al. 2013).

Organisations in search of this competitive edge are continually putting pressure on their IT departments to provide new solutions that are deemed to be more flexible, efficient and cost-effective, enabling even faster time to market. A flexible IT infrastructure can remove some of the barriers to global competition and allow smaller businesses to be efficient, competitive and also provide a degree of flexibility (Sahandi et al. 2013).

Cloud Computing has the potential to play a major role in addressing inefficiencies and make a fundamental contribution to the growth and competitiveness of organisations mainly for Small and Medium Enterprises (SMEs) (Sahandi et al. 2012). Cloud computing offers a new pathway to business agility and supports a faster time to market by offering ready-to-consume cloud enabled resources such as IT infrastructure as a service, software platforms, and business applications. These services can all be accessed on-demand and provide support to new business requirements far faster than acquiring, installing, configuring and operating IT resources in house (Marks and Lozano 2010). Instead of buying software for in-house installation, enterprises can utilise applications which are deployed as a service through the cloud (Willcocks et al. 2011). For example, Microsoft 365 allows organisations to access Microsoft office products and other applications as packages based on their sizes, which make IT management far much easier.

Cloud computing offers new capabilities and business models. These have opened up new opportunities for enterprises to enhance the design of their IT resources and architectures, and to rationalise their information systems expenditure as well as producing further competitive differentiation (Buyya 2009). These have an impact not only on service quality and business competitiveness, but also on a wide range of traditional business models.

Migration to cloud computing can offer several features that include: scalability, elastically, cost effectiveness, flexibility and improved accessibility (Kuo 2011). However, in contrast to a traditional on-premises deployment model, the multi-user nature of cloud computing usually gives a rise to amongst other things, a number of risks, concerns, and challenges.

The decision of whether to migrate a service to the cloud or not requires a thorough and careful assessment. Failure or inaccurate assessment will result in the selection of inappropriate services that can cause complexity, integration issues, and in some scenarios moving back to in house deployment. These can have negative implications including: hidden costs, performance and productivity issues. The opportunities and problems that cloud computing provides will be discussed in Chapter 2. The risks and related challenges involved in migration processes to the cloud were investigated through a two-stage survey which is conducted in this research. The survey findings will be discussed in details in Chapter 5.

1.2 Research problem

Organisations often decide to migrate their IT resources to the cloud due to many organisational and technical benefits that have the potential to enhance business productivity and competitiveness. However, the process of migrating to the cloud involves a number of risks, such as concerns about loss of privacy, disruption to business processes, legal implications, change of systems management, interoperability, data integrity, application portability, business continuity, staff productivity, as well as security issues. Furthermore, the availability of vast number of cloud-based services, cloud standards, regulations, service providers and the diversity of organisations' needs have increased the level of complexity of decisions for cloud migration.

There have been many proposed methods to assist decisions when considering migrating to cloud computing as in Li et al. (2010), Chan and Chieu (2010), Khajeh-Hosseini et al. (2011), Khajeh-Hosseini et al. (2012), Menzel and Ranjan (2012), Omerovic et al. (2013), Andrikopoulos et al. (2013a), and Andrikopoulos et al. (2013b) (These Decision Support Systems (DSSs) will be discussed in Chapter 3). They mostly concentrated with the evaluation and selection of cloud providers with cost being the main factor. The majority of the existing DSSs do not support the assessment of business processes and relevant applications, nor do they provide information for the analysis of the impact of the chosen cloud services. Although, evaluation of providers and their appropriate selection are critical, making an informed decision on whether to migrate requires the analysis of a wide range of factors at earlier stages of the decision process. Additionally, the range of information which requires consideration for migration to take place is increasing due to the development of the technology and expansion of the services offered. What support is available to guide organisations through the migration decision process systematically?

These issues have signified the requirement for a thorough process that identifies the main issues for consideration and the tasks to be performed, to ensure that informed decisions are made for migration to the cloud. This thesis attempts to provide the guide required to support the decisions process of migrating to cloud computing.

If decision makers could use a knowledge-base that provides a collection of organised information about the cloud environment, similar migrated projects as well as a collection of automated migration tools, it would assist them to effectively migrate their systems to the cloud. This research aims to establish a foundation for this direction.

This research puts a specific emphasis on planning for migration due to the following reasons:

- Cloud migration is a strategic organisational decision that should be guided by the main organisational requirements and objectives for migration by which all further steps should be analysed accordingly,

- The immaturity and the still evolving nature of cloud computing which requires a proper migration strategy and analysis as well as support for organisations in the intelligence levels which have not been considered in the majority of the existing cloud migration systems,

- The large number of information sources and their different levels of accessibility, reliability and related costs present a complex information gathering problem which requires support for organisations in identifying what areas of the cloud environment they need to develop knowledge about,

- Availability of a wide range of decision support systems and cost calculation tools which can create uncertainty for decision makers if they are used outside of a systematic process.

1.3 Aim and objectives

Aim: To improve decisions to migrate to cloud computing by developing a process model that systematically guides organisations through the areas that need support when considering migrating to the cloud.

Research Objectives:

1. Develop knowledge of the emergent cloud computing systems, and the phenomenon of migration to cloud commuting

2. Examine the cloud paradigm, infrastructure, services, and main characteristics

3. Identify the main issues of cloud services provision

4. Explore the perception and concerns of organisations about cloud computing

5. Identify the factors affecting the decisions to migrate to cloud computing

6. Identify the level of complexity in the decision to migrate to the cloud

7. Investigate the impact of cloud computing on IT management

8. Compare users security-concerns against cloud security landscape

9. Analyse the existing cloud DSSs, framework, and decision process models

10. Identify the main task and steps that organisations should consider prior to the migration

11. Identify the appropriate sequence in which the steps and tasks should be organised

12. Evaluate the proposed model

1.4 Research questions

- Why is there a need for organisations to migrate their systems to the cloud?
- What is the level of complexity in the decisions to migrate to the cloud?
- What are the existing DSS or tools for supporting the migration?
- What are the main tasks and steps that organisations should perform to ensure systematic and well-informed cloud migration decisions?
- What is the appropriate sequence in which the tasks and steps should be performed?

1.5 Methodology overview

In this research, the sequential exploratory strategy (Creswell 2007) is followed for the methodology implemented. The research is conducted in five main phases as shown in Figure 1:

1. Literature review. It firstly explored the cloud computing paradigm, cloud computing and business agility, cloud computing security, the impact of cloud computing, migration to cloud computing, and the factors and issues affecting the migration. Secondly, the investigation moved to reviewing of the research approaches and methods. Thirdly, the investigation focused on studying the decision-making process, decision support systems, knowledge-based decision support systems, cloud decision support systems.

2. Survey Stage 1. Semi-structured interviews with IT leaders, the sample included: could providers, cloud users (IT managers) as well as security professionals.

3. Survey Stage 2. The findings of the interviews were incorporated into a survey questionnaire of cloud practitioners as well as cloud systems researchers.

4. Design of a cloud migration decision process model based on Simon's generic decision-making process model (Simon 1977).

5. Evaluation of the model by analysing the views of a group of cloud practitioners as well as cloud systems researchers.

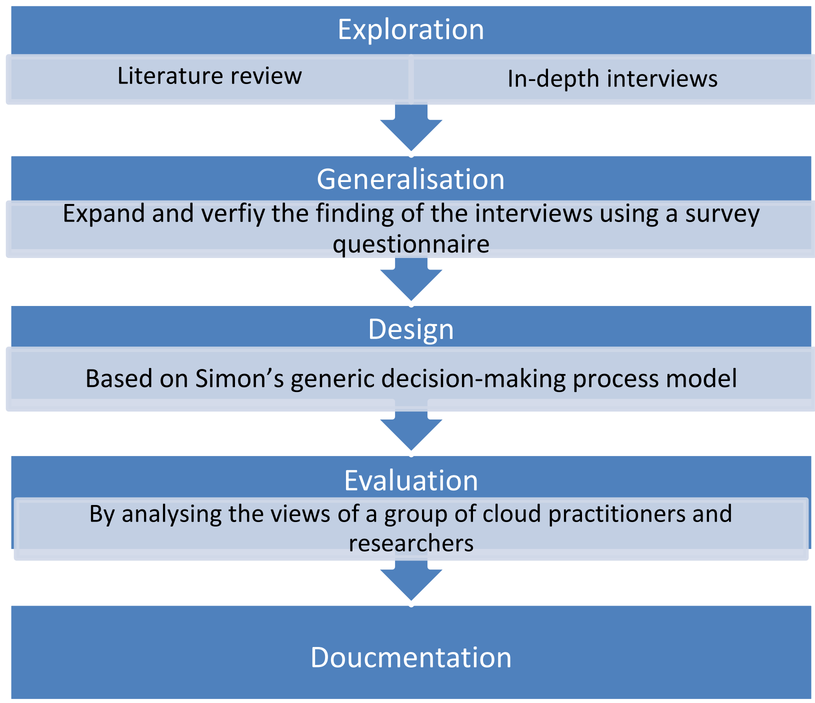


Figure 1. Methodology overview

Chapter 4 provides more details and justifications for the methodology used.

1.6 Scope of the investigation

This research is centred on supporting organisations with their decisions to migrate to the cloud. It considered technical and organisational factors that might influence organisations decisions. There are two main parts in this thesis: an exploration of the factors influencing the decision making for migration and developing a process model to aid organisation to migrate existing resources to the cloud.

The investigation in this thesis is domain-independent and aims to help organisations from different industries that are considering migration to public cloud providers. However, large institutions that deal with highly sensitive data, such as banks, fall outside the scope of this research. Unlike smaller organisations, they usually have the capabilities needed to build their own up-to-date information systems. They may follow a strategy that involves starting their own private cloud while the public cloud can be used for staff training before implementation. Further, they usually have large-scale systems, built specifically to meet their requirements which are difficult to migrate.

Despite the fact that psychological factors play a major role in any decision making, they fall out of the scope of this study. These cognitive and emotional components include personality, individual differences, affective influences (pre-decisional affective states such as current mood), and cognitive capacity (Gärling et al. 2009).

> "In relation to choice, people think about the options and the likely consequences of choosing an option, but in addition there are strong emotional factors in play. People have feelings about the decision and expectations about feelings that might result from choosing different options." (Beresford and Sloper 2008, p.14)

Moreover, the interaction between client and service provider often goes beyond the rules, agreements, and exceptions specified in a legal contract. There are always psychological elements of trust, commitment, and mutual interest that are intangible and are not easily captured in a contract (Jae-Nam and Young-Gul 2003).

1.7 Contribution to knowledge

This research has expanded the collective knowledge about the complexity of decisions to migrate to the cloud. Eleven determinants that increase the complexity of migration to the cloud were identified in this research. Those determinants are discussed in details in Chapter 3, 5, and 6. Moreover, this research has identified an impact of cloud computing on IT management' roles and responsibilities. Despite the changes that may occur to some of the existing roles, organisations will still need IT managers subsequent to migrating to cloud computing. Additionally, the research has identified a number of factors that has an effect in the decision to migrate to the cloud, such as the need for new services and cultures.

The unique contribution of this research is the proposed model which offers a systematic approach covering the necessary stages required for making decisions when considering migration to the cloud. It includes the identification of the areas of decision making that require further support. The model guides decision makers through a step-by-step approach, aiding them with their decisions for cloud migration. The model can be applied in general contexts, various domains, and the four migration scenarios. Additionally, the model includes a wider analysis than just evaluation of the technical aspects, for example legal issues and the impact of organisational culture were considered which are essential to manage to ensure successful migration. Furthermore, the systematic structure in this model will allow decision makers to effectively exploit a wide range of cloud migration tools and decision support systems that may be required during the decision process. Finally, the model offers a preliminary structure which forms the basis to the development of a cloud Knowledge-Based Decision Support System (KBDSS). KBDSSs can address the challenges in the process of migrating to the cloud. The model has the potential to minimise the efforts required in information gathering, suitability analysis, and vendor's evaluations. Security tasks were considered in all phases of the decision process, this would mitigate the concerns of security and privacy that many organisations have expressed about the migration and to ensure well-informed decision are made. The model was evaluated; a positive feedback was received that provided a level of confidence on the effectiveness of the process model as a contribution in the direction of advancing the deployment of cloud-based systems.

1.8 Summary

This research is concerned with aiding decision-making process for migration of IT resources and business processes to cloud computing. This chapter provided an introduction to the concept of cloud computing and its need for organisations due to the increase in business competitiveness. The research problem was then expressed followed by the research aim, main objectives, and questions. The sequential exploratory strategy (Creswell 2007) has been followed to identify the migration factors, the cloud impact on organisations' security, as well as the activities needed to ensure well-informed migration decisions. Finally, the contribution to knowledge of this research was discussed.

The remainder of the thesis is organised as follows:

- Chapter 2 provides a literature-based review of information systems evolvement and an overview of the cloud computing paradigm, deployment models, architecture, and applications and services. It also discusses the factors influencing the drive to migration services and the main barriers to migrate to the cloud from the business perspective.

- Chapter 3 provides a literature-based review of decision making process and decision support systems. The chapter also reviews the existing cloud DSSs as well as a review of two attempts to provide a process for cloud migration decisions.

- Chapter 4 provides a detailed explanation about the methodology employed in this research. The empirical data of this research obtained from a two-stage survey. The implementation of the two stages is discussed.

- Chapter 5 presents the main findings of the two-staged survey implemented in this research. Chapter 5 is divided into two subsections the first discusses the analysis of in-depth interviews (Stage 1). The second discusses the analysis of Stage 2 that is based on a quantitative online survey questionnaire.

- Chapter 6 proposes a novel model that can be used to guide decision makers through a systematic sequence of steps for their cloud migration decisions. Chapter 6 also includes an evaluation of the proposed model based on the analysis of the views of cloud practitioners and researchers.

- Chapter 7 concludes the thesis findings and provides some future research directions as well as recommendations.

Chapter 2 Cloud computing

2.1 Introduction

This chapter discusses the first part of the literature review to set the basis for investigating the migration to cloud computing. This review focuses on technical and business aspects related to cloud computing. First, it discusses how the literature review in this research is conducted. Second, it briefly explores the evolution of computing systems (mainframes, personal applications, client-server, and cloud computing), followed by an introduction to the concept of cloud computing is provided. It includes highlighting its main characteristics, deployment and service models, related technological paradigms and terminologies, and the cloud architecture. Third, the concept of Service Oriented Architecture (SOA), and its relationship with cloud computing is examined and how these concepts can support each other. Fourth, it considers the development of IT resources, from traditional IT provisioning models to the most recent and flexible delivery model. Finally, cloud computing advantages, issues, and impact on IT management are discussed.

2.2 Literature review analysis

> "A systematic literature review (SLR) is a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest" (Brereton et al. 2007, p.3).

The need for an SLR arises from the requirement that researchers comprehensively summarise the existing information about a phenomenon in an unbiased manner (Keele 2007). In this research the guidelines proposed by Brereton et al. (2007) for planning, conducting, and documenting were adopted for reviewing the literature.

2.2.1 Planning

An SLR was needed to examine the cloud paradigm, to identify and classify issues and challenges, and then compare the existing work for supporting migrations. More specifically, the SLR attempted to provide answers to the following questions, by conducting a methodological review of existing research:

Table 1. The main questions for the literature review

#	Research question
1	What are the factors that motivate migration to cloud computing?
2	What are the challenges that organisations face when migrating to the cloud?
3	What are the cloud computing standards and capabilities?
4	What new opportunities can cloud-based services provide to organisations and their growth?
5	How can organisations manage their IT systems after migration?
6	Does migration to the cloud create a security risk?
7	What is the level of complexity in the decisions to migrate to the cloud?
8	What level of support do organisations need for their cloud migration projects?
9	What kind of decision support systems do exist to support decisions for migrating to the cloud?

2.2.2 Search strategy

The aim of a systematic literature review is to find as many related studies as possible through the use of a neutral search strategy (Brereton et al. 2007). For example, it is essential to avoid language bias during the search. This is a main factor which differentiates a systematic literature review from a traditional one.

In this study, search strings were developed to help in finding studies related to the research questions. They were built by identifying synonyms for each of the question elements and linking them with the OR and AND Boolean operators (See appendix A). Keywords in Table 2 were defined by using the PICO (Population Intervention Comparison Outcomes) method (Keele 2007), and were used to construct search strings.

Table 2. PICO criteria used to define the scope and the goal of the SLR in this research

Population	To identify the problem, population, or an application area such as IT systems, command and control systems - Cloud computing - Migration to cloud computing
Intervention	To identify the plan to address the specified problem, including procedures that address a specific issue, such as requirements specifications, system testing, or software cost estimation - Cloud migration decision support
Comparison	To define the main alternative to address the specified issues. This is the only optional component in the PICO method. - A comparison of the existing cloud DSS with the activities required to migrate to the cloud
Outcome	Outcomes should specify what the process plans to accomplish, for example, improve reliability, reduce production costs, or reduce time to market - Improve decision making process for cloud migration

These terms were used in a wide range of digital libraries, mainly Google scholar. Journal articles, followed by peer reviewed conference papers, were the sources most used to extract related research contents. Other sources were also used, including: vendors' white papers, guidelines, books, conferences, and business articles.

2.2.3 Conducting the literature review

The literature review was conducted in three main phases:

The first phase included investigating the evolving cloud computing paradigm, the migration factors, cloud related issues, and migration challenges. In particular, this phase was to answer questions 1 to 4 in Table 1. The investigation started in early 2012; therefore, most of the references used to explore the emerging cloud paradigm were published between 2009 and 2012. By that time many industry research analysts including: Gartner, Forrester, IBM predicted that a substantial number of the world's enterprises would have migrated their IT systems to the cloud by 2011 (GoGrid 2012). However, later studies showed that the adoption of cloud-based systems was much less than expected. Therefore, the investigation focused on the issues and challenges deterring organisation from migrating to the cloud. This investigation resulted in refining the research aim, objectives, and the questions.

Key references were: Mell and Grance (2011), who provided the most commonly cited definition of cloud computing; Leimeister et al. (2010), who identified the strengths, weaknesses, opportunities and threats to the cloud computing industry; and Buyya et al. (2009), who presented the emerging trends in the area of cloud computing and explained its architecture.

This research followed the work of another researcher at Bournemouth University. The study was about the perception of Small and Medium Enterprises' (SMEs) of cloud computing. It explored their motivations, requirements, and concerns about the adoption of cloud-based services. This research helped in the investigation of important terms within the research area including: 'end users' perceptions of cloud computing', 'cloud computing and business agility', 'cloud computing security', ‘migration to cloud computing’, and ‘factors and issues affecting the migration’. Participation in the study enhanced the researcher’s understanding of the issues involved in migration to cloud computing; it also helped with refining the objectives and questions of this research.

The literature review has then moved to explore other important areas of the migration such as the impact of migration to cloud computing managing the migration to the cloud. This part of the investigation was to address questions 5 in Table 1.

The second phase included evaluating research methods, strategies, and approaches, in order to find the appropriate methodology for the research problem.

The third phase was focused on issues associated with migration to cloud computing. In particular, the investigation focused on: decision-making process, decision support systems, Knowledge-based decision support systems, and cloud decision support systems. This part was limited to studies that proposed frameworks, models, DSS, tool to support the migration to cloud computing. Only studies that were in academic journals and respected conferences in the form of scientific papers were included in this part. The analysis of this phase will be discussed in details in Chapter 3.

2.3 Cloud computing

Cloud computing is an evolution of both computer technologies and the dominant business model for delivering IT-based services (Iyer and Henderson 2010). The first generation of computing started in 1950s with mainframes computing (Ebbers et al. 2006). In those systems, multiple users through less powerful devices such as workstations are connected to a central computer. The main purpose of mainframes computers was to compute high-volume of data related to business processes, for example, processing in a huge amount of data on a daily basis such as banks and insurance systems (Ebbers et al. 2006).

The evolution of personal computers and communication technologies had a major impact on computing architectures. Networks moved from centralised architectures (mainframes the centre of networks) to decentralised client-server architectures (clients and servers). Unlike the first generation of mainframes computers where all the processes are centralised, in the client-server architecture the processes are distributed. Client-server is service-oriented, and involves a request-response protocol. This was further extended with the development of the internet and the possibility to connect to it. Subsequently, grid computing to facilitate shared computing power and storage resources was introduced. This was further extended to cloud computing that allows resources be available in a scalable and simple manner (Voas and Zang 2009).

Cloud computing may seem to be a return to the early generation of centralised commuting (mainframes), however, there are major differences. Mainframes provide restricted central computation capacity while cloud computing provide infinite computation power with possibility of scaling up and down based on users demand (Bond 2015). The following section provides further details about the cloud computing paradigm.

Cloud computing is composed of five essential characteristics, four deployment models, and three service models that are represented as layers in the cloud technology stack. Figure 2 shows such a structure.

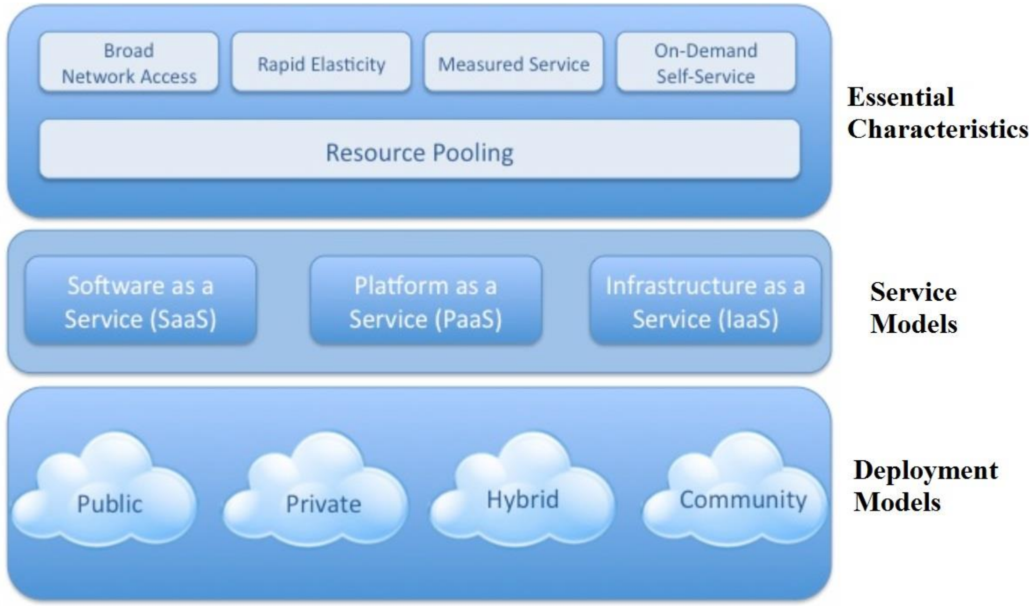


Figure 2. Cloud Computing Models (Mell and Grance 2011)

The first characteristic of cloud computing is on-demand self-service in which a consumer can individually request computing capabilities such as server time and network storage as needed automatically. Second, it is broad network access that enables access through various devices to capabilities available over the network. It promotes the use of heterogeneous client platforms including mobile phones, laptops, and PDAs as well as other traditional or cloud-based software services. Third, resource pooling facilities of providers serve multiple consumers using a multi-user model. The resources are assigned and reassigned dynamically according to consumers demand. Fourth, rapid elasticity in which capabilities are quickly provisioned with the ability to easily scale up and down. Further, they often appear to the consumers to be unlimited and can be obtained in any quantity at any time. Fifth, Measured service that allows cloud services to be automatically controlled and monitored. This is essential to ensure transparency for both the provider and consumers. (Mell and Grance 2011)

2.3.1 Cloud deployment models

According to Mell and Grance (2011) there are four deployment models of cloud computing: Private cloud, Public cloud, community cloud, and Hybrid cloud. The management, cost, and security of these models depend upon the preference of organisations in either acquisition and operation of its own cloud (private) or outsourcing to a third-party (public). Cloud services can be also hybrid deployed in which enterprises can utilise services from more than one provider.

Private cloud

The cloud provision for a particular organisation that owns, manages, and operates it (Mell and Grance 2011). Dillon et al. (2010) identified a number of reasons for setting up a private cloud within an organisation. They are: (a) to optimise the utilisation of already implemented in-house resources, (b) the wide security concerns, (c) the cost of transferring high-volume of data from local IT infrastructure to a Public cloud and (d) some organisations require full control over mission-critical activities that reside behind their firewalls. This kind of deployment is costly and therefore it is usually limited to large organisations.

Community cloud

The cloud infrastructure is provisioned for a particular use by consumers from organisations that share the same concerns (e.g., mission, policy, security requirements, and compliance). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises (Mell and Grance 2011).

Public cloud

The cloud infrastructure is provisioned to the general consumers for open use. It may be owned, managed, and operated by a business, academic, or government organisation, or some combination of them that has the full ownership of the cloud infrastructure with its own policy and costing models. Cloud computing is usually known for this kind of deployment such as (Amazon EC2 2015), (Google AppEngine 2015), and (Microsoft 365 2015).

Due to the clouds' elastic and consumption-based pricing model, outsourcing services to a public cloud provider probably offers the most effective solutions to start-ups and SMEs (Sahandi et al. 2013). Public cloud services allow these organisations to enjoy enterprise level services, products, and security with minimal cost (Wilson 2011). Further, common services such as e-mail and other office applications that are usually consumed by enterprises, can be acquired from major vendors. These vendors normally use their private cloud infrastructure to provide services to their regular outside users. For this kind of applications the use of consumption-based model offered by cloud computing is desirable for many enterprises. The focus of this research will be on systems migration to public cloud providers.

Hybrid cloud

The cloud infrastructure is a composition of two or more cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardised or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds). Organisations may use the hybrid cloud model to optimise their resources to increase their capabilities by margining out peripheral business functions onto the cloud while controlling core activities on-premise. However, Hybrid cloud has led to the issues of integration, compliance, and security issues that will be discussed later in this chapter (Mell and Grance 2011).

2.3.2 Cloud computing applications and service models

Cloud computing, as was indicated earlier, delivers its services in three deployment models which are (Infrastructure as a Service or IaaS); cloud application platform (Platform as a Service or PaaS); and cloud application (Software as a Service or SaaS) (Marks and Lozano, 2010). IaaS is a set of IT equipment that are owned, managed, and maintained by a cloud provider and then used by a cloud customer usually in a pay-as-you go manner. IaaS services include storage, where virtualized storage is delivered on demand which allows customers to pay only for the amount they use. An example of a storage service is a virtual disk synchronised to computers through the cloud that can be used for sharing data and retaining an archive amongst other purposes. IaaS also provides other services such as backup and recovery, content distribution network (CDN), service management and platform hosting. Examples of IaaS providers: (Google Compute Engine 2014) and (Windows Azure Virtual Machines 2014).

PaaS provides infrastructure and middleware without the need to manage the underlying resources (hardware and software), allowing cloud costumers to create and control their applications through the cloud. These services include databases, development applications integration, and administration tools. An example of the PaaS services is Google Cloud SQL, which allows developers to create and control their databases without requiring the installation of any software for database management, maintenance, and administration.

SaaS allows cloud customers to access applications and their associated data without the complexity of buying and installing in-house applications. SaaS is the most common cloud deployment; it includes a wide range of applications. In terms of business, SaaS can cover accounting applications such as sales, collaboration, Management Information Systems (MIS), Customer Relationship Management (CRM), Enterprise Resource Planning (ERP), billing, and Human Resources Management (HRM). Sales Force is a common example of SaaS that provides innovative and easy to access CRM tools to cloud customers. Figure 3 illustrates examples of cloud computing services (Marks and Lozano 2010).

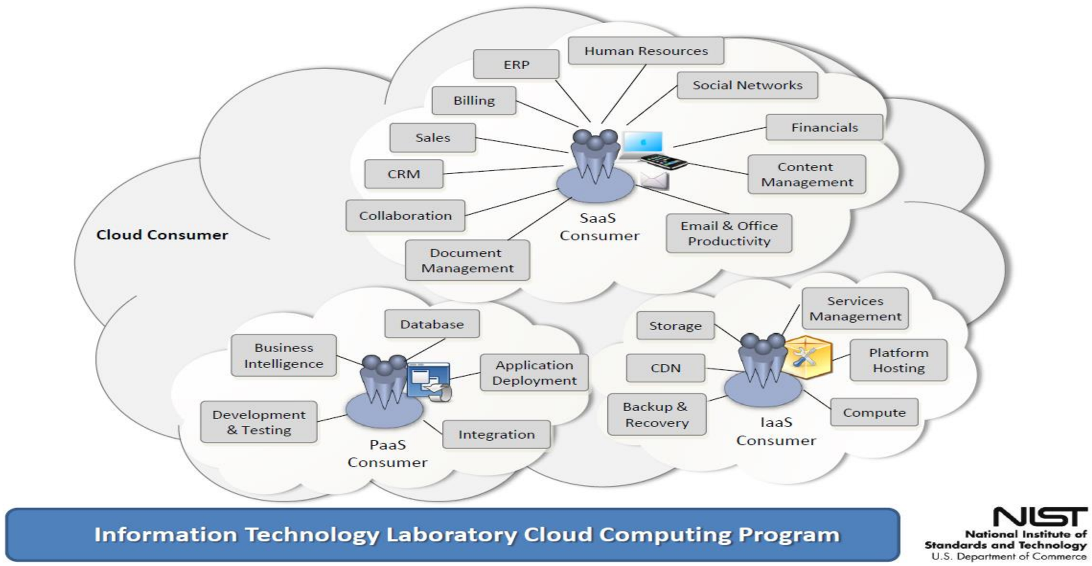


Figure 3. Examples of cloud services (Liu et al. 2011, p.6)

A study conducted by Chalef (2011) showed that there are 10 cloud-based applications that can provide enterprises, particularly SMEs a competitive edge. For human recourses, cloud-based applications such as Resumator and Paychex can enable SMEs to perform different processes and managing hiring workflow. Moreover, cloud-based applications such as SugarCRM and Pardot have the ability to provide enterprises easy to use and flexible CRM application that can improve business processes and customer needs. Google Docs and Carbonite are also valuable cloud-based applications that can enhance SMEs' collaboration and backup services.

2.4 Related technologies, concepts, and terminologies

2.4.1 Grid computing

Grid computing is a distributed hardware and software infrastructure that provides coordinated resource sharing to achieve high computational objectives such as science and engineering applications. Buyya et al. (2009) provided one of the popular definitions for Grids that is:

> ‘‘A grid is a type of parallel and distributed system that enables the sharing, selection, and aggregation of geographically distributed ‘autonomous’ resources dynamically at runtime depending on their availability, capability, performance, cost, and users’ quality-of-service requirements.’’ (Buyya et al. 2009, p.3)

Grid computing is similar to cloud computing in that they both utilise distributed resources to perform an application, however, the main difference is that cloud computing employs virtualisation technologies at different levels that can ensure dynamic resources provision. Grid computing usually aims to achieve maximum computing for scientific applications while the motivation for cloud computing is to provide on-demand scalable.

2.4.2 Utility computing

Utility computing is a model of providing computing resources including hardware, software, and bandwidth on-demand as a service. In this model, customers are charged based on their usage rather than fixed rate. If the computing resources are only in one location and involve no Virtualisation of resources, it cannot be called cloud computing (Biswas 2011).

2.4.3 Cluster

“A cluster is a type of parallel and distributed system, which consists of a collection of inter-connected stand-alone computers working together as a single integrated computing resource” Buyya (2009). Cluster computing is usually deployed to improve performance and availability over that provided by a single computer (Vasudevk 2009).

2.4.4 Virtualisation

Virtualisation allows abstraction and isolation between lower level functionalities (the physical characteristics) of a computing platform and end users. It enhances the portability of the higher level functions and also sharing of the physical resources.

The concept of Virtualisation has been known since the early generation of computing (mainframes). Alongside the advances in computing systems, the Virtualisation concept has matured and applied to a wide range of computing components including: memory, processors, software, and networks (Vouk 2008). This concept provides advanced and complex IT services that are consumed at a reasonable cost. It has become one of the main technologies driving the next generation in IT growth and it has led to another related concept that is multi-tenancy (Buyya 2009). Multi tenancy allows a single provider of application software to serve multiple clients. This enhances the utilisation of a system's resources in terms of storage and processing overhead.

2.5 Cloud computing architecture

The latency of services has become increasingly sensitive and the need to dynamically allocate and manage the underlying resources for software developers has also increased (Sarathy et al. 2010). These requirements have put cloud vendors under pressure to build a cloud infrastructure that enable real-time end-to-end visibility and dynamic allocation of resources (Sarathy et al. 2010). To achieve this, cloud computing architecture relies on virtualisation techniques that create multiple virtual versions of IT resources (servers, operating systems, platforms, and storages). These techniques provide efficiency and flexibility to cloud computing services. Cloud computing architectures include virtualisation, service automation and orchestration, and multi-tenancy. This can create unified, scalable pools of hardware, software, and network resources that enable dynamic, on-demand delivery and high application functionality (Bakshi 2009).

The design of cloud computing architecture comprises of four main layers: the hardware layer, the infrastructure layer, the platform layer and the application layer (Zhang et al. 2010). The first layer from the bottom is the hardware layer that includes all the physical resources needed, as shown in Figure 4.

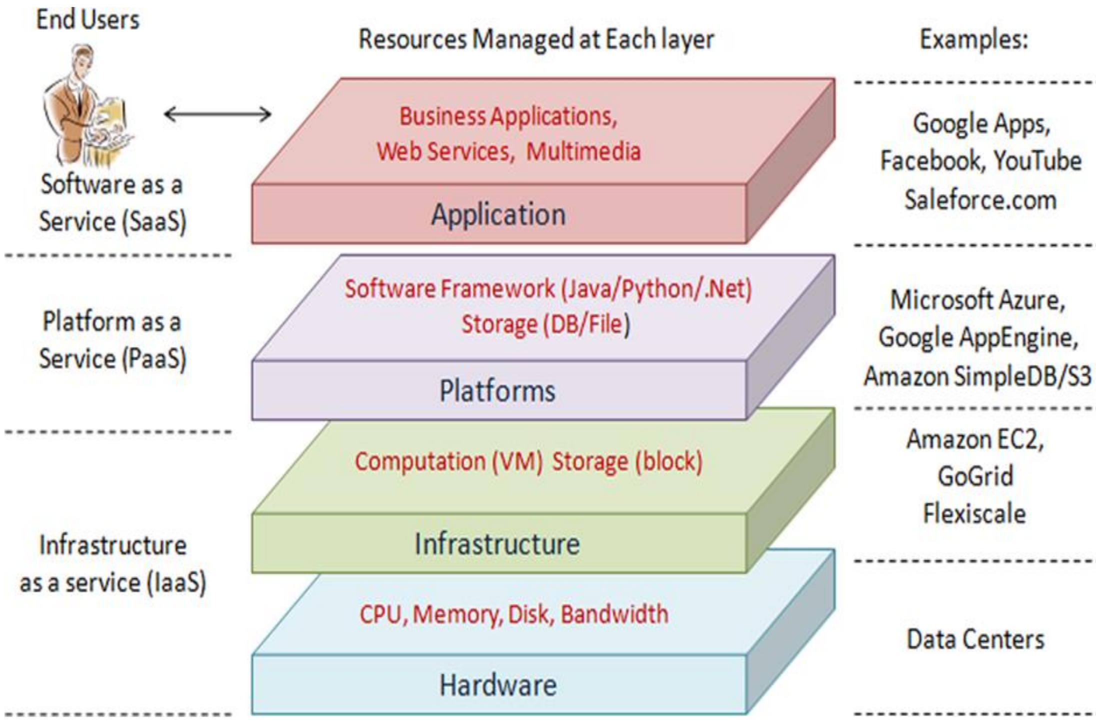


Figure 4. Cloud computing architecture (Zhang et al. 2010, p.9)

In the cloud computing architecture the physical resources at the bottom of the architecture stack are normally implemented in data centres. These resources could be distributed across different geographical locations. This layer is fundamentally important for providing many of the cloud's features as it is the foundation for the above logical layers. A major requirement of this layer is to ensure constant high capacity. In other words, the maximum rate of traffic flowing among servers should be limited only by the available capacity on the network.

Above the hardware layer, the infrastructure layer which is also known as the virtualisation layer. This layer creates multiple virtual versions of the physical resources in the hardware layer using virtualisation technologies such as Xen and VMware (Rothstein 2013). These techniques provide efficiency and flexibility of cloud computing services which make this layer an essential component of cloud computing architecture. Most of the key features, such as scalability and elasticity, can only be achieved through Virtualisation technologies.

Above the virtualisation layer is the platform layer. The purpose of this layer is to manage the deployment of applications which are difficult, if implemented directly into the virtual machines. This layer comprises operating systems and application frameworks.

At the top of cloud architecture, is the application layer. This layer manages the cloud-based applications. These are different from traditional applications in their automatic and scaling features as a result of the advancement of the lower layers.

The main advantage of cloud architecture is that each layer is loosely coupled with the layers above and below. This allows for separate advancement with each layer. It does not only enable the provision of wide range of application requirements, but also reduces management and maintenance. The relationship between cloud architecture's layers can be described in two ways: (a) each layer of cloud architecture can be applied as a service to the layer above. (b) Every layer can be considered as a customer of the lower layer. Other advantages of this architecture include: automation – "Scriptable infrastructure", auto-scaling, proactive scaling, more efficient development lifecycle, improved testability, and disaster recovery and business continuity (Varia 2010).

Despite the rapid adoption of cloud computing, there are still many technical challenges of cloud architecture that need to be addressed. Issues for consideration include: automated service provisioning, virtual machine migration, server consolidation, energy management, traffic management and analysis, data security (Zhang et al. 2010). These technical issues are implementation details and they fall outside the scope of this study.

2.6 Cloud storage models

In cloud storage models, the digital data is stored in virtualised pools and the physical storage is distributed in multiple locations, in order to support different application types. The physical environments are owned and managed by a hosting provider (Xinqiang et al 2015). Cloud storage services have two main advantages over the traditional storage model: scalability and availability (Li et al 2010). Although they are usually well-provisioned to handle high flows and the data is replicated for high availability, cloud storage services do not always offer strong consistency guarantees. Therefore, an application may retrieve stale and inconsistent data when a read immediately follows a write (Li et al 2010).

The current major cloud providers offer storage using four common types of services: Elastic Compute Clusters, Persistent Storage, Intra-Cloud, and Wide Area Network (Xinqiang et al 2015). Elastic Compute Clusters comprise a set of virtual instances that run customers' applications, in which each virtual instance can be a VM or sandbox environment. They provide multiple instances of software that can work in parallel which creates an environment that lowers deployment costs. Further, the number of server instances can be scaled based upon the incoming request rate (Xinqiang et al 2015).

In Persistent Storage Services, each application's data can be stored in a cluster. The main difference in comparison to traditional local storage is that each virtual instance is temporary and it cannot be directly accessed by other instances. There are three common types of persistent storage services: table, blob, and queue (Li et al 2010). The first stores structural data in lieu of a conventional database. It does not support complex queries such as table join. The second type of service stores unstructured blobs, such as binary objects, user generated data, and application inputs and outputs. The third implements a global message queue to pass messages between different instances (Li et al 2010).

Intra-cloud Networks provide a connection of virtual instances, with each other as well as with storage services. The network performance is critical to the performance of distributed applications such as multi-tier web services. Within cloud providers, the intra-datacentre network often has different properties compared to the inter-datacentre network. Providers vary in terms of the type of network equipment they offer as well as in their choice of routing and configuration. Unlike intra-cloud networks, Wide Area Networks (WANs) connect the cloud datacentres, where the application is hosted, with end hosts on the Internet. For consumer applications such as websites, WAN performance can affect a client's response time significantly. All cloud providers operate multiple datacentres in different geographical regions so that a user’s request can be served by a nearby datacentre to reduce WAN latency (Xinqiang et al 2015).

These four types of cloud storage model are fundamental to building any generic computation platform. For example, a typical online cloud application, such as a social network website, needs its servers to run in a compute cluster that has scalability to overcome service latency. The user data can be stored in the three storage services and can be accessed through the intra-cloud network. The WAN is used to deliver Web contents to users with minimum latency (Xinqiang et al 2015).

2.7 Service-oriented architecture and cloud computing

> “Service-Oriented Architecture (SOA) is a design pattern which is composed of loosely coupled, discoverable, reusable, inter-operable platform agnostic services in which each of these services follow a well-defined standard. Each of these services can be bound or unbound at any time and as needed” (Jamil 2009, p.1).

SOA offers a way of considering IT assets as service components. These components establish a software architectural approach for building business applications (Mirzaei 2008). In order to build integration-ready applications, the services model relies on SOA. Papazoglou (2003) has defined SOA as a way of re-organising a portfolio of previously siloed software applications and support infrastructure into an interconnected set of services. These services can be accessed through standard interfaces and messaging protocols. The transformation of the elements of enterprises architecture into services allows for existing and future applications to access these services when needed without requiring complex point-to-point solutions based on inscrutable proprietary protocols. Papazoglou (2003) has also indicated that, this architectural approach is particularly applicable when multiple applications running on varied technologies and platforms need to communicate with each other. In this way, enterprises can mix and match services to perform business transactions with minimal programming efforts.

At the core of the SOA philosophy is the modularisation of business functions for greater flexibility, manageability, and reusability (Mirzaei 2008). From an engineering and enterprise architecture perspective, SOA can offer a wide range of advantages that includes: language-neutral integration, components reusability, organisational agility, and leveraging existing systems. When an organisation develops a software component and makes it available as service, other organisations can utilise that service. For example, building credit card validation as a service that can be used for order processing applications. A common use of SOA is defining functionality of existing systems' elements. This can leverage the investment of legacy systems and also provide integration among the new and old components.

SOA and cloud computing are complementary technological environments (Raines 2009). SOA will significantly support the development of cloud computing in many ways (Marks and Lozano 2010). From a logical point of view, cloud computing builds on the concept of SOA that are provision of shared services, core enterprise services, and the clean layered architecture. Considering cloud computing services as scalable products is inspired from the componentisation concept of SOA. SOA components leverages network based software using standards-based interfaces. Cloud computing can also provide a valuable support for SOA in that the cloud increases the need for distributed software components as an integration technology. The growth of cloud adoption means growing demand for system integration and data exchange activities. These activities can leverage SOA evolvement (Marks and Lozano 2010). Cloud computing is neither a replacement of SOA nor the use of distributed software components as an integration technology. In addition, the need for broader and more consistent integration of systems will continue (Marks and Lozano 2010).

2.8 Outsourcing

Outsourcing involves an agreement in which a company transfers part of their existing internal activity to another company using a contract (Yang et al. 2007).

Many definitions of information systems outsourcing have been proposed by researchers. For example Dhar and Balakrishnan (2006) defined IT outsourcing as:

> “An act of delegating or transferring some or all of the information technology related decision making rights, business processes, internal activities, and services to external providers, who develop, manage, and administer these activities in accordance with agreed upon deliverables, performance standards and outputs, as set forth in the contractual agreement”

Vendors may provide computing assets to customers from outside their organisation which may result in transferring the ownership of the outsourced assets to the providers. Vendors may also utilise their personnel to deliver the required services (Stefanie 2010).

Over the last few decades increasing attention has been paid to outsourcing of information systems (Zhao et al. 2014). This has become an important strategic business approach to gain a competitive advantage through products or services that can be obtained more effectively and efficiently from outside providers (Yang et al. 2007). Outsourcing of IT resources is not a new phenomenon and its root established in the 1960s with the use of the traditional timesharing and professional service resources that enable multiple users to interact simultaneously with a single computer. Since then, outsourcing has extended that includes: a range and different level of services, the change from client-provider relationship to partnership, business process outsourcing, in addition to service providers taking on more responsibilities (Grover et al. 1996).

Organisations usually seek outsourcing for a number of reasons: cost savings, a focus on core competency, flexibility in management, business process improvement, access expertise, skills, and new technologies, and scalability (Lacity et al. 2009). However, there are some disadvantages that include information security and loss of control (Yang et al. 2007). Management should also consider the properties of the external environment including: service quality, market maturity, and similar outsourcing projects, when deciding to outsource services or eequrments (Yang et al. 2007).

Arnold (2000) proposed an outsourcing model (see Figure 5), which consists of four major elements: outsourcing subject, outsourcing object, outsourcing partner, and outsourcing design. In this model, all the company's activities are classified into four types: company core, core-close activities, core-distinct activities, and disposable activities. Outsourcing objects include all the necessary activities for a company's existence, but not the company core, which are outsourced to the outsourcing partner depending on the manager's decision.

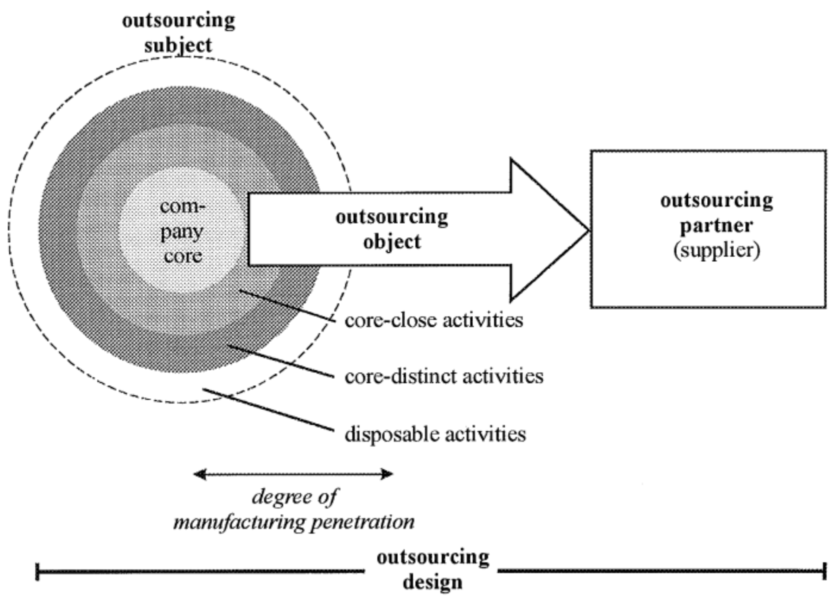


Figure 5. Outsourcing model developed by Arnold (2000)

2.8.1 Evolution from traditional outsourcing to cloud computing

The demand for cost-effective, efficient and flexible delivery of IT services from service providers, at a maximum of financial flexibility is increasing (Leimeister et al. 2008). Cloud computing has emerged as a response to the demands and challenges posed by clients. Cloud computing is a new trend to outsource some or all IT applications to a third party that provides a flexible and highly scalable platform for (Armbrustet al. 2010). It provides the technical foundations to meet customers' demands for flexibility at the business level. The cloud was started by providers that have not been known in the traditional outsourcing market such as such as Amazon and Google (Dhar 2012). These companies were active in other markets, but they developed new business models to promote their former products (e.g., large storage and computing capacity) as new products. By this, they entered the traditional outsourcing value chain and started a competition with previously established outsourcing providers.

There are some differences between the traditional information systems and cloud computing (See Table 3). In the first, the physical resources can be kept either by the customer or the provider while the latter provides an asset-free provision of technological capacities. The traditional outsourcing of information systems usually required long term contracts which can be difficult to change while cloud computing services can be provided instantly with high flexibility in terms of contract duration.

Table 3. Differences between IT outsourcing and cloud computing, adopted from Dhar (2012, p.6)

IT outsourcing	Cloud computing
Outsourcing means transferring some or all of the IT related decision making rights, business processes, internal activities, and services to external providers	The framework allows organizations to manage the building blocks of IT, provided by other people in the same way they would their in-house infrastructure, but without the challenges that such complex architecture would normally produce. Most of the benefits of the outsourcing are achieved, without the majority of drawbacks. Control is retained, and the risk profile and commitment for the organization are minimal
Initial up-front cost required in most cases	No up-front costs: the CapEx and installation are absorbed into the rental charges
Services are not necessarily on demand	On demand: near-instant scaling /adding of resources
More capacity planning required for future demand	Flexibility with regards to increasing/decreasing resources
Lots of hidden costs	Cost is more transparent
High level of customization possible	Less customization
More project management, onshore offshore coordination and governance required	Less project management, onshore offshore coordination and governance required
Outsourcing vendors can offer value-added services along with strategic and management consulting	Strategic and management consulting are beyond the scope of Cloud computing
Usually specifies where data resides, how it is protected, who has access, which measures are in place to accommodate political or natural disasters	Lack of provisions for compliance, business continuity, security, and privacy of data
Longer contracts	Shorter contracts

The impact of cloud computing on IT outsourcing is no doubt significant (Dhar 2012). Cloud computing has reconfigured the IT supply industry. It established a new culture in which new types of services can be easily developed, tested and provided (Schubert and Keith 2012). It has led to significant increase in the use of external service provision, resulting in a much smaller internal IT function. Cloud computing have made a substantial impact on outsourcing vendors, who need to adopt new strategies to include cloud-based services in order to sustain with the changes in the IT services industry (Dhar 2012).

2.8.2 Migration to cloud computing

Cloud migration, for the purpose of this thesis, can be defined as a transition process of all or part of legacy IT resources of an organisation including: hardware, software, stored data, and business processes, from on-premise deployment behind its firewalls to the cloud environment where they can be managed by a third party. The process also encompasses the shifting of IT resources between different cloud providers; this process is known as cloud-to-cloud migration. The cloud migration process may involve retaining some IT infrastructure on-site (Pahl 2013).

2.9 Cloud computing advantages

2.9.1 Technical advantages

Cloud computing can be highly valuable for applications that require massive scalability for both computation, and storage resources. The cloud can be also valuable for applications that require high reliability, availability, heavy load variations, collaboration across an organisation boundary (Kaefer 2010).

Additionally, Cloud services are usually built on a robust architecture which ensures high resiliency and redundancy. Cloud environment provide higher level of replication, multiple fault domains and deployment on multiple clouds. These distinctive characteristics enable cloud providers to handle peaks in workload and provide a higher reliability (Juan-Verdejo 2012). The cloud offers automatic failover between hardware platforms as well as providing disaster recovery. Cloud computing is generally more efficient compared to the typical IT infrastructures. It needs fewer resources to compute and consume much less energy. For example, if a server is not used, the cloud environment typically scales down, resulting in less energy consumption (Tsagklis 2013).

Cloud providers usually implement up-to-date and secure IT infrastructure such as trustworthy access control techniques, robust authentication mechanism, encrypted protocols, secure backup applications and secure physical resources (Dos Santos and Singer 2012). Cloud computing providers can enhance the availability of organisations systems by storing their data in a secure off-site backup.

In the cloud environment, applications and platforms can be constantly monitored. The collected-audit data can be used to detect applications' vulnerabilities. Additionally, cloud providers often implement security measures that detect remote access devices global position/location data points. This data trigger extra security mechanisms to enhance accessibility and authorisation (Dos Santos and Singer 2012). The ability of cloud vendors to provide robust administrative and network management that are designed to gather various measures and metrics result in a higher level of security insight that could not achieved prior to cloud computing.

The visibility provided through the cloud can also deliver further advantages in addition to security. The collected data can be used to identify usage patterns which can support a wide range of business areas, for example, enhancing experience and counterintelligence Audit Access to more granular performance data from all of the devices connected to your cloud allows deep analysis for load balancing refinement to support decisions on where and how to cache data for best end-user support (Dos Santos and Singer 2012).

The ease and speed of deployment is a key advantage of the cloud architecture. A cloud service can be up, running, and integrated into existing systems in a very short time. Cloud providers can provide high storage capacity in a way that offers almost unlimited storage capacity (Tsagklis 2013).

2.9.2 Business advantages

From the business viewpoint, three features are new in cloud computing. The appearance of unlimited computing resources that are available on demand. This eliminates the need for companies to make initial plans for resources prior to provisioning as well as the elimination of up-front costs that allows enterprises to start small and expand their hardware resources when needed. Second, the ability to pay based on usage of computing resources as needed. For example, processors by the hour and storage by the volume and day and release them as needed. These properties of cloud services provision offer enterprises a competitive advantage and also allow smaller companies to compete with anyone, anytime, and anywhere by using the cloud platform to effectively implement innovative services (Wilson 2011). Third, the cloud can also enable enterprises to focus on innovation and creation of businesses, thereby enhancing staff productivity without requiring updating software, and other IT equipment. Enterprises will have direct access to high quality business IT services on a global scale without having to spend a considerable amount of money on infrastructure. By shifting the focus from operational activities to strategy and marketing, cloud computing can support enterprises' innovation initiatives (Boss et al. 2007). Alongside these advantages, cloud computing may be utilised as a platform for business innovation. It may reduce the time of implementing new products or services from months or years to days. Additionally, it offers businesses a capability of implementing new ideas (Boss et al. 2007). Thus, the cloud should be exploited in a way that allows enterprises to move their business innovation forward. It should be used to re-invent the fundamental way in which enterprises utilise their IT services.

2.9.2.1 Business agility

Goldman et al. (1995) defined Business agility as:

> "the ability to thrive in a competitive environment of continuous and unanticipated change and to respond quickly to rapidly changing, fragmenting global markets that are served by networked competitors with routine access to a worldwide production system and are driven by demand for high-quality, high-performance, low-cost, customer-configured products and services."

Business agility has become the key to commercial success and the current economic downturn has also heightened its importance for enterprises especially for SMEs (Sahandi 2013). It is becoming vital for organisations to build infrastructures that are both fast enough to deliver real-time business processes and flexible enough to continuously evolve in response to dynamic business conditions. If the cloud is properly used within an overall IT strategy, it can provide a real competitive advantage, improve business performance, and reduce the cost of IT services for organisations (Brookbanks 2010).

Cloud computing offers a new pathway to business agility and supports a faster time to market by offering ready-to-consume cloud enabled resources such as IT infrastructure as a service, software platforms, and business applications (Sahandi et al 2013). The cloud can provide flexibility for IT resources which allow organisations to adapt to changing demands of their business requirements. Undoubtedly, this is an attractive proposition for organisations where ICT expenditure is fixed, especially in SMEs.

One of the main characteristics that distinguish cloud computing is its ability to facilitate scalable services that can handle any particular demand (Sun 2009). The ability of the cloud to supply rapid resource allocations in the events of high demand allows the cloud to offer highly scalable services. Also, cloud computing has the ability to de-allocate resources when demands have been declined. In addition to its capabilities, the cloud also comes with high speed implementation and a smooth upgrade pathway (Sahandi 2013).

Additionally, cloud computing customers also can conveniently access business applications on the move, meaning staff can work flexibly from anywhere. The range of cloud-based services now offered by vendors is growing simultaneously with the emergence of varying cloud service providers.

According to Liebenau et al. (2012a), enterprises that adopted cloud services have reported an enhancement in business agility for implementing new products or services. Moreover, cloud has allowed them in be engaged in more innovative activities. They pointed out four main factors that enabled these advantages: (1)

rapid sourcing and implementation of resources; (2) diminished licensing negotiations with vendors; (3) reduced IT assessment and overhead; (4) no requirement for in-house technical support. Enhanced productivity has been reported by organisations, as a result of the time being spent on major business activities rather than implementation of infrastructure and services and their associated operational issues. For example, enterprises reported that an extra time of 5 per cent or greater was available for other business activities (Liebenau et al. 2012a). Further, cloud based services allow organisations to reduce IT infrastructure, reduce energy usage, engage mobile workforce, and reduce up-front capital investments (UK Essays 2013).

2.9.2.2 Cost

Enterprises perceived use of cloud computing strategic for reducing the cost of IT infrastructures and operation (Sahandi et al. 2012). Further, giving a third party the control over IT infrastructure of a company can help reduce capital expenditure whilst maximising asset utilisation to provide a quantitative Return on Investment (RoI) and thereby eliminating costs associated with in-house provision of the equipment required for building up the infrastructure (Damoulakis 2010). With cloud-based computing, applications run on centralised virtual servers managed by a cloud provider thereby eliminating the need for costly equipment of the company's site. Centralising the clients' servers and applications in the cloud ecosystem will eliminate the need to maintain server room equipment and staffing, which could be capital intensive for SMEs and start-ups.

The move from a capital upfront investment model to an operational expenses one, enables enterprises especially SMEs the opportunity for development and adoption of innovative services. It converts fixed costs to variable costs, due to renting from a third-party provider where businesses only pay for the resources used (Stryer 2010). When an organisation utilises a cloud strategy, ROI yields more to effective economic benefits to the firm leveraging the cloud model (Mohan 2011). For organisations that continually aim to reduce computing cost while making innovation as their highest priority, cloud computing can offer them services with the opportunity to cut cost through improved utilisation, reduction in administration and infrastructure costs, and faster deployment cycles (Boss et al. 2007). In addition, cloud computing can assure that as demand for services increases due to business development, resources can be added on demand. This facilitates the provision of services to organisations faster without capital expense.

2.10 Cloud computing main issues

Armbrust et al. (2010) identified 10 critical areas that negatively affected the adoption and growth of cloud computing as shown in Table 4. The first three affect the adoption, the following five affect the growth, and the last two are policy and business obstacles. These are matched with opportunities that include product developments and research projects to overcome them.

Table 4. The main cloud computing obstacles adopted from: Armbrust et al. (2010, p.54)

	Obstacle	Opportunity
1	Availability/Business Continuity	Use Multiple Cloud Providers
2	Data Lock-In	Standardize APIs; Compatible SW to enable Surge or Hybird Cloud Computing
3	Data Confidentiality and Auditability	Deploy Encryption, VLANs, Firewalls
4	Data Transfer Bottlenecks	FedExing Disks; Higher BW Switches
5	Performance Unpredictability	Improved VM Support; Flash Memory; Gang Schedule VMs
6	Scalable Storage	Invent Scalable Store
7	Bugs in Large Distributed Systems	Invent Debugger that relies on Distributed VMs
8	Scaling Quickly	Invent Auto-Scaler that relies on ML; Snapshots for Conservation
9	Reputation Fate Sharing	Offer reputation-guarding services like those for email
10	Software Licensing	Pay-for-use licenses

Sahandi et al. (2012) identified a number of factors delaying the adoption of cloud services. Similar to the findings of Armbrust et al. (2010), the main factors affecting the adoption of cloud-based services, have been identified as: security, data privacy and vendor lock-in. Security and data privacy are often presented as the key risks when outsourcing IT services that may include critical data. These risks have made data privacy and security the main issues delaying cloud computing adoption (Sabahi 2011). In addition, vendor lock-in has also been presented as a major concern for adopting cloud computing. Cloud computing users are concerned about losing control of their data that could be locked-in by a cloud provider. Sahandi et al. (2012) also identified other factors including: services integration, data transferring, integrity, reliability and availability of cloud services. However, these concerns were not found to be as significant as security and vendor lock-in.

2.10.1 Cloud security risks

The Cloud Security Alliance (CSA 2011) identified 7 top threats in cloud computing:

1) Abuse and nefarious use of cloud computing

The registration process for cloud services (IaaS and PaaS) does not usually need more than a valid credit card and also some service providers offer free trial. This relative anonymity of registration and usage model could be abused by spammers, malicious code authors, and other criminals who have been able to conduct their activities with relative impunity. Areas of concerns in this regards include: password and key cracking, Distributed Denial of Service attack (DDOS), launching dynamic attack points, hosting malicious data, botnet command and control, building rainbow tables, and CAPTCHA solving farms.

2) Insecure interfaces and APIs

Cloud providers rely heavily on a set of software interfaces that allow users to manage and interact with cloud-based services. Therefore, the security of the cloud services is dependent on the security of those interfaces. This requires the interfaces to be designed and protected against accidental and malicious attempts. Moreover, some organisations build upon these interfaces to offer value-added services to their customers. This increases the complexity and risk of the new layered interface, especially when organisations are required to relinquish their identifications to third-parties to enable their agency.

3) Malicious insiders

Malicious inside is a well-known threat and amplified in the cloud that providers lack transparency about accessibility process and procedure.

4) Shared technology issues

The scalability of the service offered by the cloud is achieved through sharing infrastructure. The underlying components in the cloud infrastructure are not often designed to offer robust isolation properties in a multi-user architecture. To address this, cloud providers utilise a virtualisation hypervisor that mediates access between guest operating systems and the physical components. Though, the virtual machines (hypervisors) have presented weaknesses that enable guest operating systems to inappropriately gain unauthorised access to sensitive data, control, or influence on underlying platforms. This requires a defence strategy that should include resources security enforcement and monitoring. It should also include a robust compartmentalisation to ensure that customers do not affect the operations of other tenants using the same physical resources.

5) Data loss or leakage

The threat of data loss or compromising increases in the cloud environment. This is because of the challenges that are either unique to the cloud, or more risky because of the architectural characteristics of the cloud environment. For example, insufficient authentication, authorization, and audit control and inconsistent use of encryption and software keys.

6) Account or service hijacking

Account or service hijacking such as phishing, fraud, and exploitation of software vulnerabilities were known before cloud computing. Cloud services add a new threat to the landscape. If attackers gain unauthorised access, they can eavesdrop on customers' activities, manipulate data, return falsified information, and may redirect clients to illegitimate sites. The attacked account or service may become a new base for the other attacks.

7) *Unknown risk profile*

The reduction of hardware and software ownership including maintenance that allows enterprises to concentre on their essential business operations is a distinctive financial and operational benefit. However, this feature must be carefully weighed against the contradictory security concerns complicated by the fact that cloud deployments are driven by anticipated benefits, by groups who may lose track of the security ramifications. Versions of software, code updates, security practices, vulnerability profiles, intrusion attempts, and security design, are all important factors for estimating a company's security postures. Information about who is sharing your infrastructure may be pertinent, in addition to network intrusion logs, redirection attempts and/or successes, and other logs. Security by obscurity may be low effort, but it can result in unknown exposures. It may also impair the in-depth analysis required highly controlled or regulated operational areas (CSA 2011).

Another issue in terms of security is loss of control. Although cloud providers implement up-to-time and a secure IT infrastructure; consumers continue suffering from the loss of control and lack of trust (Almorsy et al. 2011). Moreover, the fact that before data can get to the cloud, it has to progress outside a company's firewall via an access network, that makes it vulnerable to attacks (Sahandi et al. 2012). Before moving applications outside their firewalls, organisations should be aware of the intrusion risks associated with such environment (Sahandi et al. 2012).

The design of cloud computing architecture comprises of different layers to provide IT resources. These layers are deployed in three different models (IaaS, PaaS, and SaaS). Each model comes with its own security issues. Therefore guaranteeing security of corporate data in the cloud is difficult, if not impossible (Kandukuri et al. 2009).

The IaaS cloud model, for example, is prone to attacks like XML Signature Element Wrapping (McIntosh and Austel 2005). This is a common attack on protocols using XML Signature such as SOAP (that stands for Simple Object Access Protocol) messages. These protocols are used to provide authentication for messaging through the web.

In the PaaS (Platform as a Service) model, the security of the platform used for development is the service provider's responsibility, but the security of the applications developed is the responsibility of consumer's. Concerns about cloud service integrity and binding issues with PaaS' cloud models should be taken into further consideration. The PaaS model is prone to cloud malware injection attacks and metadata spoofing attack as described by (Jensen et al. 2009).

Security concerns are the most commonly cited reasons that making enterprises not interested in SaaS (Forrester 2009). According to the (CSA 2009), in the SaaS model, service providers' are responsibility do not only include providing the physical and environmental security capabilities, but also addressing the security control for the infrastructure, applications and data. A major concern of SaaS is unauthorised access due to data being transferred to a remote server through the internet (Sahandi et al. 2012). This might allow adversaries obtain passwords, inspect data, and modify or damage the data. This would be more harmful in case of unauthorised access to sensitive information such as payments details and information on human resources (Sahandi et al. 2012). Denial of service attacks and network failure also present availability concerns of SaaS (Rai et al. 2013).

Another security issue discussed in the literature is the lack of information about the location of datacentres. Cloud computing providers often have multiple data centres at different geographical locations in order to optimally serve consumers' needs around the world (Sahandi et al. 2013). In many cloud provision scenarios, customers lack information of where their data is stored (Sahandi et al. 2013). In these scenarios legal and regulatory issues may arise which need to be considered because the physical location of data centres defines the law that can govern the management of the systems (Sahandi et al. 2013).

Availability can also be an issue with cloud computing. A number of service-outage incidents occurred, for example, Amazons EC2 users experienced service-outage several times (Miller 2012).

Security measures may be developed to tackle the above security issues. For example, implementing a robust authentication mechanism, encrypted protocols, secure backup applications and secure physical resources can improve security (Sahandi et al. 2012). Access control can be enhanced by incorporating security measures to the network layers. Web Services Security (WSS) is a security technique that can be incorporated to SOAP messages to assure the integrity and confidentiality by signing and encrypting their context (NIST 2007). The confidentiality and integrity can also be improved by incorporating cryptographic protocols such as Transport Layer Security (TLS), and Secure Socket Layer (SSL) to the transport layer. Moreover, it is highly recommended that cloud providers protect the integrity of consumers' data by complying with relevant standards including Payment Card Industry – Data Security Standards (Jansen 2011). To improve access control, Al Morsy (2011) recommended the adoption of standards for identifying and accessing management such as SPML, SAML, OAuth, and XACML. Securing of VMs is critically important to avoid unauthorised access, so it is vital to consider security practices that may ensure the security of VMs. The use of secure protocols such as HTTPS would also increase the confidentiality by encrypting data while transferring them through the cloud. Other security practises maybe considered such as implementing file integrity checks and maintaining backups.

Cloud vendors should provide a detail of their security polices to include risk management, access control, network security, physical security, and backup and system recovery. They should also provide details of how customers' systems would be segregated from others in a multi-tenant environment. However, often cloud providers tend not to reveal more details about their systems and data centres, claiming doing so would compromise their security. Moreover, cloud providers should implement regulatory compliances that cover operational and security areas that users may have concerns about. Theses compliances would improve the security by having cloud vendors and customers to be securely certified.

2.10.2 Vendor lock-in

Cloud-based services are offered with different specifications from one vendor to another. Providers develop their own specific technology solutions, remote APIs, and some even create new programming languages (Opara-Martins et al. 2014). The lack of standards in cloud computing rises interoperability and manageability issues inside and between cloud services, with possible economic impacts (Sahandi et al. 2013). Interoperability is concerned with integration of applications and data between different cloud service, whilst standardisation, attempts to support applications by different vendors to interoperate with each other, exchange traffic, and cooperatively interact with data (Yoo 2011).

In the absence of standardisation, enterprises aiming to outsource and combine a range of services from different cloud providers to achieve maximum efficiency will experience difficulty when trying to allow their in-house systems to interact with cloud providers systems (Sahandi 2012). Similarly, the lack of standardisation may also bring difficulties, when integration of services is required. Further, the necessity for factoring applications to comply with other cloud Application Programming Interfaces (APIs), can also leads to higher costs, delays and risks (Machado et al. 2009). The need for systems reconfiguration to achieve interoperability is time consuming and requires a considerable amount of expertise, which can be challenging for enterprises. Further, interoperability and portability gives rise to standard reusability, which in turn leads to faster cloud deployment (Craig 2010).

2.11 Cloud computing impacts on IT management

A global survey reveals that over half of the surveyed businesses primarily rely on their IT departments to increase efficiency of operations. Moreover, IT departments have been required to improve businesses performances and innovation while keeping cost at minimum (SMB World Asia Editors 2013). Cloud computing has been perceived from many enterprises as the solution to drive businesses growth and innovation as well as reducing cost.

The adoption of cloud computing has not only increased the efficiency of acquiring IT resources but also has had major effects on IT management roles. Cloud computing has reconfigure how IT systems are deployed, managed and implemented. Cloud computing has been increasingly accelerating the transformation from IT-based products to cloud-based business-oriented services. Enterprises instead of buying software to be installed in house, applications can be deployed as a service through the cloud (Willcocks et al. 2011). For example, Microsoft 365 allows organisations to access to Microsoft Office products and other applications as packages based on the size of the company, which makes IT management far easier.

IT services can be supplied at three different levels. Platform services such as storage and email, specialist software for distinctive business process such as CRM, and software that partner with enterprises in order to design and optimise comprehensive services ecosystem.

The transformation of IT services has raised the need for new skills to deal with cloud-based services. IT management staff are required to develop new set of cloud skills that would enable them to meet the emerging cloud responsibilities. “The IT industry recognises that the transformation to cloud computing will have a broad and substantial impact on jobs” (Albright 2012). For example, IT managers’ roles will be shifted from building and supporting internal resources to managing companies’ systems in the cloud such as configuration, monitoring and integration of cloud services with possible remaining on-premise systems. It is also important to improve managerial skills to ensure high quality of cloud services. Managerial expertise needed include: appropriate terms of contracts, knowledge of industry trends, and prices (Liebenau et al. 2012a).

2.11.1 Shift of roles from local resources management to cloud-based provision

Cloud computing adoption may affect some IT jobs by making them less needed. Traditional IT jobs such as server administration, system administration, and database administration may no longer be needed as enterprises move their servers to the cloud. Accordingly, a large number of IT and systems administrators are concerned that cloud computing will automate and self-function the environment, resulting in many jobs becoming redundant (Cruz 2012). Further, the growth in adoption of cloud computing will increase the number of servers in the cloud, thereby increasing the demand for server management jobs offered by service providers. In other words there is a strong possibility that server management jobs will move from local resources management within enterprises to cloud providers (McKendrick et al. 2012).

Liebenau et al. (2012b) indicates that employing improved technologies will increase productivity. Lowering entry barriers will also increase the opportunities afforded which in turn will increase the number of new enterprises. So, the combination of the increased productivity and new enterprises will result in the growth of new job opportunities. Several recent studies show that large number of jobs is needed as a result of the growth of cloud computing adoption. For example, a study conducted by IDC and Microsoft indicated that cloud computing potentially create at least 14 million new jobs around the world by 2015 (Linthicum 2012). Another study conducted by Wanted analytics, reported that within only 90 days more than 2,400 companies were seeking to find candidates with cloud computing skills. In addition, the hiring demands for cloud skilled workers increased by 61% (Linthicum 2012). Many industry analysts including Gartner, IDC, TechRepublic, TechTarget, and others believe that the overall effect of cloud computing on IT jobs is positive and the cloud will bring more job opportunities than will be taken (McKendrick et al. 2012). Nevertheless, new IT job opportunities created by cloud computing require new and different skills to support could-based services, such as managing virtual storage.

2.11.2 Emerging IT roles and expertise

IT departments are increasingly relied on enhancing businesses performance and innovation while keeping the cost to a minimum (SMB World Asia Editors 2013). Cloud computing has been perceived by many enterprises as the solution to drive businesses growth, support faster time to market, using reduced IT resources as well as lower costs. This has resulted in cloud computing being rapidly adopted by enterprises of different sizes and from different sectors (Sahandi et al. 2012). The adaptation of cloud computing has had a considerable impact on enterprises, not only by increasing the efficiency of acquiring IT resources, but also on IT management roles and security. This has amplified the need to develop new sets of cloud skills that would enable IT management staff to meet the emerging cloud responsibilities. Further, IT roles will be shifted from building and supporting in-house resources (for instance purchasing new hardware, installing systems and managing patches) to managing companies' systems in the cloud (such as configuration, monitoring and usually integration of cloud services with the systems that remain at the organisations' premises) (Microsoft 2012).

A study conducted by McKendrick et al. (2012) reported that three out of five of the surveyed companies needed to add new types of skillsets to their IT departments to maintain the increasing requirements of cloud services. New skills included knowledge of: cloud computing, virtual servers, and managing virtual storage in the cloud. In addition to the technical skills, IT managers are required to develop expertise in the analysis of business needs and the understanding of enterprises architectures to ensure that selected cloud services address the business requirements and processes. It is also important to improve managerial and technical skills that include: analysing organisational needs and objectives, the ability to assess the appropriate terms of contracts, knowledge of industry trends, and prices. Development of those skills could ensure high quality of cloud services (Liebenau et al. 2012b).

Normally, successful adoption of cloud computing begins with the decision on whether the chosen cloud service is appropriate for enhancing business (Taylor et al. 2007). Failure or inaccurate assessment in this analysis will result in the selection of inappropriate services that could cause complexity and integration issues. This signifies that there is a need to develop evaluation skills for relevant people in order to find the right cloud-based services for the organisation's needs.

The Information Technology Infrastructure Library (ITIL) defined a framework for describing best practices in IT service management (Taylor et al. 2007) covering five stages in the lifecycle of services strategy to ensure cloud services delivery (see Figure 6). The stages are: service strategy, service design, service transition, service operation, and continual service improvement. These stages are more critical for cloud computing than they are for traditional computing because most of the activities occur remotely, reducing the amount of control that can be levered locally which may lead to problems, unexpected outages or unmet expectations (Fry 2010).

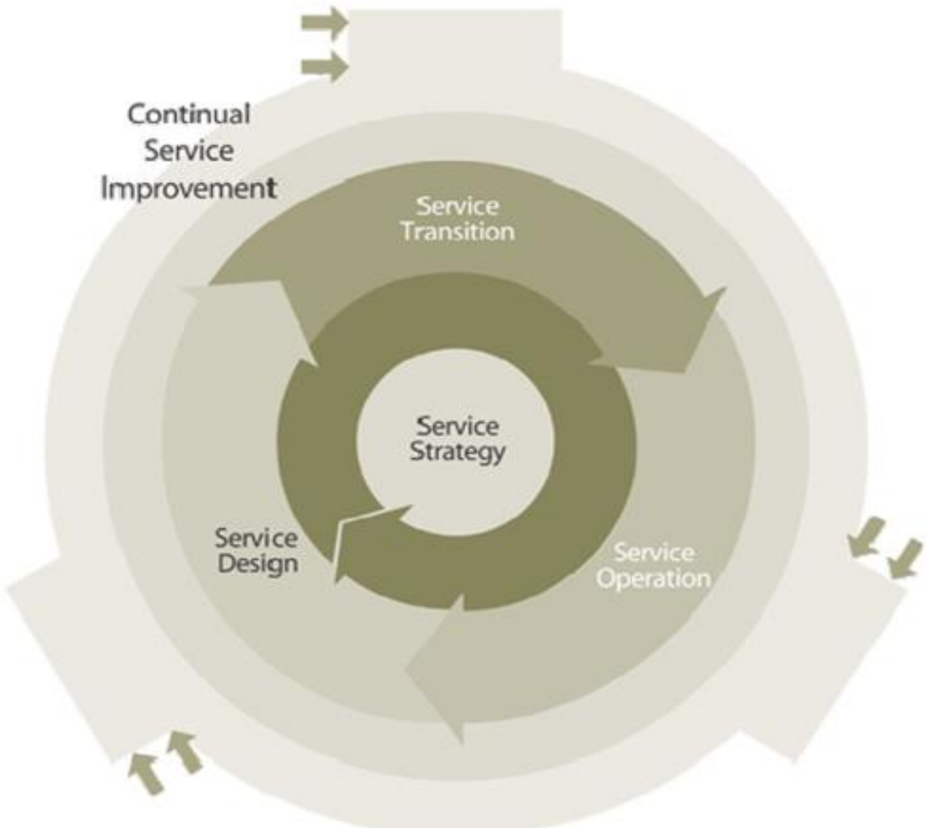


Figure 6. The ITIL Service Lifecycle *(Taylor 2007, p.11)*

According to the ITIL Service Lifecycle model (see Figure 6), the first step after deciding the service strategy is to identify cloud-based services that best meet the chosen service strategy. Therefore, the cloud has created a role for the cloud architects to select suitable services and transform local systems into cloud-based services. These roles should provide a liaison link between the technical and non-technical staff within an organisation. Usually, they do not require deep technical skills, rather it is more appropriate to have a combination of business and basic technical knowledge that could enable enterprises to design business processes focused on the cloud environment.

The cloud architect will need to work side by side with product and engineering managers to develop an optimised cloud-based solution to meet business requirement (McKendrick 2012). Once the strategy has been in place and the service is identified, the next two steps of the service life cycle would be the Transition and then Service operation. Configuration management and monitoring roles such as access management and analysing incidents are important which should be considered during these phases to ensure that services are delivered on the levels of service defined in the Service Level Agreement (SLA). Finally, the continual service improvement phase that enhances the strength of customers and service provider's relationship by continual evaluation and improvement is an important phase to ensure the successful management of services. Roles in this phase should include analytical modelling, the assessment of strategies achievement, and the measurement of service provider's performance.

2.11.2.1 The rising need for integration roles

Enterprises are likely to have at least initially, a hybrid of cloud and in-houses systems, resulting in the emergence of roles that require the development of expertise to provide integration mechanisms between cloud services and on-promises systems. Moreover, in some cases enterprises need to combine a range of cloud services from different cloud providers to achieve maximum efficiencies. These require staff with relevant expertise assess integration, develop cloud-to-cloud and cloud-to-local integration as well as cloud integration management. Further, the integration roles require the development of relevant skills such as business processes, data management, data analysis, business architecture, and SOA.

Johnston and Mahowald in IDC (2011) identified five steps to achieve a successful integrated cloud management based on a survey of group of systems integrating engineers with the cloud. They are:

- define a plan that coordinates the organisation's application modernisation strategy;

- Assess current costs and develop benchmarks for application support, provisioning, and on-going resource consumption;

- Identify opportunities to reduce costs and speed up service delivery via use of automation for integrated application and infrastructure provisioning;

- Implement systems to monitor and integrate application performance and real-time capacity planning analytics with automated provisioning solutions;

- Integrate security strategies and priorities across the application development, release, and operations life cycle of cloud integration than in an "on-premise-only" scenario.

The steps can enable faster application provisioning, actively integrating and automating application development, security, lowering application development and maintenance costs. This will improve business agility, provision of higher service levels, and also improve business and IT relationships.

2.11.2.2 Growing demand for cloud business alliance

Cloud computing is changing the relationship between business and IT. A survey conducted by Gartner (Mateo 2013) revealed that alongside faster application deployment, aligning IT to business goals has been found as the highest priority for enterprises in 2013. This signifies the emerging need for aligning cloud provisions to business strategies. Fry (2010) indicated that "adopting an external cloud is a business decision, not just an IT directive". IT managers and business executives need to identify business requirements that enable enterprises to lay out a roadmap of implementing cloud services and ensure satisfaction of business leaders of cloud services. Beveridge (2004) stated that cloud-business strategy alignment will enhance: productivity, workflow and business communication, risk control, implementation of innovative strategies, and also the ability to gain competitive advantage.

Aligning the cloud with business strategy requires IT managers to develop essential business skills. They should start by developing an understanding of their enterprise's business and operation models. They should also develop knowledge of existing and evolving business processes and operations, growing requirements of customers and personnel, and the potential of innovative ecosystems that could erode the core business. It is also essential to develop assessment skills in order to identify appropriate cloud providers and to identify the right cloud services for business processes. Such expertise would reduce the difficulties of aligning cloud services to business requirements and goals (McKendrick et al. 2012).

2.12 Conclusion

This chapter discussed the technological and business aspects related the migration to cloud computing. This included the evolution of computing systems from the early generation of mainframes to cloud computing. Cloud computing' essential characteristics, service models, deployment models, and architecture were briefly discussed. Related technological paradigms were also reviewed including grid, utility, cluster as well as visualisation and multi tenancy. The concepts of SOA and cloud computing was then briefly elaborated. A number of advantages and issues affecting the adoption and growth of cloud computing were discussed and specific attention was paid to the issues of security and vendor-lock-in. It also discussed business aspects related to cloud computing, including evolution of outsourcing, business advantages, as well as impacts of using cloud services.

The analysis in this chapter shows that cloud computing has been perceived by many as a valuable opportunity for enterprises for its business benefits. Business agility and cost was found in the literature to be the main reasons that encourages organisations to migrate to cloud computing. However, the analysis of the technical aspects shows that cloud computing is still at an early stage of maturity and it could be a high risk to implement. In order to increase the adoption of cloud service security, data privacy and interpretability standards need to be improved. The security challenge for cloud service provision requires the design of a service were security risks are reduced as well as ensuring compliance with regulators. Further, implementing a standardised framework for cloud services will support seamless cloud service integration between different vendors. This would allow cloud users to switch from one provider to another. The analysis showed also an impact of cloud computing on IT management. Cloud services have increased the efficiency of acquiring IT resources. Cloud computing has reconfigured how IT systems are deployed, managed and implemented. Cloud computing has been increasingly accelerating the transformation from IT-based products to cloud-based business-oriented services. This chapter identified a number of roles and expertise that are needed as a result of migrating to the cloud. The findings in this chapter, particularly the issues and concerns on migration, enabled the researcher to define themes in which the empirical data collection is based on. Further, the issues and concerns identified in the literature are taken in account in the proposed model that will be discussed in chapter 6. The next chapter discusses the decision making aspects for cloud migration.

Chapter 3 Decision support for cloud migration

3.1 Introduction

This part of the literature review discusses the theoretical foundations of managerial decision making as well as Decision Support Systems (DSSs). It first identifies the types and levels of management decisions. It then discusses the role of data, information and knowledge in decision making followed by a review of the decision making process model developed by Simon (1977). Simon's model provides a systematic process that is considered as a revolution in decision making, which is a major contribution to management science, economics, computer science, and artificial intelligence (Campitelli and Gobet 2010). The discussion then moves to the concept of the DSS, its evolution, and types. Subsequently, it summarizes the current situation with regards to the existing DSS designed to aid cloud migration decision. Finally, an analysis of three models to support the process of migration to the cloud is provided. The analysis of the literature in this chapter is needed in this research to determine how decisions are made, which may inform cloud migration decisions, by identifying the level of support required to ensure informed and systematic decisions.

3.2 Decision making

For more than half a century economists, psychologists, operations researchers and management scientists have investigated the growing complexity of decision making situations from various perspectives (Power and Sharda 2007). Decision making is a central organisational activity that is necessary for coordinating various activities at different levels of an organisation (Simon 1997). Decision making is often referred to as the core of the management process (Mann 1976). Decisions should be made that define the way in which business processes are performed and evaluated. Standards should be created to measure and compare the performance of business processes (March and Hevner 2007). Harris (1980) provides two standard definitions of decision making:

> "The study of identifying and choosing alternatives based on the values and preference of the decision maker. Making a decision implies that there are alternative choices to be considered, and in such a case we want not only to identify as many of these alternative as possible but to choose the one that best fits with our goals, desire, lifestyle, values and so on".

> "The process of sufficiently reducing uncertainty and doubt about alternatives to allow a reasonable choice to be made from among them. This definition stresses the information gathering function of decision making. It should be noted here that uncertainty is reduced rather than eliminated. Very few decisions are made with absolute certainty because complete knowledge about all the alternatives is seldom possible. Thus, every decision involves a certain amount of risk."

3.2.1 Theoretical foundation

Decision making are emphasised as rational processes by classical theories of choice. They are based upon expectations about the consequences of action for prior objectives, and organisational forms as instruments for making those choices (Dillon 1998). These views on decision making, referred to as normative views, are also known as rational theories of decision making (Oliveira 2007). They are based on fundamental axioms. If these established principles can be accepted, then it is possible to derive a normative theory of choice (Oliveira 2007). However, considering decision making as a rational process has been criticised by many scholars, including Simon (1976), March (1994), and Langley et al. (1995). The main reason for those criticisms is that the reality of making strategic decisions is far from what classical decision theory prescribes. Simon (1976) states that rationality is an ideal state that cannot be reached by human beings:

> "The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectively rational behaviour in the real world - or even for a reasonable approximation to such objective rationality."

Normative theories have been refined, in order to provide better description of decision making; see for example: prospect theory and subjective expected utility (Dillon 1998). Simon (1957) proposed bounded theory as an alternative for modelling decision making. Humans can be rational only to a certain extent and rationality is limited by constraints in the environment that include the information they have, the cognitive limitations of their minds, cost, and the time available to make the decision. This is because it is not always possible to define goals, and it is impossible to consider all alternatives and to evaluate all probable consequences. In addition, there are costs associated with collecting, analysing and interpreting information. The complexity of reality exceeds the human capacity to process information (Simon 1957). The work of Simon highlights the role that information processing and decision making serves as a driving force for further research on organisational decision making and behavioural decision theory.

On the other hand, descriptive theories highlight the importance of psychological factors that influence the way in which a final choice is reached (Oliveira 2007). Organisational theorists have also documented other approaches to decision making, such as judgement, intuition and negotiations (Shollo 2013) which are used by decision makers instead of the rational approach. These models rely on experience, beliefs, and unconscious automatic processing of a situation for making decisions. Proponents of these models have remarked that decision-makers do not use entirely rational information processes (Shollo 2013).

In respect of decisions that involve risks, it was assumed that people are risk averse (they always choose the least risky option) (Beresford and Sloper 2008). However, according to the prospect theory, people are both risk averse and risk seeking and that depends on the way in which the options are presented or perceived (Beresford and Sloper 2008). When faced with a decision problem, individuals form a mental representation of the problem (see Figure 7):

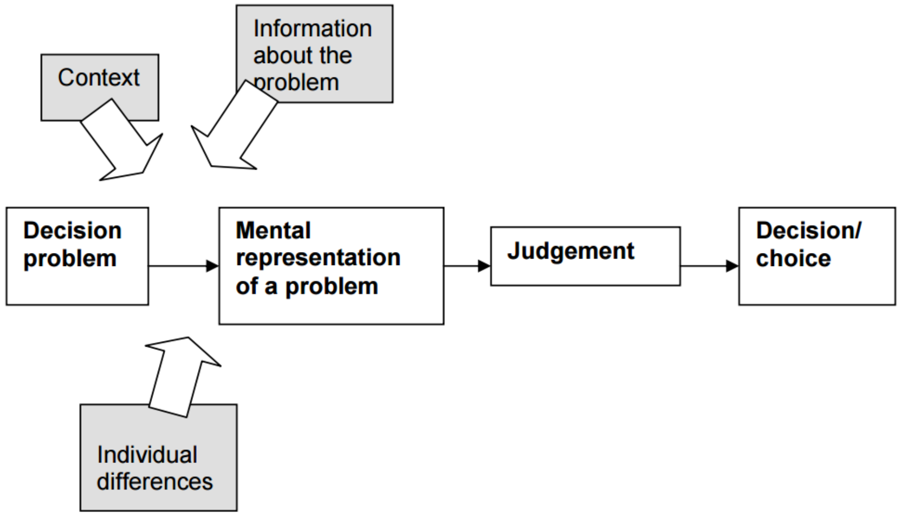


Figure 7. Mental representation in judgment and decision- making (Beresford and Sloper 2008, p.17)

The mental model of a problem includes information about the decision problem and its context. Decisions or choices made of the same decision problem will vary between individuals and within different contexts because of the differences among people in the way information can be perceived, organised and interpreted, and the differences in context (Beresford and Sloper 2008)

> "The implication of a personal and situation specific mental model is that two individuals who might be presented with the same problem stimulus might actually be solving different 'mental' problems." (Beresford and Sloper 2008, p.17)

3.2.2 Types of decisions problems

Simon (1977) suggested that there are two main types of decision problems: programmed and non-programmed. In programmed decisions, the procedures to follow when a decision is required can be specified in advance. They are structured, routine, repetitive, which can be easily solved because standard solution methods exist, and the complete automation of their solution may be feasible. In non-programmed decisions, it is not usually possible to specify in advance of the decision procedures to be followed. They are new, novel, ill-structured, have no standard solutions, are difficult to solve, rely on judgement, and automation is usually infeasible.

Turban (2007) extended this classification with structured, unstructured, and semi-structured, as shown in the Figure 8. Structured problems are those that involve goals that are clear, familiar, and for which complete information about the problem is available. Unstructured problems are those that are new or unusual, for which information is ambiguous or incomplete, and which require custom-made solutions. Semi-structured decisions can be pre-specified but not enough to lead to a certain recommended decision. The decisions involved in migration to cloud computing usually fall into the category of semi-structured or unstructured decision types because of the complexity of the decision that is influenced by a number of inconsistent criteria such as cost and quality of services (Saripalli and Pingali 2011). The complexity of cloud migration decisions will be discussed further in 5.4.1.

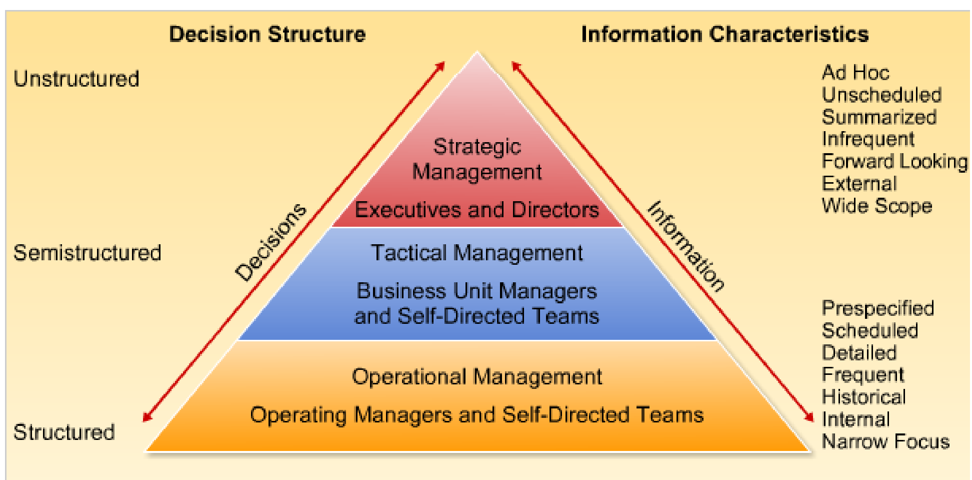


Figure 8. Levels of Management in Relation to Decision Problem Types (O'Brien 2011)

3.2.3 Organisational decision hierarchy

O'Brien (2011) defined three levels of management decision making: Strategic management, Tactical management, and Operational management as shown in Figure 9. Strategic management includes the planning processes adopted by top executives to develop the overall organisational goals, strategies, and policies. This level also includes the continuous monitoring of strategic organisational performance and the overall direction within the competitive business environment. The roles in the tactical management level include developing short-range plans, schedules, budgets, procedures, and business objectives for an organisation's sub-units. This level also includes resource allocation and monitoring of the performance of the sub-units, including departments, process teams, project teams, and other workgroups. Operational management roles comprise the development of short-range plans (such as weekly production schedules), and perform tasks according to the prescribed procedures and ensuring they are within budget.

The type of information required by decision makers in an organisation depends on the level of management decision making and the level of the decision structure (O'Brien 2011). Decision makers need information that has characteristics of the three dimensions of time (timelessness, currency, frequency, and time period), content (accuracy, relevance, completeness, conciseness, scope, and performance), and form (clarity, details, order, presentations, and media) (O'Brien 2011).

In addition, there are three vital roles that information systems can perform for a business enterprise: support of business processes and operations, support of decision making by employees and managers, and support of strategies for competitive advantage (see Figure 9) (O'Brien 2011). However, the focus of this thesis is the support of managerial decision making through decision support systems.

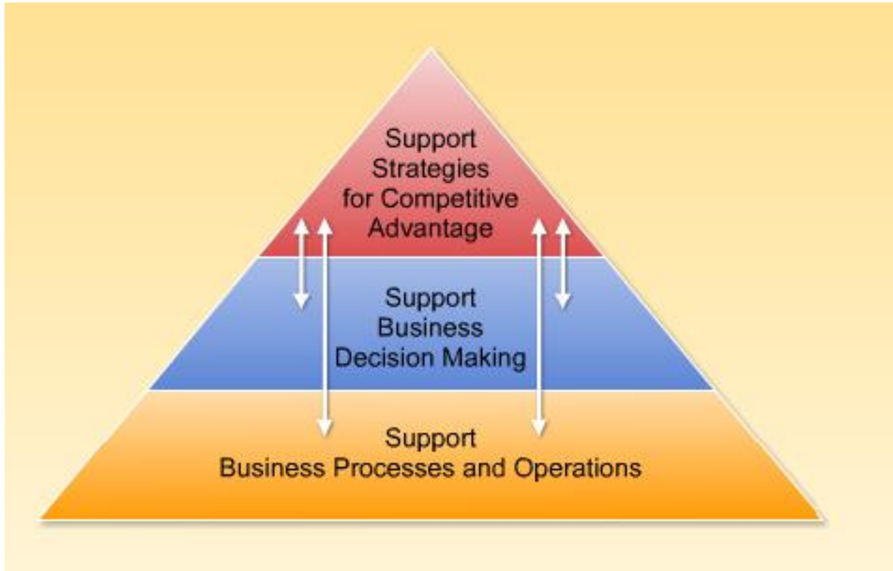


Figure 9. Levels of management decision making (O'Brien 2011)

3.2.4 The role of data, information, and knowledge in decision making

Data, information, and knowledge are fundamental requirements of, and have interrelated roles in, decision making (French et al. 2009). Understanding the roles and effects of data, information and knowledge on the decision making process is essential if we are to differentiate their characteristics and their impact during that process (French et al. 2009).

The distinction between data, information, and knowledge has been discussed within the database and information systems communities for many years, although clear distinctions are only infrequently made (French et al. 2009; Aamodt and Nygård 1995). A possible reason for this is that several perspectives easily get confused in discussions about definitions of concepts that are polymorphic (Aamodt and Nygård 1995). A polymorphic concept is a concept which cannot be defined by a classical definition; that is, as a set of necessary and sufficient features that are universally valid (Aamodt and Nygård 1995). A typical example of a polymorphic concept is a 'car'. Such a concept has complex definitions, or it has many definitions depending on the context of interpretation. For example, unlike geometrical objects such as circles and triangles, that have precise classical definitions, a car has different concepts for a mechanical engineer than it has for a logistics planner or for an environment protection activist. This example is similar to the complex concepts of data, information, and knowledge (Aamodt and Nygård 1995). In order to acquire the meaning of a polymorphic (non-classical) concept, it has to be understood within a specific context (Compton and Jansen 1989). Therefore, it is not surprising that the definition of information varies depending on whether it is defined within, for example, electrical signal theory, library science, database theory, or decision making (Aamodt and Nygård 1995).

Aamodt and Nygård (1995) defined the concepts of data, information, and knowledge in the context of the decision-making process as follows:

- Data are patterns with no meaning; they are input to an interpretation process; in other words, to the initial step of decision making.

- Information is data with meaning; it is the output from data interpretation as well as the input to, and output from, the knowledge-based process of decision making.

- Knowledge is information incorporated in an agent's reasoning resources, and made ready for active use within a decision process; it is the output of a learning process.

This definition is consistent with the idea that 'information is data which is used in decision-making', but goes beyond this 'standard' definition since it links the use of data to the underlying interpretation process that enables this use. Knowledge is what is needed in order to perform the interpretation, and what is learned from new information. Knowledge may be viewed as (a) a state of mind, (b) an object, (c) a process, (d) a condition of having access to information, or (e) a capability (Alavi and Leidner 2011). The role of knowledge, in general, is therefore to play the active part in the processes of transforming data into information, deriving other information, and acquiring new (Aamodt and Nygård 1995).

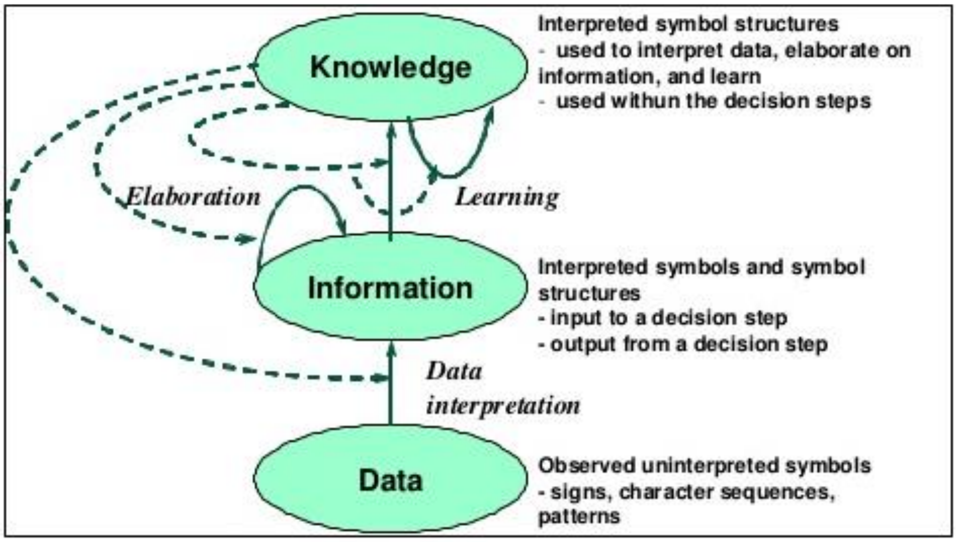


Figure 10. The Data, Information, Knowledge model (Aamodt and Nygård 1995, p.8)

The roles of data, information, and knowledge during a decision making process are interrelated (French et al. 2009). Data are characters, signals, patterns, signs, that have no meaning. Therefore, they do not provide sufficient input to a decision making. Decision makers need to understand the meaning of data within a specific context to make it useful information for decision making. Data become information after being interpreted to give meanings as shown in Figure 10 by the data interpretation arrow. After interpreting the data as information (an initial interpretation), it is elaborated upon for better understanding and to derive (infer) new information. Information is a necessary input for decision making processes; however, the decision maker requires knowledge for both the process of creating information and the decision making process itself (Aamodt and Nygård 1995). Knowledge provides the perceptual and conceptual filters required to firstly select and organise data into information that can be used to support decisions (Boisot 1998). The information can then be used to formulate an adequate understanding of the decision problem being faced.

3.2.5 Multiple criteria decision making

Multiple criteria decision making (MCDM) refers to the making of decisions that have multiple and usually conflicting criteria (Xu and Yang 2001). MCDM problems are common in many situations, including personal and business contexts. In the personal context, for example, the decision to buy a house or a car may be characterised in terms of price, size, style, safety, and comfort. In the business context, MCDM problems are more complicated and usually large in scale. For example, purchasing departments often need to evaluate a wide range of suppliers' criteria, such as after sale service, financial stability, and quality management. MCDM problems are of two distinct types. The first has a finite number of alternatives, and is more common in problems that involve the need for selection and assessment. The other has an infinite number of alternatives, and this kind is common in design problems (Xu and Yang 2001).

Although MCDM problems can be different, depending on the context, they share some common features (Xu and Yang 2001). MCDM usually form a hierarchy of attributes that maybe divided into further lower levels of attributes, called sub-attributes. The multiple criteria are often in conflict with each other, hybrid in nature, (qualitative and quantitative attributes, and deterministic and probabilistic attributes), involve uncertainty due to lack of information about some attributes, and are large in scale. For example, the business excellence model of the European Foundation for Quality Management has three levels, 9 criteria in level 1, 32 in level 2, and 174 in level 3 (Xu and Yang 2001).

According to Hwang and Yoon (1981), there are two main types of MCDM methods: compensatory and non-compensatory (cited by Xu and Yang 2001). The first allow trade-offs between attributes. A slight decline in some of the attributes may be accepted if it is compensated for by some augmentation in the others. Compensatory methods have four classifications: scoring methods, compromising methods, concordance methods, and the evidential reasoning approach. Scoring methods select or evaluate an alternative based on its score by transforming attribute values into a common preference scale, such as [0,1]. The non-compensatory methods do not allow trade-offs between attributes. Each attribute must be evaluated separately and, unlike the compensatory approach, a favourable value in an attribute cannot offset an unfavourable value in others.

The Analytic Hierarchy Process (AHP) is a decision support tool that can be used to aid solving problems of multi-criteria decision. AHP calculates the scores for each alternative based on pairwise comparisons (Saaty 1988). These comparisons are applied to acquire the weights of importance of the decision criteria and the relative performance measures of the alternatives (Triantaphyllou and Mann 1995). AHP is widely accepted and is considered to be the most reliable MCDM method by many researchers (Triantaphyllou and Mann 1995).

In order to make a decision in an organised manner and to generate priorities, decisions need to be decomposed into four steps (Saaty 2008). First, define the problem and determine the kind of knowledge required. Second, structure the decision hierarchy, starting from the goal at the top, then the objectives, the intermediate levels (criteria on which subsequent elements depend) and finally the lowest level (which usually is a set of alternatives). Third, construct a set of pairwise comparison matrices. Fourth, use the priorities obtained from the comparisons to weight the priorities in the level below. These steps are to be performed for each element. Then for every element in the level below add its weighted values and obtain its overall or global priority. The process of weighting and adding continues until the final priorities of the alternatives in the bottom level are obtained (Saaty 2008). Table 5 illustrates advantages and disadvantages of AHP method:

Table 5. AHP advantages and disadvantages adapted from Oguzitimur (2011)

Advantages	Disadvantages
• Simple and flexible model for certain problems	• There is not always a solution to the linear equations
• An easy methodology that aids decision-makers with their judgment	• The computational requirement is significant even for a small problem
• Quantitative or qualitative information can be included during the decision process	• It allows only triangular fuzzy numbers to be used
• Different details about a problem can be structured	• It is based on both probability and possibility measures
• Wide range of usage such as: planning, effectiveness, benefit and risk analysis, choosing any kind of decision among alternatives	• Rank reversal fact should be considered carefully during the application.
• The problem can be evaluated from different aspects	• The subjective nature of the modelling process is a constraint. The methodology cannot guarantee the decisions made as definitely true.
• The elasticity of the final decision can be analysed by applying sensitivity analysis	• If the number of the levels in the hierarchy increase, the number of pair comparisons also increase, which takes much time and effort
• It allows measuring the consistency of decision maker's judgments	
• It can be applied by computer software that h	

3.3 Decision making process

Since Simon (1976) disapproval of the validity of the rational model of decision-making, many researchers and theoreticians in management science were trying to define and develop a feasible decision making process that can be applicable in real life (Nooraie 2002). Donnelly et al. (1998) pointed out that many approaches to the decision making process were developed and their suitabilities depend upon the nature of the problem, the availability of resources, decision-makers' characteristics, cost, time pressure and others factors (cited by Al-Tarawneh 2012). The decision making process has emerged as one of the most active areas of current management research (Nooraie 2002).

According to Simon (1997), the context of organisational decision situations and bounded rationality of individuals demand following a structured process in organisational decision making. In his suggested model of organisational decision making process he divides it into three major phases: Intelligence, Design, and Choice (see Figure 11). A fourth phase 'implementation' was added later, and monitoring could be considered as a fifth phase as well. However, according to (Turban et al. 2001) monitoring can be viewed as the intelligence phase applied to the implementation phase.

The process starts with the intelligence phase where the 'reality' of the organisation is examined. It involves problem identification and information gathering activities about the societal, the competitive, and the organisational environments. In the design phase, a model that represents the organisation's operational systems is constructed. It simplifies the organisation's "reality" and identifies relationships between variables, as well as setting the criteria for evaluating alternative courses of action. For decisions that involve risks, decision makers must consider the possible outcomes for each alternative with a given probability of occurrence. The choice phase is to select the most appropriate alternative course of action based on the criteria identified in the design phase. It includes searching for alternatives, evaluation, and then makes a recommendation of an appropriate solution to the model proposed in the design phase. Although the phases of Simon's decision making process model are performed in a sequential manner, in that the intelligence phase is usually carried out first then the design phase, and then the choice phase, the overall process might be more complex than this sequence. Within each phase of the decision making process there might be a need to call on aspects of the other two phases before moving to the next phase within the overall decision making process. In these kind of situations the overall decision making process form a series of interdependent sub-processes, for example, the design phase may require some intelligence and choice activities; forming a sub-problem that has its intelligence, design and choice phases. Finally the chosen solution is implemented. Successful implementation results in the delivery of the required values to meet the organisation's strategic vision. Failure requires a return to an earlier phase of the process. Figure 11 shows this decision making process model.

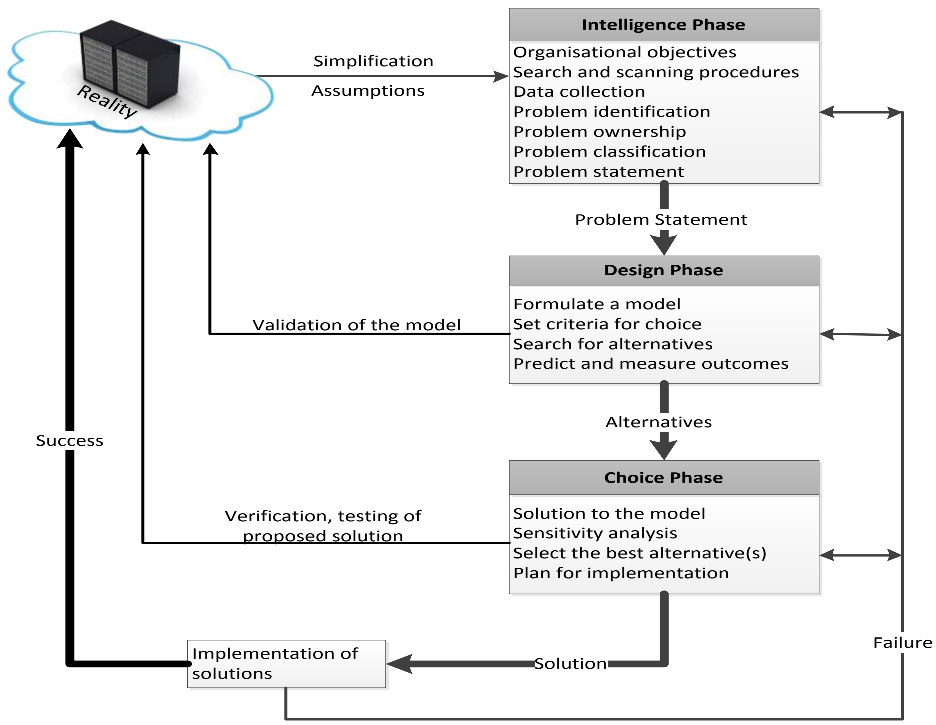


Figure 11. Decision making process Simon (1977)

3.3.1 Intelligence phase

In the current business market that includes more complex organisations, multinational influences, and rapid transmission of information, business agility has become essential for enhancing commercial success (Sahandi et al. 2013). The ability to quickly identify and evaluate problems and opportunity in the current dynamic environment is crucial for organisations (Sauter 2005). Enterprises should identify the changing landscapes, such as new competitors, suppliers, services as well as trends and how they can be exploited.

The main activities during the intelligence phase of Simon's model are problem identification, classification, and decomposition (Turban et al. 2007). Problem identification is the activity of identifying potential issues of concern and defining its relation to the organisational objectives. It requires a process of collecting and organising information. The process includes four essential activities: monitoring the environment, capturing essential measures of activates, organising the measures, and presenting the information in a way that can aid decision makers. This process can be called the competitiveness intelligence (Sauter 2005). The monitoring activity is to enable enterprises answering questions related to environmental factors and competitiveness. The basic level of this activity is to read trade journals, and white papers. In the case of dynamic markets, the information collected from the monitoring activity need to be contextualised to the specific environment, time, and location. Then, this information must be organised and digested, and must be presented in a way that aid decision makers to detect and response to changes in the environment before competitors. This information should be available to management when needed. According to (Sauter 2005) decision makers need answers to the following:

- What are competitors, customers, and suppliers doing and how will it affect business?
- What are the current trends in the marketplace?
- What strategies will aid decision makers to capitalise on those trends?
- What should companies do to compete effectively during the next five years?
- What does the sales force know that headquarters decision makers do not know?

- How would this exchange of pertinent information affect business decision making?

Decision makers need to determine whether a problem requiring a decision exists, identify its magnitude and potential implications, and then explicitly define the problem (Turban et al 2001). Turban et al (2001) identified a number of issues during the stage of monitoring and analysing the needed information. They include: obtaining data may be expensive, information are not available, subjectivity of estimating trends, information overload, and data may be qualitative.

Problem classification is to conceptualise the decision problem, in order to allocate it in a definable category. This can lead to a standard solution for similar decision problems. Problem decomposition is the dividing of complex problems into smaller sub-problems. Successful decomposition may allow focus to be placed on solving the interrelated and structured sub-problems. It may help in incorporating quantitative and qualitative factors and facilitate effective communication between decision makers (Turban et al. 2001).

In the context of IT outsourcing, according to Shoeib (2000), the intelligence phase for IT outsourcing decisions should consider the following:

- Organisational needs and circumstances. These include the use of IT to improve productivity, quality of service, and products, and to develop an appropriate IT architecture.

- The IT function. It includes two main areas: IT support and IT staffing. The first should consider among other things, IT responsiveness and processing request for system changes. The second should consider the quality and competence of IT staff and their relationship with end users.

- The IT outsourcing phenomenon. This should be studied by reading on the subject, learning from other companies' experiences, and gaining advice from outsourcing consultants.

Three main recommendations identified by Sauter (2005) to support the intelligence phase in Simons' model. (a) Combine the broadest possible experiences prior to encouraging decision makers to apply their judgement to a choice process; (b) make the process easy; (c) get information to the people who can use it at the time of the earliest warning signals.

3.3.2 Design phase

The design phase includes developing and analysing the likely courses of actions (Turban et al. 2001). It includes the understanding of the problem and testing solutions for feasibility.

The main activities during the service design phase include model formulation. In other words, it is a conceptualisation of the problem and its abstraction into an appropriate quantitative or qualitative form or a combination of both (Turban et al. 2001). It also defined by Sauter (2002) as a generalised description of a decision environment. The purpose of model formulation is to simplify a phenomenon in order to understand its behaviour, choice criteria, potential risks, and alternatives (Turban et al. 2001). The Model describes the relevant part of the system and the decision problem based on the perceived simplified reality. For many standard problems there are standard classes of models available that provide the basis for model formulation.

For IT outsourcing projects, this phase should evaluate technical, operational, and economic criteria. This analysis should reveal whether or not the IT align with the objectives of the organisation and are operating effectively and efficiently Shoeib (2000).

3.3.3 Choice phase

The choice phase is the one in which the actual decision and the commitment to follow a certain course of action are made (Turban et al. 2007). The activities in the choice phase include the search for evaluation of and recommendation of an appropriate solution to the model developed in the design phase. A solution to the model does not necessarily mean a solution to the decision problem that the model represents. It provides a recommendation solution alternative to the decision problem, and it can be considered as a solution to the decision problem only if the recommended alternative solution is successfully implemented (Turban et al. 2011).

There is increasing agreement that decision processes should not be a matter of simple choice (Langley et al. 1995), and that the role of information (intelligence level) and construction of potential alternatives are essential. Sauter (2005) stated that the use of intuition solely is not sufficient to drive decision making, instead systematic support regarding external information is needed even when the data required is qualitative in nature. The role of information is particularly fundamental in the first two phases of a decision making process because alternatives can only be chosen where there is sufficient and documented information about the available options. Information acts as a constraint on decision making. The lack of considering the role of information has been a source of discussion for many of the existing DSSs, because many designers place emphasis on the models they build into their systems, rather than on the significance of the information fed into them (Diniz et al. 2008).

3.3.4 Advantages and drawbacks of Simon's model

The model was designed to ensure a systematic process to address decisions that are highly unstructured, complex, involve risks and would have an impact on the future of organisations. It has been widely accepted and adopted as a problem-solving model (Liu et al. 2010). Turban et al. (2001) described Simon's model as the most concise, and yet complete characterisation of rational decision making. Moreover, in the literature of knowledge management systems, only Simon's decision making model provided some guidance on the relevant characteristics to build a systematic decision support system (Sauter 2005). Moreover, applying this model can result in a number of advantages. It can reduce the chance of errors, risks associated with uncertainties, assumptions, and subjectivity of choice (Beresford and Sloper 2008).

However, this model has limitations in terms of its application in the business environment. The business environment is sometimes very dynamic that could confuse decision makers. This may result in the needed information is not always available to decision makers. This problem can cause difficulties in evaluating decision context even defining the problem (Zhang 2008). Another drawback of applying this model in the business environment is time. In the current fast paced business environment, time is crucial. Applying this model may require a long time of observation, collection and analysis of information, model formulation, and evaluation of alternatives, making this model inappropriate for quick decisions. Further, the consideration of the decision context is a critical factor in decision making processes (Hall 2008). Simon's model is generic that concentrates on the process stages of decisions rather than their contexts. This could be another limitation for applying this model in the business environment.

3.4 Decision support systems

Decision making for complex problems usually requires vast amount of information gathering, efforts, model building, collaboration, evaluation of alternatives, sensitivity analysis and decision implementation (Bhargava et al. 2007). The complexity can be reduced through the availability of a Decision Support System (DSS). A DSS is:

> "An interactive, flexible, and adaptable computer-based information system, developed especially for better decision making as it supports the solution of a non-structured management problem. It utilises data which provides an easy-to-use interface, and allows for the decision maker's own insights" (Turban et al. 2005).

DSSs can provide focuses on support for improving managerial decision-making, and can be concerned with developing and deploying information systems that assist with the making of those decisions (Arnott and Pervan 2005). They have been an important area of IS practice and scholarship since first introduced in the 1970s (Arnott and Pervan 2008). DSSs can provide varying analysis to non-technical managers. Managers' main uses of DSSs may include searching, retrieving and analysing data and information to assist in summarising main points that aid in more informed decisions (Sauter 2002). DSSs usually provide graphic capabilities that allow trend's analysis and reports. They also assist managers in combining analysis for alternative scenarios that answer 'what if' queries (Sauter 2002). Therefore, DSSs can support tactical and strategic decisions and can be used to leverage manager's expertise. Figure 12 shows the relationship between DSSs and other information systems.

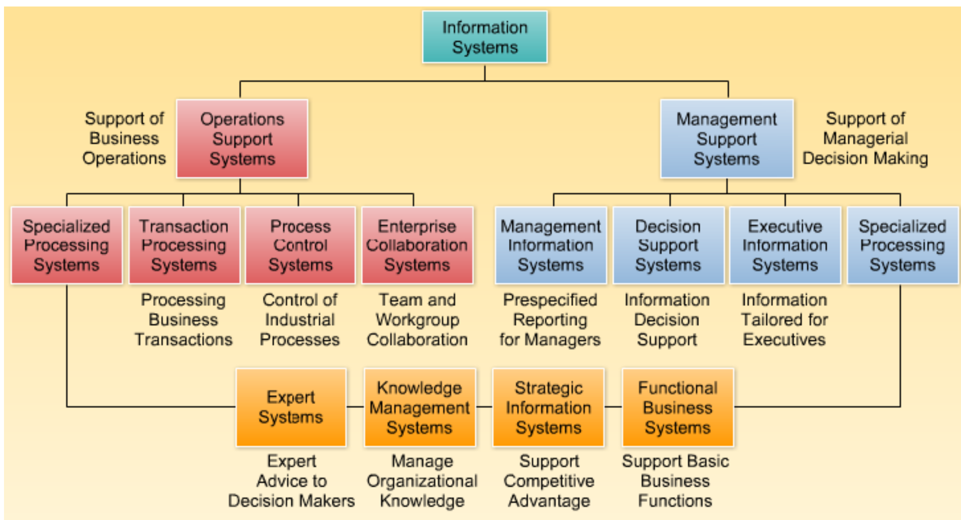


Figure 12. DSS relationship with other information systems (O'Brien 2011)

3.4.1 The evolution of DSSs

The first generation of information systems (in the 1960s) were developed to computerise business operations such as order processing, billing, and payroll (Haigh 2006). The main role of management information systems (MIS) was to provide information to management to help with decision making. However, this information was usually extensive, inflexible, and provided little valuable management information (Kautish and Thapliyal 2012). The term 'decision support systems', which first appeared in academia in 1971, was developed by Gorry and Scott Morton who developed a framework for improving management information systems (Power 2008). The framework integrated the categories of managerial activities and the classification of decision problem types developed by Simon (1977) (Courtney 2001). Table 6 shows an example of Gorry and Scott's decision types:

Table 6. An example of Gorry and Scott's decision types (Courtney 2001, p.18)

	Strategic Planning	Management Control	Operational Control
Unstructured	E-commerce	Career paths	Grievances
Semi-structured	Forecasting	Budgeting	Assignments
Structured	Dividends	Purchasing	Billing

The aim of the early generations of DSS was to create an environment that allowed decision makers and IT-based systems to work together in an interactive manner (Power 2008). The information system assists in solving problems by automating the structured components of the decision situation. The emphasis in this process was not to provide an application that solves the problem, but rather to improve the effectiveness of the decision maker.

Figure 13 shows the evolution of DSSs from its beginnings (computer-based information systems and management science) to a complex disciplinary structure of partially connected sub-fields. The decades shown on the left side of Figure 13 refer only to the DSS types and not to the disciplines. The development of the information technology is the main reason for the evolution of DSSs. They developed from personal DSSs that support individual managers on one task to group DSSs that support multiple individuals involved in a decision making process. Artificial intelligence techniques have been then embedded resulting in the appearance of intelligence DSS.

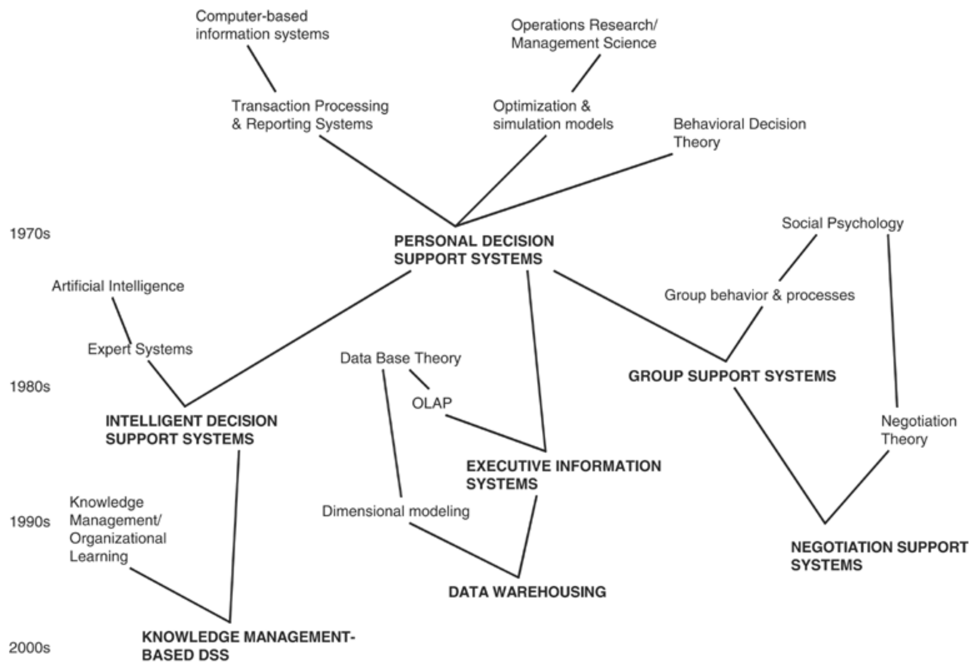


Figure 13. The evolution of the Decision Support Systems field (Arnott and Pervan 2005, p.6)

3.4.2 DSS applications development

During the past few decades, many types of decision support systems have been developed to meet the different requirements of decision makers. The following are the common types of DSS.

Model-driven DSSs

Model-driven DSSs are designed to allow a user to access and manipulate model parameters in order to examine the sensitivity of outputs or to conduct a more ad hoc 'what if' analysis (Power 2008). Two main characteristics differentiate a model-driven DSS: (a) through an easy to use interface, it can be accessed by non-technical specialists such as managers; (b) it is envisioned that it will be used repeatedly in the same or similar decision situations. The types of quantitative model used in model-driven DSSs include: algebraic and differential equation models; analytical hierarchy processes; decision matrix and decision tree, multi-attribute and multi-criteria models;

forecasting models; network and optimisation models; and quantitative behavioural models for multi-agent simulations. They should provide decision makers with a simplified and understandable representation of a decision. Generally, large databases are not required in model-driven DSSs (Power 2002).

Data-driven DSSs

The purpose of a data-driven DSS is to enable access and manipulation of internal and external real-time data (Power 2008). This kind of DSS provides a wide range of functionality, ranging from simple query to data manipulation through the use of computerised tools that are tailored to a specific task. It provides decision support that is important for the analysis of large collections of historical data.

Knowledge-driven DSSs

Knowledge-based Decision Support Systems (KBDSS) can be defined as computer information systems that support the making of effective decisions in complex and ill structured problem domains, by assisting with knowledge storage and retrieval, the interpretation of various alternatives, and providing methodological knowledge by using analytical decision models (Klein and Methlie 1995). Knowledge-driven DSSs can suggest actions to managers. These DSSs include human-computer interactions to provide specialised problem-solving expertise. The ‘expertise’ consists of knowledge about a particular domain, understanding of problems within that domain, and ‘skill’ at solving some of these problems (Power 2002).

Managerial productivity is considered to be a function of the time spent retrieving information, generating value added information and finding problems in the intelligence phase, and developing alternative solutions in the design phase of decision making (Raman and Phoon 1990). This can be addressed through the development of an effective KBDSS, because it reduces the time required for this process. Nonetheless, it is necessary to understand that the KBDSS is not designed to make decisions on behalf of users; rather it provides relevant information in an efficient and easy-to-access format that allows users to make more informed decisions (Supriadi 2014).

The success of knowledge-based systems usually depends upon their ability to represent the knowledge they possess for a particular subject (Fischer and Kunz 1995). This requires mechanisms that provide information and experiences. It requires construction of an explicit information repository, codification of information, and the selective routing of that codified information to decision makers (Parlby 1998).

Knowledge-based systems may be the solutions to: whether an organisation can obtain the right information for the right people in the right form at the right time (Sauter 2005). The likely advantages of knowledge-based systems include: improve the quickness and quality of responses to events, improved acquisition of resources, and enhanced control of strategic planning. On the other hand, the implementation of knowledge management systems are difficult and also only very few guidance exist (Sauter 2005). This is mainly because of the ambiguity associated with the implementation technique and the fact that knowledge systems are more of processes to follow rather than systems of specific procedures (Oxbrow 1998). Further, the cost of developing knowledge systems is usually high. Organisations may avoid the high cost by leveraging existing technologies and mechanisms for the collection of data and information (Sauter 2005).

Collaborative DSS

Recently, there is an increasing interest in the design of collaborative and intelligent society of agents that are capable of addressing complex problems and vast amounts of information (Adla et al. 2012). The increasing growth of DSSs, tools, and information can be exploited by forming a collective decision-making in which decision makers share the context and make decisions based on the opinions of other members within a global network of brains (Brandas and Didraga 2014).

Group Decision Support Systems (GDSS) is an effort to facilitate an environment for collaborative decisions (Turban et al. 2011). DeSanctis and Gallupe (1987) define GDSS as “an interactive, computer-based system that facilitates unstructured problem solving by a set of decision factors working together as a group". The collaboration in GDSS in which a larger number of stakeholders can efficiently and effectively participate in the decision making process is likely to lead to improved decisions (Brandas and Didraga 2014). GDSS focuses on the use of meeting systems in order to support the generation of ideas and decision making in small group settings (Turban et al. 2011). It aims to remove communication barriers; provides decision modelling and group decision techniques to reduce uncertainty in the group decision process; as well as improving group decision patterns through expert advice (DeSanctis and Gallupe 1987).

The collaboration functionality of GDSS can be enhanced through the advances of databases, artificial intelligence, operational research, and particularly the development of web technologies. They facilitate the introduction of 'web-based collaborative decision' (Antunes and Costa 2012). They are commonly known as Web 2.0 and Semantic Web (Web 3.0) which introduces an improved ability to connect and organise the content of information distributed across multiple pages or sites (Zaraté et al. 2015). This includes the application of social networks that can be used for decision-making sharing and consensus or voting process within specific contexts (Brandas and Didraga 2014) In 'web-based collaborative decision' several entities (humans and machines) liaise to reach an acceptable decision. The entities are distributed and possibly mobile along networks (Adla et al. 2012). Ensuring a collaboration of the entities requires: removing communication difficulties, and providing techniques for structuring the decision analysis and systematically directing the pattern, timing, or content of the related decisions (Karacapilidis and Papadias 2001).

The advances in these technologies can be exploited in a way that allows decision makers to address the increasingly dynamic and complex process of migrating to the cloud. Particularly, the support required at the intelligence phase of migration decisions. The intelligence phase consists of finding, sharing, and analysing information. Application of web-based collaboration tools and GDSS is to search as well as aid in sharing information among participating group members. They can increase the efficiency of gathering information and its distribution (Turban et al. 2011).

3.5 A review of the existing cloud DSSs

The increasing complexity of the decisions to migrate to the cloud (refer to section 4.7), alongside the evolution and popularity of cloud computing, has led to significant attention being paid by many industrialists and academics to the need for supported migration decisions. Cloud vendors and IT consultancy agencies have made several attempts to address this demand with a number of whitepapers, guidelines, and assessment tools (see for example, Oracle (2012), Amazon (2013), and Accenture (2013). However, these attempts have either been developed for marketing purposes or they are not publicly available, because they are based on closed proprietary technologies that usually require consultancy contracts (Khajeh-Hosseini et al. 2011). In academia also, several attempts to aid decision makers have been proposed, see for example (Li et al., 2010), (Chan and Chieu 2010), (Khajeh-Hosseini et al. 2011), (Khajeh- Hosseini et al. 2012), (Menzel and Ranjan, 2012), (Omerovic et al. 2013), (Andrikopoulos et al. 2013a), (Andrikopoulos et al. 2013b), (Garg et al. 2013), and (Santiago 2015). They mostly concentrated on the evaluation and selection of cloud providers with cost being the main factor. In other words, these systems focus on supporting decisions at the choice level by evaluating service providers. Almost none of the reviewed works considered the intelligence level and only a few attempts have focused on the design level of decision making. For example, (Andrikopoulos et al. 2013c) considers the adaptation required for migration applications to the cloud.

The suggestions made by Li et al. (2010), Chan and Chieu (2010), Khajeh-Hosseini et al. (2012), Menzel et al. (2014), García-Galán et al. (2015), and Santiago (2015) particularly focus on the selection of providers for IaaS. Khajeh-Hosseini et al. (2012) developed a cloud adoption toolkit that aids decisions on the suitability of the technology, consumption of energy, cost, impacts of stakeholders and operational viability. It incorporates two decision support tools: cost calculation and risk-benefit analysis (Khajeh-Hosseini et al. 2011). In their conceptual framework, a migration decision starts from technology suitability that is built by a checklist. It comprises of 12 questions for the characteristic of the desired technology. Then, the next step is cost modelling, which is to analyse the cost of running a server infrastructure on the cloud. The stakeholder impact analysis is then performed to evaluate the socio-political advantages and risks. If the analysis shows viability in running the system in the cloud, the decision moves to the last step that is the responsibility modelling. The operational feasibility is checked by identifying and analysing the risks associated with cloud deployment, in which responsibility of different aspects of the system are divided.

Menzel et al. (2014) developed the CloudGenius framework that provides a multi-criteria approach in decision support for selecting providers for IaaS to migrate a web server to the cloud. The CloudGenius framework defines a cloud migration process. It allows users to define multiple quantitative and qualitative requirements that are then matched against a knowledge-base of cloud service providers. The framework leverages an evaluation and decision-making framework, called (MC2) (Menzel et al. (2013) to support requirements and adopt a profound multi-criteria evaluation approach. It allows the creation of an evaluation method that contains a requirements check and an evaluation of multiple alternatives.

Li et al. (2010) considered a number of characteristics of services providers such as elastic computing, persistent storage, intra-cloud, wide-area networking, and cost. Similarly, Chan and Chieu (2010) considered physical properties and security, integrity and availability to determine the best cloud service provider for a particular application. García-Galán et al. (2015) focused on supporting the decision-making for selecting the most suitable cloud configuration, whilst Santiago (2015) focused on the evaluating of IaaS providers based on their performance and costs for migrating a workflow-based simulation environment.

The works of Andrikopoulos et al. (2013a), Andrikopoulos et al. (2013b), Strauch et al. (2014), and Juan-Verdejo and Baars (2014) were focused on supporting the migration of applications to the cloud. In addition to the selection of providers, the characteristics of applications (Andrikopoulos et al. 2013a) and the need for adaptation (Andrikopoulos et al. 2013c) to operate in the cloud environment were also taken into account. Andrikopoulos et al. (2013a) proposed a decision support system to select the cloud offerings for migrating applications that best match the parameters defined by users. Two types of concepts are identified in their conceptual view of a complete solution for decision makers considering migration of applications to the cloud: decisions that need to be made which are the focus of the system and tasks that need to be performed in order to support these decisions. Four decisions were taken into account: how to segment and distribute applications, which cloud provider and offering to choose, which elasticity strategy fits better the application, and what are the requirements in implementing application multi-tenancy. These decisions influence each other, and are dependent on 7 tasks (work load profiling, compliance assurance, performance prediction, cost analysis, identification of security concerns, identification of acceptable QoS levels, and effort estimation) that need to be performed in order to support the decisions. The decisions and tasks are formed in a network structure that provides multiple points of entry to the decision process.

In Strauch et al. (2014) the database layer of an application was taken into account when considering the migration of applications. Database layer provides data persistence and manipulation capabilities, it is necessary to address aspects such as differences in the granularity of interactions and data confidentiality, and to enable the interaction of the application with remote data sources. A number of functional and non-functional requirements were identified that should be taken into account in any methodology for migration of an application to the cloud, such as support for incompatibility identification and resolution, support for refactoring of the application architecture, security, and reusability. The step-by-step approach proposed by (Strauch et al. 2014) was a refined and adapted version of the approach proposed by Laszewski and Nauduri (2011). Their work was a vendor-specific methodology for the migration to Oracle products and services. It provides a detailed approach that guide and offer recommendations on migrating relational databases. The refined methodology by Strauch et al. (2014) implemented as a data migration tool. It provides two major functionalities: decision support in selecting an appropriate data store or service, and refactoring support during the actual migration of the data. Juan-Verdejo and Baars (2013) proposed a decision support for partially migrating an application to the cloud. Applications are usually subject to strict requirements such as privacy, security and compliance. They are also embedded into complex enterprise IT architectures with a multitude of interdependencies. For these reasons, a hybrid (local/cloud infrastructure) deployment might be the solution where only the suitable components for the cloud environment are migrated.

In an effort to facilitate comparing cloud services, Garg et al. (2013) designed the Service Measurement Index (SMI). SMI attributes are designed based on the standards defined by the CSMIC consortium on behalf of the International Organisation for Standardisation (ISO). It uses the AHP mechanism based on the quality of service attributes defined by the ISO, to rank cloud providers. The SMI has been considered to be a standard for service assessment and comparison within the Cloud Standards Coordination (CSC, 2013). It uses a number of characteristics and measures for comparing different services from various providers. The parameters considered are: Accountability, Agility, Assurance of service, Cost, Performance, and Security and Privacy. The framework was designed to aid organisation in selecting cloud service providers based on their quality of service attributes to reduce the difficulties of selecting providers among the increasing number of them.

Limited studies have considered the support required for the analysis of the requirements and characteristics of existing company-based IT resources and also the feasibility of migrating to the cloud environment. Misra and Mondal (2011) proposed four key characteristics of company based-IT resources which should be considered during the analysis for migration. They are: size of the IT resources, the utilisation pattern of the resources, sensitivity of the data they are handling, and criticality of the service. Frey and Hasselbring (2011) developed the cloudMIG to migrate legacy software systems to the cloud environment. It includes six main activities to provide a representation of the current software architecture, selecting the target architecture, and adaptation. It aims to classify the suitability of cloud environments for a specific system and the level of configuration for a reengineering process. It uses the cloud-based software Eucalyptus and the e-commerce ERP systemApache OFBiz. Juan-Verdejo et al. (2014) developed InCLOUDer that is a DSS to aid organisations in the process of adapting applications to the cloud environments. InCLOUDer enables organisations to describe their migration criteria, the architecture, properties, and the requirements of their applications. InCLOUDer provides taxonomy of organisations’ criteria related to cloud migration including: accountability, agility, assurance, cost, performance, security and privacy, and usability and follows the AHP approach to trade off.

Table 7. A review of the existing cloud DSSs

Proposed approach	Cloud service	Factors Taken into account	Method	Level of support
CloudCmp (Li et al. 2010)	IaaS	Cost, elastic computing, persistent storage, intra-cloud, and wide-area networking	Comparative approach	Provider selection
Ranking and mapping of applications Chan and Chieu (2010)	IaaS	Physical properties and security, integrity and availability	SVD	Provider selection
Suitability for the adoption of cloud computing (Misra and Mondal 2011)	Not specified	Size of the IT resources, the utilisation pattern of the resources, sensitivity of the data, and criticality of the service	ROI model	Design
CloudMIG (Frey and Hasselbring 2011)	PaaS and SaaS	Applications reengineering	Mathematical modeling	Design
Cloud adoption toolkit (Khajeh-Hosseini et al. 2012)	IaaS	Cost, characteristic social factors, political factors, performance, and practicalities	UML	Provider selection
DSS for migrating applications (Andrikopoulos et al. 2013a)	SaaS	Applications distribution, cloud providers selection, elasticity strategy, multi-tenancy requirements.	Three-tiered architecture	Design and Provider selection
DSS for migrating applications (Andrikopoulos et al. 2013b)	SaaS	Cost and providers' characteristic	Conceptual modeling	Provider selection
Applications adaptations for the cloud environment (Andrikopoulos et al. 2013c)	SaaS	The need for adaptation	Holistic approach	Design
partially migration of applications (Juan-Verdejo and Baars (2013)	SaaS	Hybrid deployment	Component placement a and AHP	Design
SMICloud (Garg et al. 2013)	Not specified	Accountability, agility, assurance, cost, performance, and security and privacy.	Component placement a and AHP	Provider selection
InCLOUDer (Juan-Verdejo and Baars 2014)	SaaS	Applications adaptations and Accountability, agility, assurance, cost, performance, and security and privacy.	AHP	Design
DSS for migrating applications (Strauch et al. 2014)	SaaS,PaaS	The database layer of an application	Step-by-step methodology	Design
CloudGenius (Menzel et al. 2014)	IaaS	Cost, performance, providers' characteristic	AHP and mathematical modeling	Provider selection
configuration support (García-Galán et al. 2015)	IaaS	Cost and providers' characteristic	Feature model	Provider selection
Workflow Infrastructure migration (Santiago 2015)	IaaS	Cost and providers' characteristic	OPAL Simulation	Provider selection

Despite of the developments of these DSSs, many challenges still remain, both from research and technical perspectives (Gonidis 2014) and (Latif et al. 2014).The majority of the existing DSSs do not support the assessment of business processes and relevant applications, nor do they provide information for the analysis of the impact of the chosen cloud services. In other words, they focused on supporting the migration at the choice level. Almost none of the reviewed works considered the intelligence level and only few considered the design level of the decision-making by considering the need for services adaptations in order to make them cloud enabled. For example, Andrikopoulos et al. (2013c) considered the adaptation required for migration applications to the cloud. Although, evaluation of providers and their appropriate selection are critical, making an informed decision to migrate requires analysis of a wide range of factors at earlier stages of a decision process. Companies should become fully aware of the cloud capabilities, guiding principle, the services offered and their potentials before coming to a decisions. In other words, the majority of the existing cloud DSSs support cloud migration decision at the choice level. A limited number considers service design and the need for adaptation and almost none of the existing DSSs consider the support of decision making at the intelligence level.

Further, the review shows a high interest in supporting the migration for IaaS model followed by AaaS while very limited support to PaaS. Additionally, existing approaches focus on the migration from on-premises to the cloud while there is a lack of support for the migration among cloud providers. This is an important aspect to be addressed to avoid the issue of vendor lock-in which is a concern for many (Opara-Martins et al. 2014).

In addition, the tasks required for the decision to migrate to the cloud are usually beyond organisations' capabilities or knowledge. Further, the majority of the existing DSSs are conceptual or experimental prototype-based. Therefore, improving the efficiency of the migration decision would require automating the migration tasks.

The vast majority provide tools and support only for a particular area within the migration process. For example, Menzel et al. (2014) focused on selecting providers for IaaS to migrate a web server, and Strauch et al (2014) focused on the database layer to support the migration of an application. The main problem with these approaches is the separation of important aspects of the migration process that are connected and dependent on each another.

Supporting earlier stages of a decision would require a process for collecting information to assist each phase of the decision making. March and Hevner (2007) pointed out that successful support of managerial decision-making is critically dependent upon the availability of integrated and high quality information that is organised and presented in a timely and easily understood manner. Some of the cloud DSSs utilise knowledge-bases that provide cloud offerings along with their pricing policies as discussed by Menzel et al. (2014) and Andrikopoulos et al. (2013a). However, to make migration decisions, a wider range of information such as cloud capabilities, services offered, pricing schemes, etc., should be considered. This information will aid organisations identify opportunities and services that can help to improve business processes and operation.

Another problem with the current approaches is the separation of important aspects of the migration process that are connected and dependent on each another. Additionally, the range of information required to be considered for migration is increasing due to the development of the technology and expansion of the services offered. Also the number of tools which are becoming available is increasing at a bewildering rate. What support is available to guide organisations through the process systematically? The next section reviews three attempts which were made for providing a systematic migration process.

3.6 Process models for migrating to the cloud

This section provides a review of three studies that aim to support the process of migration to cloud computing. The first is the only study found in the literature that aimed to support the process of decision making to migrate to the cloud. The second provided a reference model that identifies the key processes related to cloud migration based on the analysis and combination of the existing cloud DSSs. The third is a cloud life cycle model that is designed to be used for managing the migration and services in the cloud environment. The proposed models as well as their limitations are discussed.

3.6.1 A step-by-step cloud decision process

Beserra et al. (2012) proposed a step-by-step cloud decision process to support the migration of legacy application to the cloud which is organised into nine activities. The activities are ranging from the characterisation and evaluation of an organisation profile and constrains, to the define target application profile and constrains, and to the selection of cloud service provider. These activities should be carried out according to the workflow as shown in Figure 14. The process aims to aid application developers for the selection of services and the cloud models that best suit their requirements, as well as assessing the related risks and benefits. The process relies on the creation of template based profiles characterising the organisation, the target legacy application and candidate cloud providers, which are then cross-analysed to help in identifying and possibly resolving critical constraints (either technical or non-technical) that may hinder migration to the cloud.

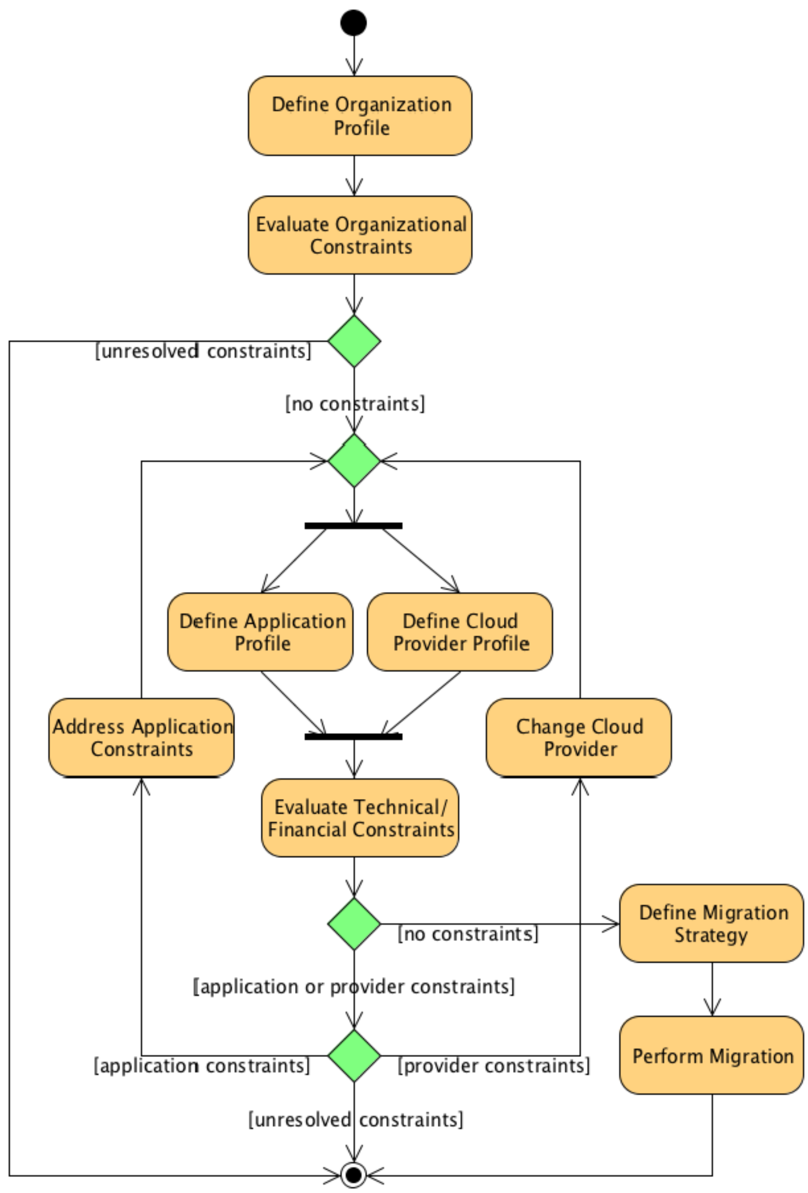


Figure 14. Step-by-step cloud decision process (Beserra et al. 2012, p.8)

The idea of creating entity profiles based on a set of provided profile templates to be stored and made easily accessible (proposed by Beserra et al. 2012) will make it easier for developers to find an existing cloud migration solution whose characteristics closely match the organisation. However, this process has a number of limitations. It focuses on the analysis of organisation, the target legacy application, and the candidate cloud provider, but does not consider evaluating the cloud environments which is essential to ensure adequate understanding of the new environment. The process is also primarily focuses on supporting software developers whereas cloud migration is a business driven decision that involves organisational risks much more than just the technical aspects. In addition to the separation between profiles' creation and constrain analysis which might be time consuming. There is a lack of an automated system explaining how the templates will be stored and how to select the candidate cloud providers. Further, the analysis of applications does not include major tasks, such as integration requirements and the main standards and regulation. This can be problematic, especially in the case of hybrid deployment scenarios. Further, the mechanism of how the templates will be stored and how to select the candidate cloud providers is not specified.

3.6.2 The Cloud-RMM reference model

In an attempt to enhance the cloud migration process by combining the existing decision support systems and tools, Jamshidi et al. (2013) introduced the Cloud-RMM reference model see Figure 15. It was developed based on the analysis of 23 existing cloud migration frameworks and the available decision support systems. The framework consists of four processes containing 20 migration tasks as shown in Figure 15. Process 1 - Migration Planning: It includes a number of initial tasks such as feasibility study, migration requirement analysis. In addition, deciding which provider should be chosen, which subsystems should be migrated and which cloud services should be used; finally, developing the migration strategy. Process 2 - Migration Execution: This is where the actual migration tasks such as data extraction, architecture recovery and adaptation as well as code modification and wrapping, and legacy-to-cloud transformation at both conceptual and concrete levels are executed. Process 3 - Migration Evaluation: This takes place in when the migrated system is ready for use and validation. In this process, tasks such as testing validation and deployment of migrated applications are performed. Process 4 - Crosscutting concerns: tasks include: governance, security analysis, training, effort estimation, organisational change, multi-tenancy, and elasticity analysis.

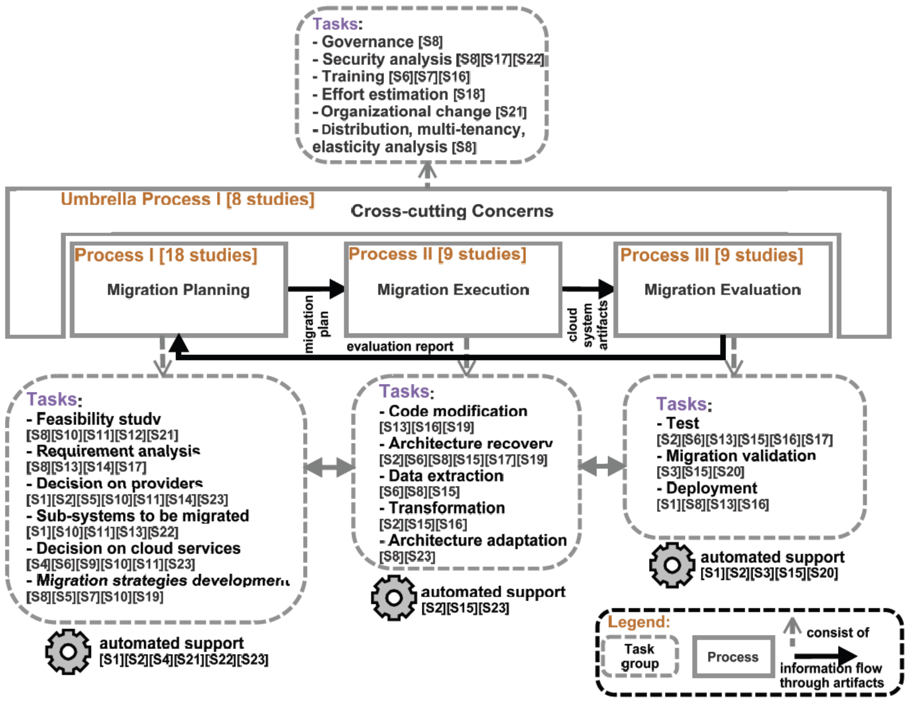


FIGURE 4. THE CLOUD-RMM MIGRATION FRAMEWORK

Figure 15. The Cloud-RMM migration framework (Jamshidi et al. 2013 p.7)

Jamshidi et al. (2013) concluded that cloud migration research is still in the early stages of maturity. They identified the need for a comprehensive framework that supports the migration process areas to help improving the maturity level and consequently trust into cloud migration. The RMM reference model provides a foundation for a process that combines DSS and tools, however it lacks a systematic procedure for utilising them.

3.6.3 Managing the migration to cloud computing

In order to fully comprehend the benefits of cloud computing and overcome its associated problems for migration, it is important, to define a framework for transition to cloud computing (Conway and Curry 2012). Conway and Curry (2012) developed a lifecycle model to manage cloud migration projects. The life cycle model utilised a combination of management of IT outsourcing projects life cycle and IT Capability Maturity Framework (IT-CMF). The first is a detailed model of IT outsourcing which is supported by many years of practical experiences. The IT outsourcing life cycle model was adapted by applying the main challenges of cloud adoption. The-IT-CMF delivers a process capability maturity management of IT functions within an Organisation to ensure greater value from IT.

The life cycle model aids organisations in assessing and controlling their migration projects and the on-going management in the cloud environment. The model applies an approach that measures organisations maturity to migrate and manage services in the cloud environment.

As illustrated in Figure 16, the cloud life cycle is divided into four main phases that are: Architect, Engage, Operate, and Refresh. These phases are then divided into 9 steps.

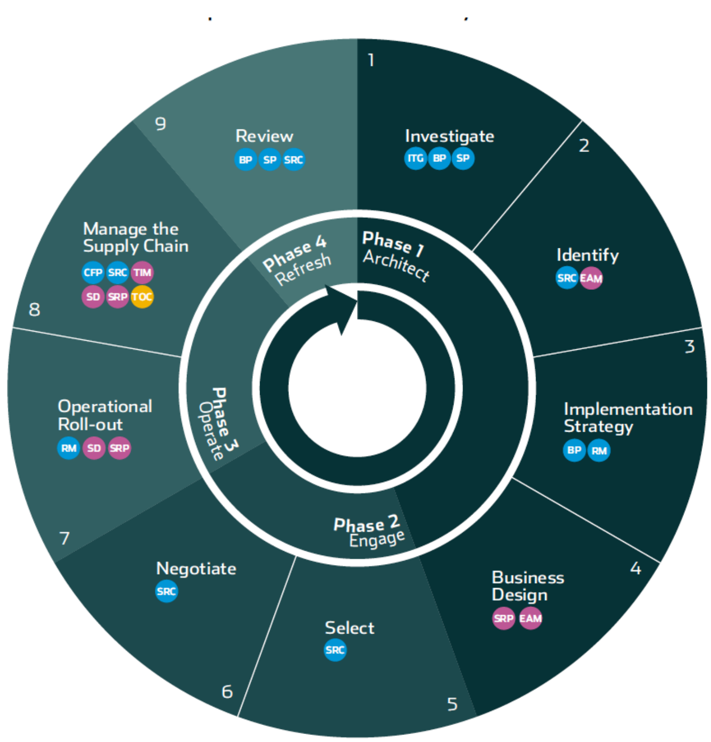


Figure 16. Cloud migration life cycle model (Conway and Curry 2012)

Phase 1: Architect: The first phase starts with the analysis and planning of the cloud project. It begins by the investigate step that outlines what organisations want to achieve by migrating to the cloud. Afterwards, the identify step is performed, which comprises an assessment of what areas businesses are appropriate for outsourcing and what impact they will have on the current delivery model. Next is the implementation step that to decides on how the services that are planned to be outsourced will be rolled-out. It includes defining strategies on: staffing, organisational rules, program roll-out, and risk assessment. The final step of the architect phase is business design that details how the new cloud service will be managed, how it will be integrated into to the existing systems, and how it will be monitored and reported.

Phase 2: Engage: The second phase is to select a service provider that can deliver the required cloud service detailed during the architect phase. Organisations may decide to stop at this stage in case the appropriate cloud services are not available, or there is no cloud provider that is able to deliver the required services. Then when the third phase (Operate) is entered that is the implementation and management of the cloud service which include manage the transition, manage the impact on staffing level and adapt accordingly, communication to all stakeholders, and acceptance sign-off. Finally, the fourth phase (Refresh) is the continuing review of cloud-based services. It includes reviewing of services requirements, changes within the business, changes within the supplier organisation, or the need to change the supplier.

The life cycle model provides organisations a structure that assist them in understanding and assessing their systems' maturity and to evaluate, implement, and manage services in the cloud environment. However, the main limitation of this model is that it is a high-level structure. According to Conway et al. (2015) although the model has been successfully applied in some migration projects, it was observed that significant detail is required, in order to sufficiently address the cloud problems. For example, in the second phase (selecting cloud providers) the approach did not specify the mechanisms for evaluating and selecting providers. Moreover, this model focuses on managing the transitions to the cloud while it is not always certain that the cloud is more effective than the in-house deployment. Therefore, organisations need further support at the planning stage to assess whether cloud-based services provide the solution for their requirements. The support should also have sufficient details about the tasks to be performed at each step.

3.7 Conclusion

This chapter explored decision making, decision problem types, the levels of management decisions, and the roles of data, information, and knowledge in decision making. Simon's decision process model was discussed. The concept of the DSS, its evolution, and types were then reviewed. The discussion then focused on the DSSs designed to aid the decisions for migrating to the cloud migration. An analysis of three models developed to provide a comprehensive cloud migration process were then discussed.

The review of the existing cloud DSSs revealed that the level of support they offer is not sufficient to enable decision makers in making informed decisions. This is because of the underestimation of the factors affecting the decision making for cloud migration in which the support is usually limited to the choice of cloud providers. They often lack information about the cloud environment, particularly for customers who are not familiar with it, and provide a limited amount of the information needed by organisations to assess the suitability of their own services for the cloud. Therefore, a comprehensive support for the decisions of migration cannot be limited to the evaluation of cloud services providers.

The analysis highlighted the importance of the intelligence and design phases (competitive intelligence) as a key factor to ensure successful strategic decisions. successful support of decision-making is critically depending upon the availability of integrated, high quality information that is organised and presented in a timely and easy to understand manner. In the context of migration to the cloud, a wider range of information such as cloud capabilities, services offered, pricing schemes, etc., should be considered. This will aid organisations to identify opportunities and services that can help to improve business processes and operation. This chapter also showed that decisions being made without considering the whole process leading to less informed decisions and possibly resulting in higher risk of failure. It shows that a coherent process that covers the whole decision aspects and explicitly describes the migration steps and tasks is still missing. These findings chapter are incorporated in the model proposed in this research which is discussed in Chapter 6.

The next Chapter discusses the analysis of the empirical data collected in this research.

Chapter 4 Methodology

4.1 Introduction

This chapter describes how the research methodology was implemented to achieve the research aim and objectives. It includes discussion and justification about the chosen strategy, methods, approaches and techniques.

A review of the literature and relevant work is usually the main part of any ground-clearing and preparatory work carried out in the initial stages of empirical research (Hakim 2000). Therefore, the research process was started by reviewing the literature and the emerging issues around the migration to cloud computing. ‘Cloud computing’, ‘cloud computing security’, and ‘systems migration to the cloud’ were the key words used to explore the research area. In order to enhance the exploration of the issues surrounding migration to the cloud, information from an existing survey that dealt with users’ perception of cloud computing was used as secondary data. The research problem, aim and objectives of the study were then identified (refer to chapter 1, sections 1.2 and 1.3), and the research then moved on to develop the research questions, selecting the research methodology and the methods that would best guide the answers to the research questions. The data was gathered from the field using multiple qualitative as well as quantitative methods.

The sequential exploratory strategy was adopted. This strategy was implemented using a two-stage survey that firstly gathered qualitative and then quantitative data. The information gathered from the survey identified a number of activities and steps that needed to be performed to ensure informed decisions for migration. Figure 17 shows the general structure of the data collection. These were then structured by following a generic decision making process model. The resulting model was then evaluated by analysing the views of a group of cloud practitioners on the main features of the model.

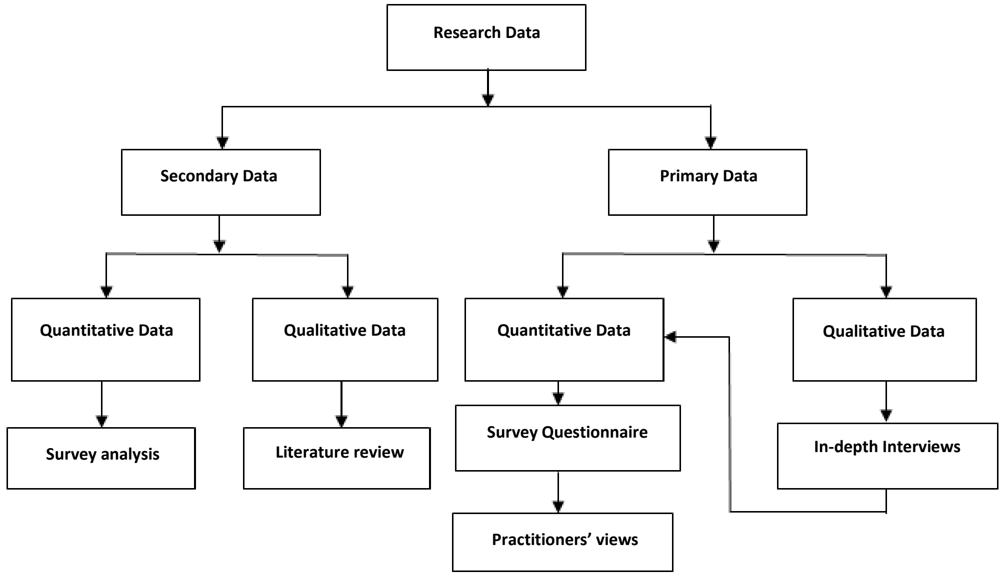


Figure 17. The structure for data collection

4.2 Research design

The term 'research design' was defined by Poit et al. (2001, p.167) as "*the researcher's overall for answering the research question or testing the research hypothesis*". Further, Green and Tull (1978) defined research design as

> "It is the specification of techniques and processes for obtaining the information required. It is the over-all operational pattern or framework of the project which states what data is to be gathered from which source by what processes."

There are a number of factors that can influence the selection of a research methodology (Bryman 2004). These include the type of research questions, the nature of the phenomenon under study, the degree of control required in a particular research context over behavioural events, as well as the researcher's philosophical stance (Zikmund 1984) and (Collis and Hussey 2003).

Three types of research design are identified in the literature as: exploratory, descriptive, and explanatory (Cooper and Schindler 2006). Exploratory research aims to identify key issues and key variables of a new phenomenon. It may be used to enhance a researcher's understanding about the phenomenon, test the feasibility of an extensive study, or to select the best methods to be used in a subsequent study. It is a broad research type and does not usually provide definite answers to specific research questions. Descriptive research aims to provide accurate descriptions of observations about a phenomenon. Explanatory studies examine the relationships between variables using hypothesis testing.

In this study, exploratory research was first employed to acquire the foundations and essential information needed to address the research problem. This involved a detailed investigation of the literature, as well as in-depth interviews, which resulted in a definition of key variables and refinement of the research problem; namely, to identify the technical and organisational factors affecting an organisation's decision to migrate to the cloud.

The following phase used a descriptive research design to define the occurrences, percentages, means, and standard deviations of the variables identified in the previous exploratory research. Explanatory research was also used to explain the relationships and associations between the variables of the factors affecting the decision to migrate to the cloud. Figure 18 shows the overall design of the research.

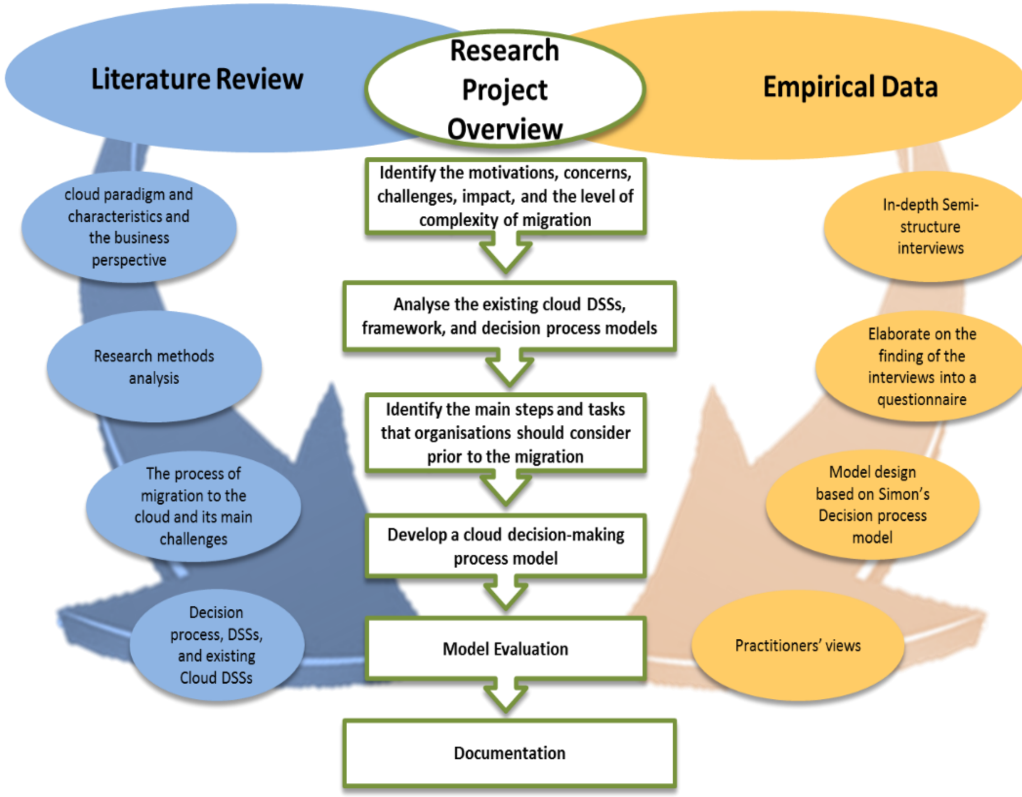


Figure 18. The overall design of the research

4.3 Research philosophy

There are two major approaches to the research methodology; they are positivism (Collis and Hussey 2003), and interpretivism. A positivist approach is commonly known as the scientific approach for natural studies and it is usually quantitative in nature while the interpretivist approach is commonly known as the qualitative approach.

4.3.1 The positivist paradigm

Positivism is a philosophy of knowledge that considers a methodology to be an approach to finding out about a phenomenon. In the 19th century, Auguste Comte's rejected the metaphysics philosophy and he asserted that scientific knowledge only can convey the truth about reality. This has resulted in the emergence of positivism as a philosophical paradigm. It was then recognised as the dominant scientific method in the early of the 20th century (Leong 2008). Positivists aim to test a theory or describe an experience to be able to predict and control the forces that surround us (O'Leary 2004, p.5). It is usually associated with quantitative methods for data collection and analysis. It complies with the view that research findings are trustworthy only when they are obtained through observation (the senses), including measurement. The role of the researcher in positivism is limited to collecting data using an objective approach; it views reality as something that can be measured and the results should be observable and quantifiable (Gall et al. 2007) and (Lichtman 2006).

4.3.2 The interpretivist/constructivist paradigm

The interpretivist, also known as constructivist, approach to research is that a reality must be understood through subjective interpretations of human behaviour and experiences and it cannot be observed in an objective manner (Bryman 2004). It tends to rely on participants' background and experience of the phenomenon being studied (Creswell 2003 p.8). Interpretivism usually depends on qualitative methods or a combination of qualitative and quantitative methods. Unlike positivism, in interpretivism meanings are important and they can be created, modified and developed through interaction. Table 8 presents a brief comparison between the two major research philosophy paradigms.

Table 8. The differences between positivism and interpretivism, adopted from Pizam and Mansfeld (2009, p.1)

Assumptions	Positivism	Interpretivism
Nature of reality	Objective, tangible, single	Socially constructed, multiple
Goal of research	Explanation, strong prediction	Understanding, weak prediction
Focus of interest	What is general, average and representative	What is specific, unique, and deviant
Knowledge generated	Laws Absolute (time, context, and value free)	Meanings Relative (time, context, culture, value bound)
Subject/Researcher relationship	Rigid separation	Interactive, cooperative, participative
Desired information	How many people think and do a specific thing, or have a specific problem	What some people think and do, what kind of problems they are confronted with, and how they deal with them

This research adopted a sequential exploratory approach, which initially involves qualitatively data collection. It follows constructivist principles during the first phase to value multiple perspectives and develop understanding about the phenomenon. As the second phase moves to quantitative data collection, the philosophical assumption shifts to positivism to identify and measure the variables and the statistical trends. Therefore, both positivism and constructivism are used in the strategy adopted in this research. Table 9 shows the philosophy, strategy, approach, and methods adopted in this study.

Table 9. The philosophy, strategy, approach, and methods adopted in this study

Research philosophy	Positivism/ constructivism
Research approach	Mixed methods
Research strategy	Sequential exploratory strategy
Methods	In-depth interviews Survey questionnaires
Time horizon	Cross-sectional
Analysis	Thematic analysis Statistical analysis

4.4 Research strategy

This research followed the sequential exploratory strategy for collecting primary data as shown in Figure 19. This strategy involves firstly collecting and analysing qualitative data. Then, based on the results (the first phase), the research continues to build the second phase which involves collecting and analysing quantitative data. In this way, a mix of data occurs between the analysis of the qualitative data and the data collection of the quantitative data.

The nature of phenomenon studied in this research is fairly new and still evolving (Conway and Curry 2012). Therefore, the sequential exploratory strategy was found to be the most appropriate way of gathering data with which to answer the research questions.

The purpose of this strategy is first to explore a phenomenon then expand on the qualitative findings. Morgan (1998) argues that the sequential exploratory is an appropriate strategy for exploring and testing elements of an emergent theory. The qualitative findings can be generalised to different and greater samples. Moreover, it is suitable when there is a need for a tool and in the case of inadequate or unavailable options (Creswell 2007).

According to the literature, a mix of interviews (qualitative) and questionnaires (quantitative) is the most commonly adopted combination for mixed methods research. "*The combination allows for the strengths of each strategy to be combined in a complementary manner with the strength of the other*" (Teddlie and Tashakkori, 2009). The qualitative data collected from interviews provides in-depth information about the phenomenon, however, it is difficult to generalise, because of the small number of responses. On the other hand, the quantitative data collected from the questionnaire provides a fairly large number of responses that can ensure a wider representation of information. Figure 19 shows the procedure for implementing an exploratory research design.

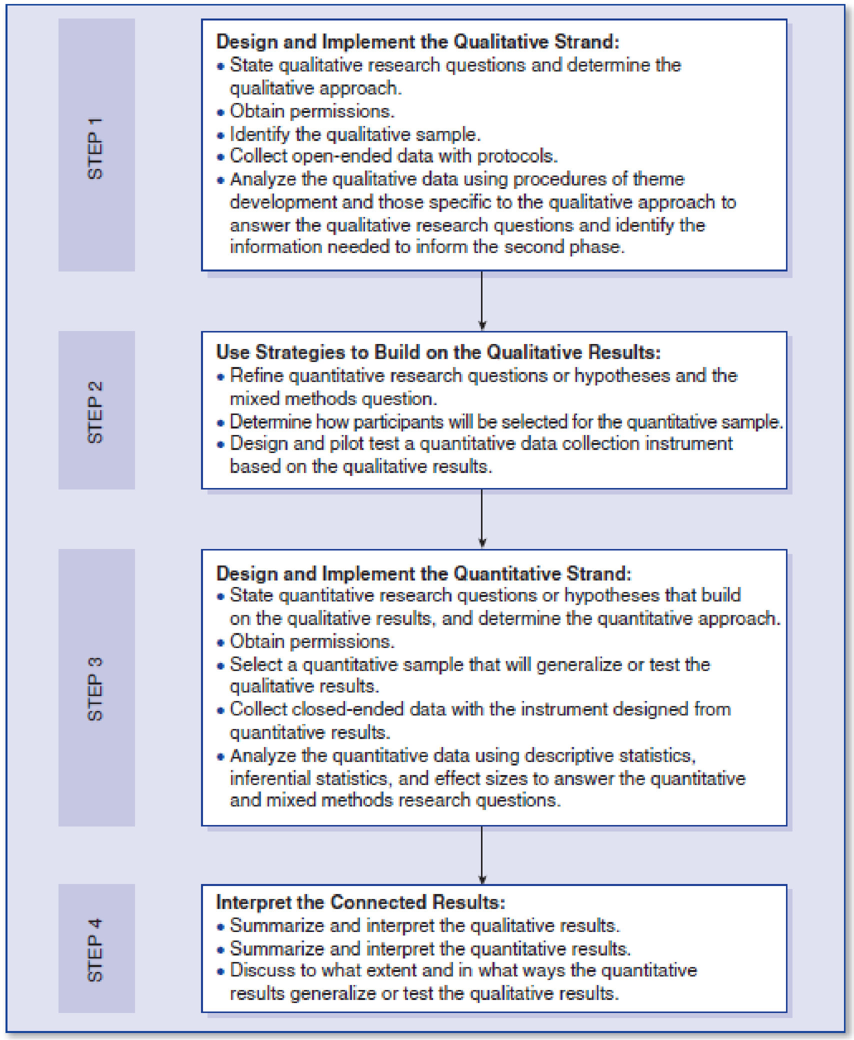


Figure 19. Procedure for implementing an exploratory research design adopted from: Creswell (2007, p.84)

The sequential exploratory strategy was applied in this research by employing a two-stage survey. It aimed to gain an insight into the perception of cloud users as well as cloud providers on migration issues and challenges that have been experienced during the migration process.

Stage1: interviews with twelve practitioners including: IT managers, security professionals, and cloud professionals (from cloud providers' perspective) were conducted. The information gathered has provided access to the perceptions, experiences and opinions of senior technical and security mangers which has been used to explore the impact of migration to cloud computing and related issues. A general interview guide approach and open ended questions were employed to ensure consistency; while it still allowed a degree of freedom and adaptability in obtaining the information from the interviewees. Broadly, the interviewees provided similar answers to the questions on the impact on IT management, however, in terms of security a wider range of views were expressed. One of the main issues raised was related to customers' lack of knowledge of the cloud environment. This has led to many issues such as unawareness of interpretability problems and costs associated with returning to the original legacy system, an overestimation of cloud-based services, as well as security and privacy concerns, (Chapter 5 provides a detailed analysis of the interviews).

4.5 Interviews

"*Interviews are particularly useful for getting the story behind a participant's experiences*" (McNamara 1999, p.1), and have been categorised into three different forms in the research methods literature: structured, semi-structured and unstructured. In this research, semi-structured interviews were used. It is an appropriate research method for working with small samples, and it is also suitable for studying a particular situation or for supplementing and validating information derived from other sources. These kinds of interviews provide access to perceptions, experiences and opinions, and are an effective means of gaining insight into problems that are not immediately distinguishable (Laforest 2009).

Semi-structured interviews provide researchers with an opportunity to obtain more in-depth information about a specific research issue. They are also an appropriate method for identifying new issues around a research topic that were not initially part of the interviews (Dawson 2002). Semi-structured interviews are considered to be a flexible method that enables the researchers to add or remove questions, based on the results of each interview. Furthermore, researchers are not expected to pose their questions in a particular order; this can vary based on the flow of the interview.

Essentially, semi-structured interviews can be used to ‘probe’ for more detailed information by asking participants to clarify their answers (McNamara 1999).

Hakim (2000) argues that the great strength of qualitative research is the validity of data. Interviews ensure that the results are correct, true, and complete because of the sufficiency of the details discussed, however, the small number of responses means that they are not representative, even when the sample is well chosen.

> “Qualitative research is valuable for identifying patterns of associations between factors on the ground, as compared with abstract correlations between variables in the analysis of large-scale surveys and aggregate data” (Hakim 2000, p.36)

Interviewing is an appropriate method for ‘why’ questions which cannot be asked nor answered in a direct way, because they usually involve a variety of circumstantial and contextual factors. They are also a useful tool for conducting exploratory work prior to large-scale or more complex study. Furthermore, they can be used to build patterns, themes, and categories from the bottom up.

4.5.1 Why was the interview method firstly chosen?

This method was chosen because of the need to gather practical experiences from both cloud providers and end-users. Alternative methods, such as starting the investigation by conducting a survey using a questionnaire or basing the investigation on a case study were considered. However, the aim of the first stage was primary data collection and not to measure or to quantify a level for the subject but to develop an understanding of the emerging phenomenon of migration to cloud computing as well as associated issues and problems for consideration. The interviews were initially chosen because of their consistency with the research questions that are exploratory in nature and required access to insightful information from experts and real life practitioners on the subject of migration to cloud computing. This type of information could not be acquired through a quantitative approach that uses predetermined options and categories, such as a questionnaire. Moreover, questionnaires would be more suitable for obtaining responses about a particular situation or to obtain a precise answer. This was not appropriate for the initial stage of this research, because in-depth and detailed answers were needed to develop a basic grounding and to enrich the exploration, which could not be achieved by administering' a questionnaire. A case study method would have provided valuable and in-depth details about the migration, however, for confidentiality reasons, organisations are reluctant to provide access to the data needed to support the study. In addition, the case study approach would be appropriate for exploring a particular type of organisation, or for supporting the migration of a particular service, but this research aimed to develop a model that would support a wide range of organisations and to be applicable in different contexts.

4.5.2 Stages of interview investigation

This research followed the seven stages of interview investigation, described by Steinar (1996), for conducting and analysing the qualitative data, as shown in Figure 20.

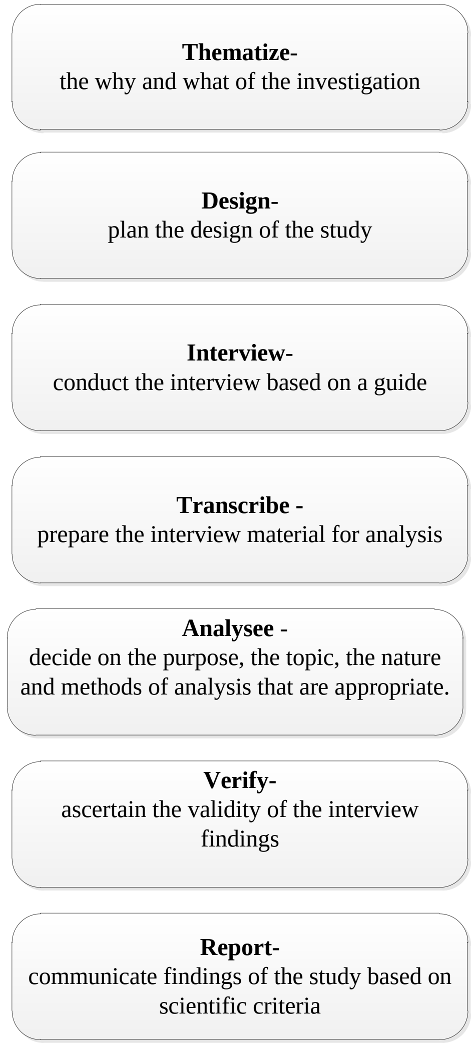


Figure 20. Stages of interviews investigation (Steinar 1996)

4.5.3 The thematize stage

The purpose of the interviews was to gain in-depth information about the emerging phenomenon of cloud computing from practitioners and experts' point of views. The literature review provided valuable data on the research subject and helped to define the themes for further investigation. The interviews were conducted to gather information within these themes as well as to explore new themes that did not appear in the literature. The interviews aimed to explore the cloud migration issues that had been experienced by the participants. In particular, the interviews were focused on:

- The main factors encouraging organisations to move their systems to cloud-based services.
- The issues that prevented organisations from moving their systems to the cloud.
- The issues organisations faced as a result of adopting cloud services.
- Reasons why organisations moved their systems back to in-house.
- Security and privacy concerns.
- Cloud services integration.
- The future of cloud computing.
- The short and long term impact of cloud computing on business.
- The impact of cloud computing on IT management roles and responsibilities.
- The type and level of support organisations require to support their migration projects.
- The main activities required to ensure informed migration decisions are made.

4.5.4 The interview approach (design)

There are several approaches for conducting interviews, including: informal, conversational, general interview guides, standardised, open-ended interviews, closed, and fixed-response interviews. For this study, the general interview guide approach was followed. This was used to ensure that the same general areas of information are collected from each interviewee; it provides more focus than the conversational approach, but still allows a degree of freedom and adaptability in obtaining the information from the interviewees based on their responses (Turner 2010). The questions dealt with opinions/values or knowledge.

4.5.5 The Interview process

The interviews were conducted face-to-face and on average each lasted about an hour. There were 12 interviewees in total who included IT managers, security professionals, and cloud technical professionals who were selected based on their subject expertise. Twelve interviewees may seem a small number; however the sample mainly targeted technical professionals who were working for cloud provider companies. The information they provided was normally based on their experience of dealing with large numbers of customers, and during the interviews, they used examples of migration of some projects. This raised the quality and reliability of the information they were able to share. Most of the meetings were held at the interviewee's place of work. A simple voice recorder was used that resulted in the collection of more than 12 hours of recorded audio. Table 10 shows details of the interviews.

Table 10. The interviews

#	Professional	Date	Location	Duration
Interviewee 1	Technical Leader at a major cloud provider company	03-04-2013	Bournemouth University (UK)	One hour and 35 mins
Interviewee 2	IT Manager	10-04-2013	Company offices (UK)	55 mins
Interviewee 3	IT Manager	06-06-2013	Company offices (UK)	One hour and 10 mins
Interviewee 4	Technical Leader at a cloud provider company	11-06-2013	Company offices (UK)	One hour
Interviewee 5	Technical Leader at a cloud provider company	19-06-2013	Company offices (UK)	One hour and 15 mins
Interviewee 6	Cloud Computing Researcher	05-07-2013	Company offices (UK)	One hour
Interviewee 7	Technical Leader at a cloud provider	10-09-2013	Company research centre (UK)	50 mins
Interviewee 8	Security analyst	07-10-2013	Bournemouth University (UK)	One hour and 20 mins
Interviewee 9	Security analyst	23-10-2013	Research Centre (UK)	One hour and 10 mins
Interviewee 10	Security Researcher	09-11-2013	Computing Conference (China)	45 mins
Interviewee 11	Technical Leader at a cloud provider and IT engineering company	28-11-2013	Company office (UK)	One hour
Interviewee 12	IT Manager	04-01-2014	Company office (Saudi Arabia)	One hour

4.5.6 Analysis

The first step in analysing the interviews was to transcribe the audio recorded interviews. Thematic analysis was then used to analyse the transcriptions (see Figure 6). Thematic analysis is a method for identifying, analysing, and reporting patterns within data (Braun and Clarke 2006). A theme can be defined as "*something important about the data in relation to the research question and represents some level of patterned response or meaning within the data set*" (Braun and Clarke 2006, p.82).

The thematic analysis was applied in six phases as suggested by Braun and Clarke (2006). First, the data was read several times, in an effort to identify patterns and valuable information. The next phase was the extraction of initial information from the data. This phase was done manually by highlighting the interesting information for coding. Coding of the data was 'theory-driven' in that the data was coded in according to specific question that the researcher had already planned to take into consideration. However, due to the adoption of semi-structured interviews, some of the data which was also coded was outside the planned questions. The third step involved sorting the different codes into themes (refer to Appendix C). In the fourth step the themes were refined by combining smaller themes and eliminating others that had limited support. The themes will be presented in Chapter 5. The fifth step was to determine what aspect of the data each theme captured, and finally the last step was to report on the analysis. These also will be discussed in Chapter 5.

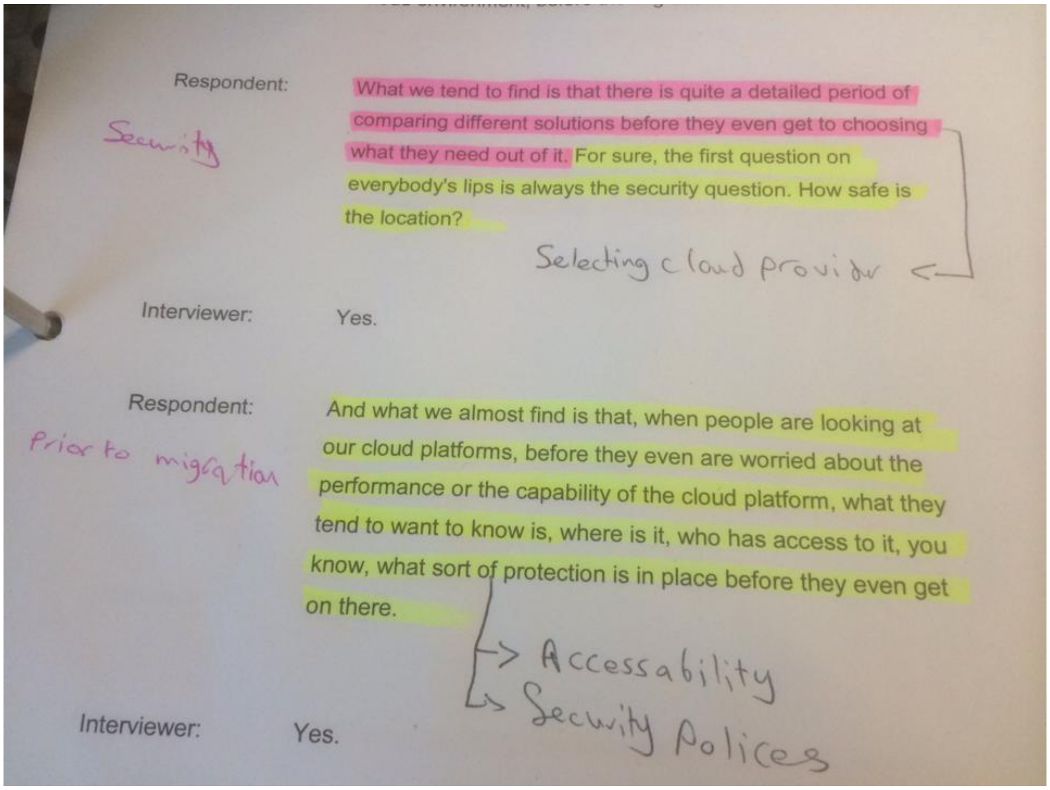


Figure 21. Analysis of interviews: an example

The issues and challenges raised in Stage 1 were incorporated into the questions used in Stage 2 that was based on a quantitative online survey questionnaire. The population consisted of a 102 professionals who had been involved in cloud migration projects and researchers in the area. Participants were from organisations of different sizes and from a divers industry sectors. They included IT managers, software engineers, system analysts, and executive managers; in addition to cloud systems researchers. The survey reflected the issues affecting the migration to cloud computing which were raised by in Stage 1. In particular, the issue of lack of knowledge about the cloud environment, and the security and privacy concerns were confirmed as major challenges in migrating to the cloud (Chapter 5 provides detailed analysis of the survey's results).

4.6 The survey questionnaire

In order to verify the findings of the interviews, a survey questionnaire was use. Survey based research can be used to characterize the knowledge, behaviours, and attitudes of a large group by studying of a subset of them (Kasunic 2005 p.1). For this reason, surveys are used extensively in software and systems engineering studies to provide insight into issues, assist with problem-solving, and support effective decision making (Kasunic 2005).

Survey questionnaires are an efficient, economical tool, and the data collected is easy to analyse. They also reduce bias because the filling in of a questionnaire is not affected by the personal characteristics or skills of the interviewer which can have an effect on other forms of face-to-face interaction (Holt 1997).

The main reason for implementing a survey questionnaire in this study was to provide further evidence about the data collected from the qualitative interviews (Stage 1) regarding the issues and challenges affecting the process of migrating to the cloud. Another reason for using a questionnaire was to avoid a bias that may occur in the selection of the informants (interviewees) in the first phase (Holt 1997).

The suggestion made by Kasunic (2005) for the process of designing an effective survey was followed for conducting the survey questionnaire. Figure 22 shows the sequence of the process.

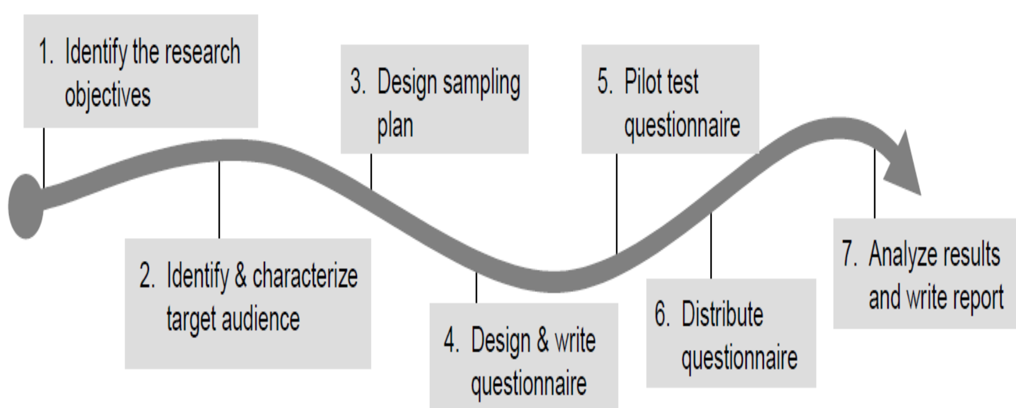


Figure 22. The process of designing an effective survey, adopted from Kasunic (2005, p.13)

4.6.1 Questionnaire Objectives

- To gather data on organisations interested in cloud computing
- Determine respondents' views with regard to migrating to cloud computing
- Identify the main factors deterring organisations from migrating
- Identify legal issues associated with migrating to the cloud
- Explore the challenges companies experienced after the adoption of cloud services
- Identify the main knowledge and skills needed to support cloud services.
- Identify the overall impact of migration to the cloud
- Assess views on the quality of existing cloud related information
- Identify the most valuable sources of information for supporting decisions for cloud migration
- Investigate the views concerning the need for a cloud knowledge-base to overcome the lack of customers' cloud-related information

4.6.2 Target audience

In research surveys, a 'population' refers to all the members of a specific group. A population can be defined in terms of demography, geography, occupation, time, or some combination of these factors. When identifying the population for a study, it then becomes the target audience for the research (Kasunic 2005).

A 'sample' is a subset of the population. In survey research, the sample is studied and the findings are generalised to the population. However, this is only possible when strict procedures are followed to ensure that the sample is representative of the population (Kasunic 2005).

In this research, any individual who had been involved in a migration to cloud computing project, including staff of organisations planning to migrate or already migrated to the cloud, staff of cloud providers, and cloud researchers, can be a member of the population. The target population was professionals, at management, or systems engineering levels, who had been involved in cloud migration projects.

Participants were from organisations of different sizes and from diverse industry sectors. They included IT managers, software engineers, systems analysts, and executive managers, in addition to cloud systems researchers.

4.6.3 Design sampling plan

Availability sampling, such that anyone from within the target audience could participate in the survey, was used in this research. There were two reasons for this. First, the population consisted of organisations that had migrated or were planning to migrate to the cloud in the UK, and there are no exact statistics concerning such companies. Second, the target audience is known to be difficult to reach; they are time constrained and not freely available to participate in unsolicited surveys for reasons of confidentiality.

4.6.4 Survey design

The questionnaire was divided into three main parts. The first part consisted of qualifying questions to ensure the participants were within the target audience and to provide demographic information that might be needed for the analysis. It also included questions related to cloud issues. The questions in the second part were about the impact of cloud computing. Part three dealt with the quality of the existing cloud related information and the need for a cloud knowledge-base.

The main findings identified in the interviews were incorporated into the questions. The majority of the questions were multiple choices that allowed participants to choose more than one category. The researcher attempted, as far as possible, to keep the question wordings simple and easy to understand to avoid ambiguity. Please refer to appendix D.1 which shows the questionnaire format.

The survey was implemented using a web-based tool (Survey monkey), and included a questionnaire consisting of 15 questions. The questionnaire accompanied by a covering letter which explained the purpose of the research and guaranteed the confidentiality of the data gathered.

4.6.5 Pilot test questionnaire

The success of a questionnaire requires the questions to be simple, easy to understand, and easy to answer, based on printed instructions and definitions (Holt 1997). To ensure that the survey measured what it was intended, a pilot survey was conducted. The conditions for ensuring valid responses to survey questions described by Holt (1997) were taken into account during the pilot. According to the guidelines proposed by Holt (1997), the questions must be understandable, and that the respondent must be both capable of providing the information requested, and willing to do so.

Four participants were used for the pilot survey. The purpose of the pilot survey was to avoid confusions and/or misinterpretations of the questions. It also aimed to detect errors. In general the feedback from the pilot survey showed that the questions were understandable and the participants were able to provide the required answers. A few amendments were suggested, which involved rewording some of the questions. It was also recommended that there should be no more than five questions per page to avoid respondent fatigue, and that all matrix questions should be on a separate page. These recommendations were implemented before conducting the main survey.

4.6.6 The survey

Subjects of the study were contacted in various ways, but mainly by sending a link via e-mail. Other methods were also used, such as handing out printed questionnaires, usually at conferences and social media websites (Twitter and linked in). Zikmund (2000) suggested that the target population is the entire group of subjects of interest who are defined by the research objectives. However, there is usually a considerable difference between the population that a researcher is attempting to study and their availably for sampling (Zikmund 2000). In this study the researcher attempted, as far as possible, to find participants from the target audience by distributing the questionnaire using various methods.

The questionnaire was distributed between May and October 2014. The total distribution list consisted of approximately 1,100 users and 118 responses were received. Sixteen responses were incomplete, therefore they were eliminated from the analysis giving the total usable responses a 102 which is approximately ten per cent of the total population and consistent with what could be expected for a survey of this kind.

The questionnaire that was handed out has achieved the highest response rate while distribution using social media tools achieved the lowest. A large number of messages which were sent through social media, might be the reason for the low response rate. It was observed during the hand-to-hand distribution of the questionnaire that women spend more time than men reading the questions before providing their answers.

4.6.7 Survey analysis

Statistical analyses were applied to the survey results. Descriptive analyses were performed for each variable independently to summarise the data. These analyses were obtained from the tool used to conduct the survey (Survey Monkey), which provides automatic descriptive analysis. The whole data set was imported to Microsoft Excel. Pivot table tools were then used to analyse the data based on the demographic values (See appendix D.2).

4.7 Model design

To ensure well informed decisions and systematic migration processes are used, a generic decision-making process model developed by Simon (1977) is followed. The model was designed to help decisions that are highly unstructured, complex, involve risks and that would have an impact on the future of organisations. It includes three major phases: Intelligence, Design, and Choice. The process starts with an intelligence phase where the “reality” of the organisation is examined. It involves problem identification and information gathering activities. This includes identifying organisational strategy and goals, and exploring the environment (the societal environment, the competitive environment, and the organisational environment) for possible opportunities to address identified goals. The intelligence phase is followed by a design phase.

In the design phase, a model that represents the organisation’s operational systems is constructed. It simplifies the organisation’s “reality” and identifies relationships between variables, as well as setting the criteria for evaluating alternative courses of action. For decisions that involve risks, decision makers must consider the possible outcomes for each alternative with a given probability of occurrence. The design phase is followed by a choice phase.

The choice phase is to select the most appropriate alternative course of action based on the criteria identified in the design phase. It includes searching for alternatives, evaluation, and then makes a recommendation of an appropriate solution to the model proposed in the design phase. Finally the chosen solution is implemented. Successful implementation results in the delivery of the required values to meet the organisation’s strategic vision, failure requires a return to an earlier phase of the process. Figure 23 shows the decision making process.

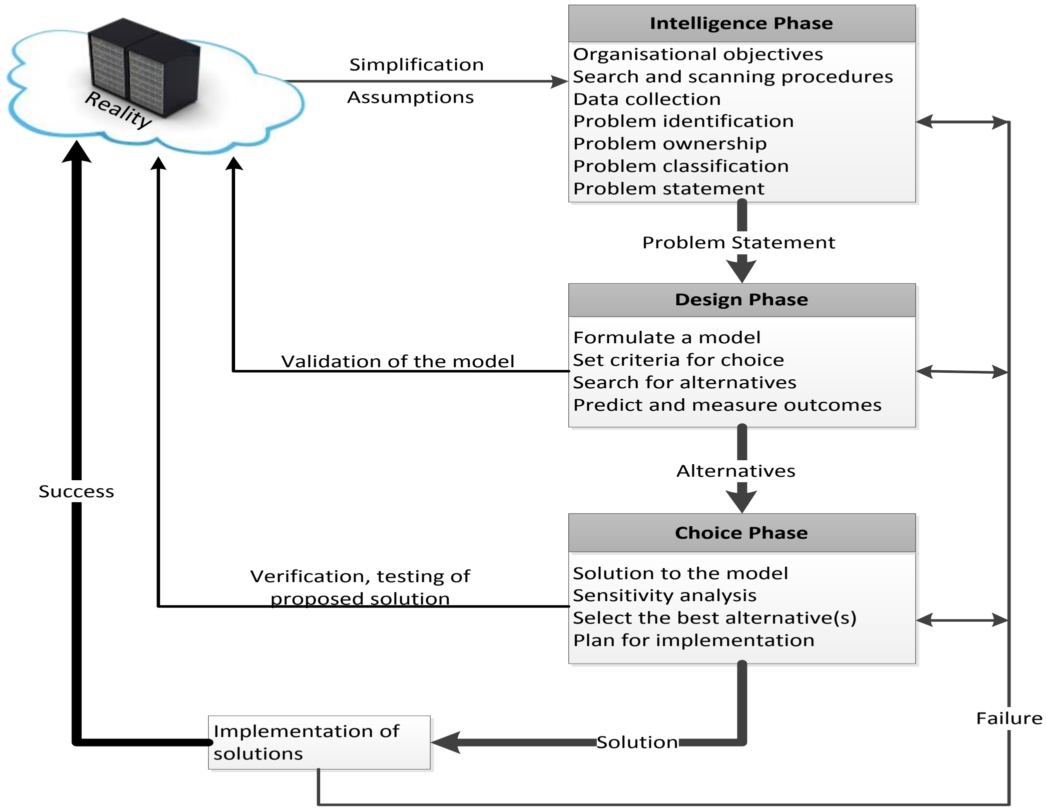


Figure 23. Decision making process (Simon 1977)

There is increasing agreement that decision processes should not be a matter of a simple choice (Langley et al. 1995), and that the role of information (intelligence) and the construction of potential alternatives are essential. Information particularly fundamental in the first two phases of a decision making process because alternatives can only be chosen where there is sufficient and documented information about the available options. Information acts as a constraint on decision making. Lack of information has been the weakness in many of the existing cloud migration DSSs, because many designers place emphasis on the models they build into their systems rather than on the significance of the information fed into them (Diniz et al. 2008). Simon's model was discussed in detail in Chapter 3. Based on this model, a model to support the decision process for migration to the cloud is proposed which will be discussed in Chapter 6.

4.8 Evaluation of the proposed model

The proposed model was evaluated by a group of cloud practitioners who provided their views on it. The method used for the evaluation of the model was a web-based questionnaire. The proposed model was accompanied by the evaluation questions and sent to the target audience mainly using e-mail. The questions included: rating, raking, multiple choice, and open ended questions (see Table 11).

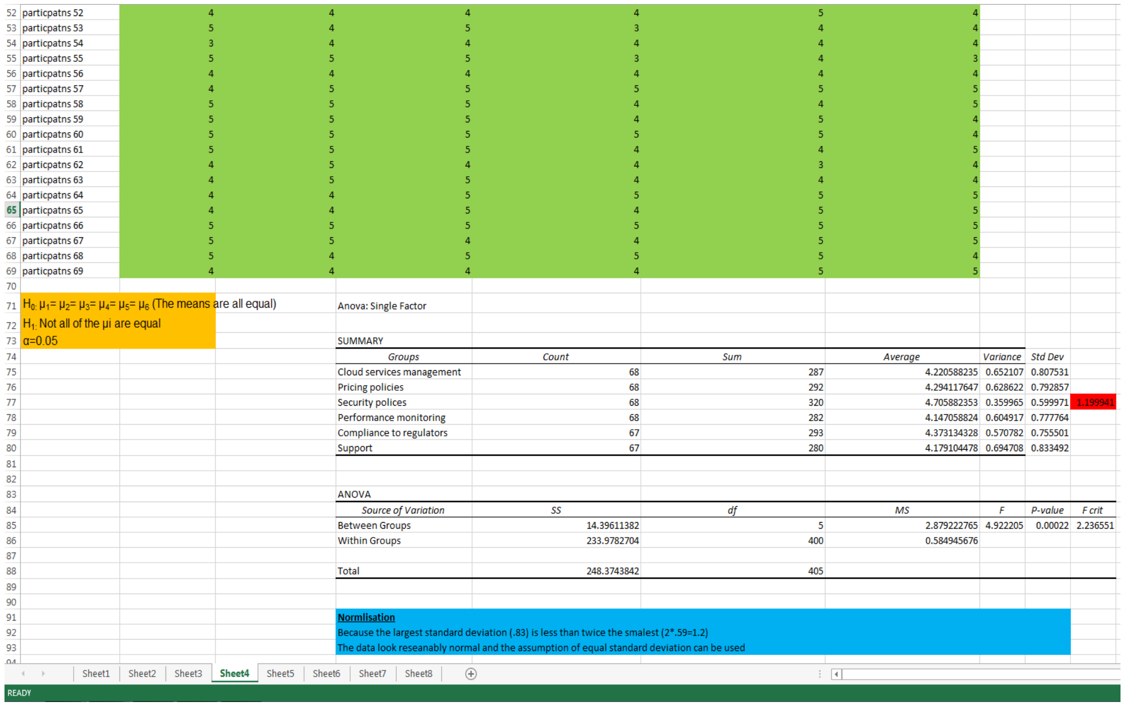
Sixty-nine practitioners participated in the evaluation. The participants had been involved in cloud migration projects, planning to migrate to the cloud, or conducting research within cloud computing. The evaluation aimed to determine the degree to which the model is an accurate representation for a systematic decision for a migration process. In particular, it aimed to validate the following:

- Was the order of the phases and steps within the model correct to ensure a systematic migration decision?
- Were the identified steps fundamental for the migration decision-making process?
- Were the tasks within the steps relevant to the migration challenges?
- Is any important aspect for the migration decisions missing in the process model?
- Does the model reflect the challenges of migrating to the cloud?
- Finally, does the model help potential cloud customers to decide whether to migrate to the cloud?

Table 11. Types of questions for the evaluation of the model

Question type	**Number**
Demographic	3
Yes/No	2
Rating Scale/Continuum	4
Rank ordering	1
Agree-Disagree	1
Open-ended (narrative response)	2
Total	**13**

Microsoft Excel was used to perform the analysis. The whole data set were imported from the tool used (Survey Monkey), and then the required data were extracted using pivoted table. Analysis of Variance (ANOVA) was performed on the variables that required analyse of the differences among group means. Figure 24 shows an example of the ANOVA test implementation.



particpatns 52	4	4	4	4	5	4
particpatns 53	5	4	5	3	4	4
particpatns 54	3	4	4	4	4	4
particpatns 55	5	5	5	3	4	3
particpatns 56	4	4	4	4	4	4
particpatns 57	4	5	5	5	5	5
particpatns 58	5	5	5	4	4	5
particpatns 59	5	5	5	4	5	4
particpatns 60	5	5	5	5	5	4
particpatns 61	5	5	5	4	4	5
particpatns 62	4	5	4	4	3	4
particpatns 63	4	5	5	4	4	4
particpatns 64	4	4	5	5	5	5
particpatns 65	4	4	5	4	5	5
particpatns 66	5	5	5	5	5	5
particpatns 67	5	5	4	4	5	5
particpatns 68	5	4	5	5	5	4
particpatns 69	4	4	4	4	5	5

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6$ (The means are all equal)

H_1: Not all of the μi are equal

α=0.05

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance	Std Dev	
Cloud services management	68	287	4.220588235	0.652107	0.807531	
Pricing policies	68	292	4.294117647	0.628622	0.792857	
Security polices	68	320	4.705882353	0.359965	0.599971	1.199941
Performance monitoring	68	282	4.147058824	0.604917	0.777764	
Compliance to regulators	67	293	4.373134328	0.570782	0.755501	
Support	67	280	4.179104478	0.694708	0.833492	

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	14.39611382	5	2.879222765	4.922205	0.00022	2.236551
Within Groups	233.9782704	400	0.584945676			
Total	248.3743842	405				

Normlisation

Because the largest standard deviation (.83) is less than twice the smalest (2*.59=1.2)

The data look reseanably normal and the assumption of equal standard deviation can be used

Figure 24. ANOVA test example

Chapter 6 provides an analysis for the evaluation.

4.9 Ethical considerations

Eisner and Peshkin (1990) suggested that in order to avoid making mistakes in addressing ethical issues, two attributes are needed: the sensitivity to identify an ethical issue and the responsibility to feel committed to acting appropriately with regard to such issues.

To ensure the integrity of the research, ethical considerations were taken into account. The interviewees were informed that the interviews would be recorded, and all accepted this approach; they were also informed about the purpose of the investigation, that the information would be used for research purposes and the results would be published only in academic articles and for the PhD thesis. For the survey questionnaire a covering letter was used. It explained the purpose of the study and gave the researcher's name and contact details. It also included the following note on privacy and confidentiality: "All answers will be treated confidentially and respondents will be anonymised during the collection, storage and publication of research material." (See Appendix D.1)

Participants' personal information, including their names, e-mail addresses, and organisations, have not been revealed in any of the research findings, either in this document or in the publicised articles.

4.10 Summary

The review of research design, philosophy, strategy, and methods allowed the researcher to develop knowledge about those terms that enabled in selecting the methodology. This chapter explained and justified the research design, philosophy, strategy, and methods used in this research. The study follows both the Constructivist and Positivist research paradigms.

A systematic literature review was conducted, focused first on developing an understanding of the cloud environment, its architecture, the migration factors, and cloud migration decision support systems. The review of literature provided valuable input that allowed the researcher to develop a number of themes upon which the study would centre.

A mixed method strategy was adopted to collect the primary data, due to its consistency with the research questions. This approach was achieved through the utilisation of a two-stage survey. In stage one, 12 in-depth interviews were conducted, that explored the migration challenges from three different perspectives cloud service providers, cloud users (IT managers), and security experts. In stage two, an online survey questionnaire was distributed to cloud practitioners to verify the interview findings, thus making them more generalizable. The analysis of the survey is discussed on Chapter 5

The information gathered from the survey was then structured by the adoption of a generic decision making process model, to produce a decision making process which applied specifically for migration to cloud computing, resulting in the construction of a cloud decision making process. The proposed model was evaluated by analysing the views of 69 cloud practitioners and researchers. The next chapter discusses the findings of the two-stage survey.

Chapter 5 Data analysis

5.1 Introduction

Chapter 4 provided detailed discussions and justification for the methodology implemented in this research. Chapter 2 and 3 presented the results of the secondary research. This chapter presents the results of the data analysis of the first two stages of primary research (survey) in this investigation. This chapter is divided into two main sections. The first section discusses the analysis of twelve semi-structured in-depth interviews (this will be referred to as Stage 1 throughout this thesis). The issues raised in Stage 1 were incorporated into the questions used in a survey questionnaire (Stage 2). The participants in Stage 2 included one hundred and two professionals who had been involved in cloud migration projects, planning for migration, or in cloud related research. The collection and analysis of the data was undertaken to address the research problem discussed in the first chapter. The main drivers for the data collection and analysis were to first explore the factors affecting the process of migration to cloud computing and then identify the areas that need consideration when migrating legacy systems to the cloud.

5.2 Interviews analysis (Stage 1)

In order to answer the research questions, which focused on the exploration and support required for decision making for organisational migration to the cloud, a literature review was carried out. It identified a number of migration decision factors and areas for consideration. The Stage 1 of the primary research was carried out in this research to further explore those factors and the issues around the migration decisions. The adoption of a qualitative approach in Stage 1 was selected to gain insights into migration issues and concerns as well as developing a foundation for further analysis.

Twelve IT Managers, security expert, and cloud technical professionals were interviewed. The information gathered has provided access to the perceptions, experiences and opinions of senior technical and security managers. The information helped in exploring factors affecting migration to cloud computing, as well as the areas that need consideration during the migration process. A semi-structured interview approach and open ended questions were employed to ensure consistency; while it still allowed a degree of freedom and adaptability in obtaining the information from the interviewees. Chapter 4 (section 4.6) provided detailed discussion and implementation of the interviews.

The interviews had identified some factors that can affect the migration to cloud computing (the questions can be found in Appendix C1). They also identified some technical and business skills that are needed for managing the migration process. Broadly, during the interviews, a wide range of factors that could affect the decision to migrate were discussed. Although the interviewees provided similar answers to the questions of the impact on IT management, however, in terms of security a wider range of views were expressed. Four themes emerged from the analysis of Stage 1: Lack of knowledge of the cloud environment, factors affecting decision making for cloud migration, managing cloud migration projects, and impact on IT management. The four themes will be discussed in the following subsections. Further, the interviews included a discussion on the future of cloud computing (see appendix F)

5.2.1 Lack of knowledge of the cloud environment

One of the main issues raised by the participants in Stage 1 was related to customers' lack knowledge on the cloud environment. Moreover, cloud users usually have higher expectations with regards to cloud services. They set much higher criteria than the criteria set in their local data-centre while expecting lower costs. Table 12 shows the theme in this regard that includes the areas identified by participants that organisations need to develop knowledge about and the resulting issues of migrating without having sufficient knowledge about certain aspects about the cloud environment.

Table 12. Lack of knowledge with regards to cloud environment

Theme 1	Category	Details
Lack of knowledge with regards to cloud environment	The need for developing knowledge about the cloud environment	Pricing and payment methods Security policies Opportunities Auditing and monitoring Standards Level of support Systems engineering Datacentres Compliance and regulation integration
	Issues	Moving back (extra costs associated with returning to the original legacy system) Hidden costs Interpretability problems Security and privacy issues Performance Legal implications Customer and staff dissatisfaction

The discussion in this regard was divided into two categories as shown in Table 12. The need to develop knowledge with regard to the cloud environment was frequently mentioned by the interviewees (particularly cloud providers) as a critical factor in ensuring successful migration. For example:

> "Enterprises should not start the migration until they are really sure that the cloud is going to give them the service that they actually need." (Interviewee 4)

This is mainly because the provision of cloud-based services is different from the traditional offerings. The difference includes pricing and payment methods, performance monitoring, regulation and compliance, architecture, security, and service support. These differences require a certain expertise that enterprises do not usually have.

One of the interviewees within a cloud engineering company pointed out:

> "The reason that we exist, and there are a growing number of these businesses, is because customers do not have the expertise to migrate to the cloud." (Interviewee 11)

Some of the interviewees who were invlolved with provding cloud servcies, emphasised the importance of consulting professionals prior to making the decision to migrate to the cloud. For example, an interviewee from a cloud provider stated:

> "To help people adopt clouds you need to provide a proper consutancy service because time and time again we have seen if you don't do that bit right you can't take adavantage of the cloud." (Interviewee 1)

Cloud providers usually offer a consultancy service to aid enterprises to design, migrate, and manage their workloads and applications. Many cloud providers also supply a list of consulting partner companies that specialise in the design and management of cloud services which can aid enterprises to adopt the cloud services that meet their special requirements. The problem with this is that it usually comes at a very high cost. Moreover, cloud users usually have high expectations with regard to cloud services and they set much higher criteria than the criteria set in their local data-centre. One cloud provider, for example, stated that:

> "In my experience, if you are moving to use an unmanaged service then your expectations are likely to be much lower than for one where there is a degree of management offered by the cloud provider." (Interviewee 7)

Another cloud provider (Interviwee 4) indicated that they were surprised by the high expectations enterprises had of cloud services, and also that customers were expecting these services to come at a lower cost. He pointed out that, "When it comes to selection of a cloud service, they seem to have a far higher expectation." An IT engineering company that provides cloud services indicated that they have systems and software engineers to help enterprises to move their systems and provide them with information about the features and costs of cloud-based solutions.

> “If their expectations are wrong, we need to sort of say If you want Plan A, it’ll cost you X. If you want Plan B, it’ll cost you 2X. If the business benefit is there for Plan B, because of all the additional stuff, then you can cost-justify it. But if you’ve only got enough money for X, they’re not going to pay 2X.” (Interviewee 5)

It also emerged from the interviews that cloud customers have high expections of the level of support. Many of the cloud services are user administered whereas many customers are expecting 24/7 support. A cloud provider interviwed pointed out that:

> “When you talk to clients and we talk about this smart code enterprise, a few cents an hour. And they say, ‘If it goes wrong, who can I phone?’ ‘Well, unless you’ve signed up for extra service, which is an additional charge, you can’t phone anyone.’ And they go, ‘But you’re providing a service.’ ‘Yes, we’re providing a service that’s user administered.’ Very often I think people are expecting a much higher level of service but actually, when it comes down to it, what they’ve signed up for is not what they think they’re getting.” (Interviewee 1)

Another cloud proivider stated:

> “I think that’s common, not just with …….. clouds but with clouds in general. People are expecting a higher level of service and so they suddenly realise that they’re not getting that level of service. Or rather, they can get it but it costs a lot more because, again, as soon as you get people involved, the costs go up quite dramatically with all of these things.” (Interviewee 7)

A security analyst indicated that a lack of knowledge about the cloud environment is the riskest part of migrating to the cloud.

> “What I do know is that it is a phenomenon that a lot of people are looking at and a lot of people are not quite sure. That’s the risky bit, that fear, that uncertainty, that doubt.” (Interviewee 9)

It was suggested by a number of interviewees that there is a need to develop an understanding about general security in the cloud environment. For example:

> "So it definitely is important to kind of understand what the general security is, and then what the security of the infrastructure is. So is it resilient? Is it in more than one location?" (Interviewee 6)

This information will aid organisations to define their requirements and ensure a clear division of responsibilities with regard to SLAs. A security expert interviewed pointed out:

> "You've got to be able to identify and make sure people are fully aware what they are responsible for, because then you can do a risk analysis, saying: 'Is this a riskier business to do or have we reduced or mitigated our risk by taking on these added bonuses that this cloud supplier's trying to offer us?' It's a risk equation. That's the beginning. The next one is, 'How safe is this?'" (Interviewee 8)

It was argued that enterprises need to ensure compliance with regulations. For example:

> "We have to be slightly careful with this when we're accepting payments online, we just have to be careful not to fall foul of things like tax, VAT and so on." (Interviewee 11)

A cloud provider (Interviewee 5) indicated that they used to run systems for various organisations that held credit card information. They removed all the payment card information from their servers because they were affected by regulations on payments, and currently they link their system to a payment card service provider. Another cloud provider pointed out:

> "We don't hold any credit card information at all. From our perspective, we don't want to. It's a security risk." (Interviewee 4)

It was noted that enterprises need to continually review the cloud market, because things are constantly changing. For example, the cost of bandwidth will change, as will the cost of services.

In terms of cloud service pricing, one cloud provider expressed (Interviewee 1): the only real variation that we have, and it is not really based on customer to customer provision, is that we have a kind of tiering model where if you take a year's contract, you will pay the lowest possible rate per virtual device. Monthly is kind of the middle price, and services are allowed to be consumed on demand and billed hourly. Cloud cutomers pay a premium for service, because a cloud provider is taking a risk that a customer may suddenly need 100 servers for an hour. Enterprises have the ability to vary the configuration within their contract; for example, they take a server, for a monthly period, then they can, during that month, increase the specification of that server and just pay the extra. They can also decrease the specification of the server, and the next month, the price will drop. The server can be cancelled as well if required. Therefore, there is a great deal of flexibility within the provison of cloud-based solutions, and organisations just need to work out which is the most suitable approach for their systems. For example, when a customer is on a monthly billing contract (that is, on a monthly pricing model), they will pay for the full month. If they only need a few days, then they probably should opt for the hourly billing rate.

5.2.2 Factors affecting decision making for cloud migration

During the interviews, a wide range of factors affect decision making to migrate to cloud computing were discussed. The factors range from drivers to deterrents, with others relate to type, size, and organisational culture. Cost reduction emerged as the main motivating factor, others being agility, the need for a new service or to develop an existing legacy service, back-ups, and testing. Security and privacy concerns were the main factors that deterred several orgnisations from migrating. The lack of systems engineering expertise and the adaptation required to migrate a service to the cloud were also identified as deterrents. Culture and an organisation's location also have an influence on the decision to migrate. Generally speaking, the IT managers and cloud providers interviewed listed similar factors that could either drive forward or delay migration, however, in terms of security and privacy a wider range of views was expressed. Table 13 illustrates the main factors affecting the decision-making for cloud migration identified from the analysis of the interviews.

Table 13. Cloud Migration Factors

Theme 2	**Category**	**Details**
Factors affecting decision making for cloud migration	Motivators	The need for new services Cost reduction Business agility Testing Back-up (a rapid and reliable technique, Lower risks, resources, and costs) High performance service (new features and functions and new patches) Outsourcing culture Vendors reputation Decision maker's Personality
	Disincentives	Security concerns (intellectual property, responsibilities, availability, and cyber security) The need for adapting existing systems Legal implication Lack of knowledge and expertise to manage service in the cloud The immaturity of cloud services and regulations Loss of control Trust The process of selection of cloud providers Decision maker's Personality

5.2.2.1 Security and privacy

The IT managers (Interviewee 2, 3, and 12) and security professionals (Interviewee 8 and 9) interviewed believe that the cloud is not yet sufficiently secure for migrating highly sensitive data. For example, an IT manager indicated that:

> "We don't use 'public cloud' mostly because the data on our systems is all either confidential or highly confidential and we have yet to satisfy ourselves and our regulators that we have a really strong control of data once it leaves our organisation boundary." (Interviewee 3)

Security professionals also raised the same concern about cloud security. For example, an interviewee with the role of security consultant pointed out that:

> "The cloud is not yet ready to migrate highly sensitive data, but maybe within 5 to 10 years". (Interviewee 9)

Cyber security is about the security of the Internet itself, which by its nature cannot be secure, because it can connect it to everything. Cloud providers require the interconnectivity of the Internet in order for users to reach them. Therefore, for organisations, it is a question of where they draw their boundaries.

From the perspective of a security analysts interviewed:

> "A cloud solution, as lovely as it is from a business perspective, and there are a lot of positives in that space, there are also a lot of negatives from the security perspective." (Interviewee 8)

They also indicated that, by migrating their systems, enterprises might place their intellectual property at a very high risk.

> "Because enterprises need to manage and protect their intellectual property, they are not managing and protecting it as a company if their systems have been handed to somebody else. There're things like trust management, reliability, safety, tolerances, availability." (Interviewee 8)

They also expressed that intellectual property is the most valuable piece of information that any company holds. Without it, it is no longer a business. With it, it is a business, it has a business process, and it has a business product. If a company's intellectual property is exposed and can be replicated, that company is more likely to go out of business. Therefore, the protection of intellectual property is paramount to any company. Below is a typical response provided by a security analyst:

> "I am a new multimedia advertising company and my product is my intellectual property. My latest sales campaign. If I deal with it on my system, my Apple environment − there we are, I'm on my Mac, and I'm doing it all on there − and it's in my company and my doors and the security are there, it's all my problem. So it's my risk. I have to manage that risk. If all this intellectual property was to be transferred to the cloud, then who's taking the risk if that property goes somewhere else, if somebody hacks into it and takes it away? The last thing I want is finding my campaign on somebody else's server. Particularly my competitor's server. I might lose my business in that way." (Interviewee 10)

The security analysts also indicated that the biggest security problem is that systems are becoming more interoperable and that, in so doing, they are becoming more and more complex. For example:

> "It's the complexity that opens up the vulnerabilities and the vulnerabilities get the instabilities in making them more and more unsafe". (Interviewee 8)

Additionally, large volumes of information can pass through the cloud, and in that type of interactive environment, among partnerships, corporations and so on, there will be questions about whether all parts are completely leak-proof, or the information is going to the wrong people. Control over this may be lacking because users are invited into the cloud and it is very difficult to know them all.

One cloud provider (Interviewee 1) commented that if a small company has basic security measures that it owns its IT assets, and it does not have any legal framework to deal with. It might have a logon password onto the system, but beyond that, it does nothing in particular to secure its data. If it moves its system to the cloud, the cloud provider offers a logon password, data encryption, and a VPN tunnel between on-premises and off-premises − therefore, by migration they increase the level of security on their systems. Additionally, the number of IT people within orgnisations is shrinking, and many SMEs have only one IT person who is responsible for manageing the on-premises system.

Another cloud provider (Interviewee 7) explained that enterprises are worried about the security of their data, but they often only have one IT person, and they, for many reasons, might not be available all of the time. How then do they expect to look after their systems? How would they deal with the situation if one server failed? In this case the cloud would ensure a higher availability of staff for managing the IT systems.

Another cloud provider expressed:

> "For a small company moving to a cloud, they actually get to a more secure system than the one they had on premises because they've got security professionals building and managing that cloud service." (Interviewee 1)

The findings of Sahandi et al. (2013) also identify security and data privacy as the main concern of organisations. It seems that enterprises still consider security as the major obstacle for the adaptation cloud services. As discussed in section 3.4.2, IT managers and security professionals interviewed for this study expressed their concerns over security with regards to the migration of sensitive data. Therefore, cloud computing has created more challenges to IT managers, because in the cloud such roles need to be translated into a technology implementation. The translation requires practical skills and an understanding of how to implement cloud services securely.

5.2.2.2 Cost

As discussed in chapter 2, cost effectiveness has been found as the main reason that drives organisations to move to cloud computing. The analysis of the interviews supports this result. For example the cloud will allow smaller organisations to gain the capabilities that they would not be able to afford using the traditional delivery model. As one of the interviwes expressed:

> "as a business model, cloud offers lots of good things, a platform as a service, a software as a service. Lots of companies can't afford that. They really can't afford it, and here it's being offered at a sensible price and a

> sensible delivery. Lots of companies will take that just because of that." (Interviewee 10)

Another interviewee stated that (Interviewee 12) "So to a lot of those small and medium enterprises it sounds like heaven".

However, cost was also found to be the main reason for enterprises that moved back from the cloud. For example a cloud provider pointed out:

> "Costs are interesting because it's an instant attraction, but actually, very often clouds tends to be more expensive than people think it's going to be" (Interviewee 1).

Another cloud provider stated that:

> "Once the thing's running, people forget about it until they receive a large bill at the end of the month. I think we've seen clients move back because they've worked out that it's actually cheaper for them to do it in-house" (Interviewee 7)

Cloud customers might need to pay for data transfers in and out, storage of data in the cloud on a gigabyte per month basis, support, and additional availability, therefore the few charges a month actually becomes a larger number. A cloud provider pointed out that:

> "I think one of the first things to remember with a cloud is that many clients look at cloud as being a cheap option because they see a few cents per hour price. But that few cents per hour is usually the base cost and then various additional services are added on, on top of it." (Interviewee 1)

Cloud-based services are not always more economical than in-house provisions. This depends upon the size of organisations and also on how long data is held. Usually, cloud computing is more cost effective for start-ups or newly started organisations. On the other hand, companies that have large legacy-data will find migration more difficult and more expensive (Interviewee 1, 5, and 11). For these types of organisations, cloud services would be more beneficial for the provision of new services, but not to replace or migrate already deployed services.

Moreover, it has emerged from the interviews that cost is the main reason for organisation to move back from the cloud. Reasons emerged for moving back are:

• Migration to the cloud without having full knowledge about how to financially manage cloud-services

• The cost of support, consultancy and other services which were expected to be provided without additional expenditure

• Cloud services running beyond working time

• Failure ROI calculation

• Vendors' standards.

5.2.2.3 Agility

Cloud computing is seen by many as a way to increase agility. Enterprises can add or subtract as their business develops. For example, one interviewee said:

> "We do not want to invest too much more into our intranet capabilities because there's this great offering of a cloud capability. The cloud gives us, in a technical sense, agility. So it gives us an agile capability, makes us a lot leaner, so we can use lean type rationales to give us the drive for into that space." (Interviewee 2)

A cloud provider stated:

> "One of the other things about the cloud that is attractive but seems to come secondary to cost, but actually, is probably more important, is around agility and the ability to get new services much quicker than they can do internally." (Interviewee 4)

For an organisation which wish to deliver services more quickly, it could be that the cloud can offer them what they cannot do internally. Interviewee 11 provided an example of a client, a company in the UK, that wanted to move to the cloud. They wanted to be shown how to run a service in the cloud, because they had a problem with agility. The challenge that they had was that their internal processes and systems were too slow for what they wanted to do.

5.2.2.4 Culture

Culture has emerged from the interviews to be an important factor that affect the decisions of migrating to the cloud. One of the interviewees who is a technical leader from a well-known cloud provider company (Interviewee 1) pointed out outsourcing culture is the main factor for migration to cloud computing. He indicated that they have a larger number of clients in the UK especially from SMEs in comparison to other parts of the world. The outsourcing culture was expressed to be the main reason for the high level of cloud adoption of enterprises within the UK. It was added that in the UK outsourcing of IT services have been developed over the last years, which is less developed in the other parts of world (Interviewee 1 and 5). Trust is a major factor that supports the decision-making for cloud migration (Interviewee 4, 8, and 10). Outsourcing culture can develop trust of migration systems to a third party.

5.2.2.5 Location

Two of the interviewees (5 and 8) indicated that ensuring that the data centre is located in the same country as its clients can remove many of the initial barriers, whereas if a company migrates to a multinational service provider, it may find some of its resources stored in other parts of the world, a situation that can create legal issues. Three interviewee from cloud proivder companies (4, 5 and 7) expressed that being in the same country as their clients is a main motivation for a company to migrate. It was indicated that:

> "The advantage that we have with all the clients that come to us is that all of our equipment is in our facilities, under our control, and they're all in the UK." (Interviewee 4)

Another cloud provider discussed examples of organisations that did not want to migrate because their systems would be located abroad (Interviewee 7).

5.2.2.6 New service

The IT managers (Interviwee 2, 12) believe that the need to implement a new service in-house, and then finding cloud-based services to be the most economical, is the main factor that drives cloud migration. An IT manager (Interviewee 2) indicated that their business had moved to a cloud-based solution because they needed a new service and, after evalauting the market, had found that running the new service on the cloud was the cheapest approach when compared to other alternatives.

5.2.2.7 Personality

The personality of the decision makers may play a major role in the decision to migrate to the cloud. A number of interviewees see that cloud solutions cause fear, uncertainty and doubt in many individuals' minds, and therefore are seen to be insecure. For example interviewee 6 stated that:

> "A lot of it's down to the personality of the people that run the business. I think that's also the problem of corporate ideas. It may sound a very good idea to the business, but the man who's running it may not believe that. It doesn't matter how good your argument is. He still may not believe it. Fear, uncertainty and doubt."

5.2.2.8 Testing

Testing in the cloud environment emerged from the interviews as an important advantage. For example, interviewee 11stated that:

> "From a migration perspective, the overwhelming advantage is that you can in most cases afford to have way more virtual hardware than you actually need, in order to allow you to test, and to have almost sandpit areas."

Enterprises can use the virtual hardware for a period of time and then turn it off, whereas many organisations simply cannot afford to have, for example, ten spare physical servers available to be used for testing for a short time, and then turn them off.

5.2.2.9 Back-up

It emerged from the interviews that the cloud environment can be a valuable, cost effective, and easy way to recover backups. As interviewee 5 pointed out:

> "It doesn't really make any sense to have an on-site facility in your office that you're worried about, concerned about, and could go wrong at any point, with hardware that may fail, when actually you could buy very, very cheaply and easily a disaster recovery backup service from another cloud provider in another location, and you'd get better performance out of it."

5.2.2.10 Disruption to business processes

According to two of the interviwees (5 and 12), migrating an existing system may result in errors and significant costs to the changes involved. Senior managers will not want to see disruption to business and many enterprises cannot afford disruption. Another Interviewee (6) stated:

> "You can't afford disruption. Just a step-change might sound like an exciting thing to do, but they'll say, 'Well, no, during that step, you will cripple our business and our reputation."

From the security analyst's perspective, it is a risky move when a company that revolves around its central service − its intranet − needs to give up what the entire business is anchored upon and move to a cloud solution. However, interviewee 4 indicated that companies can use the migration as an opportunity to improve their systems by fixing problems and removing the legacy issues of huge files.

5.2.3 Managing cloud migration projects

Table 14 shows the theme that has emerged from the interviews for managing cloud migration projects. It describes a number of steps suggested by the interviewees that organisations should consider prior to transferring services to the cloud.

Table 14. Managing cloud migration projects

Theme 3	**Category**	**Details**
Managing cloud migration projects	Strategy	Identify and classify the requirements (the must to have and the nice to have features) The opportunities and options in the cloud environment
	Identification	What applications can be migrated (based on): - Required adaptation - Critical to business - Cultural shift - Regulations Requirements specification - Impact on organisation
	ROI	Measuring the efficiency of cloud migration investment
	Organisation's readiness	Size, sort of data, integration
	Vendors' evaluation	Which cloud providers' services can meet requirements specification: - Primary requirements (location, security policies, accessibility, compatibility, compliance) - Secondary requirements (cost and performance)
	Risk assessment	Physical, personal, threats, accessibility, defining sensitivity of data and their impact on organisations, Identify security responsibilities

It was pointed out that the first step in aiding organisations to migrate to the cloud is to ensure they are aware of the options available in the cloud environment and also to understand their requirements. For example a cloud provider stated:

> "First of all, you have to understand their requirements. Then you discuss the options, because they may have only seen part of it, and they want to understand more." (Interviewee 7)

One of the cloud providers expressed:

> "We certainly have to listen to customer requirements, or investigate customer requirements, if they're in a particular sector; so if they're in financial services, if there are any FSA requirements, and so on." (Interviewee 4)

Organisations need also to be assured about the security requirements.

> "It's only after you've managed to satisfy clients about the actual safety of the overall platform, you can start getting into the performance questions." (Interviewee 5)

Therefore, in order to help organisations to decide whether to migrate to the cloud, there is a need to inform them about general security; whether the security of the infrastructure is resilient. The project manager should then move to the performance aspects by providing information about the opportunities and options which will meet the customer's requirements. The decision makers may not be interested in the technical details but it is important for them to see the business benefit. These types of information will allow enterprises to build confidence in the cloud service management. Based on this information, it should be possible to advise enterprises which cloud solution will be most suitable for them.

However, in cases where organisations need to implement a service that is tailored to their needs, cloud computing may only provide part of the solution, and then the enterprise may require additional technical expertise to integrate the cloud solution with the in-house system − so-called 'hybrid computing'.

Enterprises also need to evaluate the impact on their staff. If a company wishes to migrate an existing system that has been developed and tailored over time, all members of staff will be used to working with that particular system, and changes could require training.

A security analysts interviewed (9) highlighted the importance of conducting risk analyses, because if a business was originally based around a different type of architecture, and moving to the cloud could be seen as a dangerous way of doing business. The transfer may be risky and enterprises may need to adopt a different form of risk management going forward. If a business is newly-created, and it is based on the cloud and expands because of the cloud, then there should not be an issue.

Due to the immaturity of cloud computing, it was suggested by a number of those interviewed that organisations should move a service at a time starting with the least critical. As one cloud provider commented:

> "So for smaller businesses, we always advise they begin moving things piece by piece. As a business, we'd love them to move everything in one go, but we want things to be smooth and simple, and I think if you plan it out and take steps, it's the best way to do it, definitely." (Interviewee 4)

Enterprises need to identify the services that are business-critical, and if they need to migrate them, it has to be in a controlled manner. "It is really important to properly understand the high-level, high-priority items, and move those kind of slowly." (Interviewee 6) On the other hand, there are other systems that are more flexible and can be moved quickly, such as email and websites. Interviewee 5 stated that:

> "There are some things you can move really quickly. You can move email quite quickly, because it's almost a configuration change. Websites, on the whole, you can move quite quickly, because really you're just changing and pointing your DNS."

Websites, however, can be business-critical for some organisations. Some businesses rely on customer orders from their websites, so they cannot afford a few hours downtime, whereas others use their websites to inform their customers about events. In the first case, there is a need to make sure that the new system has been tested and run in parallel.

5.2.4 The impact on IT management

The interviews discussed the impact of migrating to cloud computing on organisations, particularly the impact on IT management. The interviewees were asked “will IT departments be needed within organisations subsequent to migration to the cloud?” Almost all the interviewees responded by expressing that there will still be a need for IT departments within organisations even after migration for a number of reasons. It was stated that, as cloud computing is in its early stage of development, it is unlikely that organisations will migrate all their systems to the cloud. Therefore, there will still be a need to run and manage local services and also to manage the integration with the implemented cloud-based services. Table 15 shows the theme emerged from the interviews regarding to the impact of migration to the cloud in respect of IT management.

Table 15. The impact on IT management

Theme 4	**Category**	**Details**
The impact on IT management	Reduced requirements	Staff Physical resources The need for physical resources support and management Space Electricity
	Increased requirements	Security Cost management Integration roles Cloud management knowledge Cloud business alliance IT roles and expertise Cloud architect Contracting
	Need change	Responsibilities for the implementation of security Shift of roles from local resources management to cloud-based provision
	Stayed the same	Strategies

It was indicated that, as computing has become more commoditised the number of IT people that each enterprise used to have, has gone down (Interviewee 6). It is also very likely that the transformation to the cloud will result in new jobs, a change in many job descriptions, and the movement of some of the existing IT management roles will be moved to cloud providers (Intervewee 1, 2, 6, and 9).

Furthermore, migration to the cloud will result in a significant transformation of responsibilities and roles of IT managers. They are required to develop a new set of cloud-related skills that would enable them to meet the emerging cloud-based responsibilities. For example, one of the IT managers interviewed (Interviewee 2) indicated that they had to go through several training sessions to develop the skills needed for managing the cloud-based services. Generally speaking, a large part of the build and run roles will go away because the running of the IT is now owned by the cloud provider and many of the building services are delivered by the cloud provider. Therefore, these roles will be shifted to cloud providers rather than remaining with the enterprise. A cloud provider pointed out that:

> "What you tend to see is that as you go higher up the stack, the more strategic things stay in-house and a lot of the more tactical and operational things go away." (Interviewee 1)

The roles that are more management related will become more important; for example, supplier relationships, service planning, contracts, negotiations, pricing, and procurement. These kinds of roles are required because enterprises need to maintain relationships with one or more cloud providers that they may not have had before. Further, organisations will still need IT departments to monitor the cloud-based services and liaise with cloud providers for an effective system integration.

Migration to the cloud will free IT managers from the burden of worrying about hardware, and they can focus on delivering a better service. For example: interviewee 4 stated:

> "So actually, it does change their perspective, but they actually focus on, 'What do my users need? What would be a better quality of service? What's a better performance time?' And completely remove themselves from the hardware level."

Another pointed out that:

> "IT managers get to focus more on the areas they probably should have focused on in the first place, instead of worrying about fixing broken power supplies and fans, and things like that, whether or not the air conditioning is going to fail overnight, and that sort of stuff." (Interviewee 7)

It was argued that customers are changing; they want to reduce their IT costs. For example, in the past, companies used to have their own IT departments, with their own software engineers writing their own software. Companies no longer do that; they may buy a software package, and may need to modify it, but they are highly unlikely to have their own software engineers. Additionally, the number of systems engineers is shrinking (Interviewee 5, 6, and 11). An interviewee who was from an IT engineering company pointed out that:

> "Enterprises get economies of scale by using our services, because we've got systems engineers and software engineers who will work on a project for them for three months. But after three months, they don't have to pay for those engineers, because they're working on somebody else's project." those engineering, IT engineering services are a key component to getting them from where they are into the cloud." (Interviewee 5)

The design of cloud computing architecture comprises of different layers to provide IT resources and each model comes with its own security issues. The distribution of responsibility for the performance of each layer varies between the different deployment models. One of the interviewees who is a security professional indicated that the main issue about cloud adoption is in defining the boundaries of responsibilities for the implementation of security. It was stated:

> "If the boundary of responsibility still remains with this company, and there is no responsibility by the cloud provider, then it's not a winnable solution. It's too risky to even contemplate going to a cloud supplier, so responsibility is a big issue." (Interviewee 8)

Further, enterprises usually have different requirements with regard to privacy and data maintenance (Interviewee 4, 6, and 7). These impact IT managers who need to develop security and data protection skills. Figure 25 shows the security responsibilities for the three cloud deployment model.

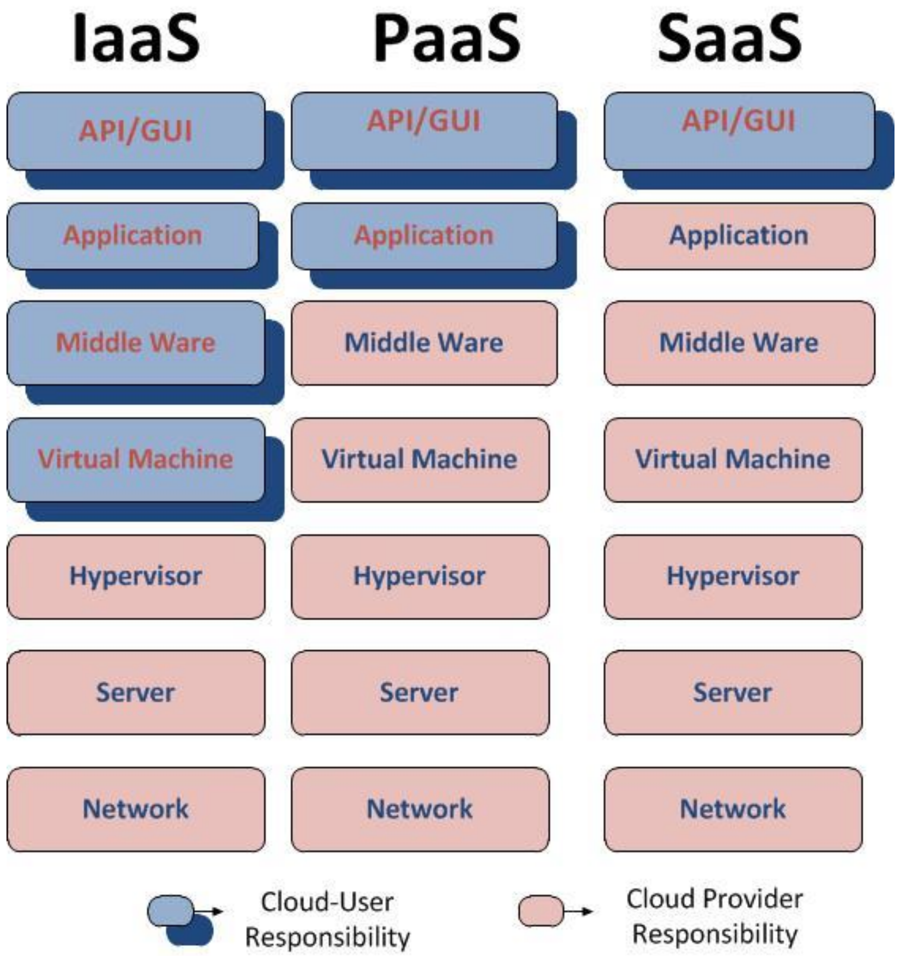


Figure 25. Security responsibilities for the three cloud deployment model

In the IaaS model, the security responsibility of the underlying infrastructure and abstraction layers belong to cloud service provider, while the remainder of the stack is the consumer's responsibility. An interviewee within a cloud provider company stated that:

> “Because we're providing the infrastructure rather than the service itself, then the responsibility for how they run the service, how they store the data, how they inform their users, remains with the IT department.” (Interviewee 4)

And he added “We have responsibility for the integrity of our data-centre than the actual services that are running.”

As discussed in 3.8.1, in the PaaS model, the security of the platform used for development is the service provider’s responsibility, but the security of the applications developed is the responsibility of consumer’s while in the SaaS model, service providers’ responsibelty do not only include providing the physical and environmental security capabilities, but also addressing the security control for the infrastructure, applications and data. Orgnisations will have very limited resposibitlites with SaaS. Interviewee 6 stated that:

> “If you can trust your provider has the right physical security for the equipment, and the right physical protection for the equipment, you can almost ignore that, because that's a commodity now”.

5.2.5 Conclusion from Stage 1

It was important to refine the focus from a macro perspective of a smaller sample to further explore the issues of migrating to cloud computing. The analysis of Stage 1 provided a foundation for the purpose of incorporating the findings into a survey questionnaire to verfiy them. It identified four themes with regard to the migration to cloud computing: lack of knowledge of cloud customers in respect of the cloud environment, factors affecting decisions to migrate to the cloud, the impact of migration on IT management, and areas to be considered to ensure successful migration.

The analysis of Stage 1 showed cost reduction, and agility were found to be the main motivations, but the outsourcing culture, the need to implement new services, testing, back-ups, and data centre location were also recognised.

IT managers and security professionals who were interviewed perceive that cloud computing has not yet reached the maturity level for companies to migrate highly sensitive data. As a consequence security is still the main concern for cloud users. On the other hand, the cloud providers interviewed in this study believed that cloud computing uses up-to-date security mechanisms which can be an advantage to organisations, particularly small ones.

A lack of customer knowledge of the cloud environment emerged as an issue affecting migration projects. The issues resulted in some enterprises migrating back to in-house.

In the literature, there are few guidelines or best practice documents that explicitly explaine the tasks to be perforemd for cloud migration projects and also the increasingly complex decision making issues surrounding migration. Thus, Stage 1 attempted to identify the important tasks which need to be considered in advance to ensure successful migration. A number of steps and tasks were identifed, including a consideration for the migration strategy, analysing service readiness, risk analysis, and evaluating providers based on primary and secondary requirements.

Cloud computing adoption has had an impact on organisations, particularly SMEs. Through advanced provision of IT resources efficiency can be increased, but this requires changes to the roles of IT managers and security staff. However, despite the changes that may occur to some of the existing roles, organisations will still need IT managers subsequent to migration. Roles need to be created to ensure services are delivered in accordance with their particular business requirements, and also for managing the service’s lifecycle. In addition, refined roles are needed both prior to the migration and also post migration to the cloud. In terms of the security responsibilties there is an increasing shift towards joint reponsibitlites as a result of the migration to cloud computing.

5.3 Descriptive statistics (Stage 2)

Stage 1 of this survey explored various aspects and issues associated with migration to cloud computing from the perspective of the professionals and practitioners interviewed. The issues highlighted are incorporated into Stage 2 that was based on a quantitative online survey questionnaire. Stage 2 is more focused on the challenges and complexity of the process of migrating to the cloud. The main reason for implementing the survey questionnaire was to provide further evidence about the data collected from the qualitative interviews (Stage 1). In other words, to provide statistical data about the outcomes explored in Stage 1. Further, the use of a questionnaire was to avoid a bias that may occur in the selection of the informants (interviewees) in the first phase. Therefore, the use of the survey questionnaire would improve the objectivity, generalizability, and reliability of the research findings.
One hundred and two responses were completed and received. Participants were from organisations of different sizes and from diverse industry sectors. They included IT managers, software engineers, systems analysts, and executive managers, in addition to cloud systems researchers. The following sub-sections provide a summary of the analysis of the responses

5.3.1 The demographic data

The first part of the survey questionnaire gathered data about the background of respondents that gives an overview of the individuals who responded and their organisations. Participants were requested to indicate the characteristic of their organisations: number of employees, industry classification, and their relation to cloud computing. The data were analysed based on this three indicators and the result are shown in Appendix D 2. Figure 26 shows the analysis:

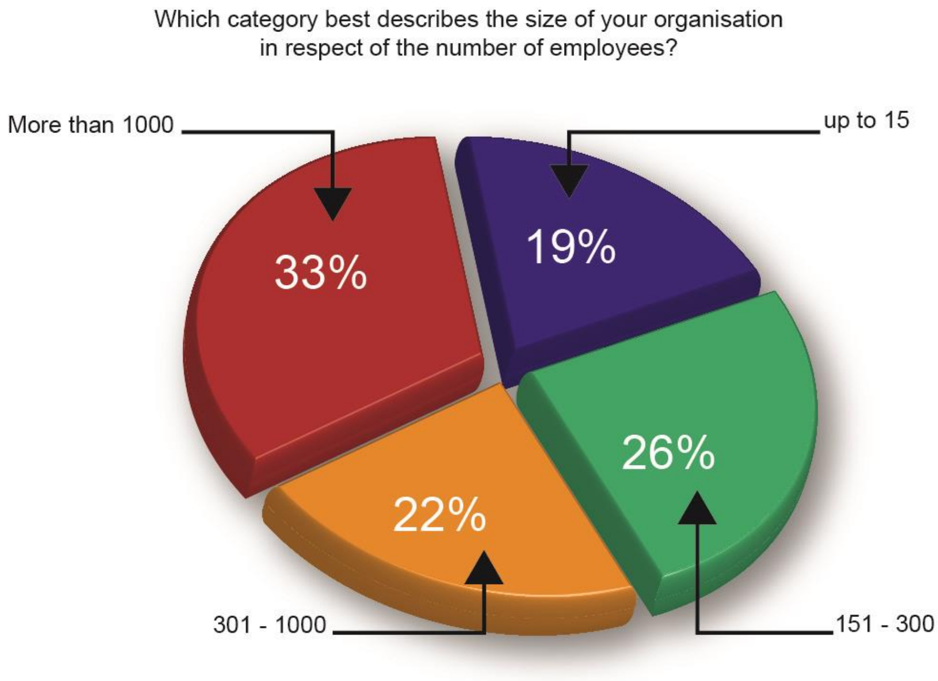


Figure 26. The size of organisations

As can be seen from Figure 26, the sample was not dominated by a specific organisation size and there was a good spread of representation across different organisation sizes. Employees within large organisation (more than 1000) were the most of respondents in the sample by about one third while small enterprises were the least with 19% of the total sample. Around 26% of the sample was employees of organisations sized 151 to 300 and the rest 22% of the participants were from organisations of 301 to 1000 employees.

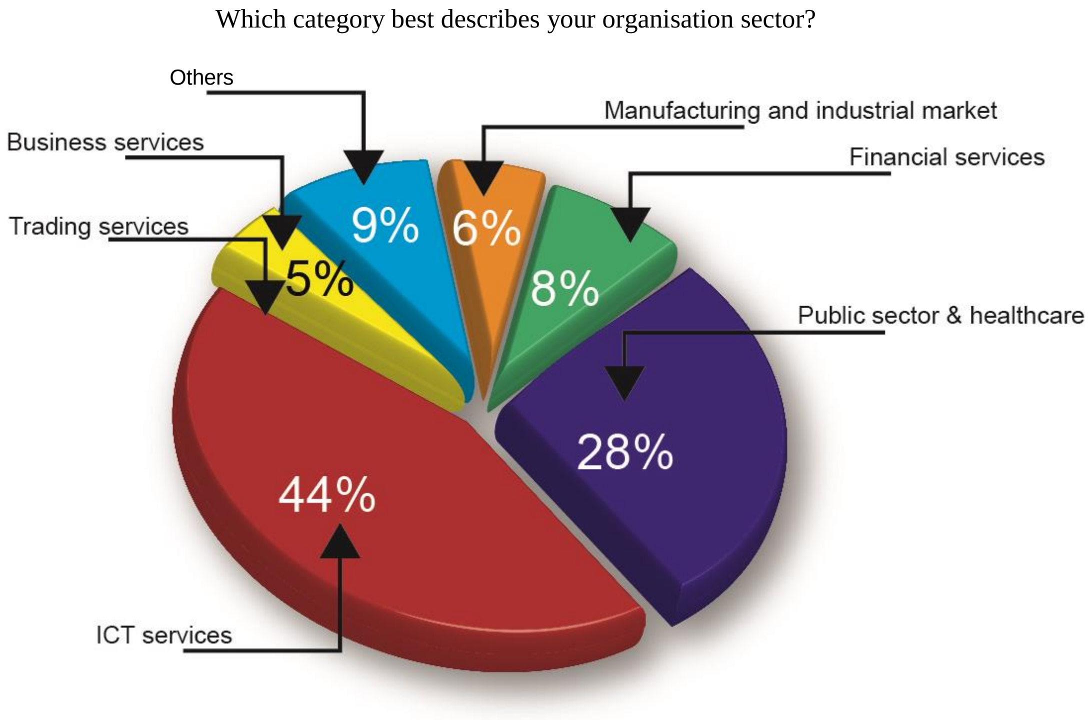


Figure 27. Industry classification

As can be seen from Figure 27, the sample was dominated by employees within ICT services companies and public sector and healthcare organisations by about (72%), (44%) were from the first and 28% were from the second category.

Respondents were then asked to indicate the activity of their organisation in relation to cloud computing as shown in Figure 28.

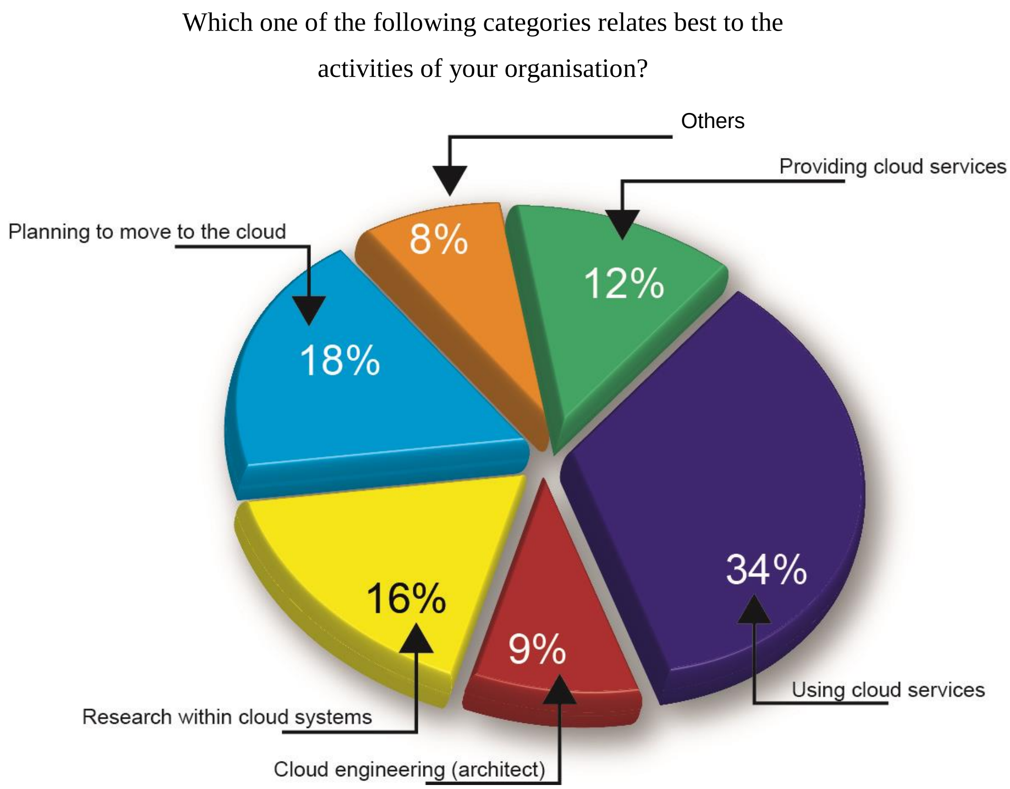


Figure 28. Organisations relation to cloud computing

Almost one third of participants were from organisations that are using cloud–based services. The others were as follows: 18% from organisations that are planning to migrate to the cloud, 16% are researchers in areas related to cloud computing, 12 % from organisations that provide cloud services, 9% of participants are cloud engineers, and 8% indicated other categories.

5.3.2 Reasons for migration

After the demographic questions the survey sought the reasons behind the decisions to migrate to the cloud. A number of reasons were identified in Stage 1 (refer to Table 13) these have been categorised into three main reasons: cost reduction, innovation, and back-up. Respondents were asked to indicate which of them are the main reasons encourage organisations to migrate to cloud computing. Figure 29 shows the analysis:

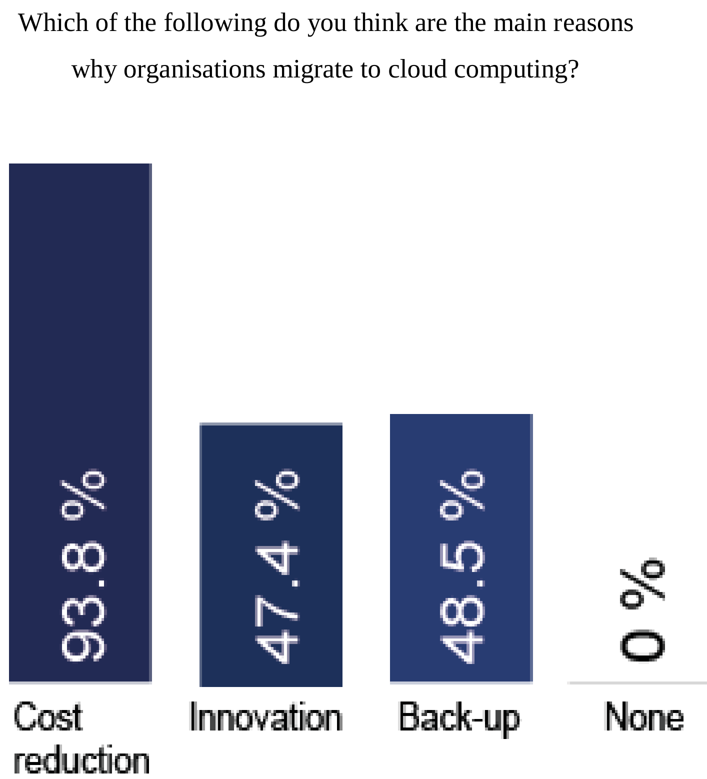


Figure 29. The main reasons why organisations migrate to cloud computing

Figure 29 shows the analysis of the main reasons that motivate organisations to migrate to cloud computing. Unsurprisingly, cost reduction appears to be the strongest motivating factor from the participants' perspective for migration to cloud computing. This can be seen in the data of response with almost 94% of the total participants. Back-up came second with (48.5%) of the participants indicating back-up as a reason for migration. Similarly, (47.42%) of the participants indicated innovation as a motivating factor for migration.

5.3.3 Main Organisational benefits

To expand on the earlier question, the benefits of migrating to the cloud or the sought advantages of adopting cloud-based services were explored as shown in Figure 30.

Which of the following in your view are the main organisational benefits for migrating to the cloud?

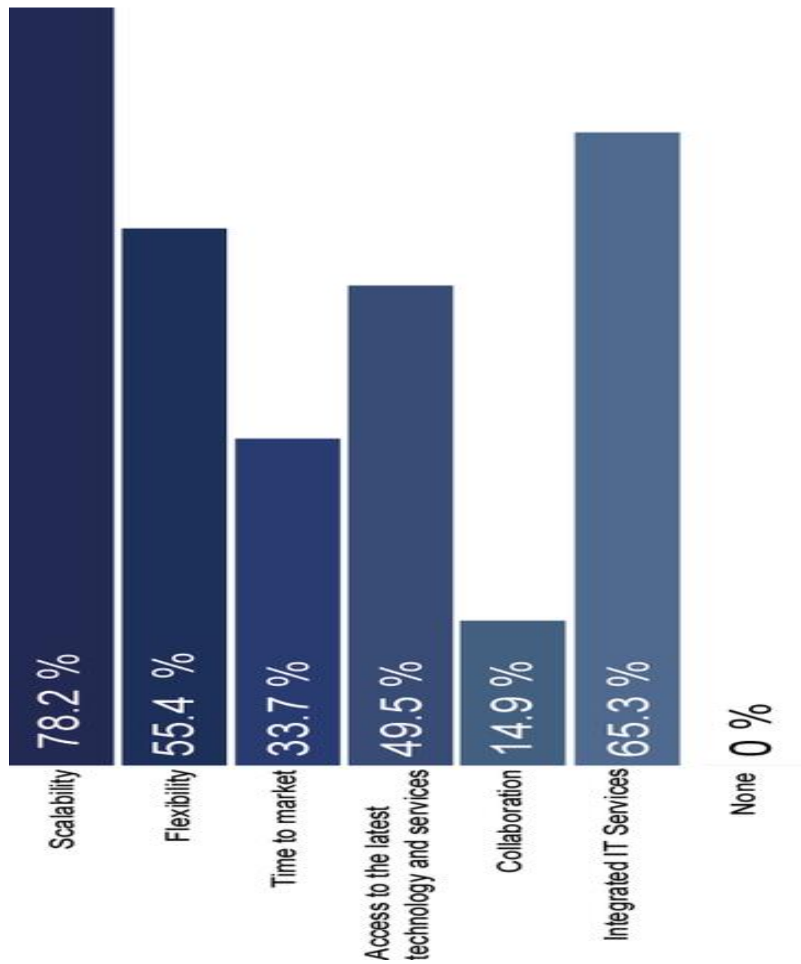


Figure 30. Views on the main organisational benefits for migrating to the cloud

Figure 30 shows the participants views about the main organisational benefits of migrating to the cloud. The majority of the respondents believed scalability was the main advantage of migrating to the cloud (78.2%). The elimination of installation of physical resources, set up, and support was frequently discussed in Stage 1 as an advantage of migrating to the cloud. This is also seen in this Stage as an important advantage by (65.3%) of participants selecting it. The flexibility of cloud-based systems and gaining access to the latest IT services and technology were also seen by respondents as key advantages (55.4%) and (49.5%) respectively. This shows that cloud-based services are seen by many as a valuable opportunity for innovation and gaining competitive advantage. Only one third of the respondents (33.7%) views reducing time to market as an advantage for migrating to the cloud.

5.3.4 Issues deterring organisations from migrating

The survey was then moved to explore the issues surrounding the process of migrating to the cloud. A total of 14 reasons, as shown in Figure 31 were provided which might negatively affect the decisions for migrating to the cloud. The classification of the reasons was identified from the analysis of stage 1.

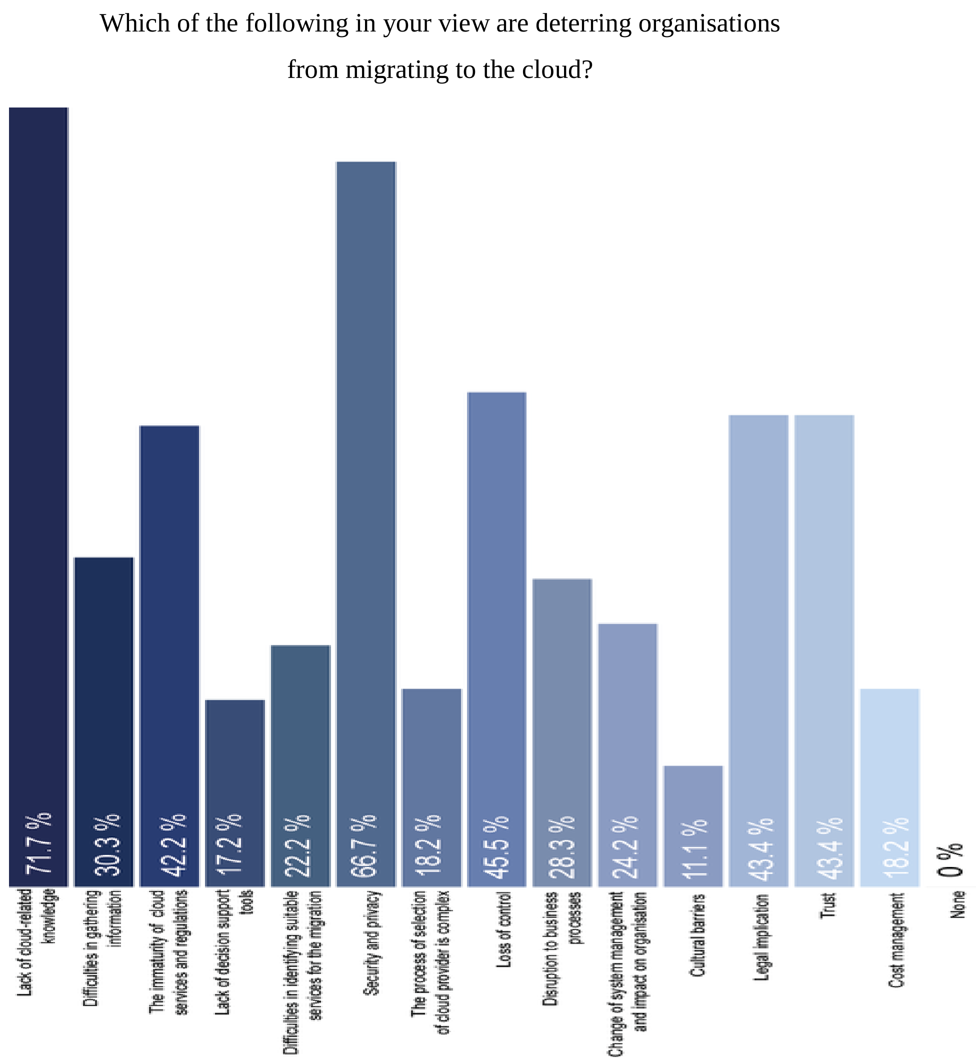


Figure 31. Issues deterring from migrating

It can be seen in Figure 31 that the majority of the participants (approximately 72%) indicated lack of cloud related knowledge as the primary factor deterring migration to cloud computing. This confirms the conclusion of stage 1 that "customers' lack of knowledge of cloud environment is a key factor that deters organisations from migrating to cloud computing". Security and privacy was found to be a major barrier for migration too with approximately 67% of participants selecting this reason. The loss of control (45%) was also found to be a concern that deters some organisations from migrating to the cloud. Lack of trust in cloud computing (43.4%) and the immaturity of cloud services and regulations (42.4%), were two other issues which had scored high in comparison to the other issues provided. Almost one third of the participants (30.3%) selected the difficulties in gathering information about cloud environment as an issue discouraging organisations from migrating. Further analysis on this aspect will be provided in section 6.3.9.

5.3.5 The main perceived problems with cloud-based provision

In section 6.3.3, 42.4% of the respondents selected the immaturity of cloud services and regulations as an issue to migrate to the cloud. In this question the participants were asked for their views on the main perceived problems with cloud-based provision. The analysis of the responses is presented in Figure 32.

Which of the following are the main perceived problems with cloud-based services?

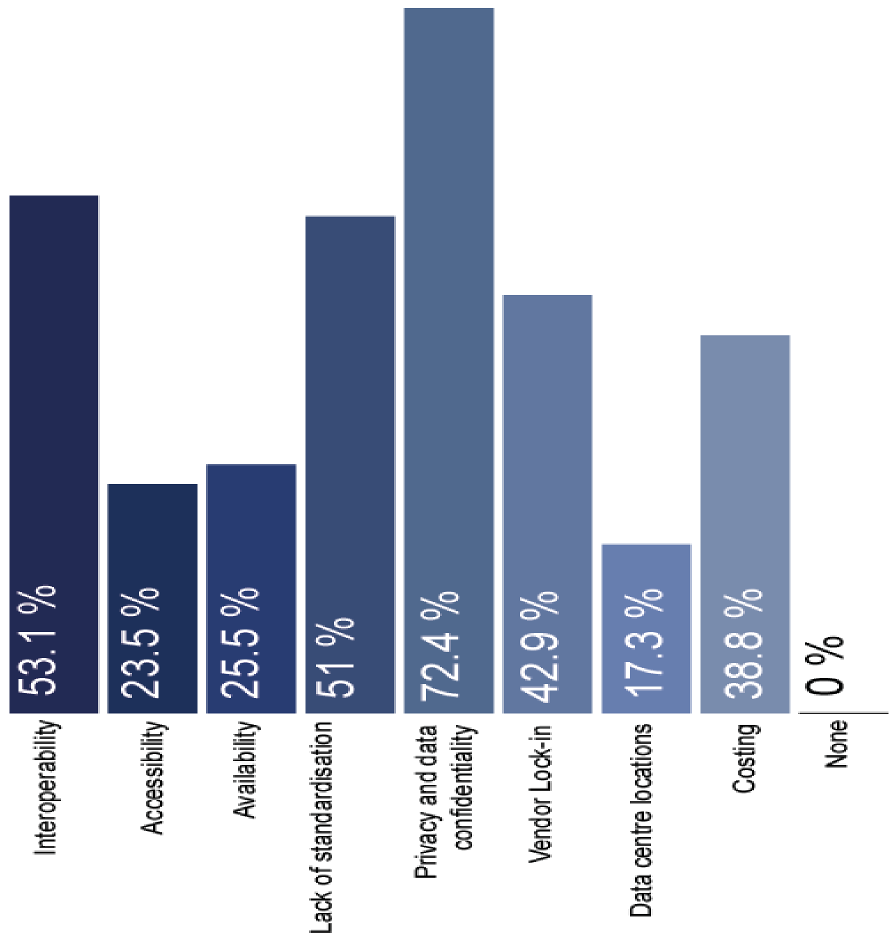


Figure 32. The main perceived problems with cloud-based provision

The multi-user nature of cloud computing usually raises questions in respect of privacy and data confidentiality. The majority of responses (72.4%) indicated that privacy and data confidentiality were their primary concerns about the cloud environment. Another dimension of cloud problems is the issue of interoperability which was indicated by 53.1% of the respondents as the main perceived problem. In order to improve trust in the cloud services, providers need to ensure privacy and data confidentiality of their customers. Further, complying with relevant standards would help in reducing the risks of vendor lock-in. This issue is partly caused by the lack of standardisation in cloud computing which was indicated by just above half of the participants. The analysis of stage 1 in this survey showed that costing of cloud services emerged as an issue some organisations faced when migrating to the cloud. However, in this question only 38.8% selected it as a problem in the cloud environment.

5.3.6 Legal Implication

With the increase of the number of rules to regulate the adoption of cloud services, regulations and legal compliance violation have become a concern for many organisations. In a question (see Figure 33) we sought the participants' views in this regard.

Which of the following are the main legal implications which can affect decisions to migrate to cloud computing?

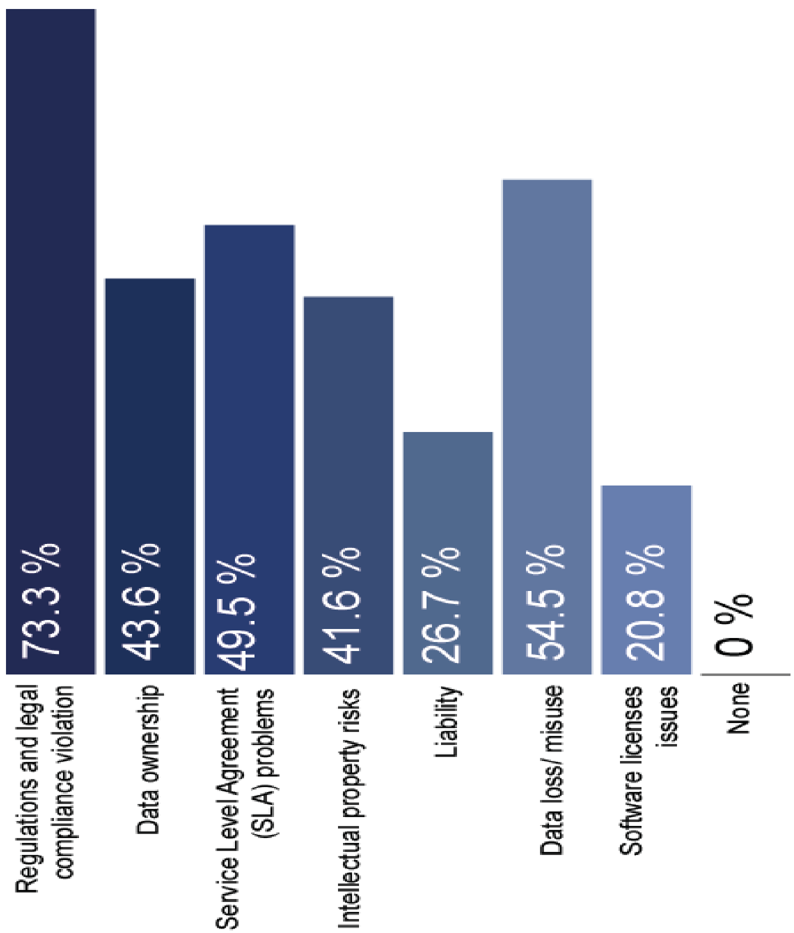


Figure 33. Legal Implication

As it is shown in Figure 33, a significant number of participants (73.3%) indicated that regulations and legal compliance violation are the main concerns that might affect their decisions to migrate to the cloud. Participants also expressed concerns in respect of legal implications of their data. 54.5% of the participants showed concerns in case of their data being lost or misused by others. The simplicity of signing up new cloud based services contracts might result in the SLA problems. About half of the participants pointed out the SLAs problems as a legal implication that affects the decisions on whether to migrate to the cloud or not. Further, 43.6% of the participants pointed out their concerns in respect of data ownership. About 41.6% indicated intellectual property rights as a legal concern.

5.3.7 Cloud knowledge and skills

Participants were given a list of 11 options in respect of knowledge and skills and they were asked to identify those which would be mostly required when dealing with cloud services. Figure 34 shows the options.

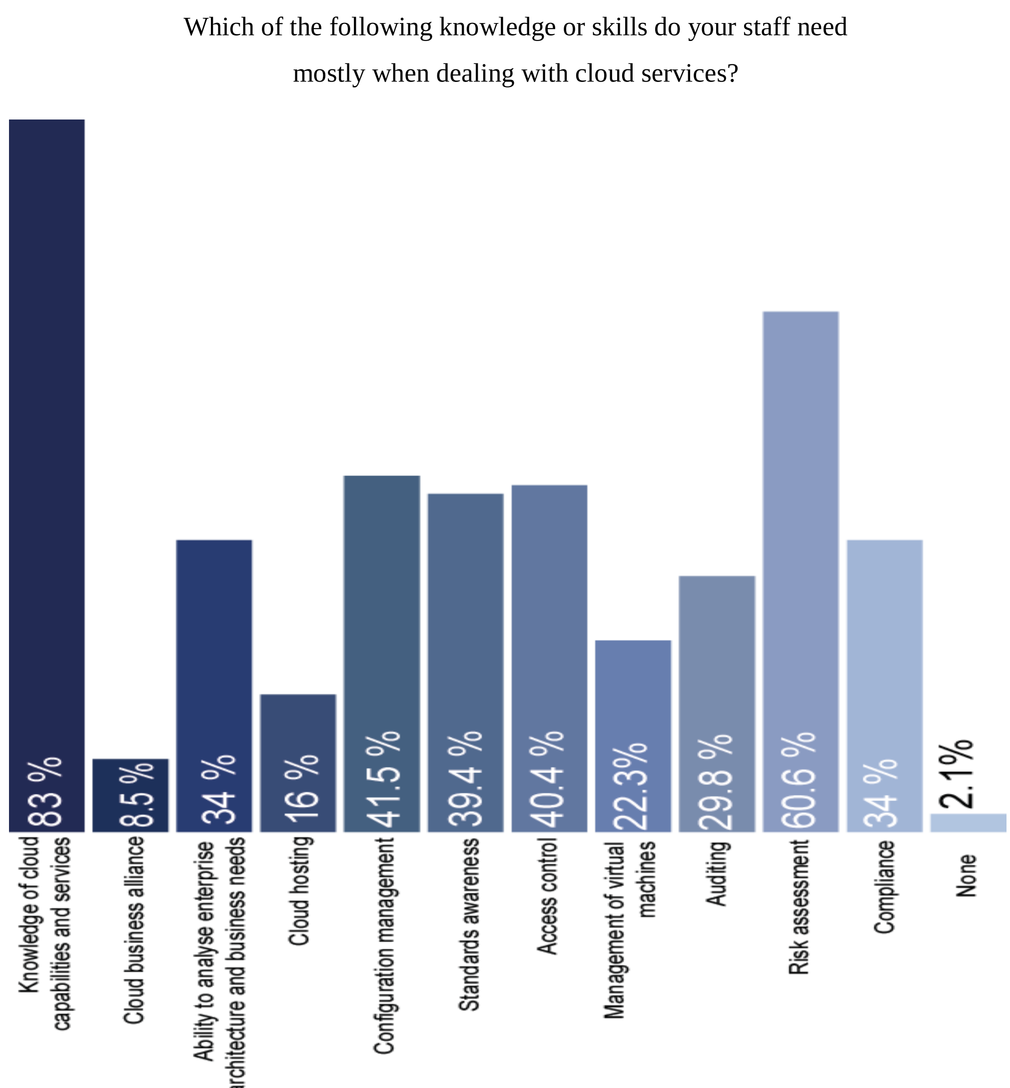


Figure 34. Cloud knowledge and skills

The vast majority of participants (83%) believed that there is a need to expand their knowledge and skills with regards to the cloud capabilities and services. The reason could be due to the rapid changes of cloud providers, services and their delivery models. The wide concerns of security and privacy were indicated again by 60.6% of the participants expressing that there is a need for cloud risk assessment skills. Other skills such as configuration management (41.5%), access control (40.4%), standards awareness (39.4%), and the ability to analyse enterprise architectures and business needs (34%) are also worth of consideration.

5.3.8 Expertise needed for IT departments

The comments made by the participants in Stage1 showed the effect of migration to the cloud on IT departments, resulting in the need for new roles. This question explores the need for expertise as a result of adopting cloud services.

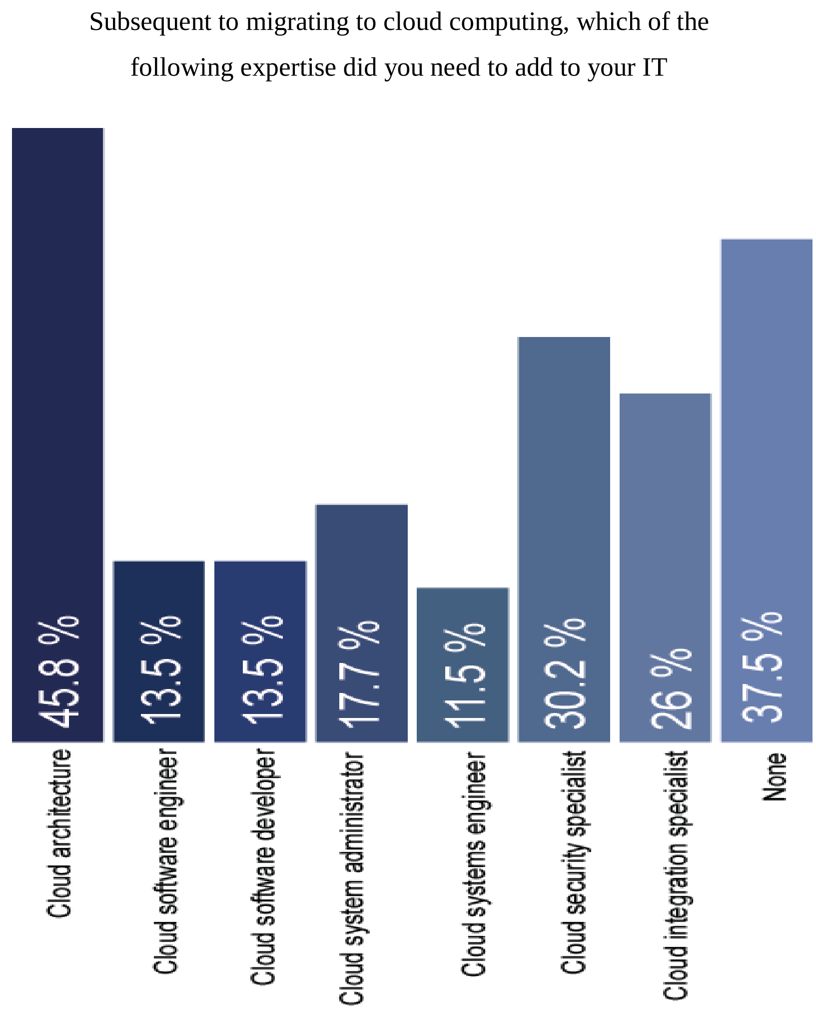


Figure 35. Expertise needed to IT department

As can be seen in Figure 35, less than half of the participants indicated that cloud architect would be the most important expertise needed for their IT departments followed by cloud security specialist (30.2%) and integration specialist (26%).

5.3.9 Impact of cloud computing on your organisation

This question sought the overall impact of implementing cloud-based services. Figure 36 shows the respondents view:

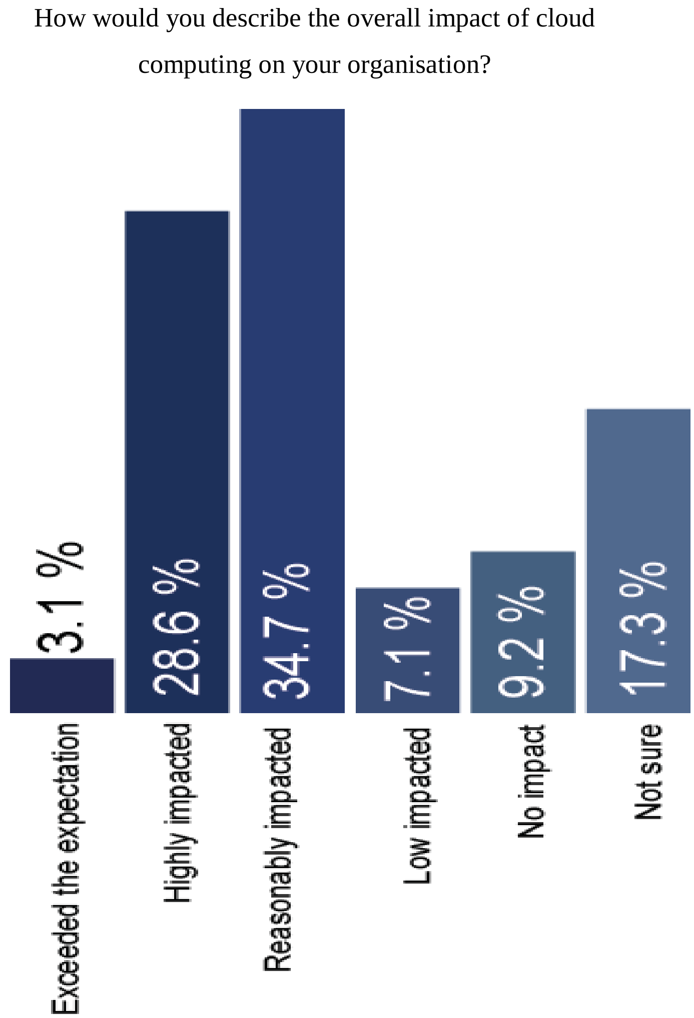


Figure 36. The overall impact of cloud computing

The majority of the respondents indicated that there was an impact of implementing cloud-based services (73.5%) while only (9.2%) indicated no impact and others (17.3 %) were not sure. The analysis shows a variance in describing the impact of cloud service on their organisations. 34.7% of participants described their overall impact as reasonable, 28.6% as high, 7.1% as low, and only 3.1% believed that the impact of adopting cloud services exceeded their expectation.

5.3.10 Quality of existing cloud-related information

The discussion on decision making process (in section 5.3) shows the importance of information for decision making, particularly during the intelligence and design phases. Participants' views with regards to the quality of the current cloud-related information were explored. A five point Likert scale from 1 (very low importance) to 5 (very high importance) was utilised. The responses are presented in Table 16.

Table 16. Quality of existing cloud-related information

Answer Options	Very low 1	2	3	4	Very high 5	Average Rating	Standard Deviation
Availability	1.12%	2.25%	25.8%	41.5%	29.2%	3.9	0.86
Sufficiency	4.44%	6.67%	38.8%	34.4%	15.5%	3.5	0.98
Accessibility	1.1%	3.4%	32.9%	38.6%	23.8%	3.8	088
Accuracy	5.5%	26.6%	36.6%	22.2%	8.8%	3.0	1.03
Consistency	14.4%	27.7%	35.5%	18.8%	3.3%	2.7	1.04
Understanda-bility	4.5%	21.3%	48.3%	21.3%	4.4%	3.0	0.89
Timely	3.3%	18.8%	48.8%	22.2%	6.6%	3.1	0.90
Diversity	3.3%	7.8%	24.7%	47.1%	16.8%	3.6	0.96
Complexity	3.3%	3.3%	28.0%	42.7%	22.4%	3.8	0.95

The analysis shows that there is a high level of availability of cloud related information. More than two-thirds (approximately 70%) of the participants rated the availability of cloud-related information as high or very high while only less than 3% indicated that there is limited information. Accessibilities and sufficiency of cloud related information were also scored highly rated by average weights of 3.8 and 3.5 respectively. Moreover, participants indicated that cloud-related information was reasonably accurate (3.0) and could be understood (3.0).

Despite the high rating of the aforementioned, participants did indicate that there is a problem with consistency in the cloud related information (with an average rate of just 2.3), a high level diversity of cloud-related information (3.6) and also it is complex (3.8). This contradiction signifies that there is a need for cloud information filtering system to reduce the information gathering difficulties and to enable organisations to develop trust.

Although many organisations believe that cloud-related information can easily be obtained and to some extent it is reliable, they do not find it easy to develop an understanding about the cloud environment. This can be due to the diversity of information sources and their complexity. This could be the reason for the issue of limited knowledge of customers in respect of the cloud environment.

5.3.11 Valuable sources of information for migration

This question explores the participants' perception on the most valuable source of information to develop knowledge with regards to the cloud environment. Figure 37 shows the analysis.

Which of the following are the most valuable sources of information for supporting decisions for migration to cloud?

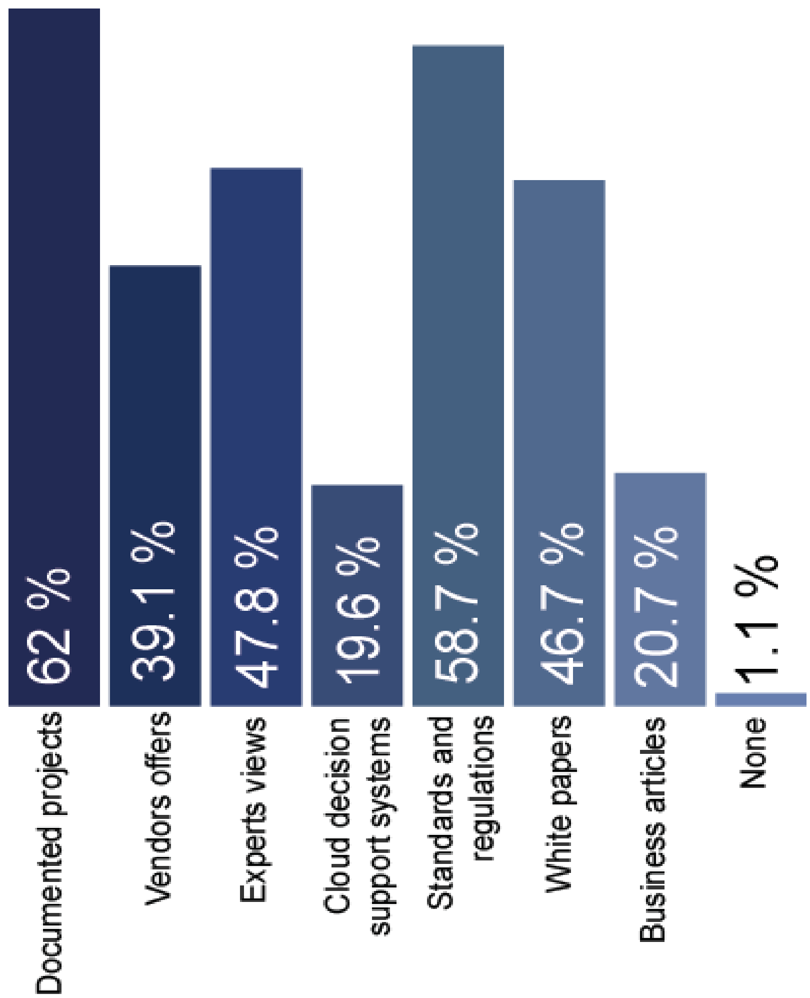


Figure 37. Valuable sources of information for supporting decisions to migrate

Documented projects scored the highest with 62% of participants, followed by reviewing the standards and regulations which was selected by 58.7% of participants. Gaining information from experts' insights was indicated by 47.8% of respondents as a valuable source of information and 46.7% for white papers. Vendors' offers were selected by 39.1% participants as an important source of information. Among these options, cloud decision support systems scored the least with only 19.6% of participations selecting it.

5.3.12 The need for cloud knowledge-base

This questions explored participants' views with regard to the need for a knowledge-base to support migration decisions. The vast majority of respondents (85%) indicated the need for a cloud knowledge-base as important while only (12.5%) expressed it is not important or they were not sure. The analysis is shown in Figure 38.

To which extent do you think there is a need for a cloud knowledge-base to overcome the lack of customers' cloud-

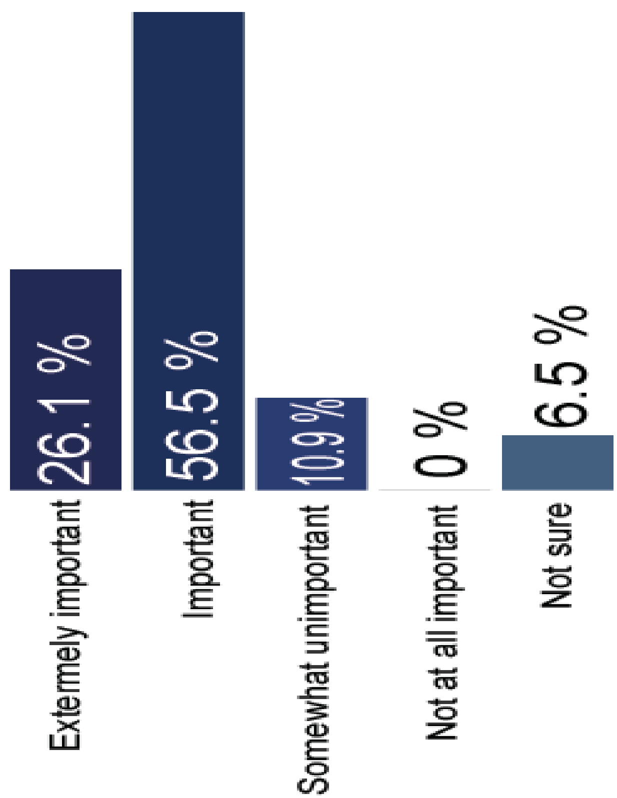


Figure 38. The need for cloud knowledge-base

5.3.13 Conclusion from Stage 2

The analysis of Stage 2 showed that the surveyed organisations sought to migrate to cloud computing mainly to reduce costs. It also showed that cloud-based services are seen by many as a valuable opportunity for innovation, for gaining competitive advantage, and for off-site back-up. Respondents identified a number of issues with regard to making decisions concerning the migration to cloud computing. A lack of customer knowledge about the cloud environment was found to be the primary issue. Respondents also identified other issues that included: security and privacy concerns, loss of control, the immaturity of cloud computing and regulation, and legal implications. The immaturity of cloud computing and regulation raised concerns about privacy and confidentiality, interoperability, and a lack of standardisation. Extensive concerns over regulation and legal compliance violations were indicated. Respondents also registered concerns about, their data being lost or misused by others, SLA problems, data ownership, and intellectual property rights. Therefore, in order to improve trust in cloud services, providers need to ensure the privacy and confidentiality of their customers' data, employ comprehensive costing models, in addition to complying with relevant standards to reduce the risks of vendor lock-in.

Respondents indicated different levels of impact as a result of migrating to the cloud. They believed that there was a need to expand knowledge and skills with regard to cloud capabilities and services and risk assessments. They also believed a cloud knowledge-base would help to overcome the complexity of migration to cloud computing.

Although many organisations believe that cloud-related information can easily be obtained and is to some extent reliable, they do not find it easy to develop an understanding about the cloud environment. This could be due to the diversity of information sources and their complexity. The identification of these issues enhances the requirement to support organisations' decisions at the intelligence level, in order to ensure adequate understanding of the cloud environment.

5.4 Summary

This chapter discussed the analysis of a two-stage survey employed in this research. The survey explored the issues surrounding the process of migrating to cloud computing. It identified factors affecting the decision to migrate. It also highlighted the levels of the various impacts of migration and areas that need to be taken into consideration to ensure successful migration. Stage 1, which was based on in-depth interviews, identified four themes with regard to the migration to cloud computing: the lack of knowledge of cloud customers in respect of the cloud environment, factors affecting decisions to migrate to the cloud, the impact of migration on IT management, and areas to be considered to ensure successful migration. Stage 2 was more focused on identifying the challenges involved in making the decision to migrate to the cloud. The issues investigated were derived in-depth from the analysis of the findings of Stage 1. The next chapter will discuss the model proposed in this study to help organisations to ensure successful migration. It will discuss the steps and tasks to be performed to tackle the issues and challenges identified in this chapter.

Chapter 6 The proposed decision process model for cloud migration

6.1 Introduction

This research is centred on supporting organisations with their decisions to migrate to the cloud. It considered technical and organisational factors that might influence organisations decisions. The investigation of the literature review (chapter 2 and 3) and the two-stage survey (chapter 5) is divided into two main parts: an exploration of the factors influencing the decision making for migration and an identification of the areas that need to be taken into account when considering the migration of existing resources to the cloud. This chapter discusses the main research findings. It includes the current situation with regard to cloud migration decisions, followed by a discussion of the factors that contributed to the complexity of migration decisions.

Additionally, this chapter discusses a decision process model proposed by the author for migrating to cloud computing in an attempt to fill the need for a comprehensive decision process. The model provides a process and a methodological approach to mitigate the complexity of migration decisions, and can be used as a guide to support the decision making process of migrating to cloud computing. This chapter also discusses an evaluation of the model that is based on analysing the views of a group of cloud practitioners and a prototype for implementing.

6.2 Cloud migration decisions

The attractiveness of cloud-based services due to their promised advantages, particularly the reduction of capital expenses and the virtually infinite resource capacity (Armbrust et al. 2010), has motivated many enterprises to migrate their applications to the cloud. According to Sahandi et al. (2013), many enterprises are very interested in cloud computing that will enable them to reduce costs, improve flexibility and scalability. Established companies as well as start-ups view cloud computing as a valuable opportunity that offers them a competitive advantage and will allow them to meet their business objectives more effectively (Buyya 2009; Armbrust et al. 2010).

Organisations are usually interested in moving only some of their systems to the cloud because not all applications can be easily migrated, for example, safety-critical software (Andrikopoulos et al. 2013c). Unlike start-ups that develop systems from scratch, organisations planning to migrate existing legacy services to cloud computing often need to deal with what is called ‘brownfield development’ where new services have to inter-operate with the existing systems (Khajeh-Hosseini et al. 2012) and (Rai et al. 2014). For this reason, many organisations have found it difficult to adopt cloud-based services (Mohagheghi and Sæther 2011).

The complexity in the decision to migrate to the cloud has been highlighted in the literature. Saripalli and Pingali (2011) indicated that decisions regarding migration to cloud computing are inherently complex, because they are influenced by a number of inconsistent criteria such as cost and quality of service. Khajeh-Hosseini et al. (2011) pointed out that conducting an evaluation of the benefits, risks and costs is also far from straightforward. Further, the shift towards the cloud is likely to result in considerable changes in how IT services are developed, deployed, supported, and paid for (Dhinesh et al. 2014). This has led to the need for organisational and socio-technical factors to be taken into account during the decision making process (Khajeh-Hosseini et al. 2011). Menzel et al. (2012) emphasised that migration to cloud computing is a decision-making problem that requires identification of criteria and value-driven comparison of alternatives with respect to the criteria selected. Andrikopoulos et al. (2013a) also pointed out that migrating to the cloud is a multi-dimensional problem with multiple decision points that may create various analytical tasks and interconnected feedback loops. Further, Shoeib (2000) indicated that outsourcing projects are difficult to evaluate due to adequate outcome feedback can only be obtained after implementation. Latif et al. (2014) stated that as cloud computing represents a fairly new paradigm; there is still a significant number of issues and risks within the process of migration.

Many previous studies explored the business benefits and barriers for adoption. They focused mostly on the cost benefits, scalability, agility and the security issues, for examples see (Low et al. 2011), (Wu et al. 2011), and (Sahandi et al. 2012), (Lin and Chen 2012) and (Morgan and Conboy 2013). While these studies identified some factors that influence the decisions to migrate to the cloud, they were developed at an early stage of the evolvement of cloud computing. The majority of them explored the factors affecting the adoption of cloud services while little attention was paid to the migration of legacy systems. Further, many models and frameworks have been proposed to aid organisations with their decision to migrate to the cloud environment (discussed in 3.5). Despite the development of those works, the decision to migrate existing systems to the cloud remains difficult (Gonidis et al. 2014). The main problem with those approaches is the underestimation of the level of complexity involved in migration decisions. They have mostly focused on supporting the migration at the choice level (selection of cloud providers). Although evaluation of providers and their appropriate selection are critical, making an informed decision to migrate requires the analysis of a wide range of factors at early stages of the decision process. While the existing literature provides a fundamental understanding of cloud computing architecture, benefits and some issues, models and frameworks to support the migration and managing cloud services, research on drivers and barriers of the broad organizational adoption is still in early stages (Hsu 2014) and (Phaphoom et al. 2015). Therefore, this research explores the issues that have increased the difficulties in organisations' decisions to migrate to the cloud. The following section discusses the main findings with regards to the factors that increased the complexity to migrate to the cloud.

6.3 The complexity in the decisions to migrate to the cloud

The literature review (chapter 2 and 3) and the two-stage survey (chapter 5) identified a number of factors and issues that confirmed to the complexity of the decisions to migrate to the cloud. Figure 39 shows the findings of the exploration. Eleven determinants that contributed to the complexity in the decision to migrate to the cloud are identified. These requirements for consideration during the decision-making process resulted in confusion in how to migrate existing systems and which service provider to choose.

Risks: the process of migration to the cloud involves: a number of risks, loss of privacy, disruption to business processes, legal implications, change to the systems management, problem with interoperability, data integrity, application portability, business continuity, staff productivity, and security issues. The complexity and lack of transparency with respect to cost and quality are further challenges for many (Motahari-Nezhad et al. 2009), (Omerovic et al. 2013) (Sahandi et al. 2013), and (Willcocks et al. 2011). The Cloud Security Alliance (CSA 2011) identified 7 top threats of cloud computing. They include: abuse and nefarious use of cloud computing, insecure interfaces and APIs, malicious insiders, shared technology issues, data loss or leakage, account or service hijacking, and unknown risk profile. These threats had led to wide concerns about the Availability and accessibility of cloud based services. The findings of the two-staged survey shows that IT managers and security professionals have high concerns over security with regards to the migration of sensitive data. Further, the analysis showed concerns about potential risks to organisations that may include: loss of control, dependability, managing relationships with different cloud providers, liability, and business continuity and disaster recovery. For example, if an organisation is unable to access cloud services at a critical time, when it is largely dependent on the cloud provider's customer service to provide information, and a lack of such information can lead to poor communication with the service's customers.

Cost management: although, cost effectiveness has been found as the main reason that drives organisations to move to cloud computing, the analysis of the two-staged survey showed that cost was also found to be the main reason for enterprises that moved back from the cloud. For example a cloud provider pointed out that "Costs are interesting because it's an instant attraction, but actually, very often clouds tends to be more expensive than people think it's going to be". Cloud customers might need to pay for data transfers in and out, storage of data in the cloud on a gigabyte per month basis, support, and additional availability, therefore the combination of charges a month actually become a considerable cost which require comprehinsive analysis. The challenges of cost analysis for migrating to the cloud include ROI calculation that require multiple factors to be taken into account, cloud venders' have different standards and payment models, and the lack of companies expertise for managing costs in the cloud environment.

Increasing service providers: another factor that influences the complexity of migration decisions is the availability of vast numbers of cloud-based services, configurations, and providers and the lack of cloud standards and regulations (Garg et al. 2013).The range of cloud-based services offered is growing simultaneously with the emergence of varying cloud service providers. Enterprises can find cloud based models of possibly everything from general-purpose applications such as email, and collaboration technologies to sales management and accounting software (GoGrid 2012). Further, According to García-Galán (2015) there are over 100 public cloud providers associated with a considerable number of confirmations, for example Amazon web services has 16.991 different configurations. Although, this rapid increase opens up new opportunities for designing new applications and enterprise architectures, new quality levels, and capabilities, it increases the difficulty of choosing a provider and a service and renders the run-time adaptation and replacement of services almost impossible (Omerovic et al. 2013). Furthermore, cloud services are usually varied in their business models, functionality, quality of service, cost, and value (Omerovic et al. 2013).

Regulation and compliance: the increase in the number of rules to regulate the adoption of cloud services, regulations and legal compliance violation has become a concern for many organisations.

Extensive concerns over regulation and legal compliance violations were indicated by the participants in Stage 1. Participants also registered concerns about, the loss or misuse of data by others, SLA problems, data ownership, and intellectual property rights. It was argued that enterprises need to ensure compliance with regulations. Further, the simplicity of signing up new cloud based service contracts might result in Service Level Agreement (SLA) problems. SLA is a vital aspect in cloud computing. It includes agreements regarding the quality of service attributes, pricing, compliance to regulation, level of support, security and privacy guarantees, and others.

Organisations need to review the general terms and conditions that providers usually include in SLAs.

Systems heterogeneity: another dimension is the organisational context. The heterogeneity of systems within organisations and their requirements have also affected the complexity of the decision making process when considering migration to cloud based solutions. Andrikopoulos et al. (2013c) pointed out that the decision whether to migrate, which cloud services to use, and at which level to outsource is not trivial and that it largely depends on multiple factors that are specific to the context of each enterprise. Further, organisations have different business processes, interdependent criteria and constraints to consider when moving their systems to cloud environments (Juan-Verdejo et al. 2014). Organisations also have different expectations and expertise about the cloud environment.

Social factors: another dimension to consider is the social factors. Ferrer et al. (2012) stated that economic factors are not sufficient for a highly dynamic environment in which relationships are created on an on-off basis with a possible high degree of anonymity between stakeholders. A broader perspective is required that should incorporate quality factors, including trust reputation management, risk assessment, green assessment, and economic sustainability.

Service readiness: another dimension is the need for service design and adaptation. According to (Bergmayr et al. 2013) the systematic and efficient modernisation of legacy applications to exploit current cloud-based technologies remains a major challenge. Applications consist of several components that are connected with each other to comply with the application's functional and non-functional requirements (Juan-Verdejo et al. 2014). These components need to be correctly adapted according to the target cloud environment. Failure or incorrect adaption might result in difficulties in meeting some quality or economic requirements (Juan-Verdejo et al. 2014). Typical adaptation problems range from compatibility issues to licensing that may forbid organisations from moving registered software components. Service performance could also be affected due to the increase in latency. These kinds of issues usually occur when a service component is shifted to the cloud while another dependent component is kept on-premises to meet security requirements (Juan-

Verdejo et al. 2014). Zhao and Zhou (2014) identified the need for holistic methodology, redesign and adaption to application for special migration, architecture refactoring, integrated development environment to support the migration of legacy applications to the cloud environment.

The immaturity of cloud services: lack of standards in cloud computing also raise interoperability, mobility and manageability issues between cloud providers which may increase the likelihood of vendor lock-in with possible economic impacts (Opara-Martins et al. 2014).

Knowledge about the cloud environment: the findings of the two-stage survey shows that the provision of cloud-based services is different from the traditional offering. The differences include the pricing and payment methods, performance monitoring, regulation and compliance, architecture, security, and service support. These differences require a certain expertise and knowledge that enterprises do not usually have.

Source of information: generally, information plays an important role in any decision making process, particularly during the intelligence and design phases of a decision making process. Participants in this research perceived that there is a high level of availability of cloud related information. Although many organisations believe that cloud-related information can be easily obtained and is to some extent it is reliable, they do not find it easy to develop an understanding about the cloud environment. This can be due to the diversity of information sources and their complexity. This could be the reason for the issue of limited knowledge of customers in respect of the cloud environment

Impact of migration: migrating an existing system may result in errors and significant costs to the changes involved. Organisations do not want to see disruptions to their business and many enterprises are anxious that system failure may affect their reputations. From the security analyst's perspective, the security experts interviewed in this study indicated that it is a risky move when a company that revolves around its central service, needs to give up what the entire business is anchored upon and move to a cloud solution. Therefore, enterprises also need to evaluate the impact of migration to the cloud on organisational culture and staff, due to possible unfamiliarity with the system and the environment.

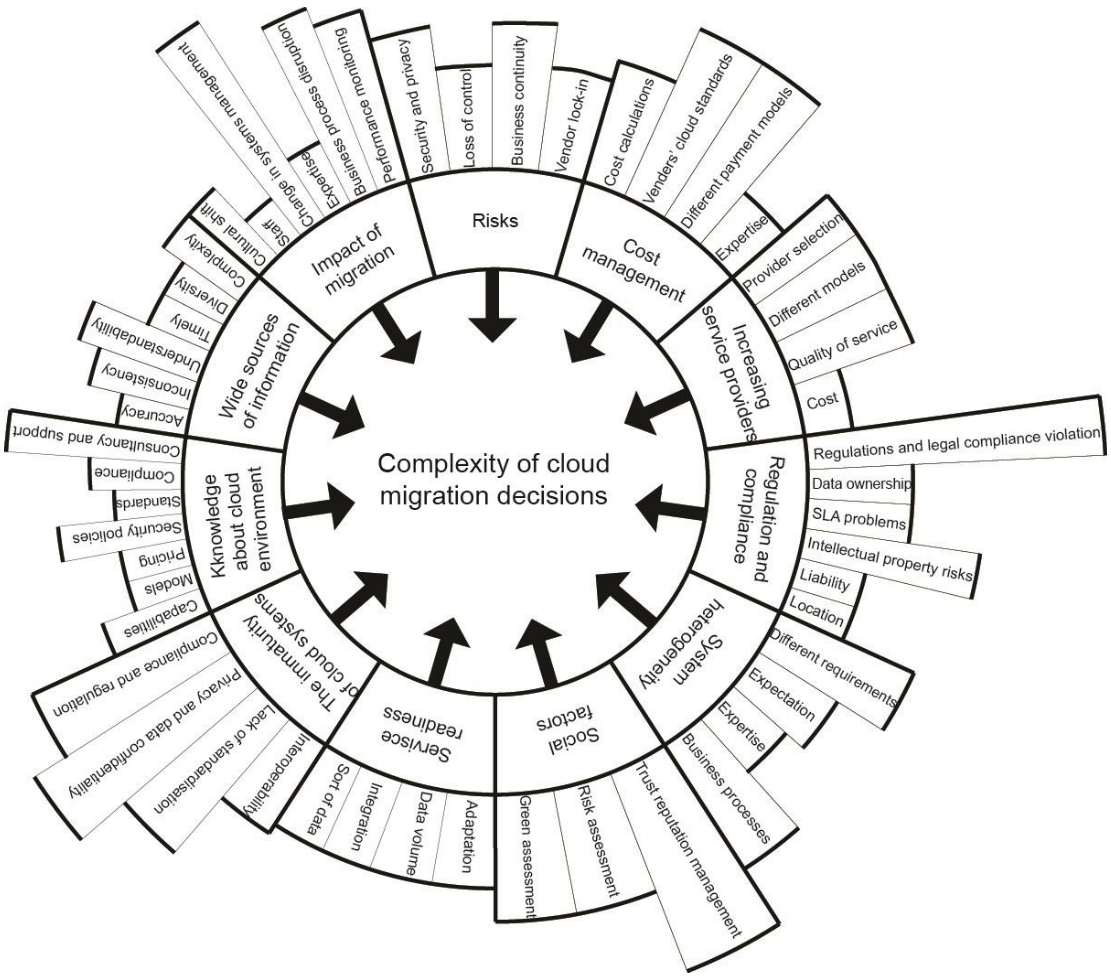


Figure 39. The complexity in the decisions to migrate to the cloud

Therefore, making the decision of whether and how to migrate existing systems to the cloud can be difficult. The cloud environment is still emerging therefore decision makers need to carefully assess the capabilities of cloud computing to determine whether this style of computing will help achieve their business goals. It requires the consideration and evaluation of a wide range of technical and organisational aspects (see Figure 40).

Cloud computing is a disruptive model of provisioning IT services, therefore perceiving it as complex environment is expected. The complexity can be mitigated by taking advantage of the testing facilities in the cloud that can allow organisations to be more familiar with the new environment. Further, the cloud is still in a growing phase and its complexity and risks are expected to be reduced.

In respect of the perceived risks, this result shows no difference from studies conducted at the beginning of cloud adoption such as (Low et al. 2011), (Wu et al. 2011), and (Sahandi et al. 2012). Therefore, security, fear of losing control, and vendor lock-in are still perceived by many as issues deterring migration. Further, to manage the impact on staffing, organisations need to analyse the anticipated change to the staffing level, roles and expertise during the design phase, before commencing the process of migrating existing services to the cloud. In order to improve trust in the cloud services, providers need to ensure privacy and data confidentiality of their customers. Further, complying with relevant standards would help in reducing the risks of vendor lock-in. This issue is partly caused by the lack of standardisation in cloud computing which was also indicated by participants as an issue that contributed to the complexity of cloud computing. In order to help organisations to decide whether to migrate to the cloud, there is a need to inform them about general security; whether the security of the infrastructure is resilient. The project manager should then move to the performance aspects by providing information about the opportunities and options which will meet the customer's requirements. The decision makers may not be interested in the technical details but it is important for them to see the business benefit. These items of information will allow enterprises to build confidence in the cloud service management. Based on this information, it should be possible to advise enterprises which cloud solution will be most suitable for them. Therefore, providers need to ensure the privacy and confidentiality of their customers' data, employ comprehensive costing models, in addition to complying with relevant standards to reduce the risks of vendor lock-in.

Successful cloud migration requires a clear understanding of the cloud environment, careful planning, system analysis, and execution to ensure the cloud solution's compatibility with organisational requirements, while maintaining the availability and integrity of the organisation's IT systems (Khajeh-Hosseini et al. 2011). Further, migration to the cloud environment requires more emphasis on business design where cloud service will interface with business systems. Therefore, the success of cloud computing is mainly based on the efficient implementation of the architecture (Sahandi et al. 2013). The range of cloud-based services currently offered by vendors is growing simultaneously with the emergence of varying cloud service providers. Consequently, along with the utilisation strategy, it is important to perceive which services are desired. Despite its offerings and ease of deployment, cloud computing requires careful consideration by management in areas such as strategic advice to enable them to decide when, what, and how services will be the most efficient option for cloud outsourcing (ACCA 2011). These requirements for consideration during the decision-making process resulted in confusion in how to migrate existing systems and which service provider to choose. Moreover, this confusion is usually associated with a lack of expertise to manage and understand the cloud's configurations and operational metrics. These have increased the requirements for supported migration decision. The review of the existing approaches discussed in sections 3.5 shows that there is a lack of a comprehensive decision support process. Particularly, there is limited consideration of the intelligence and design levels for the decisions to migrate to the cloud. The following section discusses the proposed model that attempts to address the limitation in the current cloud DSSs.

6.4 A proposed cloud migration decision process model

The review of the current state of research for migration to cloud computing revealed that, although there have been many methods proposed for supporting migration to the cloud, no systematic decision making process exists that can clearly identify the main steps and explicitly describes the tasks to be performed within each step. Therefore, this section discusses a process model to aid organisation with their decision making for migrating to the cloud in an attempt to fill the need. The eleven factors as well as the lack of a systematic migration decision process are the main drivers for designing the model.

Two main stages led to the development of the model. First, key aspects that needs consideration during the process of migrating are identified based on the outcome of the two-stage survey discussed in chapter 5 as well as the analysis of cloud DSSs and decisions. Second, these aspects are then structured into phases, steps, and tasks by following Simon's decision process model (Simon 1977) discussed in Chapter 3. Simon model was selected because it has been widely accepted and adopted as a systematic structure for making rational organisational decisions and problem-solving model. It was designed to ensure a systematic process to address decisions that are highly unstructured, complex, involve risks and would have an impact on the future of organisations which is the case for the decision to migrate to the cloud. It covers all phases of the decision making: intelligence (identify problems, requirements and opportunities within the cloud environment), design (service suitability and risk assessment) and choices.

The proposed model is focused on the identification and analysis of relevant areas that might influence the decision to migrate. Particularly, the model centred on the tasks required during the intelligence and design phases which have been neglected by existing cloud DSSs (discussed in chapter 3). The proposed model consists of four main components: Information Sources, a Knowledge-Base Decision Support System (KBDSS) platform, and a Cloud Migration Process, as shown in Figure 40.

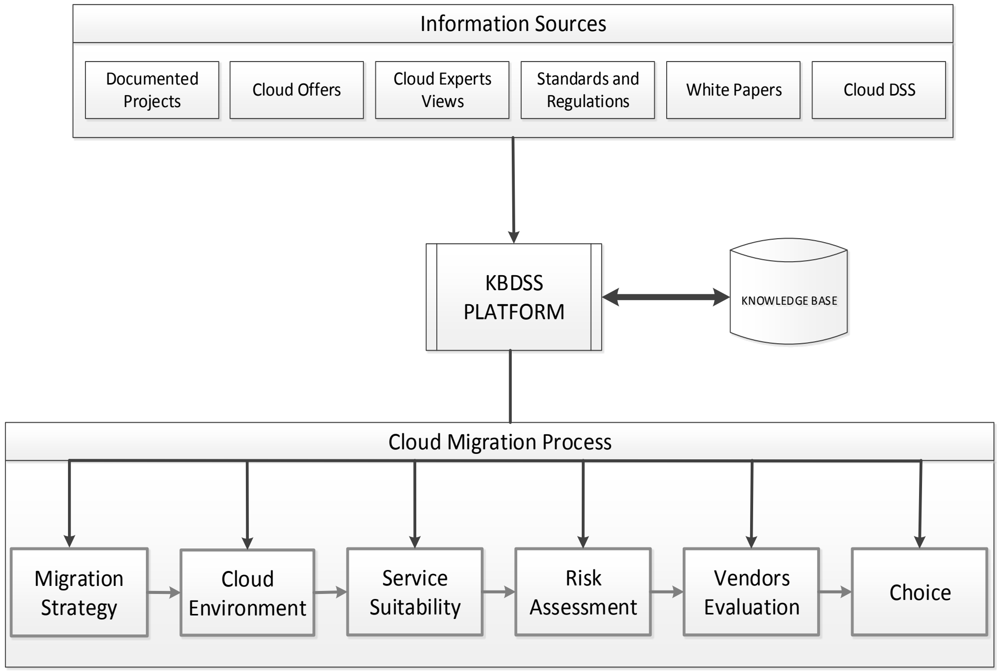


Figure 40. Cloud migration decision support system: conceptual view

Information sources:

The sources for gathering information may include: documented projects, cloud services offers, cloud experts' views, relevant standards and regulations, vendors' white papers, and existing cloud DSSs.

KBDSS platform:

A KBDSS platform can be utilised to structure the gathered information before storing them in a knowledge-base. It will also be used as an access management point to and from the knowledge-base.

knowledge-base:

The knowledge-base is a major integrated part in this model to store the gathered information to assist each phase of the migration process, particularly the intelligence phase that requires a consistent source of information. It may include facts about the cloud environment and procedural information (cloud rules). The knowledge-base could be constructed through the use of the existing intelligence techniques for knowledge acquisition and the integration of cloud DSSs and tools.

Cloud migration process:

The cloud migration process block comprises six main steps. They are: migration strategy, cloud environment, service suitability, risk assessment, vendors' evaluation, and choice. These steps would support the decision-making process by guiding decision makers through a structured hierarchy of tasks. Subsequently, using the multiple analytical techniques to analyse and select from alternative service providers.

Figure 41 shows the sequence and the inter-relationship between the six main steps of the cloud migration decision process, and the tasks to be carried out during each step. The process starts by examining the internal environment and identifying the organisational requirements and objectives for migration. The next step is to recognise the cloud guiding principles and capabilities and develop an initial understanding about the cloud environment. This step should be carried out with reference to a knowledge-base that should provide structured information about cloud offers, pricing policies, security polices, performance monitoring, compliance to regulators, and support. This information can assist organisations in recognizing the cloud environment to fill in the lack of knowledge with regard to cloud environment. These two steps constitute the intelligence phase of the decision making process and they can be supported through the intelligence level of the knowledge base by analysing the defined requirements and objectives and provision of relevant cloud environment information.

If requirements and objectives are specified and initial understanding about the cloud environment is developed, the migration decision can move to the design phase. It involves two main steps: an identification of the suitable services to be migrated and a risk assessment for each candidate service. The process of evaluating the suitability of a service includes: identifying a service's requirements, integration, data volume, critical to business, and a Return of Investment (ROI) calculation. These tasks are performed during this stage to ensure that the requirements and characteristics of business services are suitable for the cloud environment and they can be supported through the design level of the knowledge base. If a candidate service is identified, then it's critical to conduct a risk assessment for each selected service, including the risks to organisation, the legal implication, and the security threats' probabilities and their consequences.

After the risk assessment has been carried out, decision makers are required to evaluate the cloud vendors to select the appropriate providers. In this model, the SMICloud for cloud providers' ranking and evaluation developed by Garg et al. (2013) has been adopted. It uses the AHP mechanism to rank cloud providers based on the QoS attributes that defined by ISO. The final step in this process is to make the choice for the most appropriate cloud provider and then implementation. If a cloud provider is chosen, the decision making is achieved and the process moves to the implementation step that would require training members of staff on the new system, communicating the new service's information to all affected parties, and then documentation.

The significance of this approach relies on the combination of various resources that allow users to access a wider range of relevant data and information, in addition to the capabilities provided by the traditional DSS approaches, such as AHP based models. The following sub-sections provide detailed discussions on decisions involved in the process and the tasks to be performed.

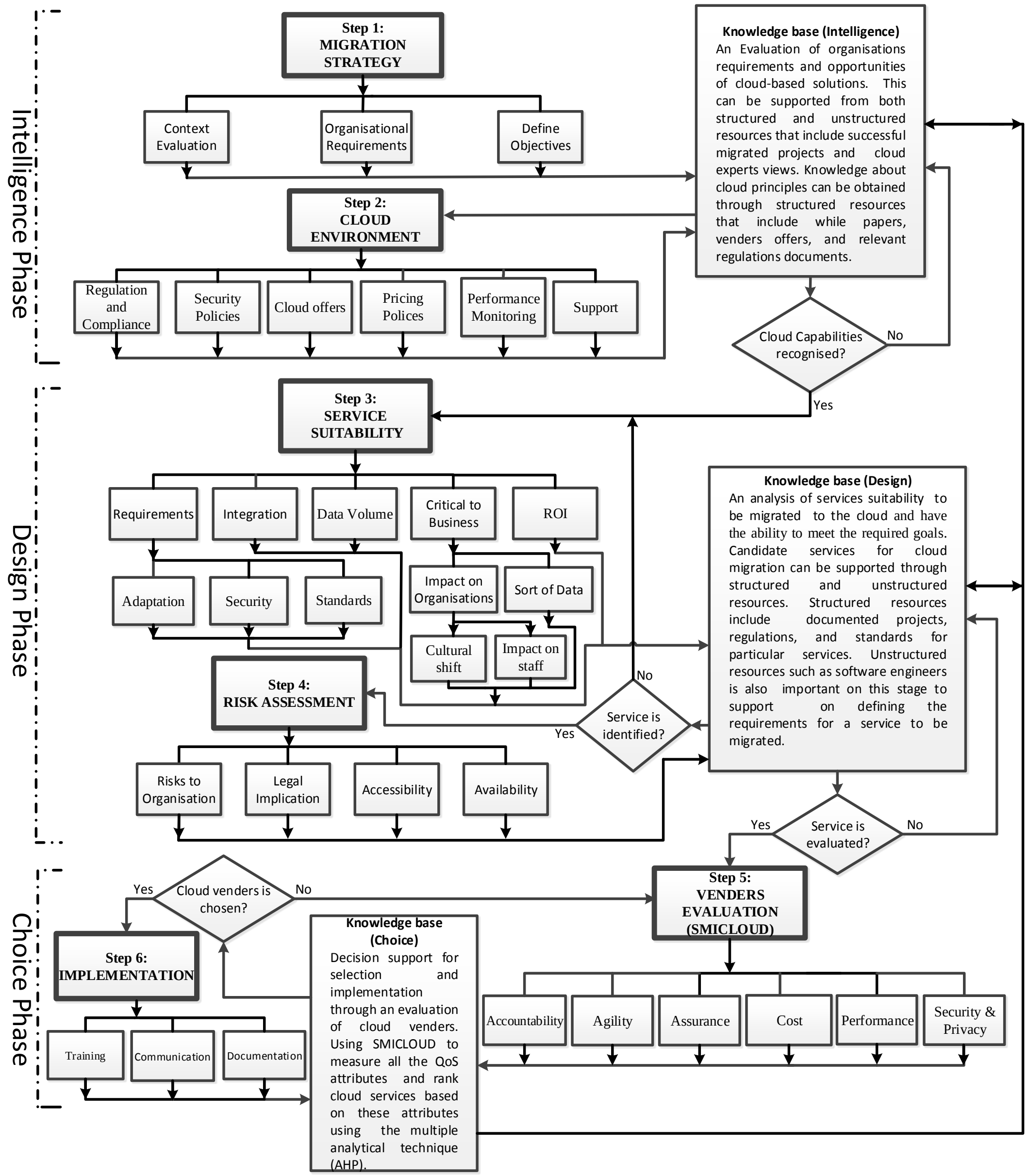


Figure 41. Cloud migration decision process model

6.4.1 Migration strategy (Step 1)

Defining the migration strategy and developing an understanding of the cloud environment constitute the intelligence phase of the decision-making process which can be supported through the intelligence level of the knowledge-base (See Figure

41). This phase includes activities for gathering information from the environment in which the system is currently operating in to identify requirements, market trends, and then to define the objectives. It also includes information gathering from the new environment, to identify its main guidelines, opportunities, suitable configurations, and potential risks. The process starts by formulating the migration strategy for migration by examining Internal and external environments. The purpose of this step is to identify what will be achieved by migrating a legacy service or implementing a new system in the cloud.

The motives of organisations for considering cloud migration are usually to gain a competitive edge, improve efficiency, business agility, and innovation. Migration to cloud computing can be a strategic decision for organisations to enhance scalability, flexibility, and time to market. The need for testing and staff training before deploying a new system can be an issue for some organisations. The time required for testing and deploying new local IT services is also another issue for many organisations. Cloud computing can reduce the requirement for an upfront cost through the rapid provision of advanced resources, an approach which may not be possible using local-based IT services. New business processes can be designed and tested through the cloud environment before their official deployment. Organisations can have a replica environment running in parallel, in the cloud and keeping the in-house legacy system running as normal. If the new system delivers the sought strategic values, organisations can then back-up their legacy data and have it available, starting the new system with a fresh configuration and then moving traffic across. This approach of deployment can significantly reduce the risk of impact as the two versions would be running at the same time with the ability of moving data across the two environments. For organisations that require remote access, the in-house system can initially be used as a back-up and the cloud version as the live system due to the high bandwidth capacity offered by the cloud.

Large organisations may follow a strategy that involves starting their own private cloud with a potential to move to a public cloud, if required in the future. Others should start by considering the migration of services that are not critical to business. For example, websites, testing, e-mail, and Constituent Relationship Management (CRM) are usually easy systems to migrate. By starting the migration with the services that are less critical to business, enterprises will be able to recognise the connection with the data centre and the new environment.

The following questions may be used as a guide for formulating a strategy for cloud migration projects:

- Why is there a need to migrate to the cloud?
- What are the current trends in the business environment?
- How does the service currently operate?
- What are the current resources and capabilities? And how these can be leveraged by migrating?
- What are the benefits that can be acquired as a result of adopting a cloud-based service?
- What are the business activities which require improvement?
- What are the main constrains?

The following sub-sections discuss that tasks that can aid decision makers in defining as systematic cloud migration strategy.

6.4.1.1 Context evaluation

Defining the strategy for migration should begin with an evaluation of the current organisational environment and the analysis of requirements and objectives (See Figure 41). It includes an understanding of organisation's characteristics and an assessment of the organisational innovation culture, trends and the competitive environment. In this task organisations should develop an organisational profile that describes the organisational factors that might be important to consider while planning for migration. These include: staff, the current IT infrastructure (hardware, applications, network architecture) and management, financial constraints, business strategy and objectives, security and privacy, organisational structure and business units. This task can be supported by developing template profiles for companies planning to migrate to the cloud. The template should consider the size of the organisation and the business sector. This task will aid organisations in deciding, if the migration will be beneficial.

Organisations should also evaluate their competitive environment. The dynamic force in the contemporary business market is rapidly eroding competitiveness, thereby causing products and skills to become obsolete (Sahandi et al. 2013). Organisations are under pressure to find and implement new strategic ideas at an even faster pace to gain the competitive edge over their rivals within the global market. In order to increase competitiveness, organisations need to gain access and analyse data and information about competitors, performance metrics, customer behaviour, and market trends. These are increasingly important in the contemporary competitive business market (Sauter 2005). These tasks can be supported by business intelligence techniques such as data mining, data warehousing, score-carding, dash-boarding, and financial analysis. These techniques should be used to gather related data and information to be stored in a knowledge-base and should be provided to cloud customers in an organised and timely manner.

6.4.1.2 Organisational requirement

Based on the information gathered from evaluating the organisational context, the next task is to identify the organisational requirements (See Figure 41). The purpose of this task is to detect potential organisational constraints that might affect cloud migration decisions. These may be legal, financial, security, policy, level of service, guideline or administrative in nature. An example of the organisational requirements is the geographical location constrains. This task is essential because the analysis of the subsequent tasks will be based on the requirements and constrains specified in this task.

6.4.1.3 Define objectives

Based on the data and information gathered from organisational context, and requirements identified in the first two tasks, organisations will be able to define the exact objectives for migration. The analysis of data collected in this research (see chapter 5) suggests that organisations usually seek to exploit the applications within the cloud to achieve three main objectives: cost reduction, business innovation, and back-up.

6.4.2 Cloud environment (Step 2)

In support of the findings of this research about customers' lack of knowledge with regard to the cloud environment, as discussed in Chapter 5, a recent study conducted by Enterprise Management Associates (EMA) revealed that there is confusion in the cloud market (McKendrick 2014). Their survey of 415 executives showed strong interest in cloud computing, but there was confusion about alternatives and available services. Moreover, the study showed that many enterprises acknowledged that they lacked the expertise to manage and understand the cloud's pricing models and operational metrics. The EMA report identified four main aspects that cloud customers are demanding from cloud vendors: transparent pricing, ease of management, support, and help in understanding their own strengths and limitations (McKendrick 2014).

Accordingly, the second key step proposed in this research is to examine the guiding principles of the cloud environment and to assess the cloud's capabilities (Figure 41). The purpose of this step is to aid decision makers in acquiring the knowledge they need prior to the migration. Six main areas are identified which are depicted in Figure 41 as tasks that would aid cloud customers to become more familiar with the cloud environment. They are: cloud offerings, pricing policies, security policies, performance monitoring, compliance with regulations, and support. Organisations may complete this step by using the knowledge-base, which should provide the necessary information with regard to the cloud environment. It also aims to enable them to identify services offered by the providers which are appropriate to their needs.

The analysis of the two stage survey discussed in Chapter 5 identified an impact of adopting cloud services on roles and expertise. Developing knowledge about the cloud environment at the intelligent level will aid organisations in identifying the expertise needed for systems management. Completing this step will also aid enterprises in enhancing trust in cloud environment and ensuring transparency. Organisations could define service management metrics that are suitable for cloud computing environment. Developing knowledge about the cloud environment will also aid organisations in ensuring an appropriate SLA which is a vital aspect in cloud computing. SLA includes agreements regarding the quality of service attributes, pricing, compliance to regulation, level of support, security and privacy guarantees, and others. Organisations need to review the general terms and conditions that providers usually include in SLA.

6.4.2.1 Regulations and compliance

The survey analysis (see Chapter 5) showed that the majority of the surveyed respondents indicated that regulations and legal compliance violation are a main concern with regard to decision making for cloud migration. Simply signing up a contract for new cloud based services might result in legal and SLA problems. It is critical for organisations to ensure the validity of their cloud services. Therefore, achieving this requires compliance information gathering from different regulators. These include reviewing national and international standards for industry related services and the cloud providers' regulations. The gathered compliance information will then help organisations to design and implement control objectives to meet the relevant compliance requirements.

Many organisations comply with regulators in their internal systems management, however, by adopting cloud-based services, part of their services management will be shifted to the cloud providers. In this scenario organisations need to know how to continue their compliance with the regulators. There are a wide range of regulations that require compliance covering many areas, from government regulations, such as the Federal Risk and Authorisation Management Program (FedRAMP) and the European Union Data Protection Act, to industry related regulations such as the Payment Card Industry Data Security Standard (PCI DSS) and the Health Insurance Portability and Accountability Act (HIPAA). These regulators have strict rules that should be followed in terms of accessibility and data centre locations. For example, the European Union Data Protection Act applies strict rules to the transfer of data outside the European Union. Similarly, the HIPAA applies strict access and monitoring requirements. Therefore, companies need to review vendors' standard contracts, to see if their basic terms are sufficient for their organisational compliance requirements, and to ensure service providers' compliance with their regulators.

6.4.2.2 Security policies

The security issues and responsibilities vary in the three deployment models (SaaS, PaaS, and IaaS). This requires organisations to have full awareness of the security responsibility for each model. Confidentiality is a critical aspect for all organisations. To ensure confidentiality of migrated data to the cloud environment, organisations are required to have full details of who has accessed or requested access to their data. This signifies the importance of developing knowledge about how to track accessibility to the cloud services and the different tracking tools offered by cloud providers. Organisations need to develop general knowledge about security landscapes such as data protection and encryption, digital signing, identity management, authentication methods, and auditing. Information about data-centres location, physical resources accessibility, administration, operation, and disaster recovery plans are also vital for organisations.

Reliable access to resources is a key aspect of interest for organisations. A wide range of technical information such as network vulnerabilities and how an organisations' data can be securely transferred are required to ensure highly-available cloud services. Further, cloud providers utilise multi-tenancy approaches that allow multiple users to share the same resources for performance optimisation and costs reduction purposes. Organisations need to develop knowledge on what safeguards are in place by cloud providers to prevent any compromise. Based on this, organisations may need to consider using appropriate measures such as encryption depending on how critical is their data.

Organisations may need to review the potential security opportunities in the cloud environment. The change of security and compliance management is expected to assist organisations in enhancing important security landscapes such as data protection, encryption, digital signing, identity management, authentication methods, privacy standards, and auditing (Microsoft 2012). Cloud computing has the ability to detect the global position/location data points of remote access devices (Dos Santos and Singer 2012). This data can trigger extra security mechanisms to control accessibility and authorisation. It is possible to constantly monitor applications and platforms within the cloud and the collected audit data can be used to detect applications' vulnerabilities.

The development of technologies and provision of services is normally matched by a constant change of security threats. In other words, security mechanisms developed even a year ago may not be appropriate for security threats today. This signifies that security is about keeping the defence mechanisms up to date. The continuous development of cyber security mechanisms that can be exploited through the cloud can enhance organisations' security through enhancing detection and enabling a rapid response to cyber intrusions. In this aspect, cloud computing could provide a security advantage, as many small organisations may find it impractical to bear the high cost of keeping their defence mechanisms up to date. Moreover, the cloud tools for migrating applications could also provide another level of detectability that can enhance security and application management. The detectability obtained from this analysis can provide several security advantages such as ensuring an organisation's compliance, support for disaster recovery, and the identification of vulnerabilities within legacy applications (Santos and Singer 2012).

6.4.2.3 Cloud offers

The cloud environment is still emerging therefore decision makers need to carefully assess the capabilities of cloud computing to determine whether this style of computing will help achieve their business goals (See Figure 41). The opportunities in the cloud environment need to be assessed that include: management, compliance, technology, security, and list of potential providers.

Management: with the increase of competitiveness in the contemporary business market, it is vital for organisations to build an infrastructures that can deliver real-time business processes and continuously evolve in order to response to dynamic business conditions. The cloud can automate organisations' IT resources which allow them to adapt to the changing demands of their business needs. Cloud computing customers also can conveniently access to business applications on the move, meaning staff can work flexibly from anywhere. Cloud computing can enable companies to focus on innovation and creation of business values, thereby enhancing staff productivity without requiring The updating of software, and other IT equipment. Further, by effectively utilising the current communication technology capabilities, enterprises have the potential to compete with anyone, anytime, anywhere, and of any size by using the cloud platform to deliver innovative services quickly.

Technology: cloud computing can help eliminate costs associated with in-house provision of the equipment required for building up the infrastructure. It also provides the IT resources required for a scalable business, without demanding the IT budget of a large enterprise to put these systems in place. In addition to its capabilities, the cloud also comes with fast implementation and a smooth upgrade pathway. Organisations need to review the cloud offers and appreciate how the advantages of the cloud provisions can be exploited in improve their business performances.

The levels of details of functionality provided to cloud users for managing and controlling the underlying cloud infrastructure varies in the three cloud service models (SaaS, PaaS, and IaaS) (Sahandi et al. 2013). Organisations need to develop knowledge of how their services can be managed in the different cloud models.

Although cloud providers tend to automate the management of the service they provide, for example, auto-scaling and upgrades; organisations still need to develop knowledge of how these features can improve their performance. A lack of knowledge about how to manage cloud based services has resulted in the growth of third-party tools that provide performance management, accounting, governance, and security services for public customers (Linthicum 2015). Developing knowledge and expertise about the cloud systems' management will enable organisations to fully take advantage of the cloud features and also to minimise the cost of using third-party tools.

6.4.2.4 Pricing policies

Cost reduction has been the main reason that drives organisations to move to cloud computing, as discussed in Chapter 2 and 5. However, cloud-based services are not always more economical than in-house services provisions. This depends upon different factors such as the compatibility of the pricing models with customers' applications, size of organisations, and the data volume used. Additionally, as was discussed in Chapter 5, cost was also the main reason for organisations to move back from the cloud. Reasons that emerged for moving back from the cloud are: migration to the cloud without having full knowledge about how to financially manage cloud-services, the cost of consultancy and other services, failure in accurate estimation of ROI, and vendors' consumption models. Therefore, it is important to develop knowledge about the pricing models during the intelligence level (See Figure 41) to avoid the cost related issues as discussed in section 6.2.2.2. Ng (2010, p.2) states that:

> "Today, price models are less straightforward and the modern service economy has moved from exchanged-based pricing to more sophisticated models that incorporate relational, temporal and behavioural issues".

Unfamiliarity with the new pricing model offered by cloud providers has created uncertainty. According to Al-Roomi et al. (2013), developing adequate pricing techniques is an essential factor to ensure successful implementation of cloud-based services in the IT market.

Cloud services are usually offered by providers in a fixed pricing model (tariffs). Some organisations may have their own usage models. Therefore, they may have to adapt their services usage according to the cloud tariffs. This could be a challenge for some organisations, particularly the larger ones which usually have fixed usage models.

Cloud-based services are usually provided with a range of different pricing options. Pay-as-you-go or consumption-based is the most commonly used in cloud computing. In such a model, customers pay a fixed price per unit of use. This model has attracted many enterprises, to avoid upfront expenditure. Major cloud service providers, including Amazon, Google, and windows Azure, have adopted this model for pricing their services. Amazon, for example, charges a fixed price per hour for using its virtual machines (Amazon 2015). Another common scheme employed in the cloud environment is the 'pay for resources' model in which a customer pays for the amount of bandwidth or storage utilised. Subscription, where a customer pays in advance for the services that will be received for a pre-defined period of time, is also common. The price is usually calculated by applying one of the following approaches: fixed price regardless of volume, fixed price plus per unit rate, assured purchase volume plus per unit price rate, per-unit rate with a ceiling, or per unit price (Iveroth et al. 2013). Therefore, organisations need to develop knowledge about these pricing schemes to avoid unnecessary costs.

6.4.2.5 Performance monitoring

Resource sharing techniques and virtualisation in the cloud environment often affect performance and degradation causing computing nodes to respond slowly or even become temporarily unavailable (Meng et al. 2012). Moreover, cloud services are usually hosted over distributed web servers, application servers and data-bases to achieve high scalability and reliability (Garg et al. 2013). These issues have an impact on performance monitoring which is a necessary building block for many distributed applications and services hosted in cloud datacentres. It includes safeguarding performance, consumptions and cost, end-user experiences, detection of attacks, availability, measurement of service outages, and application response time. Therefore, it is vital for organisations to develop knowledge on how to monitor performance when using cloud services, the different levels of monitoring and also on the tools that are available for systems monitoring (See Figure 41).

6.4.2.6 Support

Support is a critical aspect for managing outsourced services. The analysis in Chapter 5 shows a high expectation and overestimation about the level of support in the cloud environment.

Support in the cloud environment is based upon the premise similar to the fact that security is a shared responsibility. Organisations need to understand their part in that responsibility and account for it in their analysis for migration. McKendrick (2014, p.1) states:

> "The cost and quality of support, as well as the medium by which it is delivered (ticketing system, email, phone), can significantly hamper or accelerate cloud success. Consider the support model and it's pricing when making a cloud selection."

Cloud services are usually offered without the cost of sales. Therefore consultancy and support services offered by cloud providers require extra expenditures. Support services are provided at different levels and costs, thus organisations need to identify the level of support they require and whether this support is available at an acceptable cost.

The outcome of the intelligence phase should be as follows:

- A cloud migration strategy that includes: the intention of migration, clear objectives, requirements and constrains, and a description of the current operation and infrastructure

- Documented intelligence about the cloud environment that identifies the opportunities, capabilities, offering models, suitable configurations, level of support, risks, pricing models, list of potential providers, and the required expertise to manage applications in the cloud environment

6.4.3 Services suitability (Step 3)

After developing the intelligence required for migration, the decision process moves to the design phase (See Figure 41). The purpose of this phase is to aid the selection of the services for migration. This phase involves two main steps: (a) an identification of the services that are suitable to be migrated; (b) performing a risk assessment for each candidate service.

The process of evaluating the suitability of a service includes: selection the service's requirements, integration, data volume, criticality to business, and ROI calculation. These tasks are performed during this stage to ensure that the requirements and characteristics of business services are suitable to be supported by the cloud environment. The design level of the knowledge-base can provide information to support in the performance of these tasks. When a service is selected it is critical to conduct a risk assessment for each of the selected service, including the risks to the organisation, the legal implication, the security threats and their consequences.

6.4.3.1 Requirements

The first task is to identify a suitable service to conduct a comprehensive analysis for the required adaptation, security, and relevant standards (shown as separate tasks in Figure 41). Typically, organisational services have different characteristics and requirements which make the analysis far from straightforward. Failure or inaccurate assessment in this step will result in the selection of inappropriate services that can cause complexity and integration issues.

While many applications have already been developed specifically for the cloud environment, others must be adapted to be suitable for the cloud which involves making them cloud enabled (Andrikopoulos et al. 2013b). Adaptations may be required at a number of levels: data layer, data-base layer, accessibility, and business processes to enable existing applications to function in a multi-client and distributed environment. These adaptations will also ensure the acquirement of the main cloud features such as scalability and availability. However, many applications are not ready to be moved to the cloud because the environment is not mature enough for them e.g. safety-critical software (Binz et al. 2012).

Cloud security is a joint responsibility between cloud providers and users. The cloud users' responsibility starts by migrating the services that their security privileges can be addressed by the cloud vendors. Organisations must make sure that the appropriate authentication and identity management capabilities are integrated into the applications to protect and have access to encrypted data, particularly while data is transferred across cloud boundaries. Securing APIs and key management must also be ensured during the design phase of applications migration (CSA 2013).

As discussed in section 7.3.3.1, it is critical for organisations to specify the industry related standards during the analysis for a service to be migrated. This will enable enterprises to ensure that their chosen provider adheres to industry standards for service provision.

6.4.3.2 Integration

Companies are likely to have hybrid of cloud and in-houses systems, resulting in the assessment of integration of candidate services to ensure smooth interactions between cloud services and on-premises systems. Moreover, in some cases companies need to combine a range of cloud services from different cloud providers to achieve maximum efficiencies which require further assessment of integration (Baum et al., 2014). Assessment of integration requires relevant expertise in developing cloud-to-cloud, cloud-to-local integration mechanisms as well as cloud integration management. Further, the integration roles require the development of relevant skills within areas such as business processes, data management, data analysis, business architecture, and service oriented architecture.

6.4.3.3 Data volume

Organisations are required to predict their data volume as it has a direct impact on cost calculation. Usually, cloud computing is more cost effective for start-ups or newly started organisations. On the other hand, companies that have large legacy-data will find migration more difficult and more expensive. For these organisations, cloud services, would be more beneficial for the provision of new services but not to replace, or migrate and deploy services.

6.4.3.4 Critical to business

Although, cloud computing uses up-to-date security mechanisms, it has not yet reached the maturity level for migrating highly sensitive data. Therefore, organisations are recommended to analyse their services in terms of the type of data, and their impact on the organisation (the tasks shown in Figure 41 under Critical to business). Services that deal with highly sensitive data such as finance usually have more stringent requirements, resulting in more difficulties during migration. Additionally, it is very likely that the transformation to the cloud will result in new jobs and change to many job descriptions. To manage the impact on staffing, organisations need to analyse the anticipated change to the staffing level, roles and expertise during the design phase, before commencing the process of migrating existing services to the cloud.

Adopting cloud computing requires a fundamental shift in organisational culture and possibly business processes, both within and outside of IT. Organisations should develop a full understanding of the impact of migrating services to the cloud, bearing in mind the organisational culture and the resulting cultural shift. This will minimise the impact of the change (disruption) and allows the cloud culture to be integrated within the organisations. This includes institutional values, business processes, resource utilisation, knowledge sharing, interaction between members monitoring and internal audit, user access provisioning, departments, and relationship with other organisations. Organisations should start migrating less critical services first and then gradually move to critical ones.

6.4.3.5 Return on Investment (ROI)

For the majority of organisations, cost reduction is the main motivation for migrating to the cloud. The investment for migration requires organisations to conduct evaluation on ROI that is the financial metric to estimate the financial outcome of the investment. Several factors are required to be considered when exploring ROI. They include the business benefits against extra costs such as the need to invest in higher bandwidth, integration and staff training. The time, efforts, and cost of moving the service back to in-house or to another provider should also be considered during the analysis. The variety of cloud services, their deployment models and payments polices has increased the complexity of ROI. Additionally, organisations have different sets of requirements such as legal requirements and they are in different positions with regard to the maturity and the legacy of their existing systems. The other factor that needs to be considered during the evaluation of ROI is the cost of the organisational impacts.

6.4.4 Risk assessment (Step 4)

The second key step in the design phase is conducting a risk assessment for each candidate service. The extensive concerns about the risks of migrating to the cloud (discussed in Chapter 2 and 5) require thorough risk assessments that include a wide range of tasks. They should examine the magnitude of the potential losses and their probabilities by performing a number of tasks. These tasks are categorised into four main areas: risk to the organisation, legal implications, accessibility, and availability, as shown in Figure 41. This will allow cloud customers to determine the acceptable level with respect to each risk and to negotiate risk balancing or avoidance. The risks to the organisation may include: loss of control, dependability, managing relationships with different cloud providers, process disruption, liability, business continuity and disaster recovery, and performance monitoring. For example, if an organisation is unable to access cloud services at a critical time, it is largely dependent on the cloud provider's customer service to provide information, and a lack of such information can lead to poor communication with the service's customers'. Legal implications may include: intellectual property rights, compliance with regulations, software licenses, and lack of standardisation. Increased distance, as a consequence of migration, can result in higher security risks and bring about changes with regard to accessibility and availability.

The outcome of the design phase should be:

- Identification of candidate services to be migrated to the cloud.
- They should be combined with a document that includes: its required adaptation and integration, financial benefits, impact of staff and business process, and the level of risks.

6.4.5 Vendors evaluation (Step 5)

After identifying a suitable service for migration, the next step is to evaluate the cloud vendors to select appropriate providers. In this model, the SMICloud (discussed in section 2.1) has been adopted for ranking and evaluation of cloud providers. It consists of six primary areas that are shown as tasks in Figure 41 that are needed by cloud customers for selecting a service provider. The Accountability attribute is used to measure specific characteristics of cloud providers to build the trust of a customer on a cloud provider by ensuring accountability of security exposures and compliance that includes a measurement of auditability, data ownership, provider ethicality, and sustainability. Agility is to measure how quickly new capabilities are integrated into IT as needed by the business. The assurance characteristic is monitored to ensure that the cloud service is performing as expected or as specified in the SLA. Cost tends to be the most quantifiable attribute, but it is important to measure cost in such a way which is relevant to a particular business requirements. Cloud offers usually have different performance in terms of functionality, service response time and accuracy. Organisations need to understand how their applications will perform on different cloud services and whether their deployments meet their expectations. Security and privacy are major concerns for the majority of organisations. They are multi-dimensional in nature and include many attributes such as protecting confidentiality and privacy, data integrity and availability. Organisations need to know about the location of the datacentre.

The outcome of this step should be a prioritising list of providers based on the SMIcloud attributes that are weighted based on the organisational requirements.

6.4.6 Implementation (Step 6)

The final step in this process is to make the choice of the most appropriate cloud provider. At this level, the decision making process as a component of the problem solving is completed and the process then moves to the implementation step. It requires the tasks of training members of staff on the new system, communication of the new service's information to all affected parties, and then producing relevant documentation.

6.5 The use of the process model

In this model, the range of information required for consideration during the process of migration is augmented by the existing cloud migration tools for applications analysis and selection of providers. This information can be provided to decision makers through a knowledge-base. Decision makers will be guided through the key decisions which they need to consider by going through a number of tasks which are identified in the intelligence phase.

Unlike the previously discussed DSSs (section 5.5), this model was not designed to support the migration of a specific service. Therefore, the model can be applied in general contexts and to various domains. Additionally, the model includes a wider analysis than just evaluation of the technical aspects, for example, legal issues and the impact of organisational culture are considered. Furthermore, the systematic structure in this model will allow decision makers to effectively exploit a wide range of cloud migration tools and decision support systems that may be required in the later phases (Design and Choice).

The proposed model can be used as a guide to systematically make well informed decisions. The following are a number for possible applications:

- A guiding process for decision makers through the steps and tasks that needs consideration for cloud migration projects

- It can be used as a reference for developers who are interested in designing a DSS to support cloud migration projects, in particular, the model provide the foundation that can lead to the development of a cloud Knowledge-Based Decision Support System (KBDSS).

- It can be used as a reference for intelligence systems developers for developing knowledge-base for cloud migration

- It can be used as a checklist for organisations planning for implementing cloud services.

The process model can be applied in the four scenarios for implementing cloud-based services.

6.5.1 The migration of legacy service

Exisiting organisations that have already had working practices growing up around thier systems that probably have been modified or configured to suit their requirements. Therefore, to migrate their systems, IT engineering work would be required. The analysis of this research was mainly intended to support this kind of migration scenario. In this case decision makers are recommended to consider all the steps and tasks identified in the model to ensure successful migration. All the steps in this scenario are equally important. This kind of migration is usually more expensive and requires extensive analysis to ensure data integrity and integration.

6.5.2 Adopting cloud service for start-up

A newly formed company can start with the cloud services straight off. This scenario is probably the easiest way for implementing cloud service. The process model can be used in this scenario, however not all the tasks will be needed. The context evaluation task during the intelligence phase will not be needed as much as for migrating legacy systems. The service suitably will be less important in comparison to the other scenarios. The required adaptation, data volume, and impact on organisations will not be required for this type of migration.

6.5.3 New service to be integrated to existing system

The analysis of survey (stage 1) showed that the need for new service is a main driver for many originations to implement cloud-based service. This scenario is similar to the migration of legacy system; however, some tasks will not be needed especially in the design phase such as the required adaptation, data volume. In this scenario it is important to ensure integration of the new service with the existing ones.

6.5.4 From cloud to cloud

Organisations may need to shift their systems from one cloud provider to another. The process model can be used in this scenario to support their decisions. In this scenario the intelligence and design phases might be less important in comparison to the other migration scenarios while vendors' evaluation should be carefully conducted.

6.6 Evaluation of the model

The proposed model was evaluated by a group of cloud practitioners who provided their views on the model's attributes. Participants consisted of 69 practitioners within three categories: those who had been involved in cloud migration projects, those planning to migrate to the cloud, and those conducting research within cloud computing. The evaluation aimed to determine the degree to which the model is an accurate representation for a systematic migration decision process. In particular, it aimed to validate the following:

- Was the order of the steps within the model correct to ensure a systematic migration decision?

- Were the identified steps fundamental to the migration decision-making process?

- Were the tasks within the steps relevant to the migration challenges?

- Does the model overlook any important task to be performed within the migration process?

- Does the model reflect the challenges of migrating to the cloud?

- Finally, does the model aid potential cloud customers to decide whether to migrate to the cloud or not?

The overall results (See Figure 42) show that the participants agreed with the structure steps and the tasks identified within this model. The vast majority (88%) stated that the model was an effective guide that can support cloud computing migration decisions.

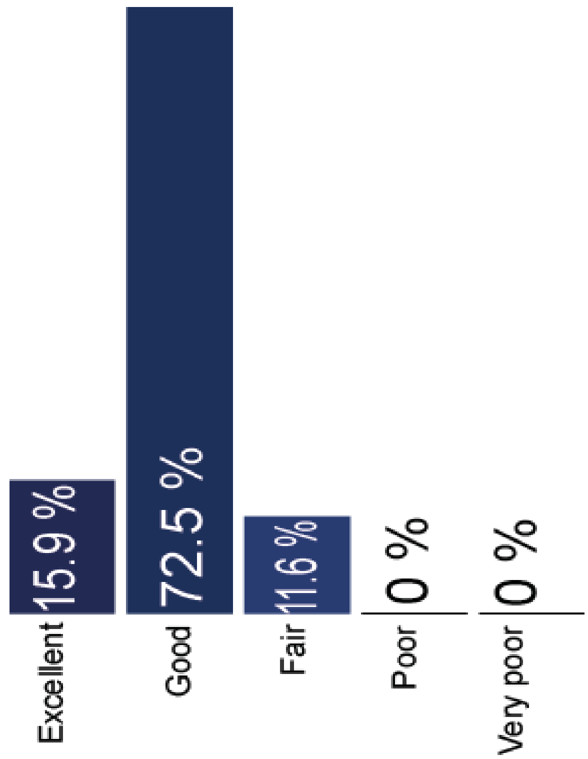


Figure 42. Participants' agreement with the structure and the tasks

An example of participants' responses is: "In terms of an overall project the model holds up well and is a thorough approach". Another participant in favour of a cloud knowledge base indicated that enterprises should make more efforts to make migration decisions and discards the security concerns that holding many from viable projects:

> "The knowledge base concept is sound and companies should work harder to make the decision making and move to cloud as simple as possible, fear of the unknown and easy excuses about security etc. are used to put off a cloud move, this is holding back very viable projects."

On the other hand, it was indicated that enterprises do not have sufficient time to apply such an intense approach. For example, a participant stated that:

> "It is rare for businesses to have the luxury of time for a detailed research and evaluation phase, moving from problem identification, to evaluation and implementation much more rapidly than the model allows."

Moving from problem identification to evaluation and implementation are probably the steps which are applied to most migration projects. Moreover, as discussed in Chapter 3, the existing cloud DSSs focus only on the evaluation stage. However, the stance in this research is that the complexity of the decisions needed to migrate to the cloud requires much further analysis, particularly in the intelligence and design phases. It may be true that organisations do not have the time and tools to apply such a detailed process. The model provides a comprehensive approach, and organisations may need to consider all or some of the steps and tasks identified, depending on their needs. Moreover, the main purpose of developing the approach was that it could be used as a foundation for a KBDSS that can potentially automates the tasks identified in the model.

In addition, 84% of the respondents indicated that the model was an accurate reflection of the issues involved in migrating to the cloud. Figure 43 shows respondents' answers to the question "*How well do you think the model is an accurate reflection of the issues involved in migrating to the cloud?*"

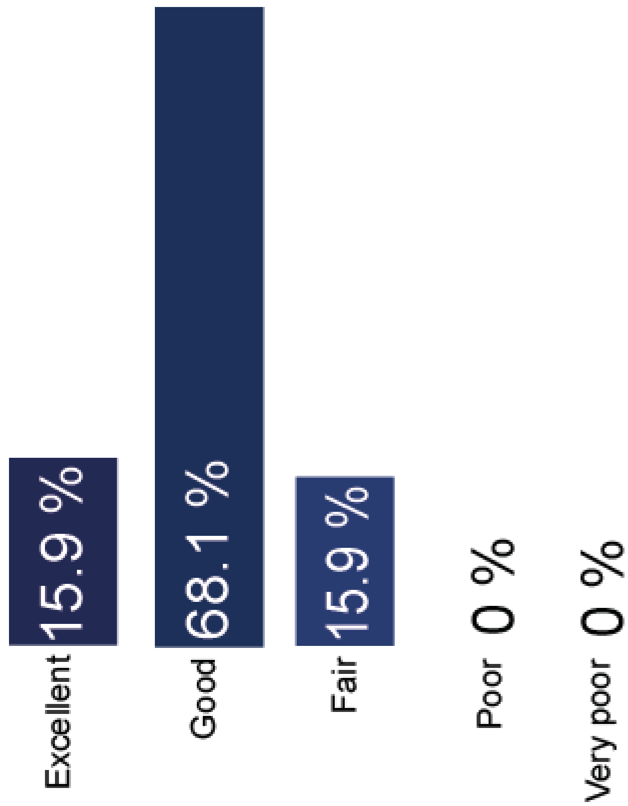


Figure 43. The model's reflection of the issues involved in migrating to the cloud

The analysis shows that a substantial number of responses highly rated the tasks related to assessing risks and security throughout the model. For example, in the second step acquiring information with regard to cloud security policies obtained an average rating of 4.71out of 5 whereas the other five tasks rated on average 4.32. This validates the continuing security concerns associated with migration to the cloud which this model tries to mitigate by including security and risk assessment tasks throughout the steps. To evaluate the model, the following sections provide the analyses of the participants' responses to the main questions asked.

6.6.1 Order of the steps

One of the main motivations for this research is to remedy the lack of a process that ensures a systematic migration decision. The participants were asked to rank the steps identified in the model which were presented to them in a random order. The question was: *The following is a list of the steps within the model that organisations should go through for migrating to cloud computing. If you do not agree with the order, please indicate the order that you wish to see in the model*. The analysis of the responses is presented in Table 17*.*

Table 17. The order of the steps

Steps \ Order	1	2	3	4	5	6
Migration strategy	87.50%	4.69%	1.56%	3.13%	0.0%	3.13%
Cloud environment	4.69%	71.88%	17.19%	4.69%	1.56%	0.0%
Services suitability	7.81%	9.38%	64.06%	6.25%	12.50%	0.0%
Risk assessment	0.0%	10.94%	9.38%	40.63%	35.94%	3.13%
Vendors evaluation	0.0%	1.56%	4.69%	45.31%	46.88%	1.56%
Implementation	0.0%	1.56%	3.13%	0.0%	3.13%	92.19%

It can be seen in Table 17 that there is a high level of agreement with the model's structure. In particular, the participants agreed strongly with the order of the first three steps and the last one. However, about 35.9% would have placed the risk assessment in the fifth step (after the vendor evaluation step) compared to 40.6% who would have placed it in the fourth step. The participants who preferred this sequence (that is, provider evaluation prior to risk assessment) did so largely because they would prefer to include the vendor evaluation within the risk assessment. However, the risk assessment step in this model is within the design phase to ensure service suitability for migration to the cloud environment. In addition, the vendor evaluation step includes a number of tasks that assess the potential risks of choosing a particular provider.

6.6.2 Importance of the steps

In this research the six steps identified in the process are assumed to be equally important for making a systematic migration. The participants were asked to rate the importance of the steps Table 18 shows the results.

Because the largest standard deviation (0.94) is less than twice the smallest (2*0.59=1.2), the data look reasonably normal and the assumption of equal standard deviation can be used. An Analysis Of Variance (ANOVA) test was performed on the data to see if there is any significant difference on the importance of the tasks with the cloud environment. The analyses displayed an F (5,402) = 8.52 which is greater than the critical value (2.23) as shown in Table 18. Therefore, the null hypothesis can be rejected (that there is no difference between the ratings of the tasks). This result supports conclusions to be drawn based on a comparison of means.

The overall average is 4.34 out of 5 and the range was relatively small from 3.99 to 4.66, as shown Table 18. The risk assessment step was rated most highly with an average rating of 4.66 out of 5, followed by defining the migration strategy with an average rating of 4.65. The average rates of the other steps were as follows: Evaluating vendors, 4.35; Identifying suitable services for the cloud environment, 4.28; and identifying the cloud guiding principle and capabilities, 4.16; and implementation 3.99.

Table 18. The importance of the steps

Steps	1	2	3	4	5	Average	Variance	Std Dev
migration strategy	0	0%	5.80%	23.19%	71.01%	4.65	0.35	0.59
Cloud environment	0	1.47%	16.18%	44.12%	38.24%	4.16	0.59	0.76
Services suitability	0	1.45%	10.14%	46.38%	41.03%	4.28	0.50	0.70
Risk assessment	0	1.45%	5.80%	17.39%	75.36%	4.66	0.44	0.66
Vendors evaluation	0	296%	13.04%	28.99%	55.07%	4.35	0.68	0.82
Implementation	0	7.35%	22.06%	35.29%	35.29%	3.99	0.88	0.94

ANOVA

Source of Variation	SS	df	MS	F	Critical value
Between Groups	24.40	5	4.8804	8.5235	2.23
Within Groups	230.17	402	0.5726		
Total	254.57	407			

6.6.3 Tasks within the intelligence phase

The tasks within the migration strategy step scored average ratings of 4.47. The tasks were rated as follows: context evaluation, 4.40; organisational requirements, 4.50; and define objectives, 4.51.

Table 19 shows the analysis of evaluating the importance of the tasks within the cloud environment steps. The results show strong agreement with the need to acquire a wide range of information about the new environment. The data look reasonably normal and the assumption of equal standard deviation can be used. The ANOVA test was performed that displayed an F (5,400) =4.92 which is greater than the critical value (2.23) as shown in Table 19. Therefore, there is no significant difference between the ratings of the tasks.

With an average rating of 4.32 out of 5, the participants acknowledged the areas identified within this step. This average is the highest in comparison to the averages of the tasks within the other steps in this model. Being aware of the security policies within the cloud environment was rated highest with (95.59) of respondents rating it high or very high. Compliance with regulations also scored highly with (89.56) of participants rating it high or very high, while identifying the level of support scored the least with an average rate of 4.17.

Table 19. The tasks within the cloud environment

Tasks	1	2	3	4	5	Average	Variance	Std Dev
Cloud offers	0	1.47%	19.12%	35.29%	44.12%	4.22	0.65	0.80
Pricing policies	0	2.94%	11.76%	38.24%	47.06%	4.29	0.62	0.79
Security polices	0	1.47%	2.94%	19.12%	76.47%	4.70	0.35	0.59
Performance monitoring	0	1.47%	19.12%	42.65%	36.76%	4.14	0.60	0.77
Compliance to regulators	0	2.99%	7.46%	38.81%	50.75%	4.37	0.57	0.75
Support	0	4.48%	13.43%	41.79%	40.30%	4.17	0.69	0.83

ANOVA

Source of Variation	SS	df	MS	F	Critical value
Between Groups	14.39	5	2.87	4.92	2.23
Within Groups	233.97	400	0.58		
Total	248.37	405			

6.6.4 The tasks within the service suitability step

The participants were asked to rate the importance of the tasks identified in the Service suitability step. Table 20 shows the results. The largest standard deviation (1.03) is less than twice the smallest (2*0.67=1.35) which indicates that the data are reasonably normal. The ANOVA calculation produced an F (7,543) =9.88 which is greater than the critical value (2.02) as shown in Table 20. This supports conclusions to be drawn based on a comparison of the means.

With an average rating of 4.02 out of 5, the results show the respondents' level of agreement with the tasks identified within this step. Similar to the Cloud environment step, security requirements task was seen by the participants as the most important factor when selecting a service to be migrated. It obtained an average rating of 4.49 respectively while the impact on an organisation's culture and staff scored the lowest rating of 3.49. As expected, the Return on Investment (ROI) calculation task was highly rated with an average rating of 4.25. Identifying the integration requirements task was also highly rated in this step, with an average rating of 4.22.

Table 20. The tasks within the service suitability step

Tasks	1	2	3	4	5	Average	Variance	Std Dev
The required adaptation	2.90%	5.80%	24.64%	35.29%	44.12%	3.88	1.07	1.03
Standards and regulation compliance	0	2.94%	14.71%	39.71%	42.65%	4.22	0.65	0.80
Security requirements	0	0	10.45%	29.85%	59.70%	4.47	0.45	0.67
Integration requirements	0	1.45%	21.74%	30.43%	46.38%	4.21	0.70	0.83
Data volume	1.45%	4.35%	17.39%	47.83%	28.99%	3.65	0.99	0.99
Sensitive of data	1.45%	4.35%	17.39%	47.83%	38.99%	3.98	0.77	0.88
Impact on organisations' culture	1.45%	14.49%	30.43%	40.58%	13.04%	3.49	0.90	0.94
Return of Investment (ROI)	0	2.90%	11.59%	43.48%	42.03%	4.246	0.600	0.774

ANOVA

Source of Variation	SS	df	MS	F	Critical value
Between Groups	53.322	7	7.617	9.88	2.02
Within Groups	418.41	543	0.770		
Total	471.73	550			

6.6.5 Tasks within the risk assessment step

The participants were asked to rate the importance of tasks to be performed within the Risk assessment step for each candidate service. The participants were given a list of 17 tasks which were categorised into four main areas in the model. Table 21 shows the results.

Table 21. The tasks within the risk assessment step

Tasks	1	2	3	4	5	Average	Variance	Std Dev
Loss of control	0	1.45%	17.39%	34.78%	46.38%	4.26	0.63	0.79
Dependability assessment	0	8.82%	17.56%	38.24%	35.29%	3.98	0.89	0.94
Managing relationship with cloud providers	4.41%	8.82%	17.65%	38.24%	35.29%	3.55	1.38	1.17
Process disruption evaluation	0	7.25%	28.99%	39.24%	27.54%	3.84	0.84	0.91
Service level and performance monitoring	0	2.94%	16.18%	54.41%	26.47%	4.02	0.55	0.74
Privacy and data confidentiality	0	0	15.94%	28.99%	55.07%	4.36	0.64	0.80
Auditing	0	725%	27.54%	33.33%	31.88%	3.91	0.87	0.93
Liability	1.45%	4.35%	34.78%	33.33%	29.09%	3.76	0.88	0.94
Response times	0	10.14%	28.99%	40.58%	20.29%	3.72	0.82	0.90
Business continuity and disaster recovery	0	2.90%	17.39%	43.48%	36.23%	4.14	0.65	0.80
Flexibility of service	2.90%	8.70%	27.54%	34.78%	26.09%	3.72	1.02	1.01
Compliance with regulations	0	2.90%	15.94%	39.13%	42.03%	4.21	0.67	0.82
Ease of ending the arrangement	0	11.59%	20.29%	43.48%	24.64%	3.79	0.89	0.94
Data ownership and IP rights	0	1.45%	10.14%	43.48%	44.93%	4.27	0.53	0.73
Legal implication	0	1.45%	15.94%	42.03%	40.58%	4.20	0.58	0.76
Accessibility	0	0	15.94%	46.38%	37.68%	4.20	0.49	0.70
Availability	0	0	14.49%	42.03%	43.48%	4.29	0.48	0.69

ANOVA

Source of Variation	SS	df	MS	F	Critical value
Between Groups	67.72716771	16	4.232947982	5.576719436	2.02
Within Groups	872.8949403	1150	0.759039078		
Total	940.622108	1166			

The largest standard deviation (1.03) is less than twice the smallest (2*0.69=1.38) that shows a normality of the data. An F (16,1150) = 5.57 (ANOVA based analysis) is greater than the critical value (2.02) as shown in Table 21. This supports conclusions to be drawn based on comparing the means.

Privacy and data confidentiality, followed by data ownership and intellectual property rights, were rated most highly among these tasks with average rates of 4.39 and 4.32 respectively. The availability and accessibility assessment tasks were also highly rated at 4.20 and 4.29 respectively. Similarly, the Legal risk assessment tasks were highly rated. Assessing the potential legal implication obtained an average rating of 4.20 and compliance with regulations obtained an average rating of 4.21.

6.6.6 Tasks within the vendor evaluation step

The participants were asked to rate the importance of tasks to be performed within the vendor evaluation step for each candidate service. The data look reasonably normal and the assumption of equal standard deviation can be used. ANOVA test was performed that displayed an F (5,401) = 8.65 which is greater than the critical value (2.23) as shown in Table 22. Therefore, there is no significant difference between the ratings of the tasks. Table 22 shows the results.

The tasks in this step scored an average rate of 4.34. Security and privacy followed by Performance were chosen by the participants as the main factors when selecting a service provider by an average rate of (4.75) and (4.52) respectively. The other tasks scored high as well; Cost (4.37), Agility (4.24), Accountability (4.16), and Assurance (4.0).

Table 22. The tasks within the vendor evaluation step

Tasks	1	2	3	4	5	Average	Variance	Std Dev
Accountability	0.0%	2.94%	14.71%	0.4559	36.76%	4.16	0.62	0.78
Agility	0.0%	2.94%	17.65%	0.3235	47.06%	4.24	0.72	0.85
Assurances	0.0%	4.41%	27.94%	0.3088	36.76%	4.00	0.84	0.91
Cost	0.0%	0%	13.24%	36.76%	50.00%	4.37	0.50	0.71
Performance	0.0%	1.49%	5.97%	31.34%	61.19%	4.52	0.47	0.68
Security and Privacy	0.0%	0.00%	3.03%	16.67%	80.30%	4.75	0.25	0.5

ANOVA

Source of Variation	SS	df	MS	F	Critical value
Between Groups	24.47772	5	4.895544	8.65833	2.23
Within Groups	226.7311	401	0.565414		
Total	251.2088	406			

Finally, the participants showed an agreement with the importance of the tasks identified within the last step (Implementation) of the model scored average ratings of 4.09. The tasks were rated as follows: need for staff training, 4.12; communication, 4.16; and documentation, 3.99.

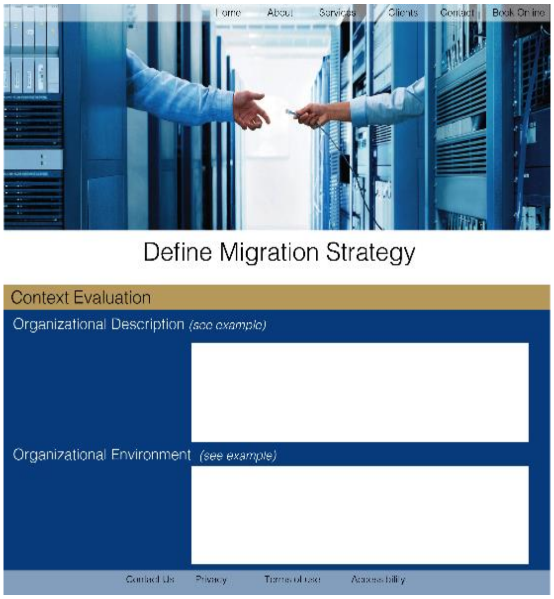
6.7 Prototype

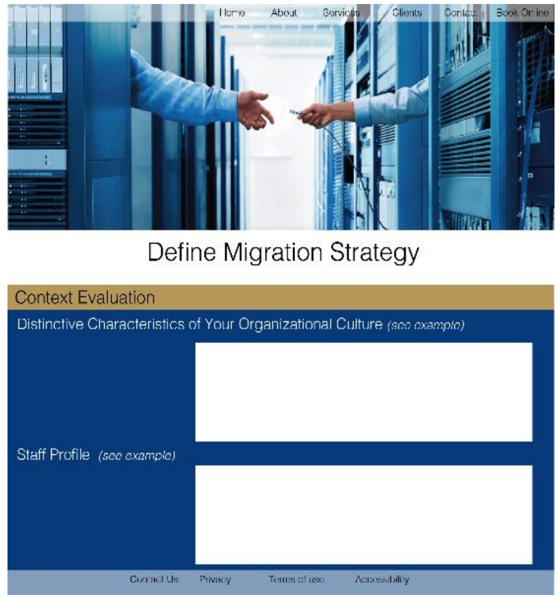
The complexity of the decision making process for migrating existing resources to the cloud leads to the requirements of implementing the main tasks. Further, businesses usually have limited time for planning and managing projects as well as limited expertise with which to manage and understand the cloud's configuration and operational metrics. Therefore, this section describes a prototype of the proposed model. The prototype describes how decision makers can perform the migration process. The purpose of the system is to guide decision makers through systematic steps and automated tasks that will lead to the making of more informed migration decisions. It will help to overcome the hype and information overload that surrounds the subject of cloud computing by providing accurate and timely information for decision-making, and a user-friendly system for analysing, comparing and selecting cloud services. It allows users to interact with a collection of cloud-related information, rules, requirements, and constraints, as well as tools for service design, risk assessment, and cost calculation, and provides rankings for selection'. It provides a single user interface that allows customers to access an integrated source of information. Further, users can use the interfaces to enter their requirements and place queries to a knowledge-base. The system also allows users to access, edit, modify, add to and view the information in the knowledge-base.

The main page displays the five main steps suggested in the proposed model (see Figure 44).

Figure 44. The main page of the prototype

It is recommended that users start the process at the first step (define the migration strategy. It first asks users to enter their organisational profile, requirements and constraints, and objectives. The organisational profile includes: the environment in which the organisation exists, distinctive characteristics, organisational culture, staff profile, customers and stakeholders, and vision (see Figure 45). Users then need to enter their requirements. In this system, there are six main categories in which users may have requirements, as shown in Figure 45. Then, users need to specify their main objectives for migration. The user interface can help organisations to enter these details by showing examples of what should be included in each section. After completing this step, a PDF document will be generated for users to reference. An example can be seen in Figure 46.


Home
About
Services
Clients
Contact
Book Online
Define Migration Strategy
Context Evaluation
Organizational Description (see example)
Organizational Environment (see example)
Contact Us
Privacy
Terms of use
Accessibility


Home
About
Services
Clients
Contact
Book Online
Define Migration Strategy
Context Evaluation
Distinctive Characteristics of Your Organizational Culture (see example)
Staff Profile (see example)
Contact Us
Privacy
Terms of use
Accessibility


Home
About
Services
Clients
Contact
Book Online
Define Migration Strategy
Context Evaluation
Customers and Stakeholders (see example)
Competitive Environment (see example)
Contact Us
Privacy
Terms of use
Accessibility


Home
About
Services
Clients
Contact
Book Online
Define Migration Strategy
Context Evaluation
Purpose
Vision
Values
Contact Us
Privacy
Terms of use
Accessibility

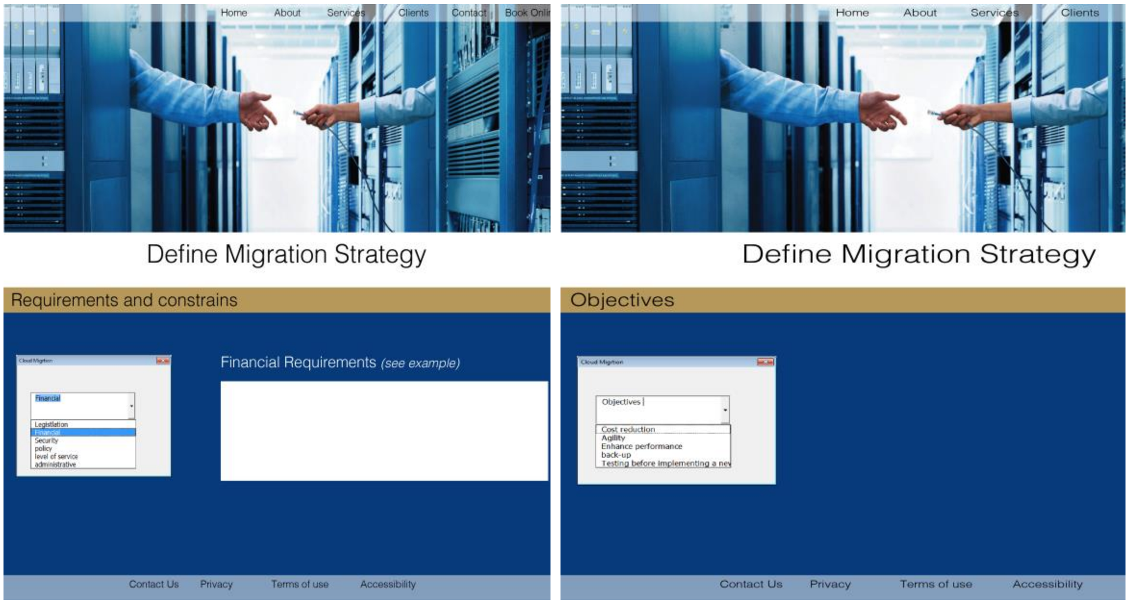
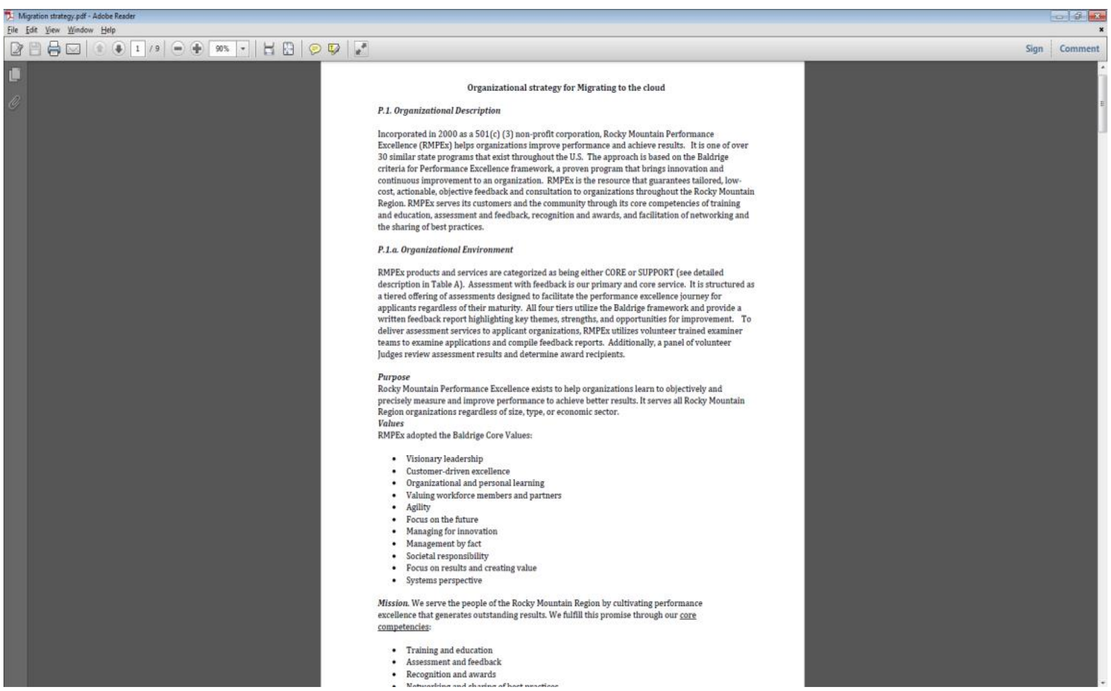


Figure 45. The migration strategy



Organizational strategy for Migrating to the cloud

P.1. Organizational Description

Incorporated in 2000 as a 501(c) (3) non-profit corporation, Rocky Mountain Performance Excellence (RMPEx) helps organizations improve performance and achieve results. It is one of over 30 similar state programs that exist throughout the U.S. The approach is based on the Baldrige criteria for Performance Excellence framework, a proven program that brings innovation and continuous improvement to an organization. RMPEx is the resource that guarantees tailored, low-cost, actionable, objective feedback and consultation to organizations throughout the Rocky Mountain Region. RMPEx serves its customers and the community through its core competencies of training and education, assessment and feedback, recognition and awards, and facilitation of networking and the sharing of best practices.

P.1.a. Organizational Environment

RMPEx products and services are categorized as being either CORE or SUPPORT (see detailed description in Table A). Assessment with feedback is our primary and core service. It is structured as a tiered offering of assessments designed to facilitate the performance excellence journey for applicants regardless of their maturity. All four tiers utilize the Baldrige framework and provide a written feedback report highlighting key themes, strengths, and opportunities for improvement. To deliver assessment services to applicant organizations, RMPEx utilizes volunteer trained examiner teams to examine applications and compile feedback reports. Additionally, a panel of volunteer Judges review assessment results and determine award recipients.

Purpose
Rocky Mountain Performance Excellence exists to help organizations learn to objectively and precisely measure and improve performance to achieve better results. It serves all Rocky Mountain Region organizations regardless of size, type, or economic sector.
Values
RMPEx adopted the Baldrige Core Values:

- Visionary leadership
- Customer-driven excellence
- Organizational and personal learning
- Valuing workforce members and partners
- Agility
- Focus on the future
- Managing for innovation
- Management by fact
- Societal responsibility
- Focus on results and creating value
- Systems perspective

Mission. We serve the people of the Rocky Mountain Region by cultivating performance excellence that generates outstanding results. We fulfill this promise through our core competencies:

- Training and education
- Assessment and feedback
- Recognition and awards

Figure 46. An example a generated PDF document for a migration strategy

This information will then be analysed in order to provide users with information about the cloud environment based on the details specified in the organisation's strategy. For example, the first task in the cloud environment step is to focus upon regulation, thus the system should filter the information provided in this regard based on information specified in the first step, such as industry type, size, and location. Figure 47 shows an interface that provides general information about regulations. Similar to the first step, a pdf document will be generated that provides an organised information about the cloud environment including opportunities, capabilities, offering models, suitable configurations, level of support, risks, pricing models, list of potential providers, and the required expertise to manage applications in the cloud environment. For the subsequent steps, the system will systematically guide decision makers to access to tools that aid in performing the migration tasks.

Figure 47. The tasks in the cloud environment step

6.8 Summary

This chapter discussed a proposed process model for cloud migration decisions in an attempt to fill the need for a systematic decision process. The complexity of the decisions involved in migrating to the cloud, identified in this research (see Chapter 3 and 5), was the main driver for developing the model. The generic decision process model developed by Simon (1977) was adopted to ensure a systemic structure for the new model. The decisions to be made and the tasks to be performed were discussed. Then, a number of potential applications for the model were presented. Finally, the model was evaluated in terms of the views of a group of cloud practitioners, and the analysis was discussed. It showed a high level of acceptance with regard to the structure, tasks involved and issues addressed.

The next and final chapter of this thesis concludes the research findings and provides some future directions for cloud migration decision support.

Chapter 7 Conclusion

7.1 Research summary

This research aimed to aid decision makers by developing a process model that systematically guides organisations through the areas that need support when considering migrating to the cloud. Migration to cloud computing is a strategic organisational decision that can be complicated, dynamic, and highly unstructured. The cloud environment is still emerging therefore decision makers need to carefully assess the capabilities of cloud computing to determine whether this style of computing will help achieve their business goals. It requires the consideration and evaluation of a wide range of technical and organisational aspects. The level of support offered by the existing cloud DSSs is not sufficient to enable decision makers in making informed decisions. This is mainly because of the underestimation of the factors affecting the decision making for cloud migration. These have made it difficult for many organisations to make the decision to migrate to the cloud. Therefore, understanding the level of complexity in the decision to migrate existing resources to the cloud environment is necessary for organisations interested in migration and for developing DSS for cloud migration. Accordingly, this research intensively explored the factors affection the decision making for migrating to the cloud. The exploration provided valuable information for developing the decision process model for migrating to the cloud proposed in this research.

The investigation in this research began with a review of the concept of cloud computing and related business aspects. It resulted in the identification of research themes that were examined through empirical data collection. They included drivers and barriers to migration, security and vendor-lock-in concerns, regulation, service design and engineering, and the impact of migration. The empirical data collection followed the sequential exploratory strategy (mixed methods), due to its consistency with the research questions (discussed in Chapter 4). This approach was achieved through the utilisation of a two-stage survey that explored the issues surrounding the process of migrating to cloud computing. Stage 1 was based on in-depth interviews.

Information based on practical experiences about migrating to the cloud was gathered from cloud providers, end-users, as well as some security experts. The qualitative analysis enabled insights to be gained on issues and concerns about migrating to cloud computing. The analysis identified some challenges, issues, and factors that effect on the decision to migrate to the cloud. It also identified the levels of the various impacts on migration and areas that should be considered to ensure successful migration. The main findings of the interviews were incorporated into the questions used in Stage 2 that was based on an online survey questionnaire. Stage 2 was more focused on the challenges involved in making the decision to migrate to the cloud. The statistical analysis of Stage 2 verified some of the findings of Stage 1. For example, the surveyed organisations sought to migrate to cloud computing mainly to reduce costs. In addition to the security concerns, customers' lack of knowledge and expertise about the cloud environment was confirmed to be a primary issue affecting the decisions to migrate. Respondents also registered concern about loss of control, immaturity of cloud computing and of the regulation, and legal implications.

In this research, a number of the existing cloud DSSs was evaluated. They mostly provide information to support the evaluation and selection of vendors with cost being the main factor, while many fundamental issues had been left unsupported. They often lack information about the cloud environment, particularly for customers who are not familiar with it. They also provide a limited amount of the information needed by organisations to assess the suitability of their own services for the cloud. Although, evaluation of providers and their appropriate selection are critical, making an informed decision to migrate requires the analysis of a wide range of factors at earlier stages of a decision process. As it was discussed in section 3.5 that successful support of decision-making is critically depending upon the availability of integrated, high quality information that is organised and presented in a timely and easy to understand manner. In the context of migration to the cloud, a wider range of information such as cloud capabilities, services offered, pricing schemes, etc., should be considered. This will aid organisations to identify opportunities and services that can help to improve business processes and operation.

The motivation for developing the model was the complexity of migrating process as well as the range of information required for consideration are increasing. These are due to the heterogeneity of organisational systems, the increasing number of cloud providers and their configurations, as well as the still evolving nature of cloud computing in which many issues such as security and vender lock-in still unresolved. Further, the number of tools which are becoming available is increasing at a bewildering rate. Therefore, what support is available to guide organisations systematically through the process? These have signified the requirement for a thorough process that identifies the main issues for consideration and the tasks to be performed, to ensure that informed decisions are made for migration to the cloud.

The model was evaluated, using the views of 69 of cloud practitioners who participated in a questionnaire survey. The model was seen by practitioners as an comprehensive guide for decision makers to make informed decisions for migrating to the cloud. The analysis of the views demonstrated a high level of acceptance by the practitioners with regard to the structure, tasks, and issues addressed by the model (refer to Chapter 6). This positive feedback provides a level of confidence on the effectiveness of the process model as a contribution in the direction of advancing the deployment of cloud-based systems.

Although the model was evaluated, the unavailability of a DSS for real testing and implementation of the model is a limitation of this study. This research is focused on the migration decision model and did not consider other issues with regards to cloud-based services. The small sample size has limited the conclusions to be drawn based on the need and concerns of certain organisations which may be a limitation of this study.

7.2 Contribution

The findings of this research has expanded the collective knowledge about the complexity of the issues that have to be considered when making decisions to migrate to the cloud. Eleven determinants that increase the complexity of migration to the cloud were identified. Therefore this study provides support by increasing the understanding about a wide range of factors that affect the decision making process for migration to the cloud. It contributes to the literature that addresses the complex and multidimensional nature of migrating to the cloud. In particular, this research highlighted the lack of knowledge about the cloud environment. It also identified a lack of expertise that organisations need to design and manage cloud services. The research has also confirmed that the maturity level of cloud computing is in early stages, and the cloud environment is still evolving. Further, the research substantiated that since the emergence of cloud computing, security has been the main perceived problem by many organisations.

This research found that organisations are highly interested in the business benefits offered by cloud computing that enables them to reduce costs and to improve agility. These benefits are seen by many as key driving factors to adopt cloud computing services. However, this research shows that financial benefits of cloud services vary and also cost found to be the main reason for companies that moved back from the cloud. In terms of security, the cloud providers participated in this study believed that by migrating to the cloud, organisations can enhance the security level of their systems. They argued that cloud providers use up-to-date security mechanisms, offer extra security measures, security professionals, and would ensure a higher availability of staff for managing the IT systems. However, the IT managers, security professionals, and others who participated in this research perceive that cloud computing has not yet reached the maturity level for migrating highly sensitive data. As a consequence, security is still the main concern for cloud users. This research shows that cloud computing adoption has had an impact on organisations particularly SMEs. Through advanced provision of IT resources efficiency can be increased, but this may require changes to be made in the roles of IT managers and security staff. Emergent roles are needed to ensure services are delivered in accordance to their particular business requirements, and also for managing the services lifecycle. This research identified some technical and business skills that are needed for managing the emergent roles in respect of cloud computing. The impact of this is that there is a need to provide adequate knowledge and expertise for managing the migration to the cloud and maintaining day-today operation. This could include comprehensive cloud management training sessions for IT managers and updates to job descriptions and skill-sets.

This research addressed the need for a comprehensive support for migration by proposing a cloud decision process model. It can help to reduce the complexity in the migration decisions. The proposed model is based on the generic decision-making process model developed by Simon (1977). This model was selected since it covers all phases of the decision making. Simon's model has been widely accepted as a systematic structure for making rational organisational decisions. It includes three phases: intelligence (identify problems, requirements and opportunities within the cloud environment), design (service suitability and risk assessment) and choices.

In the proposed model, a particular attention was paid to the actions required during the intelligence and design phases which have been neglected by the existing DSSs that are in favour of vendors' evaluation. These phases are expanded into six key steps, each with a number of tasks to be performed. The steps and tasks were discussed in Chapter 6. The steps and tasks can be performed in conjunction with the information that resides in a knowledge-base. These will enhance efficiency, especially for the tasks in the cloud environment step which can help customers who are not familiar with the new environment. One of the key features of the model is guiding decisions makers through a structured hierarchy of tasks. It would enable them to effectively exploit a wide range of the existing cloud migration DSSs.

7.3 Future work

Despite much research, there is still a lack of tools that can automate the migration tasks. The model is expected to guide further research on the development of the next generation cloud migration decision support system. It offers a preliminary structure for developing a cloud KBDSS. KBDSSs can address many of the challenges of migration process. Implementation of the model will reduce the amount of effort required for information gathering, suitability analysis, and evaluation of vendors. It can enhance the understanding of how and why an organisation makes related decisions for migration, and improves the efficiency of the migration process. A prototype was designed as a first stage for the implementation of the proposed model. It provides user interfaces that allow access to a collection of cloud related information as well as migration DSSs and tools. However, the majority of the proposed cloud DSSs and tools have not been implemented, so there is a need to automate the tasks to support the decision makers. Further, developing a framework for integrating cloud DSSs with knowledge management processes including, discovery and detection of trends and patterns, and knowledge acquisition, application, and sharing will be required. The knowledge-base also need to be constructed through the use of knowledge engineering and existing intelligence information gathering using artificial intelligence. Complete implementation of the prototype will enable applying the model in a specific context that has particular requirements such as health care systems.

7.4 Recommendations

- Organisations should rationalise their business needs, applications, and on-premise data, and then consolidate the desired IT infrastructure accordingly.
- In order to improve trust in cloud services, providers need to ensure the privacy and confidentiality of their customers' data, ensure the compliance of customers' legal requirements, and to comply with relevant standards to reduce the risks of vendor lock-in.
- Decision makers should become fully aware of the cloud capabilities, guiding principle, the services offered and their potentials before coming to a decision.
- Cloud providers should provide details of their security polices to include risk management, access control, location, network security, physical security, and backup and system recovery.
- Cloud providers should provide details of how customers' systems would be segregated from others in a multi-tenant environment.
- Cloud providers should implement regulatory compliances that cover operational and security areas that users may have concerns about. These compliances would improve the security by having cloud vendors and customers to be securely certified.
- The decisions of whether to migrate to the cloud should be taken systematically. For example, following a model such as the one described in this thesis.

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Appendix A Search strings

In this study, search strings were developed to help in finding studies related to the research questions. They were built by identifying synonyms for each of the question elements and linking them with the OR and AND Boolean operators. These terms were used in a wide range of digital libraries, mainly Google scholar. Journal articles, followed by peer reviewed conference papers, were the sources most used to extract related research contents.

- Cloud OR/AND computing AND Migration OR adoption OR evolution OR integration OR services OR systems OR applications OR architectures OR infrastructure OR models OR design OR environment

RQ1

- Benefits OR advantages OR driving factors OR requirements OR needs OR importance AND cloud OR/AND computing OR systems OR based-services OR migration OR adoption OR implementing OR utilising OR integrating OR deployment

RQ 2

- Issues OR challenges OR problems OR factors AND affecting OR deterring OR delaying AND cloud AND migration OR adoption OR implementation OR utilisation OR integration OR deployment

RQ 3

- Cloud OR/AND computing OR migration OR adoption AND tool OR DSS OR model OR framework OR guidelines OR recommendation OR decision process

RQ 4

- Steps OR phases OR stages OR tasks OR activities OR managing AND migration OR adoption OR implementing OR utilising OR integrating OR deployment AND cloud AND computing OR systems OR services OR applications OR infrastructure OR platform

Appendix B Emerging cloud roles

> "Just as cloud computing is a game-changer for many companies; it is also changing the nature of jobs-not only within the information technology department, but in the other parts of the enterprise as well" (Mackendrick 2011).

CompTIA found that 46 per cent built new roles, like cloud architect or integration specialist (Cruz 2012). The following are summary of some of the emerging roles as a result of the evolution of cloud computing:

Cloud Architect:

Cloud architect serves a fundamental role within enterprises by designing and transforming local systems into cloud-based services. It serves as a link between the technical and non-technical staff within an organization. The role of cloud architect does not require deep technical skills it is rather essential to have a combination of business and basic technical. This combination would enable enterprises to design a business process focused cloud computing environment (McKendrick 2012).

Cloud software Engineer:

Software engineers are expected to be in high demand. According to CareerCast in 2011, software engineers are expected to be the best job to have in today's economy, as a result to the rise of cloud computing (Strieber 2011).

> "A proliferation of companies making applications for smartphones and tablets, along with the push to develop 'cloud' software hosted entirely online, has made the job market for software engineers broader and more diverse." (Strieber 2011)

With the emerging adoption of cloud services, there is a need for cloud software engineers who are capable of designing and building high quality tools for software developers to scale their web applications. These tools are automatically deploy, maintain and monitor hosting architectures. In addition to traditional needed skills for a software engineer, cloud software engineer need extra skills such as cloud hosting experience, configuration management, and experience of LAMP-based hosting environments (Microsoft. 2012). In order to take the most of cloud services, set of skills need to be developed such as custom application development.

Cloud system Administrator:

System administrators are one of the main jobs that are excepted to be shifted from individual companies to cloud provider or cloud services brokerage and management (Heath 2012). However, cloud systems administrator role includes wider range of responsibility, in comparison to traditional system administrator. Similar to local systems administration, cloud system administration include: user access management, system software lifecycle, and data centre policy compliance (Wolski 2012). Unlike local administration, cloud system administration are differ in that there is a need to maintain two separate system software domains. The skills need for cloud system administration include: management of virtual machines (managing network, VLAN configurations, and backup processes, setting up VPNs and security controls, and managing systems monitoring), systems administration for different operating systems environments (example Unix and windows).

Cloud Systems Engineer:

Cloud Systems Engineer is a member of the system engineering team that can support an initiative transition of systems to cloud computing environment. This job will include developing cloud computing strategy, cloud suitability and risks assessment, administrative, and support. Communication skills are critically important for such jobs, as well as the capability of conducting research and identify solutions.

Cloud Services Developer:

The responsibilities of this job involve designing and developing the next generation of software that could build high business value applications. Could computing offer application developers the ability to build and host their applications on scalable cloud servers. This would allow for faster development, deployment, and easier administration. Moreover, developers are no longer need to maintain hardware upgrades, patches or backups. For example, Google's App Engine and Amazon

Web Services (AWS), and are common cloud-based development platforms that enable developers to build enhanced performance, scalable and security cloud-based applications. Building cloud-based application require new views about systems architecture, especially on leveraging huge scalability. Cloud computing platforms usually provide different perspective of databases than the standard relational model (Wolski 2012).

Cloud Security Specialist:

As most of the emergent cloud roles, it is necessary for security specialist to have knowledge of managing cloud services. This would enable to understand the procedures that are required for availability, security and continuity of cloud-based services. Security of cloud services does not necessarily need having full knowledge about technical breaches (CSA 2011). It, however, requires full knowledge of cloud service management, for example, legal issues and standards.

Knowledge of service management is necessary for understanding the processes required to manage availability, security and continuity of these services. In dealing with cloud services provided by third parties, SLA play a major role, especially in ensuring that changes, incidents and problems are dealt with appropriately.

Cloud Services Integration

To implement cloud-based services, there is a need for mechanisms to get the in-house systems to be smoothly interacted with the cloud services. As enterprises are more likely to keep their core business processes in house while migrating the other to the cloud (Oracle 2015). Enterprises' systems are expected to expand into a mix of on-premise and public cloud applications and services (Baum et al., 2014).

The integration of cloud services is fairly complicated and require set of values skills, including data management, data analytics, and security. Service Oriented Architecture (SOA) is the platform that can address cloud integration difficulties because most cloud applications support SOA .So, developing skills of SOA would be increasingly required to support cloud-based systems integration.

Appendix C Interviews

C.1 The main questions in the interviews

The interviews were semi-structured that the same general questions were asked in the interviews. However, different questions were asked as well that based on the interviewees responses during the discussions. Also, the questions vary slightly depending on the expertise of the interviewees (Cloud provider, user, security analyst). The following questions are the general areas asked during the interviews:

- Why have you migrated to the cloud? What are the reasons behind organisations' decisions to implement cloud-based services?

- From your experience in implementing cloud services within your organisation, what are the main challenges have you faced?

How about

- ➢ Integrating cloud services into existing local architecture
- ➢ Have your staff faced difficulties in dealing with cloud services
- ➢ Did you need to redesign a business process
- ➢ Interoperability of different cloud providers
- ➢ Security issues

- Subsequent to the adoption of cloud computing, what changes to staffing levels were required, for example did you need to cut some jobs or to add others? And what responsibilities have you required the new jobs for?

- What expertise were required updating their job specification? And what skills they have been required to acquire

- Did you need to implement could services from multiple cloud providers? (if yes what was the reason)

- Did you need to use a third company to help you with the planning, setup and integration? (if yes what was the reason)

- Has your organisation experienced any security issues since migration to the cloud? (Could you please tell me about the incident) and what security knowledge and skills do you think are mostly needed within your organisation to prevent security problems

- Is it just a concern or still an issue? Are there security problems?

- Do you have customers that asked to withdraw their system back or moved to another cloud provider? Their reasons?

- In terms of cyber security, what do you think is the impact of the cloud on cyber security?

- What applications type have you migrated to the cloud?

- I would like to ask about your approach of migrating the cloud? Which steps have you considered as part of the migration process?

- What were other issues that you experienced in the migration?

- What standards do you follow? For example, different sectors, probably they have different requirements. Is that an issue for the migration of the data?

- What are the reasons that let your clients to choose your company?

- When you speak with a company, and they want to upgrade their system to move it to the cloud, what sort of questions do they usually ask? Or what sort of information do they seek?

- What do you think about the future of cloud computing?

- Would you like to talk about anything else? About the cloud in general and the process of migrating

C.2 Interviewees responses

Table 23 provide the initial categories and data extracted from the transcribed interviews. This phase was done manually by highlighting the interesting information for coding. Coding of the data was ‘theory-driven’ in that the data was coded in according to specific question that the researcher had already planned to take into consideration. However, due to the adoption of semi-structured interviews, some of the data which was also coded was outside the planned questions. The third step involved sorting the different codes into themes as shown in the table below.

C.3 Table participant responses

Table 23. Participant responses

Categories	Participants Responses		
	IT managers	**Cloud providers**	**Security professionals**
knowledge with regards to cloud environment			
The need for knowledge about cloud environment	- Security polices - Auditing and monitoring performance - How to many cloud-based service - How to ensure performance as specified in SLA	- First question how is safe the location - Where is it - who has access to it - What sort of protection in place? - Is it resilience - Is it in more than one location - Cloud solutions opportunities - Pricing and payment methods - what security policies have in place - backups - monitoring - standards - support - integration - The competitive environment	- Who has access
Issues		- Moving back (extra costs	- legal and compliance

		associated with returning to the original legacy) - hidden costs - interpretability problems - security and privacy issues - performance - Legal implications - customer and staff dissatisfaction	violation - Intellectual property risks - Availability
Factors affect the migration			
Factors encouraging to migrate	- Indirect cost (cloud-based product was found the cheapest in the market) - Reduce equipment's - Support - Business agility - The need for new services - Direct cost and - Vendor reputation - High performance service (new features and functions and new patches) - Improve efficiencies	- Cost - Business agility - To train how to deliver agile systems - Ease of access - Security features - Outsourcing culture - Customers Knowledge - Ease of testing on the cloud - Trust - Networking development - High performance - enable enterprises access to services that they have not been able to afford - High resilience services - quick and reliable technique for recovering and	- Lower cost

		restoring data - back-up in the cloud is probably the lowest risk of impact - back-up resources and costs)	
Factors delaying the migration	- Security concerns - More reliant on internet connection - Loss of control - Early stage of development - The process of evaluating the market and selecting cloud providers	- Services integration (cloud to in-house applications and cloud to cloud) - The possibility of getting data back to in-house - Security concerns - compliance (views-media) - Size of data and how old the system - Disruption to existing business processes - Culture - The need for adaptation	- Security risks - Failure of earlier outsourcing projects - The need to migrate existing systems - Lack of cloud-based business processes - Loss of control - Defining the boundaries of responsibilities - Trust - Reputation and brand protection - Organisations have different security requirements - Uncertainty - The immaturity of cloud services
Manage the migration			
Prior to migration	- The need for project management skills - Requirements specifications - The need for vendors evaluation	- The need for knowledge about cloud services - Pricing knowledge - The need for project management	- Risk assessment (physical, personal, threats, accessibility) - Reviewing security documentations

	- Risk assessment - Contract (to know how the system is set-up, what security policies have in place, backups, performance monitoring) - To make sure British and international standards are taken into account and they have the right certifications - To know who else using the product - Ensure free support when needed (to not to pay for each incident) - Ensure in the cloud-services integrate well with the in-house	skills - Workload and how critical the service to the business - Sort of data - Legal implication (does cloud provider give the guarantee to meet your legal requirements - e.x UK standards financial data has to be within the UK - The needed service level - Risk assessment - Vendors assessments - Transferring the data in and out	- Vendors evaluation - Defining sensitivity of data and their impact on organisations - Identify security responsibility - How to manage SLA
Impact on IT management			
Less required	- Staff - Freed up the space in the data centre by reducing servers - Eliminate the need for physical recourses support - Eliminate the need to backup	- Large part of building and running services move to cloud providers - Staff - Approval processes	

Higher requirements	- Contact with cloud providers - New expertise - Performance monitoring - The need for training sessions - Migration of management roles to cloud providers - Shift members of staff to other roles - Redirect staff to more efficient tasks to do such as projects, IT developments and operational support	- Supplier relationships - Contracts negotiations - Pricing and procurements - Business need - Service planning - Business process management - Services integration roles	- Cloud-based business processes - Importance of contracting - Monitoring - Risk managements
Stayed the same	- Strategic things	- Strategic things	
Reasons for moving back to in-house			
Issues		- Cost management - Vendor standards (companies not being able to consume standardised services) - High expectations for higher level of service - Legal requirements - Not turning the system off when they aren't using it - Migration	- Increase of risks - Protecting assets - Hybrid issues - Systems becomes more interoperable which increased complexity and vulnerability

		without having full knowledge about the services	
Security			
Advantages	- (No security issues, no breaches, no data lost)	- Advance security measures cannot be deployed in-house - Clients have never experienced security problems - Compliance certification - Security policies explanations - Security professional for building and managing cloud services - Encryption	- Up to date defence mechanisms
Issues	- Concerns about migrating highly sensitive data - Loos of control - Regulator satisfaction	- Different security requirements for different sectors	- Increasing the distance increase the risks - Change of potential threats - Targeted threats for cyber attacks - Intellectual property risks - Traffic issues - Loss of control - Trust - Dependability - Internet security - Process disruption - Assurance issues - Accessibility - Availability

Appendix D The survey questionnaire

D.1 The questions

Migration to cloud computing: A decision Process Model

Welcome to My Survey

This survey is being conducted for PhD research that is in progress at Bournemouth University, United Kingdom. Thus far, a model to aid the decision making process for migrating organisations IT resources and software applications to cloud-based services has been proposed. It includes a structure consisting of six steps that systematically guides the decision makers through the main tasks to ensure effective migration decisions.

The aim of this survey is to determine the degree to which the proposed model is an effective guide to support the decision making process. The Survey is divided into two main sections:

A: General questions with regards to cloud computing and migration issues

B: Questions to evaluate the main features of the proposed model

Privacy and confidentiality

All answers will be treated confidentially and respondents will be anonymised during the collection, storage and publication of research material.

Should you have any comments, enquirers, or you wish to receive a copy of the results, please contact the researcher via the email address below:

aalkhalil@bournemouth.ac.uk

Definitions:

Cloud Migration: The process of transitioning all or part of a company's data, applications and services from on-site premises behind the firewall to the cloud, where the information can be provided over the Internet on an on-demand basis.

Should you have any comments, enquirers, or you wish to receive a copy of the results, please contact the researcher via the email address below:

aalkhalil@bournemouth.ac.uk

Definitions:

Cloud Migration: The process of transitioning all or part of a company's data, applications and services from on-site premises behind the firewall to the cloud, where the information can be provided over the Internet on an on-demand basis.

Knowledge-base: Organised repository of information in the form of subject-problem-solution consisting of concepts, data, objectives, requirements, rules, and specifications that pertains to a specific topic or subject of interest. The data is typically stored in a searchable database.

Next

1. Which category best describes the size of your organisation in respect of the number of employees?

- ◯ Up to 150
- ◯ 151 to 300
- ◯ 301 to 1000
- ◯ More than 1000

2. Which category best describes your organisation sector?

- ◯ Manufacturing and industrial market
- ◯ Financial services
- ◯ Public sector & healthcare
- ◯ ICT services
- ◯ Trading sector
- ◯ Business sector

Other (please specify)

3. Which one of the following categories relates best to the activities of your organisation?

- ◯ Providing cloud services
- ◯ Using cloud services
- ◯ Cloud engineering (architect)
- ◯ Research within cloud systems
- ◯ Planning to move to the cloud

Other (please specify)

4. Which of the following do you think are the main reasons why organisations migrate to cloud computing? Tick all boxes that apply

- ☐ Cost reduction
- ☐ Innovation
- ☐ Back-up
- ☐ None

Other (please specify)

5. Which of the following in your view are the main organisational benefits for migrating to the cloud? Tick all boxes that apply

- ☐ Scalability
- ☐ Flexibility
- ☐ Time to market
- ☐ Access to the latest technology and services
- ☐ Collaboration
- ☐ Integrated IT Services (no need for installtion, set up, and management)
- ☐ None

Other (please specify)

6. Which of the following in your view are deterring organisations from migrating to the cloud? Tick all boxes that apply

- [ ] Lack of cloud-related knowledge
- [ ] Difficulties in gathering information
- [ ] The immaturity of cloud services and regulations
- [ ] Lack of decision support tools
- [ ] Difficulties in identifying suitable services for the migration
- [ ] Security and privacy
- [ ] The process of selection of cloud provider is complex
- [ ] Loss of control
- [ ] Disruption to business processes
- [ ] Change of system management and impact on organisation
- [ ] Cultural barriers
- [ ] Legal implication
- [ ] Trust
- [ ] Cost management
- [ ] None

Other (please specify)

7. Which of the following are the main perceived problems with cloud-based services? Tick all boxes that apply

- [ ] Interoperability
- [ ] Accessibility
- [ ] Availability
- [ ] Lack of standardisation
- [ ] Privacy and data confidentiality
- [ ] Vendor Lock-in
- [ ] Data centre locations
- [ ] Costing (cloud standards, different payment models)

- [ ] Data centre locations
- [ ] Costing (cloud standards, different payment models)
- [ ] None

Other (please specify)

8. Which of the following are the main legal implications which can affect decisions to migrate to cloud computing? Tick all boxes that apply

- [ ] Regulations and legal compliance violation
- [ ] Data ownership
- [ ] Service Level Agreement (SLA) problems
- [ ] Intellectual property risks
- [ ] Liability
- [ ] Data loss/misuse
- [ ] Software licenses issues
- [ ] None

Other (please specify)

Prev Next

9. What are the main challenges you have experienced after the adoption of cloud services? Tick all boxes that apply

- ☐ I have **not** been involved with migration to cloud computing
- ☐ Security and compliance
- ☐ Integrating cloud services into existing local architecture
- ☐ Cultural shift
- ☐ Impact on staff and responsibility
- ☐ Legal requirements
- ☐ Monitoring and service management
- ☐ Productiveness
- ☐ The need for collaboration with other departments
- ☐ The need for business processes to be redesigned
- ☐ Interoperability of different cloud providers
- ☐ None

Other (please specify)

10. Which of the following knowledge or skills do your staff need mostly when dealing with cloud services? Tick all boxes that apply

- ☐ Knowledge of cloud capabilities and services
- ☐ Cloud business alliance
- ☐ Ability to analyse enterprise architecture and business needs
- ☐ Cloud hosting
- ☐ Configuration management
- ☐ Standards awareness

- [ ] Standards awareness
- [ ] Access control
- [ ] Management of virtual machines
- [ ] Auditing
- [ ] Risk assessment
- [ ] Compliance
- [ ] None

Other (please specify)

11. Subsequent to migrating to cloud computing, which of the following expertise did you need to add to your IT department? Tick all boxes that apply

- [ ] Cloud Architect
- [ ] Cloud Software Engineer
- [ ] Cloud Software Developer
- [ ] Cloud System Administrator
- [ ] Cloud Systems Engineer
- [ ] Cloud Security Specialist
- [ ] Cloud Integration Specialist
- [ ] None

Other (please specify)

12. How would you describe the overall impact of cloud computing on your organisation?

- ( ) Exceeded the expectation
- ( ) Highly impacted
- ( ) Reasonably impacted
- ( ) Low impacted
- ( ) No impact
- ( ) Not sure

Prev Next

13. Using a scale of 1 to 5, please rate the quality of existing cloud related information for each of the following.

	Very low 1	2	3	4	Very high 5
Availability	○	○	○	○	○
Sufficiency	○	○	○	○	○
Accessibility	○	○	○	○	○
Accuracy	○	○	○	○	○
Consistency	○	○	○	○	○
Understandability	○	○	○	○	○
Timely	○	○	○	○	○
Diversity	○	○	○	○	○
Complexity	○	○	○	○	○

Other (please specify)

14. Which of the following are the most valuable sources of information for supporting decisions for migration to cloud computing? Tick all boxes that apply

- ☐ Documented projects
- ☐ Vendors offers
- ☐ Experts views
- ☐ Cloud decision support systems
- ☐ Standards and regulations
- ☐ White papers
- ☐ Business articles
- ☐ None

Other (please specify)

15. To which extent do you think there is a need for a cloud knowledge-base to overcome the lack of customers' cloud-related knowledge?

- ○ Extremely important
- ○ Important
- ○ Somewhat unimportant
- ○ Not at all important
- ○ Not sure

Prev Next

D.2 Survey results based on organisations' profile

D.2.1 Reasons for migration

Which of the following do you think are the main reasons why organisations migrate to cloud computing?

Tasks	Up to 150	151 to 300	301 to 1000	More than 1000
Cost reduction	15.38%	27.47%	24.18%	32.97%
Innovation	19.57%	23.91%	30.43%	26.09%
Back-up	21.28%	17.02%	31.91%	29.79%

Tasks	Business sector	Financial services	ICT services	Manufacturing and industrial market	Public sector & healthcare
Cost reduction	4.40%	7.69%	45.05%	4.40%	29.67%
Innovation	2.17%	15.22%	43.48%	4.35%	26.09%
Back-up	4.26%	4.26%	36.17%	6.38%	34.04%

Tasks	Cloud engineering (architect)	Planning to move to the cloud	Providing cloud services	Research within cloud systems	Using cloud services
Cost reduction	9.89%	17.58%	12.09%	15.38%	35.16%
Innovation	10.87%	17.39%	13.04%	17.39%	36.96%
Back-up	6.38%	12.77%	10.64%	19.15%	40.43%

D.2.2 Main organisational benefits

Which of the following in your view are the main organisational benefits for migrating to the cloud?

Tasks	Up to 150	151 to 300	301 to 1000	More than 1000
Scalability	16.46%	27.85%	22.78%	32.91%
Flexibility	26.79%	23.21%	14.29%	35.71%
Time to market	26.47%	20.59%	17.65%	35.29%
Access to the latest technology and services	18.00%	26.00%	26.00%	30.00%
Collaboration	20.00%	20.00%	40.00%	20.00%
Integrated IT Services (no need for installation, set up, and management)	18.18%	22.73%	24.24%	33.33%

Tasks	Business sector	Financial services	ICT services	Manufacturing and industrial market	Public sector & healthcare
Scalability	3.80%	8.86%	45.57%	7.59%	26.58%
Flexibility	5.36%	7.14%	46.43%	8.93%	21.43%
Time to market	14.71%	8.82%	38.24%	5.88%	29.41%
Access to the latest technology and services	6.00%	6.00%	42.00%	6.00%	32.00%
Collaboration	6.67%	0.00%	46.67%	0.00%	33.33%
Integrated IT Services (no need for installation, set up, and management)	3.03%	9.09%	39.39%	4.55%	28.79%

Tasks	Cloud engineering (architect)	Planning to move to the cloud	Providing cloud services	Research within cloud systems	Using cloud services
Scalability	10.13%	18.99%	13.92%	15.19%	35.44%
Flexibility	10.71%	12.50%	17.86%	16.07%	30.36%
Time to market	5.88%	14.71%	14.71%	17.65%	41.18%
Access to the latest technology and services	10.00%	20.00%	12.00%	14.00%	36.00%
Collaboration	13.33%	0.00%	0.00%	20.00%	60.00%
Integrated IT Services (no need for installation, set up, and management)	9.09%	16.67%	10.61%	16.67%	36.36%

D.2.3 Issues deterring organisations from migrating

Which of the following in your view are deterring organisations from migrating to the cloud?

Tasks	Up to 150	151 to 300	301 to 1000	More than 1000
Lack of cloud-related knowledge	22.54%	26.76%	26.76%	23.94%
Difficulties in gathering information	20.00%	23.33%	30.00%	26.67%
The immaturity of services and regulations	23.81%	19.05%	26.19%	30.95%
Lack of decision support tools	23.53%	29.41%	11.76%	35.29%
Difficulties in identifying suitable services	18.18%	13.64%	31.82%	36.36%
Security and privacy	22.73%	18.18%	19.70%	39.39%
The process of selection of cloud provider is complex	44.44%	22.22%	5.56%	27.78%
Loss of control	20.00%	20.00%	20.00%	40.00%
Disruption to business processes	14.29%	25.00%	32.14%	28.57%
Change of system management and impact on organisation	20.83%	16.67%	29.17%	33.33%
Cultural barriers	27.27%	0.00%	18.18%	54.55%
Legal implication	18.60%	16.28%	20.93%	44.19%
Trust	18.60%	18.60%	23.26%	39.53%
Cost management	11.11%	27.78%	27.78%	33.33%

Tasks	Business sector	Financial services	ICT services	Manufacturing and industrial market	Public sector & healthcare
Lack of cloud-related knowledge	7.04%	7.04%	42.25%	7.04%	29.58%
Difficulties in gathering information	6.67%	23.33%	30.00%	6.67%	30.00%
The immaturity of services and regulations	7.14%	9.52%	42.86%	7.14%	28.57%
Lack of decision support tools	11.76%	11.76%	35.29%	0.00%	23.53%
Difficulties in identifying suitable services	4.55%	9.09%	22.73%	0.00%	36.36%
Security and privacy	4.55%	7.58%	45.45%	6.06%	25.76%
The process of selection of cloud provider is complex	16.67%	5.56%	38.89%	11.11%	27.78%
Loss of control	8.89%	8.89%	40.00%	4.44%	28.89%
Disruption to business processes	14.29%	10.71%	32.14%	0.00%	35.71%
Change of system management and impact on organisation	8.33%	4.17%	33.33%	4.17%	33.33%
Cultural barriers	18.18%	9.09%	18.18%	0.00%	45.45%
Legal implication	4.65%	9.30%	37.21%	4.65%	37.21%
Trust	4.65%	6.98%	37.21%	9.30%	30.23%
Cost management	11.11%	11.11%	33.33%	5.56%	38.89%

Tasks	Cloud engineering (architect)	Planning to move to the cloud	Providing cloud services	Research within cloud systems	Using cloud services
Lack of cloud-related knowledge	12.68%	16.90%	11.27%	18.31%	32.39%
Difficulties in gathering information	13.33%	23.33%	0.00%	20.00%	33.33%
The immaturity of services and regulations	9.52%	14.29%	7.14%	19.05%	38.10%
Lack of decision support tools	17.65%	0.00%	11.76%	17.65%	47.06%
Difficulties in identifying suitable services	9.09%	13.64%	9.09%	13.64%	54.55%
Security and privacy	9.09%	12.12%	15.15%	18.18%	33.33%
The process of selection of cloud provider is complex	5.56%	22.22%	16.67%	11.11%	38.89%
Loss of control	8.89%	15.56%	15.56%	17.78%	31.11%
Disruption to business processes	14.29%	14.29%	3.57%	14.29%	42.86%
Change of system management and impact on organisation	8.33%	12.50%	12.50%	16.67%	41.67%
Cultural barriers	18.18%	0.00%	9.09%	36.36%	27.27%
Legal implication	9.30%	13.95%	9.30%	25.58%	32.56%
Trust	11.63%	18.60%	13.95%	16.28%	37.21%
Cost management	11.11%	27.78%	0.00%	11.11%	44.44%

D.2.4 The main perceived problems with cloud-based provision

Which of the following are the main perceived problems with cloud-based services?

Tasks	Up to 150	151 to 300	301 to 1000	More than 1000
Interoperability	25.00%	32.69%	21.15%	21.15%
Accessibility	17.39%	4.35%	30.43%	47.83%
Availability	24.00%	12.00%	28.00%	36.00%
Lack of standardisation	14.00%	28.00%	28.00%	30.00%
Privacy and data confidentiality	19.72%	22.54%	23.94%	33.80%
Vendor Lock-in	19.05%	26.19%	19.05%	35.71%
Data centre locations	17.65%	11.76%	17.65%	52.94%
Costing (cloud standards, different payment models)	15.79%	34.21%	26.32%	23.68%
Cost management	11.11%	27.78%	27.78%	33.33%

Tasks	Business sector	Financial services	ICT services	Manufacturing and industrial market	Public sector & healthcare
Interoperability	7.69%	9.62%	46.15%	5.77%	26.92%
Accessibility	4.35%	13.04%	26.09%	8.70%	30.43%
Availability	4.00%	16.00%	28.00%	12.00%	28.00%
Lack of standardisation	6.00%	4.00%	44.00%	2.00%	38.00%
Privacy and data confidentiality	4.23%	9.86%	43.66%	5.63%	26.76%
Vendor Lock-in	7.14%	7.14%	47.62%	2.38%	30.95%
Data centre locations	11.76%	5.88%	41.18%	0.00%	29.41%
Costing (cloud standards, different payment models)	5.26%	10.53%	50.00%	5.26%	26.32%

Tasks	Cloud engineering (architect)	Planning to move to the cloud	Providing cloud services	Research within cloud systems	Using cloud services
Interoperability	5.77%	19.23%	11.54%	17.31%	36.54%
Accessibility	8.70%	17.39%	4.35%	17.39%	39.13%
Availability	4.00%	20.00%	12.00%	16.00%	36.00%
Lack of standardisation	14.00%	10.00%	4.00%	20.00%	48.00%
Privacy and data confidentiality	8.45%	15.49%	15.49%	16.90%	33.80%
Vendor Lock-in	7.14%	14.29%	11.90%	26.19%	35.71%
Data centre locations	0.00%	5.88%	5.88%	17.65%	58.82%
Costing (cloud standards, different payment models)	13.16%	28.95%	2.63%	10.53%	34.21%

D.2.5 Legal implication

Which of the following are the main legal implications which can affect decisions to migrate to cloud computing?

Tasks	Up to 150	151 to 300	301 to 1000	More than 1000
Regulations and legal compliance violation	18.92%	27.03%	22.97%	31.08%
Data ownership	27.27%	11.36%	20.45%	40.91%
Service Level Agreement (SLA) problems	16.00%	28.00%	22.00%	34.00%
Intellectual property risks	21.43%	19.05%	26.19%	33.33%
Liability	7.41%	29.63%	18.52%	44.44%
Data loss/misuse	16.36%	21.82%	23.64%	36.36%
Software licenses issues	28.57%	9.52%	23.81%	38.10%

Tasks	Business sector	Financial services	ICT services	Manufacturing and industrial market	Public sector & healthcare
Regulations and legal compliance violation	5.41%	6.76%	43.24%	6.76%	31.08%
Data ownership	6.82%	11.36%	36.36%	0.00%	29.55%
Service Level Agreement (SLA) problems	8.00%	8.00%	36.00%	6.00%	32.00%
Intellectual property risks	7.14%	7.14%	38.10%	7.14%	30.95%
Liability	7.41%	3.70%	33.33%	7.41%	40.74%
Data loss/misuse	7.27%	7.27%	43.64%	5.45%	25.45%
Software licenses issues	9.52%	19.05%	33.33%	9.52%	23.81%

Tasks	Cloud engineering (architect)	Planning to move to the cloud	Providing cloud services	Research within cloud systems	Using cloud services
Regulations and legal compliance violation	10.81%	16.22%	12.16%	18.92%	35.14%
Data ownership	9.09%	11.36%	15.91%	20.45%	31.82%
Service Level Agreement (SLA) problems	2.00%	16.00%	6.00%	18.00%	42.00%
Intellectual property risks	9.52%	16.67%	9.52%	19.05%	38.10%
Liability	7.41%	14.81%	3.70%	25.93%	40.74%
Data loss/misuse	10.91%	10.91%	9.09%	20.00%	40.00%
Software licenses issues	4.76%	14.29%	9.52%	14.29%	47.62%
Software licenses issues	4.76%	14.29%	9.52%	14.29%	47.62%

D.2.6 Cloud knowledge and skills

Which of the following knowledge or skills do your staff need mostly when dealing with cloud services?

Tasks	Up to 150	151 to 300	301 to 1000	More than 1000
Knowledge of cloud capabilities and services	19.23%	26.92%	24.36%	29.49%
Cloud business alliance	37.50%	0.00%	0.00%	62.50%
Ability to analyse enterprise architecture and business needs	31.25%	25.00%	15.63%	28.13%
Cloud hosting	40.00%	6.67%	13.33%	40.00%
Configuration management	23.08%	28.21%	15.38%	33.33%
Standards awareness	13.51%	24.32%	32.43%	29.73%
Access control	21.05%	13.16%	26.32%	39.47%
Management of virtual machines	33.33%	4.76%	19.05%	42.86%
Auditing	17.86%	14.29%	25.00%	42.86%
Risk assessment	12.28%	29.82%	21.05%	36.84%
Compliance	21.88%	25.00%	28.13%	25.00%

Tasks	Business sector	Financial services	ICT services	Manufacturing and industrial market	Public sector & healthcare
Knowledge of cloud capabilities and services	5.13%	7.69%	43.59%	7.69%	33.33%
Cloud business alliance	25.00%	0.00%	12.50%	0.00%	50.00%
Ability to analyse enterprise architecture and business needs	9.38%	12.50%	53.13%	6.25%	15.63%
Cloud hosting	20.00%	13.33%	33.33%	6.67%	20.00%
Configuration management	10.26%	7.69%	38.46%	10.26%	28.21%
Standards awareness	8.11%	8.11%	27.03%	5.41%	43.24%
Access control	2.63%	7.89%	31.58%	5.26%	47.37%
Management of virtual machines	14.29%	9.52%	23.81%	4.76%	38.10%
Auditing	7.14%	3.57%	32.14%	7.14%	42.86%
Risk assessment	7.02%	10.53%	35.09%	7.02%	35.09%
Compliance	6.25%	12.50%	40.63%	6.25%	28.13%

Tasks	Cloud engineering (architect)	Planning to move to the cloud	Providing cloud services	Research within cloud systems	Using cloud services
Knowledge of cloud capabilities and services	10.26%	16.67%	11.54%	17.95%	34.62%
Cloud business alliance	12.50%	0.00%	12.50%	25.00%	37.50%
Ability to analyse enterprise architecture and business needs	12.50%	12.50%	18.75%	15.63%	28.13%
Cloud hosting	13.33%	6.67%	13.33%	20.00%	40.00%
Configuration management	10.26%	20.51%	5.13%	20.51%	33.33%
Standards awareness	10.81%	18.92%	2.70%	21.62%	37.84%
Access control	5.26%	18.42%	7.89%	23.68%	34.21%
Management of virtual machines	9.52%	14.29%	9.52%	23.81%	38.10%
Auditing	3.57%	14.29%	10.71%	28.57%	39.29%
Risk assessment	12.28%	19.30%	5.26%	22.81%	35.09%
Compliance	12.50%	18.75%	6.25%	18.75%	34.38%

D.2.7 Expertise needed to add to IT department

Subsequent to migrating to cloud computing, which of the following expertise did you need to add to your IT department

Tasks	Up to 150	151 to 300	301 to 1000	More than 1000
Cloud Architect	18.18%	29.55%	20.45%	31.82%
Cloud Software Engineer	7.69%	30.77%	7.69%	53.85%
Cloud Software Developer	0.00%	30.77%	15.38%	46.15%
Cloud System Administrator	23.53%	11.76%	0.00%	58.82%
Cloud Systems Engineer	18.18%	27.27%	18.18%	27.27%
Cloud Security Specialist	10.34%	24.14%	10.34%	51.72%
Cloud Integration Specialist	20.00%	16.00%	20.00%	40.00%

Tasks	Business sector	Financial services	ICT services	Manufacturing and industrial market	Public sector & healthcare
Cloud Architect	4.55%	9.09%	54.55%	2.27%	27.27%
Cloud Software Engineer	7.69%	7.69%	23.08%	0.00%	53.85%
Cloud Software Developer	0.00%	15.38%	38.46%	0.00%	38.46%
Cloud System Administrator	11.76%	11.76%	17.65%	5.88%	35.29%
Cloud Systems Engineer	0.00%	9.09%	45.45%	9.09%	27.27%
Cloud Security Specialist	6.90%	6.90%	31.03%	3.45%	44.83%
Cloud Integration Specialist	4.00%	12.00%	36.00%	4.00%	40.00%

Tasks	Cloud engineering (architect)	Planning to move to the cloud	Providing cloud services	Research within cloud systems	Using cloud services
Cloud Architect	11.36%	13.64%	11.36%	20.45%	40.91%
Cloud Software Engineer	7.69%	7.69%	7.69%	15.38%	38.46%
Cloud Software Developer	7.69%	7.69%	7.69%	15.38%	53.85%
Cloud System Administrator	5.88%	5.88%	17.65%	17.65%	35.29%
Cloud Systems Engineer	18.18%	18.18%	9.09%	9.09%	36.36%
Cloud Security Specialist	10.34%	10.34%	6.90%	24.14%	37.93%
Cloud Integration Specialist	0.00%	12.00%	8.00%	28.00%	36.00%

D.2.8 Quality of existing cloud-related information

Using a scale of 1 to 5, please rate the quality of existing cloud related information for each of the following

Tasks	Up to 150	151 to 300	301 to 1000	More than 1000
Availability	16.85%	29.21%	23.60%	30.34%
Sufficiency	17.78%	28.89%	23.33%	30.00%
Accessibility	17.05%	29.55%	23.86%	29.55%
Accuracy	17.78%	28.89%	23.33%	30.00%
Consistency	17.78%	28.89%	23.33%	30.00%
Understandability	17.98%	29.21%	23.60%	29.21%
Timely	17.78%	28.89%	23.33%	30.00%
Diversity	17.98%	29.21%	23.60%	29.21%
Complexity	17.98%	28.09%	23.60%	30.34%

Tasks	Business sector	Financial services	ICT services	Manufacturing and industrial market	Public sector & healthcare
Availability	4.49%	7.87%	43.82%	6.74%	29.21%
Sufficiency	4.44%	8.89%	43.33%	6.67%	28.89%
Accessibility	4.55%	7.95%	44.32%	6.82%	28.41%
Accuracy	4.44%	8.89%	43.33%	6.67%	28.89%
Consistency	4.44%	8.89%	43.33%	6.67%	28.89%
Understandability	4.49%	8.99%	43.82%	6.74%	28.09%
Timely	4.44%	8.89%	43.33%	6.67%	28.89%
Diversity	4.49%	8.99%	43.82%	6.74%	28.09%
Complexity	4.49%	8.99%	42.70%	6.74%	29.21%

Tasks	Cloud engineering (architect)	Planning to move to the cloud	Providing cloud services	Research within cloud systems	Using cloud services
Availability	7.87%	19.10%	10.11%	16.85%	37.08%
Sufficiency	7.78%	18.89%	10.00%	16.67%	36.67%
Accessibility	7.95%	19.32%	10.23%	17.05%	37.50%
Accuracy	7.78%	18.89%	10.00%	16.67%	36.67%
Consistency	7.78%	18.89%	10.00%	16.67%	36.67%
Understandability	7.87%	19.10%	10.11%	15.73%	37.08%
Timely	7.78%	18.89%	10.00%	16.67%	36.67%
Diversity	7.87%	19.10%	10.11%	15.73%	37.08%
Complexity	7.87%	17.98%	10.11%	16.85%	37.08%

D.2.9 Valuable sources of information for supporting decisions for migration

Which of the following are the most valuable sources of information for decisions to migrate to cloud computing?

Tasks	Up to 150	151 to 300	301 to 1000	More than 1000
Documented projects	8.77%	38.60%	19.30%	33.33%
Vendors offers	27.78%	22.22%	27.78%	22.22%
Experts views	20.45%	20.45%	18.18%	40.91%
Cloud decision support systems	27.78%	22.22%	16.67%	33.33%
Standards and regulations	16.67%	24.07%	24.07%	35.19%
White papers	25.58%	25.58%	27.91%	20.93%
Business articles	10.53%	10.53%	31.58%	47.37%

Tasks	Business sector	Financial services	ICT services	Manufacturing and industrial market	Public sector & healthcare
Documented projects	5.26%	8.77%	43.86%	8.77%	28.07%
Vendors offers	8.33%	5.56%	33.33%	8.33%	36.11%
Experts views	4.55%	6.82%	40.91%	2.27%	29.55%
Cloud decision support systems	5.56%	16.67%	38.89%	5.56%	27.78%
Standards and regulations	3.70%	11.11%	37.04%	7.41%	31.48%
White papers	4.65%	6.98%	60.47%	2.33%	18.60%
Business articles	5.26%	26.32%	31.58%	5.26%	26.32%
Documented projects	4.49%	8.99%	43.82%	6.74%	28.09%
Complexity	4.49%	8.99%	42.70%	6.74%	29.21%

Tasks	Cloud engineering (architect)	Planning to move to the cloud	Providing cloud services	Research within cloud systems	Using cloud services
Documented projects	5.26%	19.30%	5.26%	19.30%	40.35%
Vendors offers	5.56%	25.00%	16.67%	13.89%	27.78%
Experts views	11.36%	9.09%	13.64%	18.18%	38.64%
Cloud decision support systems	0.00%	22.22%	11.11%	22.22%	44.44%
Standards and regulations	9.26%	12.96%	3.70%	22.22%	42.59%
White papers	11.63%	11.63%	13.95%	9.30%	46.51%
Business articles	5.26%	26.32%	15.79%	15.79%	26.32%

Appendix E Evaluation of the model

16. The following is a list of the steps within the model that organisations should go through for migrating to cloud computing. If you do not agree with the order, please indicate the order that you wish to see in the model

- Define the business strategy
- Identify the suitable services for the cloud environment
- Evaluate venders
- Implementation
- Identify the cloud principles and capabilities
- Conduct risk assessment

Please use the scale of one to five (1= Not at all important to 5=Very important) when answering the following questions.

17. Please rate the importance of each of the following steps for the process of cloud migration.

	Not at all important 1	2	3	4	Very important 5
Evaluate organisations requirements	○	○	○	○	○
Define the business strategy	○	○	○	○	○
Identify the cloud principles and capabilities	○	○	○	○	○
Identify the suitable services for the cloud enviroment	○	○	○	○	○
Conduct risk assessment	○	○	○	○	○
Evaluate venders	○	○	○	○	○

Implementation	○	○	○	○	○

18. Please rate the importance of each of the following tasks to be performed when identifying cloud principles and capabilities (step 2).

	Not at all important 1	2	3	4	Very important 5
Cloud services management	○	○	○	○	○
Pricing policies	○	○	○	○	○
Security polices	○	○	○	○	○
Performance monitoring	○	○	○	○	○
Compliance to regulators	○	○	○	○	○
Support	○	○	○	○	○

Other (please specify)

19. Please rate the importance of each of the following tasks for the process of identifying the services that are suitable to be migrated (step 3).

	Not at all important 1	2	3	4	Very important 5
The required adaptation	○	○	○	○	○
Standards and regulation compliance	○	○	○	○	○
Security requirements	○	○	○	○	○
Integration requirements	○	○	○	○	○
Data volume	○	○	○	○	○
Sensitive of data	○	○	○	○	○
The impact on organisations' culture and staff	○	○	○	○	○

Return of Investment (ROI) calculation	○	○	○	○	○
Risk Assessment	○	○	○	○	○

Other (please specify)

20. Please rate the importance of each of the following risk assessment tasks or criteria (step 4)

	Not at all important 1	2	3	4	Very important 5
Loss of control	○	○	○	○	○
Dependability assessment	○	○	○	○	○
Managing relationship with different cloud providers	○	○	○	○	○
Process disruption evaluation	○	○	○	○	○
Service level and performance monitoring	○	○	○	○	○
Privacy and data confidentiality	○	○	○	○	○
Auditing	○	○	○	○	○
Liability	○	○	○	○	○
Response times	○	○	○	○	○
Business continuity and disaster recovery	○	○	○	○	○
Flexibility of service	○	○	○	○	○
Compliance with regulations	○	○	○	○	○
Ease of ending the arrangement (termination)	○	○	○	○	○
Data ownership and intellectual property rights	○	○	○	○	○

Legal implication	○	○	○	○	○
Accessibility	○	○	○	○	○
Availability	○	○	○	○	○

Other (please specify)

21. Please rate the importance of each of the following vender evaluation tasks (step 5).

	Not at all important 1	2	3	4	Very important 5
Accountability	○	○	○	○	○
Agility	○	○	○	○	○
Assurances	○	○	○	○	○
Cost	○	○	○	○	○
Performance	○	○	○	○	○
Security and Privacy	○	○	○	○	○

Other (please specify)

22. Please rate the importance of each of the following tasks for the implementation step (step 6).

	Not at all important 1	2	3	4	Very important 5
Training	○	○	○	○	○
Communication	○	○	○	○	○
Documentation	○	○	○	○	○

Other (please specify)

23. How well do you think the model is an accurate reflection of the issues involved in migrating to the cloud?

○ Excellent

◯ Good

◯ Fair

◯ Poor

◯ Very poor

24. Please use the box below if you would like to provide comments about the model:

25. Please use the box below to provide any further information with regards to the process of migrating to cloud computing:

26. To what extend do you think the model is an effective guide to support the decisions for migration to cloud computing?

◯ Excellent

◯ Good

◯ Fair

◯ Poor

◯ Very Poor

27. Please provide your e-mail address if you wish to receive a copy of the result

Prev Done

Appendix F The future of cloud computing

The future of cloud computing was discussed with the participants in Stage 1 of the survey implemented in this research. The participants expected that there will be more of customers moving their services to the cloud environment. Interviewee 6 stated that:

> “They will carry on going to the cloud. Not necessarily slowly, they'll probably speed up. But people are using the cloud, and the cloud is growing”

Interviewee 5 also pointed out

> “In five years' time, I think you can already see the trends. There is a growing use of the cloud, because there are benefits of it”

Further, according to the Global Technology Outlook, more than a quarter of all applications will be available via cloud by 2020 (Menegaz, 2014). Additionally, cloud computing will be more desired in the future to support the current technology trends such as the internet of things.

One of the predictions about the future of cloud computing is that, enterprises will become more aware of total cost of ownership. According to Linthicum (2015a) this knowledge will slow or may stop cloud adoption within some enterprises. Cloud customers are expected to develop better understanding about which types of cloud services are best for their requirements. The focus when it comes to business-critical workloads and security measures will be on where organisations should put their boundaries, what intend to be on their side of the boundary and what can be on the other side of the boundary.

From the perspective of IT systems provision, the evolvement of cloud computing will change the focus from just selling IT resources to managing hardware and software. A cloud provider interviewed in this research indicated

"That's definitely happening now, we're seeing more of that, and we expect that to continue" (Interviewee 1). A cloud provider pointed out that:

> "It's absolutely an area of development, and it's absolutely expected that we'll have much more of the equipment in a data-centre will probably be our own equipment, running a cloud service for our customers, rather than our customers' equipment." (Interviewee 4)

Interviewee 5 stated that: "I think the way the cloud is administered will change". It was also predicted that there will be more desire for national cloud computing that are politically and national security driven (Interviewee 5 and 11). Additionally, more hybrid cloud adoption and increased cloud development are expected too. It was anticipated that there will be new businesses and new business processes coming about as a result of the development of cloud computing (Interviewee 1, 5, and 8). So there will be new businesses that are cloud-centric. The entire business requires the cloud to be part of the business process. Interviewees in this research indicated that working patterns are changing because of better, more reliable, greater bandwidth, and the availability of virtual computing. The developments in these technologies will speed-up the adoption of cloud-based services. Finally, change in IT systems is happening all the time, it is evolving through the businesses, and the businesses should develop their knowledge and expertise in order to properly exploit them.

Glossary of terms

CAPTCHA: Completely Automated Public Turing test to tell Computers. and Humans Apart

Compartmentalization: is an unconscious psychological defense mechanism used to avoid cognitive dissonance, or the mental discomfort and anxiety caused by a person's having conflicting values, cognitions, emotions, beliefs, etc

Data centre: a collection of physical computing resources that includes physical servers, networking hardware (routers, switches), power and cooling systems.

DDOS: Distributed Denial of Service attack.

Eucalyptus: an open-source software framework for cloud computing that implements IaaS systems that give users the ability to run and control entire virtual machine instances deployed across a variety physical resources.

IaaS: Infrastructure as a Service

Leverage: The power to influence a person or a situation

Metaphysics The branch of philosophy that deals with the first principles of things, including abstract concepts such as being, knowing, identity, time, and space.

On-premises: Installed and run on in the building of the person or organisation using the system

PaaS: Platform as a Service

PDAs a handheld device that combines computing, telephone/fax, Internet and networking features.

Rainbow tables:	a precomputed table for reversing cryptographic hash functions, usually for cracking password hashes.
RoI:	Return on Investment: measuring the efficiency of cloud migration investment
SaaS:	Software-as-a-Service
Siloed software	a siloed application is any software that functions on its own to solve a problem.
SLA:	Service Level Agreement
SMEs:	Small and Medium Enterprises
SOA:	Service-Oriented Architecture
SOAP:	Simple Object Access Protocol
SOAP:	Simple Object Access Protocol
UML:	The Unified Modelling Language. It is a general-purpose, developmental, modelling language in the field of software engineering that is intended to provide a standard way to visualize the design of a system.
VPN:	Virtual Private Network