Cloud computing: can it play a role in the future of legacy applications

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Abstract

The research project sets out to determine the most suitable criteria for evaluating legacy applications for migration to the cloud.
Cloud computing has become established as the platform of choice for deploying applications and it represents a fundamental shift in how businesses access IT services. However, not all applications can take advantage of cloud computing, many companies have legacy applications, these are typically in-house developed or customised applications where the development skills are either scarce or non-existent. This dissertation conducted research to identify the most suitable criteria to analyse legacy applications for migration to the cloud.

The literature reviewed common characteristics of legacy applications and explored the issues associated with them. Possible solutions to these issues were outlined, and the option of migrating to the cloud was developed. It contains analysis on the thinking on the benefits of migrating legacy applications to the cloud, migration approaches and the criteria for evaluating legacy applications for migration to the cloud.

The study was carried out using an interpretive philosophy, the research method was semi-structured interviews, and the findings were analysed using a qualitative approach combined with thematic analysis and inductive reasoning.

The findings revealed that the issues with legacy applications are likely to increase into the future, particularly the skills shortage. The criteria which the findings revealed as being important when evaluating legacy applications for migration to the cloud were the number of integration points, level of change required, data criticality and cost. Organisations typically based their migration decision on one of these criteria. The study also questions the value of carrying out an in-depth evaluation of legacy applications as the skills are lacking for such an exercise. The preferred approach is to replace specific capabilities with cloud capabilities or functions and gradually replace the application.

The conclusions of the research are that legacy applications are often core applications and having them prone to failure could have disastrous consequences for an organisation. These applications are already failing to fulfil some business requirements and given the frequency of changes required to secure applications and data, the issues need to be addressed sooner rather than later.

Declaration

I declare that the work described in this dissertation is, except where otherwise stated, entirely my own work, and has not been submitted as an exercise for a degree at this or any other university. I further declare that this research has been carried out in full compliance with the ethical research requirements of the School of Computer Science and Statistics.

Signed: ________________________________

James Maughan
1st September 2017

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I agree that the School of Computer Science and Statistics, Trinity College may lend or copy this dissertation upon request.

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Abbreviations:

API	Application Programming Interface
BCM	Business Continuity Management
CAPEX	Capital Expenditure
CRM	Customer Relationship Management
ERP	Enterprise Resource Planning
EU	European Union
GDPR	General Data Protection Regulation
HR	Human Resources
ISA	Instruction Set Architecture
NIST	National Institute of Standards and Technology
OPEX	Operating Expenditure
SaaS	Software as a Service
SLA	Service Level Agreement
SMB	Small and Medium Businesses
SOAP	Simple Object Access Protocol
VM	Virtual Machine
XML	eXtensible Markup Language

1 Introduction

This chapter introduces the dissertation and the background to the study, it will introduce the research question in addition to outlining the aims and objectives of this research. In addition, a brief review of the literature landscape including what is meant by cloud computing, legacy and migration will be provided. Next, the scope of the study will be provided including the approach and methods undertaken to answer the research question and meet the aims and objectives.

1.1 Background to this Research

Over the past twenty years, there has been a dramatic change in computing particularly in terms of hardware and infrastructure. The large mainframes with dumb terminals of the 1970’s and 1980’s have given way to servers powered by inexpensive microprocessors with x86 architecture. The x86 architecture is an instruction set architecture (ISA) series developed by Intel Corporation. This trend has been driven by frequent innovations in processors to make them smaller yet more powerful. These hardware advances from companies such as Intel and AMD have occurred in parallel with significant software advancements in operating systems by Microsoft and to a lesser extent Unix and Linux.

This has given rise to department level Intel based servers which are much more accessible to a broader range of technology users. Business departments found it cheap and easy to buy their own servers for new projects, in some cases even bypassing central IT. The systems were affordable and easy to scale. Before long IT departments found that their server racks were filling rapidly as departments acquire precisely the computing power their business needed. These servers were typically organised into data centres for program and data storage.

The success of the x86 servers led to problems of “server sprawl” for many enterprises. Server sprawl is a situation in which multiple, under-utilised servers take up more space and consume more resources than can be justified by their workload (Khanna, et al., 2006). The ease of buying yet another server for yet another application led to a boom in demand for data-centre real estate, with huge demands for electricity and cooling. Servers are normally sized for peak loads and as a result at off peak a lot of server resources are idle. The number of servers also provide an IT management headache in terms of ensuring the operating systems are patched to adequate levels for security and managing the variety of applications spread across a multitude of servers. Those x86 servers were starting to look more expensive than initially perceived.

1.1.1 *Virtualisation*

Virtualisation offered a possible solution, now all the resources of one physical server could be shared across multiple virtual machines (VM). The upshot of virtualization for enterprises was that they could keep applications and operating systems separated from each other on the same hardware while consolidating onto fewer physical machines. Virtualization brought mobility. Servers could bounce from machine to machine by being cloned or snapshots were taken and moved from one physical server to another. Because of the lowered cost of adding another virtual server rather than a physical one, virtual machines grew and grew. Virtualization may have addressed the issue of physical server sprawl but it created a whole new sort of server sprawl, VM sprawl, where instead of a proliferation of physical servers this was replaced by virtual machines (Khanna, et al., 2006). The management requirement of multiple applications and multiple operating systems remain, or in a lot of cases becomes much worse, due to ease with which virtual machines can be deployed.

1.1.2 *Cloud computing*

Looking for approaches to managing the soaring numbers of virtual servers at big enterprises such as Amazon led directly to the development of cloud computing.

Amazon's cloud computing offering started when Chris Pinkham (VP of Engineering) was looking for a way to make the company's infrastructure accessible to development teams in multiple locations. Rather than have all the teams constantly working out how they could access each other's servers and interface with any applications or services running on these servers, they wanted to provide the developers with a set of dependable tools and a reliable infrastructure upon which they could build products. (Clarke, 2012)

The solution Amazon devised was to place their servers in an environment where they could be accessed via the internet. This provided accessibility for development teams irrespective of their location. The company then layered several services on top of these platforms which could be accessed via an external interface. This interface was well defined and to interface with a service all a developer needed to know was how to access the interface.

The new platform proved so popular that Amazon decided to open it up to other companies and what we now call cloud computing was born.

The cloud is open and accessible to all. Businesses can choose to use as little or as much as they like and only pay for what they use. This allows businesses to maintain control of their expenditure whilst taking advantage of all the cloud has to offer.

This service based architecture was revolutionary compared to productised offerings from other companies. (Vallecillos, et al., 2016). The traditional approach was that a company would build a product, make it available and then add to it to make it the best product possible. The problem with this approach is that the company needs to be able to predict what the users want and then build and deploy it in a manner that users like and are happy to interact with. This can prove to be very difficult as well as consuming a lot of resources for design and development. The service based approach that Amazon promoted with their cloud platform allows companies to build their own solutions using the services the platform provides. Amazon, in turn, can analyse which services their clients are using and what they are using them for and then adapt future offerings for areas where they see interest.

Cloud computing is frequently the topic of conferences, workshops, white pages and blog posts, however, it is not a descriptive term and is only understood by someone with prior knowledge of the topic. This confusion led Larry Ellison Oracle's CEO, to say "*The interesting thing about cloud computing is that we've redefined cloud computing to include everything that we already do…. I don't understand what we would do differently in the light of cloud computing other than change the wording of some of our ads*." (Armbrust, et al., 2010)

Cloud computing has become established as a modern platform hosting leading edge innovative solutions. The software as a service (SaaS) model has revolutionised the software industry offering advantages such as:

- Lower costs
- Reduced time to benefit
- Scalability and integration
- High Availability
- Seamless upgrades

Industry analysts, Gartner, conducted a survey which claims that 58% of organisations use or planned to use cloud services by the end of 2015, with a further 13% planning to do so by the end of 2017. (Scott, 2016)

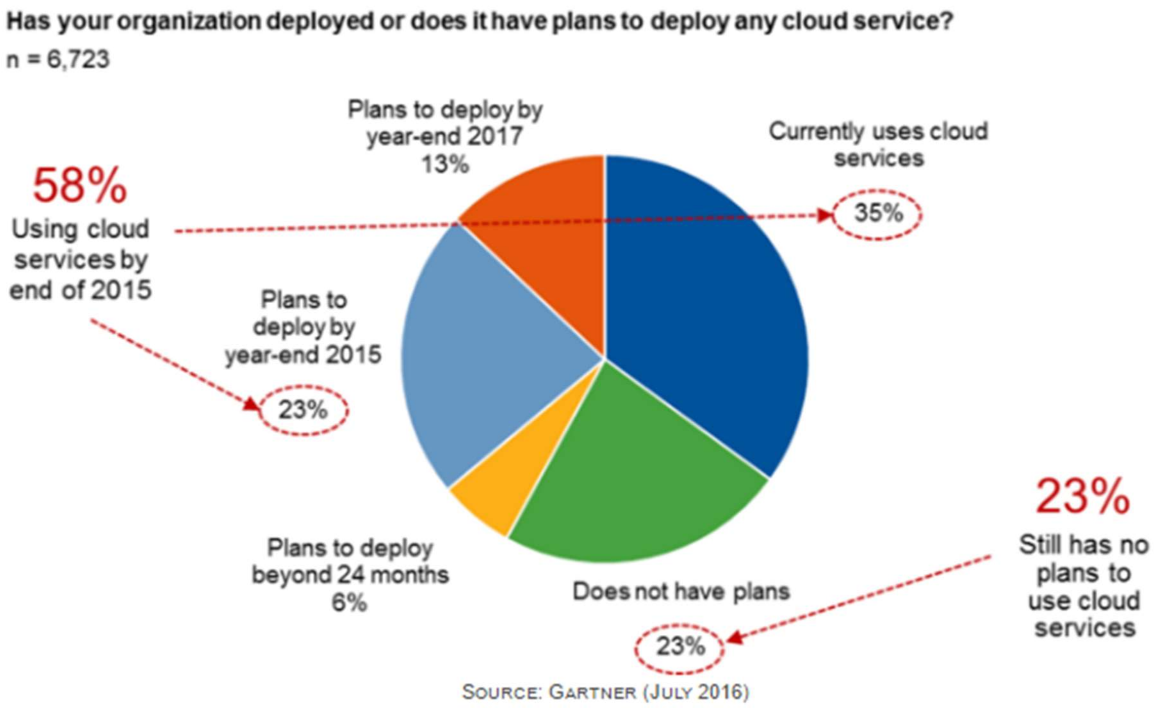

Figure 1 - Organisations' plans to deploy cloud services

(Scott, 2016)

Cloud computing represents a fundamental shift in how businesses pay for and access IT services. It has created new opportunities for IT service providers and the outsourcing vendors. Cloud computing is having a big impact on outsourcing vendors, who have had to develop new approaches to include Cloud services as part of their offerings to keep up with profound changes in the IT service industry. (García, et al., 2015) (Subhankar Dhar, 2012)

Most companies agree that there are many benefits to using the cloud, however, not all are in a position to take advantage of cloud computing and the SaaS model in particular. Many companies have what are described as legacy applications, these are typically in-house developed or customised applications where the development skills are either, scarce and expensive or in some cases non-existent.

1.1.3 Legacy applications

Applications are deemed legacy for several reasons but primarily because the skills required to support and develop them are not available. Typically, any resources with knowledge of these applications spend all their time ensuring an adequate level of service. There is a reluctance to change the application as the effort involved in analysing the consequences of any change and to carry out sufficient testing to ensure a stable production environment is not cost effective. The effort involved outweighs any potential benefit from the change.

1.1.4 The issue with legacy applications

While the desire to migrate legacy applications to the cloud exists it is not straightforward. These applications are built on an infrastructure which is not easy to replicate in the cloud. These applications have also evolved through many iterations of changes and sometimes features are added which are not related to the core application but because the development skills existed at the time the feature was included in the application. Migrating a legacy application to the cloud involves unravelling all the features of the applications, separating out the various components that the application comprises of and understanding how the application interfaces with the storage infrastructure and interdependencies on other applications.

Possible outcomes of this analysis are:

- The application is suitable for migration to the cloud
- Some features or components can be migrated to the cloud
- The application should be replaced

This dissertation will conduct research to identify the most suitable criteria to use to analyse whether legacy applications are suitable for migration to the cloud. These criteria can form a framework for any company undertaking such an exercise.

A report by Dell EMC® (2016), found 91% of the companies they worked with admitted to not having an organised and consistent means of evaluating legacy applications for the cloud. (Dell EMC, 2016). This study aims to fill this gap and identify a set of criteria that companies can use to evaluate their applications.

1.2 Research question

The primary research question addressed in this study is:

- What are the most suitable criteria for evaluating legacy applications for migration to the cloud?

The aims and objectives of this study are to:

- Define legacy applications
- Consider issues associated with legacy applications
- Review possible solutions for issues with legacy applications
- Explore criteria for analysing legacy applications.

1.3 Scope of the study

The success or failure of a business's cloud computing strategy in the longer term will depend on the choices made at the planning stage (Beserra, et al., 2012). These choices are often made by senior technical staff who are tasked with formulating the direction the company should take. Cloud strategies are often driven by IT or technical requirements rather than by the business requirements as adopting cloud applications is normally viewed as a technical decision. Senior management are obliged to support these decisions and it is up to the technical staff to present their case for adopting a cloud service or application to senior management.

An aim of this dissertation is to investigate what criteria are most beneficial to senior technical staff when analysing the suitability of their portfolio of applications for adoption to the cloud. The criteria identified should be used to determine the suitability of each application for cloud and help in forming both a short and long term transition plan for cloud adoption.

To answer this research question and meet the aims and objectives, semi-structured interviews were conducted with twelve senior technical staff whose companies have already taken a strategic decision to move their applications to the cloud. These senior technical staff are IT Managers or Technical Architects who have been tasked with evaluating their company's suite of applications and developing a plan for adapting or migrating their applications to the cloud.

Participants were asked several questions about their approach to evaluating legacy applications for migration to the cloud, how they categorise their applications and the criteria they use to evaluate each application.

1.4 Beneficiaries

This research will be of interest to IT managers, portfolio managers, solution architects and researchers who need to determine the best criteria for evaluating legacy applications for migration to the cloud.

The research will provide a framework that they can apply to their applications to analyse them and produce the data on which their decisions will be based.

There was not an intended benefit for participants but all participants mentioned how participating in this research provided a space for them to think more about their work practices in relation to the topics under investigation.

1.5 Dissertation roadmap

Chapter 1 introduces this research, provides the background to the study and the research questions.

Chapter 2 reviews the relevant literature covering legacy applications, issues and possible for legacy applications, cloud computing, benefits in migrating a legacy application to the cloud, criteria for analysing legacy applications and choosing a migration strategy.

Chapter 3 describes the research philosophy, approach and methods.

Chapter 4 presents the findings and an analysis of the data.

Chapter 5 contains conclusions and proposes some possible areas for future research.

1.6 Conclusion

This chapter introduced this dissertation and outlined the research question, aims and objectives, the approach and methods employed to answer the research question, mode of analysis, ethics and brief mention of literature relating to cloud computing and legacy applications.

The next chapter will review literature relevant to the research question.

2 Literature Review

2.1 Introduction

The previous chapter introduced this dissertation and all it will entail and this chapter reviews the literature relevant to the research question; what are the most suitable criteria for evaluating legacy applications for migration to the cloud?

Several topics are explored, as follows:

- Legacy applications
- The issues with legacy applications
- Possible solutions
- Cloud computing background
- Benefits of Cloud computing
- Legacy applications – criteria for analysis
- Choosing a migration strategy

2.2 Legacy applications

Legacy applications are described by Khadka et al. (2014), as old applications, perhaps up to twenty or thirty years old, business critical and often at the core of the business, built with proven technology and reliable, but not fitting into strategic technology goals and lacking in documentation and knowledge or skills to make changes to fulfil the requirements of a modern business (Khadka, et al., 2014).

An alternative definition of legacy applications is any application that significantly resists modification and evolution to meet new and constantly changing business requirements, regardless of the technology from which it is built (Abi-Antoun & Coelho, 2005).

Reviewing the various definitions of legacy application three key attributes emerge, which will be outlined below:

- Business Critical
- Proven Technology
- Reliable Systems

2.2.1 *Business critical*

Legacy applications are frequently the core systems of their organisations and their failure can result in serious consequences for daily business. The longevity of these applications and the fact that they support core business processes mean that their failure would have a significant impact on an organisation. The fact that an application that is up to thirty years old is retained long enough to reach legacy status points to the importance of the application, if the application was not business critical then it would never have reached legacy status (Khadka, et al., 2014).

Erradi et al. (2006) state an application's business value contribution should be determined based on the application criticality in achieving business objectives and its ability to generate business returns both in terms of financial benefits and/or improved customer satisfaction (Erradi, et al., 2006).

2.2.2 *Proven technology*

Legacy applications have been developed, tested and have been in a production environment for years. Hence, it is an indication that legacy systems are a proven technology that remains as the core applications of many organisations. Proven technology is often the reason why these applications are still in use, they are stable and are up and running 24/7 or very close to this (Khadka, et al., 2014).

2.2.3 *Reliable systems*

Legacy systems are reliable systems, primarily, because they are running in a production environment for decades. Technical issues have normally been resolved over the years and they have been tuned for stability, robustness and availability. In general, legacy systems are perceived as reliable systems due to the fact that they have been in production for years and possible bugs and errors have already been fixed in the past and the applications have stabilised (Khadka, et al., 2014).

2.3 Issues with legacy applications

Applications must be capable of supporting changing business requirements, have reasonable maintenance costs, have up to date documentation that is easy to maintain and continue to be stable despite any changes to the application (Khadka, et al., 2014).

Legacy applications tend to have issues in some or all of these areas:

- Changing Business Requirements
- Cost of Maintenance
- Vulnerable to Failure

2.3.1 Changing business requirements

Organisations must be agile and capable of adapting quickly to various changes, including intra-organisational changes, compliance with updates to laws and regulations, changes in business collaboration (mergers and acquisitions), and to provide new products or services (Van Deursen, et al., 1999). While legacy applications are critical to the business and reliable systems, they are also inflexible when it comes to supporting new business requirements. There is a concern that the business can lose control of their processes so that a business manager is requesting permission from an application owner whether a process can be changed, thus the legacy applications are having a negative impact on the business (Khadka, et al., 2014).

2.3.2 Cost of maintenance

A significant driver to modernise a legacy application is the high cost of maintenance which can cause an organisation to lose its competitive advantage. Maintenance costs are increasing as legacy applications are not developed in modern programming languages so the skills to maintain them are very specialised. There is a lack of documentation of legacy applications leading to a scarcity of knowledge and legacy experts, developers must have the expertise to analyse code to determine how functions should operate and this is time-consuming and thus costly (Brodie & Stonebraker, 1993).

Resources maintaining legacy systems tend to work exclusively on legacy systems as their skills are unique. Organisations are looking at the cost of maintaining these applications and then comparing them to the costs of maintaining a modern system developed in a modern programming language and believe that if they modernise the applications then the maintenance costs will reduce (Khadka, et al., 2014).

2.3.3 *Vulnerable to failure*

Being reliable is one of the benefits attributed to legacy applications, however, there is also a concern that a legacy application may fail due to lack of experts and support from suppliers or vendors. Legacy applications are business critical and organisations cannot afford their legacy applications to fail. This concern can also contribute to a reluctance to change the application, the risk is that the change will impact the stability of the application and introduce a vulnerability to failure that did not exist previously. The desire to mitigate against the risk of failure is often a driver to modernise a legacy application (Khadka, et al., 2014).

There is also a concern that a legacy application will break and not be recoverable. This concern combined with a lack of techniques to fix legacy systems can result in the legacy application consuming a majority of technical support resources. This consummation of resources by legacy systems means that there are not sufficient resources available to work on replacing or migrating a legacy system. Consequently, management are driven to migrate against this risk by addressing this issue with legacy systems (Brodie & Stonebraker, 1993).

2.4 Possible solutions

Erlikh (2000) purposes four options for addressing these aforementioned difficulties with legacy applications:

- Recycle
- Nurture
- Modernise
- Trash

The decision on which option to take depends on how critical the legacy application is to the organisation and the quality of the legacy code. Figure 2 shows where legacy transformations make the most sense. A low-quality legacy system that offers little value to the organisation should be trashed and replaced by an off the shelf package. A high-value legacy application that gives an organisation a competitive advantage is worth nurturing unless there are business pressures to change it. The modernisation region in Figure 2 represents any approach used to bring the legacy system into the modern world. Low-quality but strategic legacy applications are the best candidates for modernisation (Erlikh, 2000).

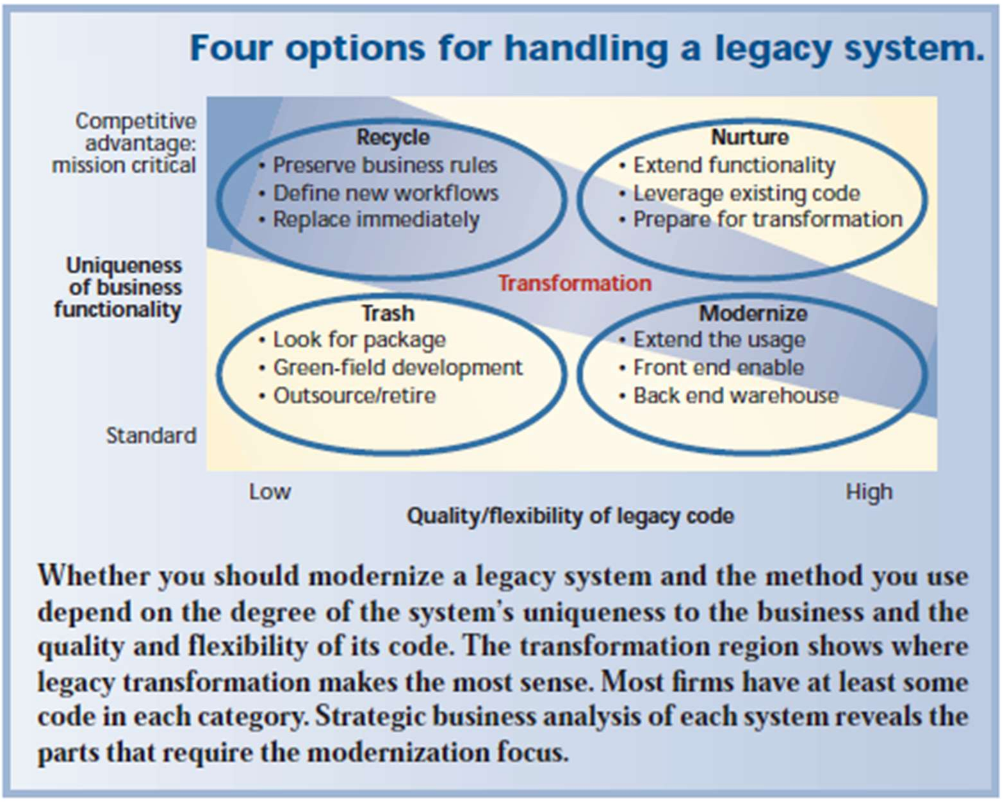

Figure 2 - Options for handling a legacy system

(Erlikh, 2000)

Bisbal et al. (1999) suggest approaches similar to Erlikh (2000), for dealing with legacy systems. These approaches are *redevelopment*, which entails rewriting the applications, *wrapping*, which is to create a new interface to the legacy application, making it more accessible from other applications, and *migration*, which is to move the legacy application to a modern environment whilst retaining the original data and functionality.

Wrapping is regarded as a partial solution and as such its value is short-term, over time the additional components can add to the burden of the legacy application.

Redevelopment is a huge undertaking as it entails a complete rewrite of the application, this is frequently ruled out due to the expense and time required to deliver. Senior management are frequently reluctant to sign off on such an expensive project that only promises to reduce future maintenance costs (Bisbal, et al., 1999).

Erlikh (2000) says that the ideal solution is to migrate the legacy application to newer, more productive platforms so that organisations can exploit faster and cheaper development technologies. The focus can then shift from infrastructure to functionality, allowing an organisation respond more quickly to its changing business requirements and technology enhancements (Erlikh, 2000).

Brodie and Stonebraker (1993) warn that there is a risk in any legacy application migration that the target application can become a legacy application. To mitigate against this risk the choice of target platform is key. The right target platform will ensure that the application can be accessed by a wide variety of current and future desktop computers and the database will operate on a wide variety of platforms (Brodie & Stonebraker, 1993).

2.5 Cloud computing background

Brodie and Stonebraker (1993) state that the choice of target platform is key to a successful legacy application migration and the cloud platform has become the platform of choice for application deployments.

Cloud computing is defined by the National Institute of Standards and Technology (NIST) as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (such as networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. (Mell & Grance, 2011). Cloud computing has also been referred to as “Utility computing” (Han, 2010) and is frequently compared to other utility services like Electricity. To use electricity a personal generation plant is not required, instead, a device is plugged into a socket which is connected via a series of wiring to a central power plant. Electricity is billed on a per usage basis and it is the responsibility of the power plant management to ensure that there is sufficient electricity produced to fulfil the demand. This is the same model incorporated by Cloud computing where the consumer of the service or application is charged for what they use and it is the responsibility of the cloud provider to ensure sufficient resources to meet the demand.

2.6 Benefits of cloud computing

The NIST definition of cloud computing identifies five essential characteristics:

- On-demand self-service
- Broad network access
- Resource pooling
- Rapid elasticity
- Measured Service

  (Mell & Grance, 2011)

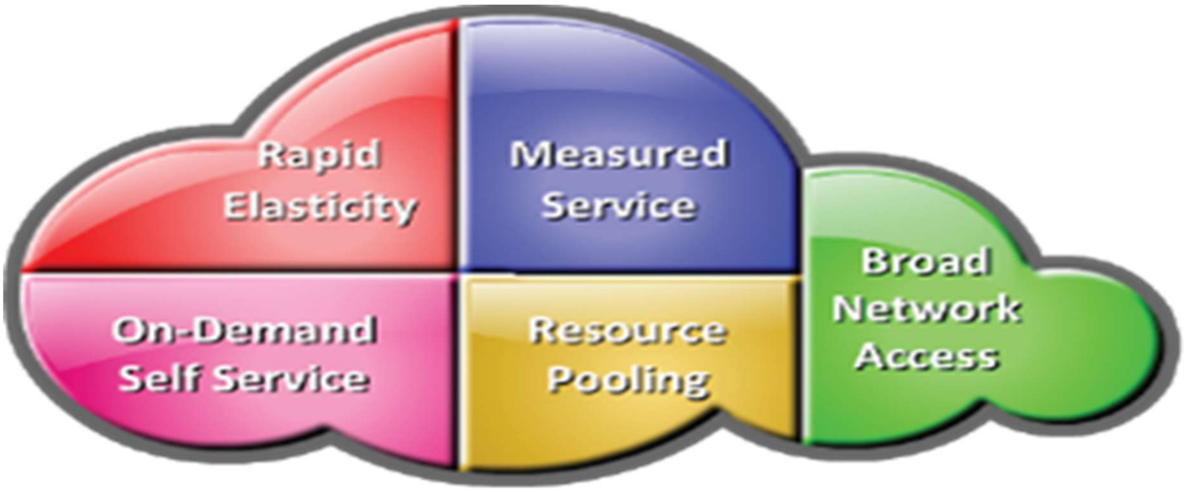

Figure 3 - Essential characteristics of cloud computing

(Mell & Grance, 2011)

2.6.1 On-demand self-service.

The provision of computing capabilities is done automatically by the consumer without requiring any interaction with the service provider. Services such as email, applications, storage or network services can be commissioned to provide a solution for end users. This is normally done using templates provided by the cloud service provider accessed through a web browser over the internet. Typically, billing is based on a monthly subscription or a pay-as-you-use basis. End users can then access these services based on the level of access permitted in their security profile (Buyya, et al., 2008).

2.6.2 Broad network access

Pallis (2010) describes broad network access as not being location dependent and the solutions are accessible once the end users, wherever they are located, can establish an online connection. End users can access business solutions using various devices such as computers, laptops, smartphones or tablets This mobility is particularly beneficial to businesses as employees can have the same level of access to applications when they are out of the office as they would have in the office. This allows the employees to be more productive and provides the capability to be able to access project information, contracts and customer documentation as and when they need it (Pallis, 2010).

2.6.3 Resource pooling

Multiple consumers share a common pool of resources which are allocated dynamically. Access to these resources allows end-users to enter and use data within the business solution hosted in the cloud at the same time, from any location, and at any time. This is particularly beneficial to organisations who have an office in multiple locations and/or those that have employees who frequently work outside the office such as sales teams or service personnel. The cloud resources which are pooled can be located at different data-centres' which might be in the same location or can be geographically distributed (Stieninger & Nedbal, 2014)

2.6.4 Rapid elasticity

Elasticity is the ability to have flexible and scalable solutions to suit the immediate business needs. This flexibility in scaling may even occur automatically based on a response to a demand placed by consumers. Elasticity is often considered a core justification for the adoption of cloud computing, primarily as the ability to quickly scale up or down resource usage, is an important economic benefit as it transfers the costs of resource overprovisioning and the risks of under-provisioning to the Cloud providers (Shawish & Salama, 2014). Businesses such as retailers can take advantage of this to provide additional resources during periods of peak demand such as the holiday season or sales events and then scale back to normal levels afterwards.

The biggest Cloud vendors can offer the greatest range of elasticity as they have the resources at their disposal to invest in the infrastructure required (Azeemi, et al., 2013).

2.6.5 Measured service

The amount of resources that are used can be monitored and controlled from both the consumer side and the cloud provider's side which provides transparency. The consumer and the cloud provider can measure storage levels, processing, bandwidth usage, and the number of user accounts and this is the basis for pay for what you use billing (Mell & Grance, 2011).

2.6.6 Resilience

In addition to the five essential characteristics put forward by NIST, Gong et al. (2010) propose that resilience as another essential characteristic of cloud computing.

Resilient computing is a form of failover that distributes redundant implementations of IT resources across physical locations. IT resources can be pre-configured so that if one implementation fails or is not accessible, processing is automatically handed over to another redundant implementation. Within cloud computing, the characteristic of resiliency can refer to redundant IT resources within the same cloud (but in different physical locations) or across multiple clouds. Cloud consumers can increase both the reliability and availability of their applications by leveraging the resiliency of cloud-based IT resources. Figure 3 below shows an illustration of this where Cloud B hosts a redundant instance of Cloud Service A, in the event of failure of the service on Cloud A, processing can be automatically continued by Cloud B (Gong, et al., 2010).

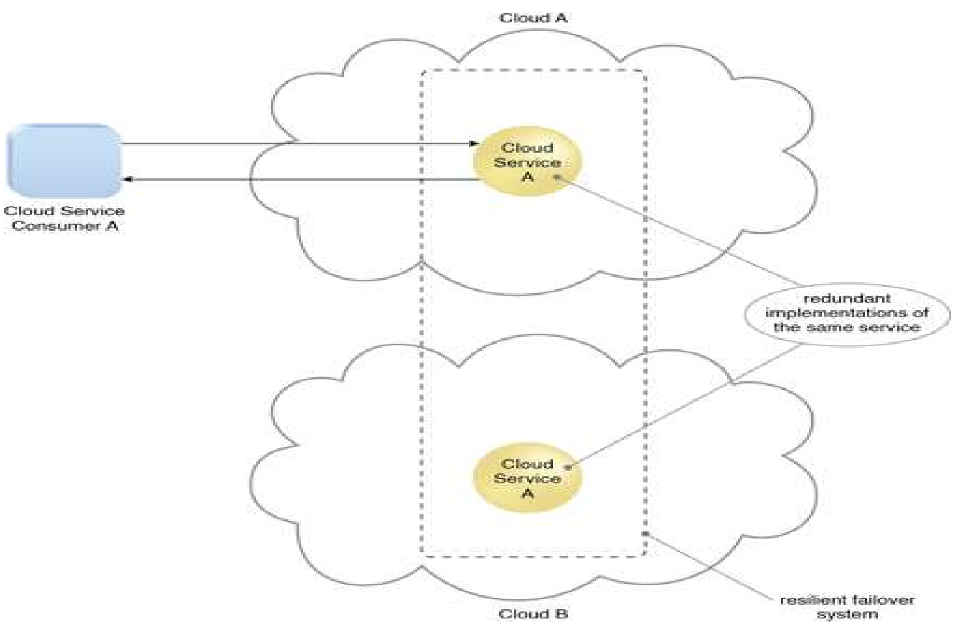

Figure 4 - Cloud Resilience

http://www.surfcloudtech.com/characteristics-of-cloud-computing/

2.6.7 Benefits of SaaS model

The SaaS model is an alternative to the standard software installation in the business environment (traditional model) where a consumer should build the server, install the application and configure it. The SaaS layer in the final layer in the cloud computing models, this is the layer where software programs are positioned as a shared cloud service and made available as a "product" or generic utility to end users. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, except for limited user specific application configuration settings. (Mell & Grance, 2011)

With the SaaS model, the consumer does not pay for the software itself, instead, it works like a rental. They have the authorisation to use it for a period of time and pay for the software that they are using.

The benefits of this model of application deployment are:

- **Reduced time to benefit**
  Different from the traditional model, in SaaS the software application is already installed and configured. The user has the advantage of provisioning the server for an instance in the cloud and in a matter of hours they can have the application ready for use. This reduces the time spent in installation and configuration and can reduce the issues that can get in the way of the software deployment (Varia, 2010).
- **Costs**
  SaaS has a differential regarding costs since it usually resides in a shared or multi tenant environment where the hardware and software license costs are low compared with the traditional on-premise model.
  Another advantage is that the customer base can be increased since it allows small and medium businesses (SMB) to use a software that otherwise they would not use due to the high cost of the license.
  The costs associated with this model are also classed as operating expenditure (OPEX) as opposed to capital expenditure (CAPEX). This allows organisations budget more effectively as they do not have to have a large upfront investment following by smaller maintenance charges, instead, the costs are billed monthly or annually on a subscription basis (Casier, et al., 2006).

- **New releases (upgrades)**
  SaaS providers upgrade the solution and it becomes available for their customers. Costs and effort associated with upgrades and new releases are lower than the traditional model that usually forces the user to buy an upgrade package and install it, or pay for specialised services to get the environment upgraded.
  The user does not have to be concerned with the normal risks associated with the upgrade, such as carrying out acceptance testing to identify bugs, scheduling downtime for production deployment, post deployment issues (Wu, et al., 2010).
- **Easy to use and perform proof of concepts**
  SaaS offerings are easy to use since they already come with best practices and samples inside it. Users can do a proof of concepts and test the software functionality or a new release feature in advance. Also, they can have more than one instance with different versions and do a smooth migration. Even for large environments, users can use SaaS offerings to test the software before buying it (Ouf & Nasr, 2011).

2.7 Legacy applications – criteria for analysis

The promised advantages and initial success stories of cloud computing are prompting many organisations to explore how they can leverage the advantages of cloud computing for their legacy applications (Hajjat, et al., 2010).

Cloud migrations are not an all-or-nothing proposition; organisations do not have to go "all in" with cloud migrations. In most cases, it will make sense to move certain applications to the cloud while continuing to operate others on-premises (Parveen & Tilley, 2010).

Cloud and some applications are made for each other while other applications are best if they run on premise. Architects should compare cloud and on premise for all new application developments and only after carrying out proper analysis should they choose the most suitable environment. Rejecting cloud without considering pros and cons is not advisable, similarly choosing cloud without understanding the application is also not advisable (Jamshidi, et al., 2013).

Organisations need to take a hard look at their existing investments in infrastructure -- from hardware to application portfolios to network architecture and beyond -- to determine if a move will be beneficial. Some of the migration questions are technical, such as whether a given application can perform adequately in the cloud; some questions will involve nontechnical, budgetary issues, such as whether a cloud migration is cost-effective given current investments in infrastructure.

A generic set of criteria for evaluating legacy applications does not exist, many sets of criteria are proposed but different solutions are proposed for specific types of applications (SABIRI, et al., 2016).

Reviewing the various sets of criteria, several common criteria emerge as being the most important:

- Cost to Operate
- Security, Data Confidentiality and Regulatory Compliance
- Availability and SLA’s
- Network Latency (Performance)
- Integration and Interoperability
- Infrastructure Requirements
- Disaster Recovery

These criteria are explored in the following sections.

2.7.1 Cost to operate

One of the first considerations is an organisation's existing data centre investment. Despite technologies such as server virtualisation, there are real costs associated with deploying on-premise servers. There are not only licensing costs involved but also costs associated with hardware resource consumption and support infrastructure. As such, there is almost always a significant investment associated with an on-premise server. Outsourcing a server's data and/or functionality to the cloud may mean abandoning an on-premises investment unless an on-premises server can be repurposed. Although this rip-and-replace approach to cloud migrations may not make financial sense for organisations that have a large investment in an on-premise data centre, an organisation can still benefit from migrating certain on-premise resources to the cloud (Lewis, et al., 2008).

Regardless of its suitability, any server hardware eventually becomes obsolete. Enterprise-class organisations have traditionally coped with this expected obsolescence by adopting a hardware lifecycle policy. An organisation, for example, might choose to retire servers after five years. An organisation could integrate a cloud services roadmap into its hardware lifecycle policy. Doing this allows IT teams to migrate on-premise resources to the cloud instead of moving them to newer hardware (Wu, et al., 1997).

The prospect of using cloud services is often particularly attractive for smaller organisations and start-ups. In the case of a smaller organisation, the use of cloud services provides access to enterprise-class hardware and fault-tolerant features that would otherwise be unaffordable. Similarly, start-ups can benefit from cloud services because they can get their operations running quickly without having to invest in on-premises data centre resources (Cătinean & Cândea, 2013).

The cost to operate an on-premise application can be underestimated which results in unfair comparisons to cloud operating costs, it is not enough to compare the on-premise licensing costs to the subscription costs of an application in the cloud. There are several on-premise costs that can be frequently overlooked as they are not direct costs resulting in an unbalanced comparison (Tak, et al., 2011).

On-premise operating costs to consider in the evaluation include acquisition and maintenance of the operating environment and operating infrastructure, personnel costs associated with customising and maintaining the operating environment, training employees to operate and support it, monitoring costs and maintenance costs - such as licensing and hardware/firmware upgrades. An important consideration is that cloud operating costs are considered operating expenditure (OPEX) as opposed to commissioning on-premise application which involves capital expenditure (CAPEX). OPEX is more favoured by the finance department as it provides for more straightforward budgeting. (Casier, et al., 2006)

Figure 6 below highlights how the hidden or indirect costs are frequently not accounted for, leading to an inequitable cost comparison between on-premise and cloud deployments. The directly attributed annual costs of an on-premise application are the software license costs (9% in Fig 6) and with cloud applications, it is the annual subscription costs (68% in Fig 6). Figure 6 shows that the cloud subscription costs include several services that should be accounted for when comparing cloud to on-premise costs (Auro, 2017).

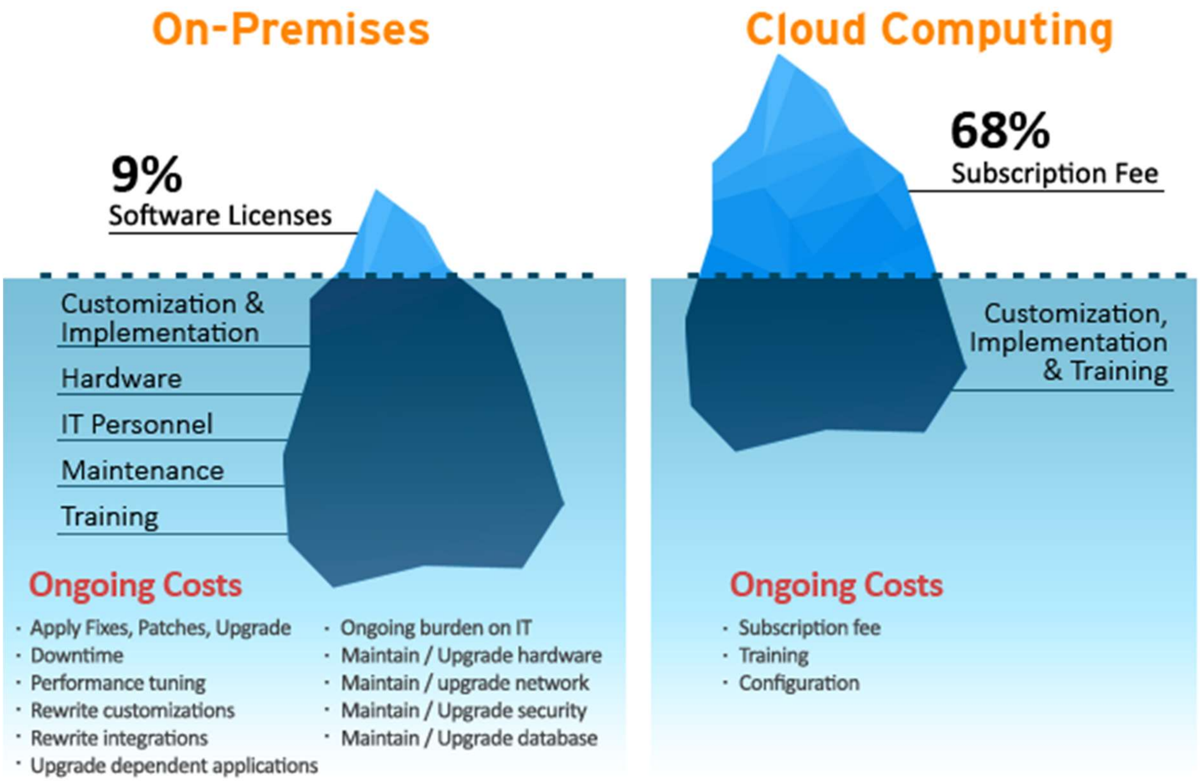

Figure 5 - Cloud vs on-premise cost breakdown and comparison

Source: (Auro, 2017)

The pay-as-you-go cost model for the cloud makes an attractive entry point but there are hidden costs. Scaling an application to consume lots of resources may rapidly incur large costs, this is like the pay-as-you-go mobile phone model which can be cheap for low usage but very expensive for high usage. Another hidden cost can be resilience, with a cloud application it is very straight forward to deploy an application to multiple data centres, however, this can rapidly increase costs as there are charges for the application in each data centre and the cost of the bandwidth usage between them (Subashini & Kavitha, 2011).

2.7.2 Security, data confidentiality and regulatory compliance

The integrity of personal information has become a major issue not only for cloud computing but also for on-premises computing. It is nearly impossible to guarantee 100% security and privacy protection against all possible sources of violation, including the inevitable software bugs, the growing sophistication of the hackers, inadequate procedures and human errors. Cloud computing providers must adopt the most sophisticated and up-to-date tools and procedures, and strive to provide better security and privacy than is available for on-premises computing. (Kim, 2009)

Data confidentiality and regulatory compliance requirements will vary by industry and country. Some business-critical applications, particularly in financial services and health care, will have strict requirements that may not be easily achieved in the cloud. Systems of record are almost always repositories for some of an organisation's most sensitive information, including customer data and financial records. Regulatory compliance and governance best practices may prevent storage of this data in the cloud (Gorelik, 2013).

An organisation must understand exactly how the cloud provider vendor meets their particular security requirements. Applications that deal primarily with non-restricted data are more appropriate candidates for deployment in the Cloud. Applications that process private or proprietary data, on the other hand, are highly sensitive and therefore more compatible with on-premise deployment or alternatively a secure private cloud operation. Whether Private or Public is determined to be the most appropriate Cloud solution, there are several questions that organisations should consider before opting for a cloud based solution: (Mohagheghi & Sæther, 2011)

- How secure is the Cloud provider's infrastructure?
- Is the Cloud infrastructure a multi-tenant or single-tenant environment?
- Is the storage layer secured appropriately?
- Does the service provider comply with industry standards such as ISO 27001?
- Is connection to the Cloud provider secured via encryption
  (Rabbani, et al., 2016)

Due diligence (a comprehensive appraisal) must be carried out to ensure regulatory compliance. An organisation must determine which jurisdiction's laws apply, they may be operating in one jurisdiction and have their data stored in another. Some jurisdictions allow for data to be stored outside the jurisdiction boundaries and others don't so it is important to be aware of the regulations applicable to the service being offered in each jurisdiction (Gorelik, 2013).

The importance of data storage location is prompting the establishment of cloud providers who guarantee local storage. Both Deutsche Telekom and Vodafone Germany has established cloud operations that promise to keep data in German data centres. However, closer examination shows that they are using technology from US companies which raise concerns that they can be influenced by the US security department and requested to introduce methods to allow the US government access data if it deems it to be of importance to national security. (Sayer, 2017)

Regulations change regularly so it is necessary to monitor the regulations and obligations as updates are made and implement procedures to re-evaluate risks and gaps and to implement changes as required. A recent example of this is the EU General Data Protection Regulation ("GDPR"), which will become effective on May 25, 2018. This legislation aims to protect all EU citizens from privacy and data breaches in an increasingly data-driven world. This is a major regulatory change in relation to data privacy, as it applies to all companies processing the personal data of citizens residing in the EU. This legislation applies to the processing of personal data by controllers and processors in the EU, regardless of the location of the company or whether the processing takes place in the EU or not (European Commission, 2016).

2.7.3 Availability and SLA's

Application availability and service level agreements (SLAs) are a concern for many business-critical applications, and in such cases, users should demand that their availability needs can comfortably be met based on the terms of the provider's service-level agreement (SLA). Many public cloud computing providers are not willing to commit to the kinds of availability levels that most corporate users demand for their business-critical applications.

Organisations must define time windows in terms of full functionality and partial functionality, and each application should (at minimum) meet its on-premise standards for availability and data recovery when operating from within the Cloud environment. The primary factors to consider when evaluating availability and recoverability are:

- What happens when there is a failure?
- How robust is the disaster recovery offered by the provider?
- What is the Cloud provider's communication procedure in the event of an incident?
- How much downtime and data loss can be tolerated before systems are restored? (García, et al., 2015)

It is possible to mitigate against the risk of a major failure at a cloud provider by using a second cloud provider for disaster recovery. The costs of using multiple cloud providers in this fashion are high and this should be weighed up against the costs of downtime to the business (Armbrust, et al., 2010).

2.7.4 Network Latency (performance)

Network latency is the term used to indicate any kind of delay that happens in data communication over a network. Network connections in which small delays occur are called low-latency networks whereas network connections which suffer from long delays are called high-latency networks. Network latency can be described at the total of all the delays along a communication link (Tomanek, et al., 2016).

A study performed by Tomanek et al. (2016), monitored network latency to cloud service providers over a period from 2013 to 2016. The results of this study show that the network latency was variable and this variability was difficult to predict and trace to a particular source. The study found that there was evidence that the network latency decreased over the three-year period of the observations which show that cloud service providers are working to reduce their network latency which will make their services more suitable for applications that are sensitive to network latency (Tomanek, et al., 2016).

Some applications are very sensitive to latency such as those that operate in real-time or those that have a high volume of database transactions. Cloud solutions operate over the network so network latency can be high, it is essential to understand how high latency can impact on an application. This could determine the level of SLA possible with the application in a cloud environment and it may exclude the cloud as an appropriate deployment platform for a particular application type (Beserra, et al., 2012).

2.7.5 *Integration and interoperability*

Interoperability signifies easy migration and integration of applications and data between different vendors' clouds. The primary goal of interoperability is to enable a seamless flow of data between the application in the cloud, applications in other clouds and on-premise applications (Kim, 2009).

Most applications interact with other applications and systems and it cannot be expected that a cloud provider can meet all required integration points locally, therefore, there is a requirement to link to multiple clouds or even on-premise applications. When an organisation is deploying an application to the cloud then all the other applications and systems it integrates with must be analysed. This analysis should include the number of applications interacted with, the location of the applications and the frequency of the interaction and the amount of data or bandwidth consumed transferring data to and from the application. There is a danger that an application that performs well on-premise can perform poorly when deployed to the cloud solely due to the network latency impact of interacting with other applications which are not in the same environment (Li, et al., 2013).

Interoperability is essential for applications that are deployed on the cloud. An organisation may require that IT assets and capabilities associated with their core competencies are kept on-premise while outsourcing marginal functions and activities (such as the Human Resources (HR) system) to the cloud. In this case, frequent communications between cloud application (the HR system) and on-premise applications (such as an Enterprise resource planning (ERP) system) becomes crucial and indispensable to run a business. Poor interoperability will dramatically increase the integration difficulties, causing difficulties for the IT department. For optimisation, an organisation may need to outsource several marginal functions to cloud services offered by different vendors. For example, it is highly likely that a small organisation may use Gmail for the email services and SalesForce.com for the HR service. This means that the many features (such as address book, calendar, appointment booking and so forth.) in the email system must connect to the HR employee directory residing in the HR system. (Dillon, et al., 2010)

Each cloud provider has a unique method of interaction between applications and services, this severely hinders the development of cloud applications by forcing clients to use their services and not those from other cloud providers, this is commonly referred to as vendor lock-in. More importantly, proprietary cloud application programming interfaces (APIs) make it very difficult to integrate cloud services with an organisation's own existing legacy systems. The scope of interoperability here refers both to the links amongst different clouds and the connection between a cloud and an organisation's local systems (Scandurra, et al., 2015).

2.7.6 Infrastructure requirements

Many applications are tied to very specific infrastructure and were not created with portability or virtualisation in mind. Some applications will only operate on older versions of an operating system, or require legacy proprietary databases or require a specific hardware environment. Other applications such as a database or performance-intensive applications run best when used with dedicated hardware. An example of one such system is a financial services trading application where the speed of execution of the transaction directly influences the revenue returns. The cloud is not a good choice of platform for these types of applications. (Humphreys, 2013)

2.7.7 Disaster recovery

Continuation of organisations' key processes in the aftermath of disasters plays an important role in the different businesses. Business continuity management (BCM) is an effective precautionary approach to mitigate the consequences of disasters and making organisations resilient against disruptions (Rabbani, et al., 2016).

A study in the United States found that 50% of businesses without a disaster recovery plan never reopen for business after a major disaster (Livingston, 2011).

It is not just disasters, a study in 2014 by Avaya found that 82% of those surveyed experienced some type of network downtime caused by IT personnel making errors when configuring changes to the core of the network. 80% of companies experiencing downtime from core errors in 2013 lost revenue, with the average company losing $140,003 per incident. It is not just a financial cost, there can be a human cost as well as the same study found that one in five companies fired an employee because of human error causing downtime (Avaya, 2014).

Traditional disaster recovery approaches involved replicating the data to other data centres, which are geographically remote from the primary data centre. The remote data centre may be owned by the organisation or managed by a third party and shared amongst multiple organisations. The advancement of cloud technology revolutionised the approach to disaster recovery as cloud providers have a ready-made environment to store an organisations data (Arean, 2013).

The cloud can clearly play a central role in provisioning recovery and continuity as applications and their associated data can be replicated to one or more locations sufficiently distant from the primary data centre that they are unlikely to be vulnerable to the same disaster (Liebmann, 2014).

Cloud environments have resilience built in as they normally employ at least two sites with the data replicated from the primary site to the secondary site. Practices vary depending on the cloud vendor, Microsoft Azure, for instance, ensures both sites are within the same jurisdiction, in Western Europe the sites that are paired for disaster recovery purposes are Ireland and Netherlands (Tulloch, 2013).

Cloud-enabled backup provides organisations with a highly scalable and elastic repository for their backup data. Cloud storage gateways installed on-premise can enable seamless access to cloud storage allowing a range of standard data backup applications utilise the cloud storage as the storage media when creating backups (Taneja, 2012).

While the cloud offers excellent overall continuity and availability, any application accessed over the Internet is susceptible to the occasional interruption in service, for applications where even a relatively brief interruption can have significant consequences, organisations may be better off investing in high-availability infrastructure in an on-premise data centre (Liebmann, 2014).

2.8 Choosing a migration strategy for legacy applications

Legacy applications were developed before cloud computing was available and their design is often not capable of utilising the characteristics of cloud computing environments. Migrating these applications to the cloud is more complex since some legacy applications may have been developed without considering the unique requirements attributed to cloud environments such as elasticity, multitenancy, interoperability, and cloud service/platform selection. These requirements present new challenges, often requiring software re-development or infrastructure changes before a legacy application can be migrated to the cloud. (Gholami, et al., 2016)

Cloud migration decisions are complex since they are influenced by multiple, possibly conflicting factors, such as cost, performance, security and compliance concerns (Saripalli & Pingali, 2011).

The wide variety of cloud computing services and models currently available complicates the selection of the cloud solutions that are best suited for the computing requirements and needs of a given organisation (Beserra, et al., 2012).

Technical constraints often mean that it is not possible to reuse functionality of legacy applications by exposing it as a service. The user interface code may be tightly coupled with business or core function code resulting in a considerable amount of redevelopment to separate out what is purely functional, given that services should be user-interface agnostic for deployment in a cloud environment. Cloud applications expect to interface via modern technologies such as XML (eXtensible Markup Language) or SOAP (Simple Object Access Protocol) and such interfaces may not be available in a legacy application. Legacy applications are frequently synchronous whereas the nature of cloud applications is asynchronous. A batch-oriented legacy system may conflict with the request-response nature of cloud application where close to immediate responses are expected. The result is that the cost of exposing parts of a legacy system as services could be higher than replacing the legacy system with a new cloud native application (Lewis, et al., 2008).

The migration strategies purposed by Erlikh (2000) and Bisbal et al. (1999) can be summarised into four options.

- Migrate
- Wrap (and Migrate)
- Retain
- Retire and Replace

2.8.1 Migrate

Following application analysis, if the decision is to proceed with the migration then the process moves on to the next stage which is to define an adequate migration strategy for the legacy application (Beserra, et al., 2012).

Characteristics of Legacy applications that are most suited to be migrated are:

Non-restricted data - Applications that deal primarily with non-restricted data are more appropriate candidates for deployment in the Cloud (Mohagheghi & Sæther, 2011).

Good Interoperability – Applications that have good interoperability allows for easier migration and integration of applications between the cloud vendors (Kim, 2009).

Few dependencies – Applications such as email or HR applications that have little or few dependencies on other applications are good candidates to migrate to the cloud (Dillon, et al., 2010).

The drivers behind a migration decision must be documented and any requirements and constraints (such as time, cost, and feasibility) detailed. The migration may be complicated by taking advantage of cloud attributes such as scalability, consistency and elasticity, there may be a need to extend the core functionality of the application to utilise additional cloud services to provide added value to the business (Scandurra, et al., 2015).

The adoption of additional services may be necessary to convince senior management to support the migration by promising a better system than the original (Brodie & Stonebraker, 1993).

Beserra et al. (2012) state that migrating a legacy application can have a high risk of failure for several reasons:

- **Business conditions constantly change**

The development of a large, complex application could take years to complete. While this work is underway the legacy application may need to be changed to handle urgent business requirements. There may be changes in the business processes that the application needs to support, no business is static. During a migration, the requirements for the new application must be kept in line with the evolving legacy application (Rugaber, 1999).

- **Specifications do not exist**

Documentation for legacy applications may not exist or are out of date, the original developers are no longer available. This leaves the code as the only documentation of the functions of the application. The original specifications may not be evident from the code as it relies on the skill of the developers at the time. Deciphering this code is time-consuming and can increase the cost of the migration (Brodie & Stonebraker, 1993).

- **Cut-over window requirements are too big**

Many legacy applications must be operational almost twenty-four hours a day. They contain a lot of data which could require days or even weeks to download in its entirety. Once the application's code is migrated the time required to migrate the live data may exceed a window within which the business is prepared to operate without its mission critical application. This reason could render the complete project unfeasible (Bisbal, et al., 1999).

- **Large projects tend to bloat**

The difficulty of most large projects is seriously under-estimated resulting in a tendency for them to grow, particularly in head count. There is also a tendency to introduce new approaches, even perhaps new technologies and incorporate them into the project. This is achieved by adding additional groups to the project team, these groups are not essential to the migration and can lead to budget increases and management complexity. This makes the migration project more likely to be terminated prior to completion (Brodie & Stonebraker, 1993).

2.8.2 Revise and migrate

If the result of the application analysis is that a migration to the cloud is not recommended, then there are several approaches that can be employed to attempt to resolve the constraints preventing the migration. The code can be changed to make the application more suitable to the cloud environment, however careful consideration should be given to stability and reliability when undertaking such a change (Saeidi, et al., 2013). The scope of the migration can be changed, it can be reduced to migrate a subset of the functionality or increased to include additional components or systems that interface with the core application. Following changes to the application or scope, then the analysis of the application should be repeated to determine if a different outcome is warranted (Beserra, et al., 2012).

2.8.3 Retain

The aphorism “If it ain’t broke, don’t fix it" is frequently applied to legacy applications, there is a reluctance to change these applications, they have been working adequately for several years thus leading to a reluctance to risk changing them, which could impact on their stability (Saeidi, et al., 2013).

According to Vu & Asal (2012), there are several considerations that may result in a decision not to migrate a legacy application to the cloud:

- **Cost**

The feasibility of migrating a legacy application can often be determined by the cost of the migration and the cost of operations in the cloud. If the cost of the migration is more expensive than the cost of developing a new application in the cloud which has the same functionality as the legacy application, then migrating is not considered a feasible option. In addition, if the operating costs in the cloud are more expensive than the costs of hosting the application on-premise then this may justify a decision to retain the application on-premise (Khadka, et al., 2014).

- **Data Compliance**

Applications that contain sensitive or important data that cannot be stored outside the organisation or outside the country's jurisdiction due to compliance regulations or perhaps a company's directive. In this case migrating the application to the cloud could violate that regulation. Some cloud vendors offer their clients options on the location of the primary data centre where their application will be hosted, in some cases this is down to country level but in others, it is region based. The failover and disaster recovery options in the cloud frequently have the secondary data centres in different countries. Storing an organisations data in the secondary data centre may violate a regulation on where data should be stored, this could prevent an organisation from availing of the cloud vendor's failover and disaster recovery capabilities, thus reducing the benefits from a migration to the cloud (Sayer, 2017).

- **Special Hardware**

Some legacy applications require special hardware devices or special physical configurations that are only possible to provide on-premise. For instance, some applications may require a specific disk array to support data replication or an application may require a specific hardware bios revision to operate. Cloud providers often use standard servers which are shared for multiple uses and special hardware requirements or configuration requests cannot be met. This would make it impossible for the application to maintain the same functionality following a migration (Vu & Asal, 2012).

- **Speed of Transactions**

Some applications are required to process a large amount of data in a time critical manner. Examples of this would be banking systems or trading systems. In the case of trading systems, the computational time directly impacts on the financial return from each transaction. To achieve the fastest results these applications should be located within close physical proximity to the data so that the organisation has full control over the applications and the data being streamed into it (Beserra, et al., 2012).

2.8.4 Retire

Due to technical constraints, it may not be possible to migrate a legacy application. Some of these technical constraints stem from the nature of the legacy system, and others are because of lack of modern technology for a particular legacy environment. This can result in the cost of migrating functions of a legacy system to services being higher than the cost of replacing the legacy system with a cloud native one. Some scenarios where this would be the case is if the user interface layer is not distinct from the business or core function layer, this would require a large effort of rework to separate these layers and there is no added value from this effort. Other reasons are that Cloud applications expect to use technologies such as Web Services and the interfaces for these may not exist in the legacy application. Legacy applications tend to process transactions in a synchronous manner whereas cloud applications are typically asynchronous, the core application would require major changes to deal with this difference. Cloud applications operate on a request-response model whereas legacy systems can operate in batch mode and this would cause a conflict (Lewis, et al., 2008).

2.9 Summary

This section reviewed the literature on legacy applications, issues with these applications and possible solutions. The literature on cloud computing characteristics and the benefits that organisations can obtain from utilising cloud computing was also reviewed. The criteria to evaluate legacy applications prior to a cloud migration was explored which worked towards answering the research question; what are the most suitable criteria for evaluating legacy applications for migration to the cloud?

The criteria discussed included:

- Costs to operate
- Security & Regulatory Compliance
- SLA’s & Availability
- Network Latency
- Integration
- Infrastructure
- DR

The possible outcomes of evaluating legacy applications were reviewed with the aim of determining if it is feasible or unfeasible to migrate an application to the cloud and the reasons behind these decisions, which led the way to meet the aims and objectives of this research as detailed in Chapter 1.

The next section will detail the research methodology employed in this study, with an emphasis on philosophies, approaches and strategies adopted and disregarded.

3 Methodology

3.1 Introduction

The previous chapter reviewed the relevant literature to answer the research question; what are the most suitable criteria for evaluating legacy applications for migration to the cloud?

The findings from the reviewed literature suggest several criteria, with cost, security and availability being the most important and this chapter will outline philosophies, approaches and strategies adopted and disregarded.

According to Park et al. (2016), qualitative and quantitative approaches are sufficient when seeking reliable and valid results. This chapter will outline both the research approaches and methods considered to meet the aims and objectives of this study culminating in the method and approach adopted (Park & Park, 2016).

The crucial element to consider when choosing a methodology is how it fits with the posed research question (Denscombe, 2014).

The data collection methods and data analysis approaches will be further explained.

Ethics will be discussed at length since it provides the framework for the moral and values based compass for this study; sub-themes of ethics such as trustworthiness and bias will also be discussed. Following on from ethics, informed consent, confidentiality, trustworthiness and bias, participant profiles and study limitations will be further explained.

3.2 Research philosophies

Saunders et al. (2016) research 'onion' model, presented in figure 6, advises the researcher to initially choose a research philosophy. The research philosophy promotes consideration on how knowledge should be developed in order to answer the research question. The research philosophy includes significant assumptions about the techniques from the perspective of the researchers. The research philosophy can be broadly categorised under four ways of thinking, positivism, realism, pragmatism or interpretivism (Saunders, et al., 2016).

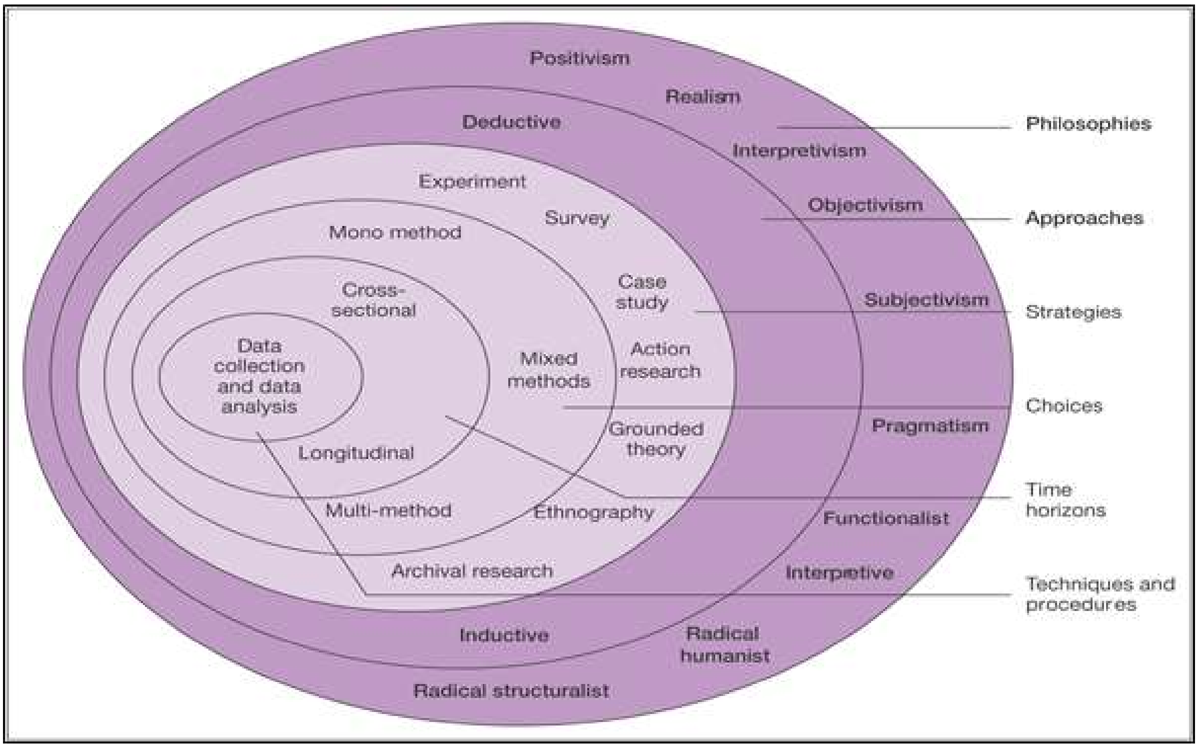

Figure 6 - Saunders research onion

(Saunders, et al., 2016)

3.2.1 *Positivism*

Positivism consists of some important key elements such as truth and validity and it is concentrated highly on facts and collected directly from surveillance and experience. Positivism is evaluated empirically by quantitative methods such as surveys and experiments and statistical analysis (Easterby-Smith, et al., 2008). From a theoretical perspective, positivism based on the concept of neutrality and objectivity which the researcher can remain separate from and not affect the research field (Skinner & Edwards, 2009).

Positivism was rejected for this study as it is evaluated by quantitative methods and this study is based on qualitative methods.

3.2.2 *Realism*

Realism is a research philosophy presuming that there is a knowable and objective reality. Fisher (2010) contends that the realist researcher generally attempts to provide generalisable explanations, and contrary to the positivists, they do not generally offer predictions. All realists stand somewhere between positivism and interpretivism, and they neither believe that by general laws they can define the things they study precisely, nor these studied things are unique and random. The sub-set of realism, critical realism posits that there are many potential causal mechanisms for what we observe impossible to separate from their effects and plan them, while realists believe that they can approximately model the social reality by developing and testing hypotheses (Fisher, 2010).

Realism was dismissed as it does not value experience and this study seeks to explore participants experience and opinions.

3.2.3 Pragmatism

Pragmatism is a research approach that requires using the research method that appears most appropriate in addressing the research question. Pragmatic researchers believe that there are many ways of interpreting and undertaking research and use a variety of methods and techniques that include both qualitative and quantitative methods. Their view is that if the research question does not decisively suggest that a particular method then it is acceptable to use multiple methods within one study to answer the question (Saunders, et al., 2016).

Pragmatism was not employed for this due to time constraints as only one data collection method was utilised.

3.2.4 Interpretivism

The interpretivist approach is generally associated with qualitative research. Researchers who take this position believe that reality is socially constructed. This approach appeals to the social curiosity of the author. Interpretative research seeks human's accounts of how they make sense of the world and the structures and processes within it. This is directly relevant to capturing data on expectations and experiences of the value of one approach versus another, which is a very subjective matter (Saunders, et al., 2016).

Interpretivism was chosen as the philosophy for this study as it best comprehends the meaning participants attach to their experiences. This study focuses on participants experience and opinions of the various approaches to migrating a legacy application to the cloud. The interpretative approach allows researchers to get close to participants to interpret their subjective understanding of reality (Saunders, et al., 2016).

3.3 Research approaches

There are two main choices for research approaches, deductive or inductive reasoning. A deductive approach is consistent with developing a theory and testing it through research, whereas an inductive approach collects data to develop a theory (Saunders, et al., 2016).

Inductive reasoning begins with specific observations and measures from past experience, from which patterns and regularities are detected. These patterns are formed into some tentative hypotheses which are developed into general conclusions or theories (Thorne, 2000).

The participants' experience is key to answering the research question so for this reason an inductive approach was chosen for this study. The deductive approach requires a theory as a starting point and this study does not attempt to test a theory.

Inductive approaches are generally associated with qualitative research, while deductive approaches are more commonly associated with quantitative research.

3.3.1 Qualitative research

Park et al. (2016) suggests

> *the qualitative method provides a basis for a "thick" description of discovery, to the extent that the interviewer and the respondent share an ongoing reference point, it makes it easier to locate the respondent's concrete discourse in a meaningful abstract theoretical context of interest to the interviewer.* (Park & Park, 2016, p. 6).

Park et al. (2016) and Pathak et al. (2013) believe the goal of qualitative research is discovery and is focused on practical and theoretical findings. Its design gives a multifaceted view of the topic being researched using aspects such as participant observations, focus groups and interviews. "*Qualitative Research aims to address* *questions concerned with developing an understanding of the meaning and experience dimensions of humans' lives and social worlds*" (Fossey, et al., 2002, p. 717).

3.3.2 Quantitative research

Quantitative approaches are most commonly used for gathering large amounts of data, most often numerical data ((Matthews & Ross, 2014; Elo, et al., 2014). As data for quantitative research is collected through surveys, questionnaires and structured observation, this requires mostly closed questions and leaves no opportunity for further investigation (Park & Park, 2016). Kumar et al. (2005) suggest quantitative research leads to a process of collecting data which is then analysed using mathematical processes such as statistics (Kumar & Krob, 2005). Quantitative methods incorporate an "*empiricist or positivist paradigm wherein philosophical underpinnings, assumptions and values are not explicitly articulated*" (Duffy & Chenail, 2008, p. 24).

3.4 Chosen approach and method

Quantitative methods incorporate an "*empiricist or positivist paradigm wherein philosophical underpinnings, assumptions and values are not explicitly articulated*" (Duffy & Chenail, 2008, p. 24). Quantitative research uses statistical techniques which allow the researcher to discuss how "true" a topic is for the chosen research group.

Qualitative research focuses on the experiences of others which cannot be presented numerically as it focuses on interpretations and descriptions that may lead to new concepts. In addition, qualitative methods involve an in-depth interview process, primarily concerned with *"subjective understandings, feelings, opinions, and beliefs*" and the data collected consists of verbatim accounts of experiences (Matthews & Ross, 2014, p. 142)

Qualitative methods produce more detailed information thus increases the depth of understanding of the cases and situations (Patton, 2001). A qualitative approach assumes that each participant brings various interpretations and values to the research and since it is a person centred as opposed to variable-centred approach (Newman & Benz, 1998; Hancock, et al., 2007).

For these reasons, a qualitative (inductive) approach was chosen for this study, this approach was deemed the most suitable approach to answer the research question and meet the aims and objectives of the research.

3.5 Strategies and data collection

The purpose of a qualitative research approach in this study is to undercover the most suitable criteria for evaluating legacy applications to determine if they are suitable for migration to the cloud. Qualitative researchers usually look towards understanding participants' perspectives connected to the chosen theme and to convey meanings which the participants construct because of that perspective (Hanson, et al., 2011).

Qualitative approaches can involve, among other methods, observation, focus groups and structured, unstructured and semi-structured interviews (Kvale, 2013).

Data analysis from focus groups can be troublesome and highly complex according to Kitzinger and Barbour (1999) and for this reason and the short timeframe within which to complete this study it was eliminated as a possible data collection tool. Observation was not a suitable tool to meet the aims and objectives of this study and was discounted at the outset. Structured and unstructured interviews were deemed unsuitable as structured would have inhibited the richness of data to be collected due to its rigid nature, conversely, unstructured interviewing has the potential to stray too far from the topics under discussion thus reducing the quality, richness and depth of the data collected (Collins, 1998). In addition, misunderstandings in a structured interview do not allow for questions to be asked by the participant or misunderstanding to be resolved during the interview process (Myers & Shaw, 2004).

Data for this study was collected through semi-structured interviews with twelve participants and was recorded and thematically analysed. A total of twenty participants were identified, through a snowballing approach, out of this group, twelve participants agreed to participate. Data analysis will be discussed in depth later in this chapter. Semi- Structured interviews were deemed the most suitable data collection tool for collecting primary data for this study, as opposed to the other tools mentioned, in that they provided the opportunity, spontaneity, and flexibility in the interview process (DiCicco-Bloom & Crabtree, 2006; Fossey, et al., 2002)

Bryman (2015) describes semi-structured interviews as a sequence of questions that are in the common arrangement of an interview scheme but with the flexibility to vary the structure of questions. Furthermore, this type of interviewing provided the opportunity to ask additional questions to what was viewed as important responses to the questions whilst also providing the opportunity for the participant and the interviewer to discuss responses in further detail (Bryman, 2015; Hancock, et al., 2007).

The use of open ended questions within this data collection tool broadened the scope of answers provided as the expansion of certain points was possible by asking open ended questions which provided an opportunity for more lengthy discussions to arise (Qu & Dumay, 2011) and (Newman & Benz, 1998).

Gathering the primary data in this manner provided unique answers, filled with information that was valuable and pure with a core meaning which was directed at answering the overall research question (Galletta, 2013) and (Robson, 2011). Gilliam (2010) states that flexibility makes semi-structured interviews a productive research tool as it provides a very rich form of data with Larkin and Thompson (2012) describing the adoption of this form of data collection as 'giving a voice' to the research topic in relation to how it is answered.

3.6 Data Analysis

Thematic analysis with an interpretive philosophy was chosen as the data analysis approach. The aim of this analysis was to explore and understand participants' experiences from an interpretivist perspective (Guest, et al., 2012). According to Braun & Clarke (2006) "*thematic analysis is a method for identifying, analysing and reporting patterns (themes) within data*" (Braun & Clarke, 2006, p. 79). Williams (2008) stated the interpretivist method is established by the integration of the experiences that are known to the interviewer.

The first step in the data analysis process was to explore the data in depth by repeatedly reading and listening to each recorded interview. It is necessary to gain a thorough understanding of the data before attempting to identify patterns or themes. The second step was to code the data by highlighting reoccurring themes. Each theme represents something that supported or contradicted the literature (Miller, 2016). The points that were coded were then grouped into broad themes narrowing down the findings. It was for this reason thematic analysis was used in the research, as it is useful in gaining the attitudes and an understanding of the participant's human experience of the topic. Lastly, the findings were then construed and noted in a descriptive summary. The themes were then conveyed individually, incorporating participant quotes to augment a particular point which showed a link between the data and the results.

3.7 Ethics

Ethics must always be considered, especially in a qualitative study where 'humans are involved' (Guillemin & Gillam, 2004; Miller, et al., 2012; Thomas & Magilvy, 2011). Ethics pertains to the notion of doing good and trying to avoid harm when conducting research (Leathard & McLaren, 2007; Orb, et al., 2001). Conducting research in an ethical manner involved ensuring that work was carried out with integrity and with the greatest respect for people involved including interview participant's and any organisations involved (Denzin & Lincoln, 2011).

Both Matthews and Ross (2010) and Munn-Giddings and Winter (2002) understand that when collecting data, some ethical principles to consider include informed consent, confidentiality, anonymity and voluntary participation and data storage. All the above will be discussed in more detail.

Prior to any data collection ethical approval was obtained for this study from the Ethics Committee of the School of Computer Science and Statistics, Trinity College Dublin.

3.8 Informed Consent

Throughout this process, it was necessary to gain informed consent, which is the foundation for ethical conduct when undertaking research involving human participants (Rothstein & Shoben, 2013). According to Patel et al. (2016) and Drew et al., (2008) it is the responsibility of the researcher to inform each participant what the research they are conducting involves, the duration and the exposure of what the participant will disclose in the interview.

Obtaining informed consent from participants without the presence of any coercion, prior to the commencement of the study minimised the risk of harm, protected their confidentiality and avoided using deceptive practices and give participants the right to withdraw from the study at any time (Hawkins & Emanuel, 2008; Kennan, et al., 2012).

The informed consent form details the research questions and the main aims and objectives of the study and the contact details of the researcher and their supervisor. It also guaranteed the privacy, anonymity and confidentiality of each participant (Kvale, 2013; Oliver, 2010). It is only after this information has been provided and understood that the participants are accepted to be part of the research project.

It was clearly stated on the consent form that consent from the participant may be withdrawn, without consequence or explanation, at any time. If consent is withdrawn, there will be no further collection of data from the participant and any data previously collected will be discarded and not used in the research. The researcher will allow the participant the option to refuse through the consent form (Flick, 2007). This is also supported by Chwang (2008) who believes any individual who takes part in the research has the right to withdraw at any stage and are not compelled to explain why. The participants for this study were also reassured that their contribution is voluntary, that they had no obligation to complete the interview and that they could withdraw from participating or having their data included at any time (Holosko, et al., 2009).

3.9 Confidentiality and anonymity

The most important ethical issue to be considered was confidentiality and anonymity. Confidentiality and anonymity, while carrying out the research, is to protect the identity of each participant (Kennedy, 2008).

Wiles et al. (2008) suggest that confidentiality and privacy can contain grey areas, therefore it is important to be mindful of appropriate means to ensure each participant displays confidence in the researcher and their ability to maintain their confidentiality and anonymity. The confidentiality and anonymity of this research were considered in depth, this aspect of the research is very important and it is vital that the participants have a clear understanding of how their confidentiality and anonymity will be maintained (Bryman, 2015). Frost (2011) recommends removing or changing participant's personal identifiers from the written data and presentations of analysis (Frost, 2011).

The participants were assured that both their identity and the organisations they worked for would be anonymised in any published work.

To ensure confidentiality, the researcher assigned ID codes to each participant, these were assigned in random order to guarantee anonymity. The ID codes used were PA to PL.

3.10 Trustworthiness and Bias

Trustworthiness involves being "*prepared to be open to the scrutiny of others for our actions*" (Parrott, 2014, p. 73). There is an inherent responsibility to safeguard the interests of those participating in or affected by the study and "*to report findings accurately and truthfully*" (Noaks & Wincup, 2004, p. 38). There is no doubt that the researcher must be, irrespective of the supposed outcome, benevolent and empathetic towards the participants.

Thomas and McGilvy (2011) note four components to trustworthiness. First, credibility, which they suggest includes researchers endeavouring to accurately report. Thus, those who may have similar experiences would be able to immediately recognise their shared circumstance. As a researcher, a way to ensure credibility would be to provide evidence the data exists and to ensure accurate interpretations. Also, each participant would be provided with results of the research. Second, transferability implies methods adopted for the study or research findings, would be applicable in any other research context. If the study was repeated with the same method, the study would yield similar results. A third component is dependability. In this case, if another researcher was to follow each step taken throughout the research process, they could easily follow the process but also similar results would be found. A final component to consider is confirmability. This implies researcher engage in reflective critical practice. This enables researchers to identify their bias, which can affect outcomes of research. This conscious effort to confirm open and transparent results gives the reader a sense of trust and credibility for the researcher.

Pannucci and Wilkins (2010) define bias as "*any tendency which prevents unprejudiced consideration of a question. In research, it has become clear bias occurs when encouraging one outcome or answer over others and at any phase of research, including study design or data collection, as well as in the process of data analysis and publication*" (Pannucci & Wilkins, 2010, p. 619). Norum (2000) and Šimundić (2013) is certain all research has bias and it can occur '*intentionally or unintentionally*' (Šimundić, 2013, p. 12). Norum (2000) goes on to say researchers need to be mindful of "*how much of our own experience dictates what we hear and what we do not hear when we are interviewing*". (Norum, 2000, p. 320). Recognising it is not possible to remain a silent author, Charmaz and Mitchell (1997) suggest the researcher must ensure to acknowledge and at best avoid bias. This can be achieved by accepting what is written has consequences and thus efforts must be made to reflect and be truthful in what is reported.

With the aim of minimising and/or avoiding research bias, firstly it was acknowledged that even though areas of bias for this study have not immediately come to mind, research bias may still exist within personal beliefs. Having this understanding allowed for a conscious effort to avoid bias in all phases of this study.

3.11 Participant profile

Participants were chosen through purposive sampling and snowball techniques. Purposive sampling is defined as a strategy that allows the researcher to choose selected participants to take part in the study, that they feel are most affected by the chosen topic (Valerio, et al., 2016; Silverman & Patterson, 2015; Matthews & Ross, 2014). Participants that were interviewed were selected based on their occupation and from there snowballing took over as the sampling technique as participants chosen through purposive sampling were asked if they could recommend others that might be suitable to participate in the study.

For the research to begin, contact was made via email to potential participants to inform them of the interview process, a date and time to conduct the interview and to communicate to the participants what was required in order to participate. Once a suitable time was organised which best suited the interviewees the interviews commenced. The interviews were carried out during June and July 2017.

3.12 Limitations

Kvale (2013) suggests that to gain the most accurate understanding around the suggested topic it is recommended to include a wide range of participants in a study. However, due to the time constraints and some potential participants not agreeing to participate, this study was conducted with twelve participants, using a larger range of participants would have produced a broader set of data. The use of semi-structured interviews counteracted this limitation somewhat as they facilitated a deeper exploration of certain topics depending on answers to previous questions.

The challenges faced through conducting qualitative research are many, the academic and disciplinary resistances to qualitative research are shown through the politics embedded in this field particularly around subjectivity (Denzin & Lincoln, 2011).

Norum (2000) argues that all researchers are biased and that this is inevitable due to influences such as the researcher's education or personal experiences. Personal interest and experience have led the researcher to choose a particular topic to study. The researcher must acknowledge some bias may exist and be continually aware of its possible influence. In particular, as Norum (2000) advocates, researchers need to be mindful of "how much of our own experience dictates what we hear and what we do not hear when we are interviewing" (Norum, 2000, p. 320). This can be achieved by being aware of the significance of written results and taking efforts to ensure what is reported is truthful and an accurate reflection of the data. As a researcher, a way to ensure credibility was to provide each participant with results of the research.

Interviews are potentially subject to interviewer bias, and this was kept in mind during the interview and analysis process and when creating an outline of the interview questions and topics to be discussed.

3.13 Summary

This chapter outlined the philosophies, approaches and strategies adopted and disregarded for this study. It outlined the data collection methods and data analysis approach. Ethics was discussed and information was provided on informed consent, confidentiality, trustworthiness and bias, participant profiles and study limitations.

The next chapter will present the data analysis process carried out on the data collected during the research process and the resulting findings.

4 Findings and Analysis

4.1 Introduction

The previous chapter outlined the approaches and methods adopted and disregarded for data collection and analysis, ethics and study limitation. This chapter presents data analysis process carried out on the data collected during the research process and the resulting findings.

It is structured as following

- Participant overview   background information on the participants
- Data Analysis   details of the analysis process and themes identified
- Findings   presentation of the findings for each theme

4.2 Participant overview

Data for this study was collected through semi-structured interviews with twelve participants. These participants work for organisations in the Banking, Insurance, Legal and Charity sectors. The participants' roles are Solution Architects, Technical Architects, Data centre Managers, IT Managers or IT Consultants. All participants have some degree of responsibility for their organisation's application portfolio at either a strategic level or a technical level. All participants have experience with deploying cloud applications or evaluating cloud applications and dealing with legacy applications within their organisation.

4.3 Data analysis

The data was analysed using thematic analysis with an interpretive philosophy as outlined in section 3.11.

Firstly, the data was explored in depth by repeatedly listening to each recorded interview. The second step was to code the data by highlighting reoccurring themes, five themes were identified. Following this, three sub-themes were identified. The interviews were then listened to again and quotes were identified from the data under the themes and sub-themes. Lastly, the findings were then construed and noted in a descriptive summary, interspersed with participant quotes to augment a point.

There were five themes and three sub-themes identified, these were:

- Legacy applications
    - Definition
- Problems with legacy applications
- Cloud strategy
    - Benefits
    - Concerns
- Legacy migration approaches
- Migration Criteria

4.4 Findings

This section details the findings under the themes and sub-themes identified.

4.4.1 Legacy applications

All participants were asked to state what their definition of legacy applications was and the participants provided a broad range of criteria that they use to characterise an application as legacy and this criterion varied considerably depending on the organisation.

A common characteristic proposed by ten participants was the age of the application. Legacy applications were described by ten participants as old applications, with ages ranging from 10 years to 30 years. Legacy applications usually are built with old technologies and operated on old infrastructure. This can be seen when participant F describes how to recognise if an organisation has legacy applications, is "w*hen you have 25 or 30 years of systems and there are overnight batches and processes, they run every night and it's 10 years since anyone looked at it, and the chances are the person who wrote it is gone*"

Six participants stated the support status of legacy applications tend to be either out of support or supported in a limited capacity. However, four participants did not agree with this view and would characterise an application as legacy even if it is still supported and would rate other criteria higher, such as the age of the technology or if the application is fulfilling the business needs.

Fulfilling the business needs was a characteristic used by five participants to rate if an application was legacy or not. Applications that are failing to meet the business requirements or cannot be adapted to meet new requirements are classified as legacy systems.

A broader definition was purposed by participant C who said that any application that "*wasn't web friendly or did not lend themselves well to the cloud*" were legacy applications. Participant I agreed with this saying that any application that "*doesn't run in the cloud*" could be classified as legacy.

The characteristics identified by the participants tend to portray legacy applications in a negative light, however these applications are often core applications in organisations, a point raised by participant I is that "*legacy applications by default get a bad rap because everyone assumes that by legacy it means useless and well past its sell by date, but actually that's not the case in many instances, legacy applications keep business's running*".

4.4.2 Issues with legacy applications

The findings highlight several issues with legacy applications, the most prominent being that these applications are difficult to change, five participants highlighted this as a key issue. Participant A stated his organisation is reluctant to change legacy applications as "*we don't have the knowledge and are afraid to change, due to lack of understanding of the impact of the change*".

Three participants believe this is compounded by a lack of documentation, while documentation may have existed when these applications were first implemented, it may not have been updated following for subsequent enhancements or bug fixes. Participant K added to this by stating "w*hen you are using a product a long time and you make it do things that it did not necessarily do initially you have to be aware of this*".

Participant F believes there is a difficulty analysing what a legacy application does, "*you know what goes in and you know what comes out but trying to unscramble the rules is very difficult*".

The findings highlighted another issue, namely a skills shortage which is a view shared by four participants. Participant I stated, "*nobody knows how the legacy application is built so, therefore, the only options available are to leave it on-premise or outsource the support of the application*". Participant F believes that age profile of staff capable of supporting legacy applications is getting older and as staff retire or focus their skills on more modern technologies the skills shortage becomes more apparent and "*best case we are 10 years away from these guys retiring, recent graduates are not interested in learning legacy systems and when I try to hire in that area the best I can find are semi-retired*". This shortage of skills can even be contributing to applications becoming legacy, participant I agrees with this and states "*to a certain extent one of the reasons applications become legacy and there* *is no idea about how they could go on the cloud is because the skills are lacking, there is no one promoting the application*".

Five participants also pointed to lack of support for legacy applications, in particular, those supplied by 3rd party vendors. This is a big risk for an organisation and as participant K states "w*hen your legacy product becomes 10 or 15 years old, time is against you, and at some point you will get the call to say 'we can't support your product suite any longer', or 'there are security issues we can't address'*". Some organisations have legacy applications which are already out of support or sunset by their vendors, participant H highlighted that "*paying extended support for an application is not desirable*" and this would be a driver to examine alternative solutions.

4.4.3 Cloud strategy

All participants were asked about their organisation's cloud strategy and how it pertains to legacy applications and to outline the benefits they expect from using the cloud and to also talk about their concerns about the cloud. The findings varied quite considerably, some organisations have a clear documented cloud strategy while others acknowledge that cloud applications will form part of their organisation's application portfolio and have guidelines on choosing and deploying cloud applications. Participant I pointed out "*an organisation needs to be really clear on why they are moving to the cloud, it can be a combination of factors*".

Benefits

Accessibility and broader access to applications were benefits identified by nine participants. Accessibility was of particular concern to organisations that had home workers or remote locations, participant H adds that the cloud offered "*much better accessibility for remote users*".

Ease of deployment was a key benefit for six participants, all spoke of the issues deploying on-premise systems. Deploying on premise is not technically difficult however the participants noted long delays due to internal procedures and multiple levels of approval required to get a system deployed. Participant A asserts that in one recent instance "*it took up to 7 months to prepare a server due to internal procedures and red tape*". This also applies to deploying additional modules within an application, participant F stated: "*If you want another module, they just turn it on and you can use it*".

Scalability was mentioned as being an important benefit for six participants. Participant F stated they "*need to be able to scale up and down, we do 50 to 60% of our business between December and March, so we double in size for these months*", and the cloud allows them to scale their systems based on demand.

Five participants reported that using the cloud enabled them to provide additional services or higher levels of service compared to what they could provide on-premise. Participant H said, "*there is no longer an expectation that everything can be done on-premise, you need to use the cloud to obtain specific functions or features*". Participant C agrees with this and comments that to use functions like "*AI you need to use PAAS, why would you build your own solution?*".

Participant I summed up what a good cloud strategy should entail,

> you should have a view of using it to break free of the application chains you have at the moment, because you should be looking at utilising the power of the cloud, maybe utilising it from a scalability, recoverability and performance point of view or maybe utilising it to add new capabilities like machine learning or AI facilities available in the cloud or indeed the whole myriad of capabilities that are now only available in the cloud.

Concerns

There remain several concerns about using the cloud and the most prominent of these is security and data protection. All participants rated security as their primary concern with the cloud.

Participant B asserted they "*have to be 100% certain their data is secure*", to do this they "*have to go through due diligence to ensure the cloud solution being delivered is as safe if not safer than what could be delivered on-premise*". Participant J is in agreement with this and said that in their organisation "*it is impossible to get information security to agree to move banking data to the cloud*".

Issues were highlighted with auditing a cloud vendor's security and agreeing on the contract for the provision of services, participant H reported: "*from a contractual perspective, getting some contractual obligations agreed, has proven to be arduous in some cases and impossible in others*". Participant I pointed out "*auditing is one difficulty, but another difficulty is having the skills to actually figure out if it is doing what it is meant to do*".

Participant C stated the right skills are very important when it comes to securing a cloud system and "*the danger is that you can accidentally open ports without the right security and controls*".

Despite these concerns participant G believes "*the bigger cloud providers are probably capable of making their systems more secure than us, they have a huge reputation to protect, and they get economies of scale*".

Participant H agrees with this view, noting "*security concerns are more a reason to go to the cloud than not to go to the cloud"*.

Another concern raised were limitations on jurisdictions on where applications or data could be stored, this is closed linked to data security concerns. Eight participants stated their data must be stored within the European Union, in some cases, this was due to legislation and in others, it was driven by an organisation's best practice policy. Participant B stated, "*data must be stored within the EU or the vendors must sign up to privacy shield*". Participant F also raised concerns with where the cloud vendors support staff operated from, saying "*vendors supporting our cloud operations offer follow-the-sun support but we can't use that as support must be within Europe*". Participant K noted "*following the collapse of safe harbour they made a decision to move any data stored in the US to EU data centres*".

EU General Data Protection Regulation ("GDPR") was mentioned as a concern by five participants. Participant C pointed out "*GDPR applies to both on-premise as well as cloud systems*". Participant G said that establishing "*roles and responsibilities is key*", "*when we deal with a cloud provider, our legal team always try to insert a clause in the contract, to say if we are exposed that the cloud provider would be exposed as well. This has been a blocker*". Participant F agrees with this "*technology has not been the biggest issue, it has been security audits, compliance audits, data protection rules and GDPR all add layers you need to get through before migrating to the cloud*".

4.4.4 Legacy migration approaches

All participants were asked about their approaches to migrating a legacy application to the cloud. The findings show that standard approaches were not used by any participant, and even within organisations the approach varied by application, participant H stated: "*we use a case by case basis, we don't have a cookie cutter approach where if you can tick 18 of these 20 boxes you are good to go*".

The options identified were:

- Migrate
- Modify and migrate
- Replace

Migrate

The migration option is often driven by there being a clear path from the on-premise application to the cloud. Participant C said that when they need to update a legacy system they first check if there "*is a SaaS model, for example, SharePoint on premise could move to Office365, if there's a pure SaaS model there, all my headaches suddenly disappear*". Participant K agrees with this but said: "*even if the SaaS model only handles 80% of the functionality the business are still happy to go with it as it is in the cloud*".

In the absence of a clear migration path to the cloud, the participants say that they are required to try and determine their own path. According to participant B, this can result in certain capabilities of the application being migrated as opposed to the complete legacy application.

Characteristics of legacy applications that are most suited to be migrated are those with less secure data, few dependencies on other applications or web applications.

Migrating email applications was mentioned by eight participants as a good starting point to using the cloud. The next most popular were CRM (Customer Relationship Management) applications as the cloud offerings for these applications are quite mature. HR applications were also included as good candidates for migration.

Web applications are suited to migration to the cloud according to three participants, the reason being is that architecture of these applications tends to be compatible with the cloud architecture which makes migration much easier.

Modify and migrate

Participant G said that their preferred option was to wrap the application with functions and services that work well in the cloud and then migrate the application. This is essentially a lift and shift migration but the with the additional services wrapped around the legacy application it can appear a SaaS solution.

Modifying a legacy application can be a very daunting task, one participant spoke of a project which is to update the version of a legacy system being estimated at taking one and half years. The application will still be a legacy system at the end of this process, just more up to date.

Replace

Participant B stated they "*won't migrate any legacy systems to the cloud but they will be replaced with cloud systems*" and that their preferred approach was to "*migrate capabilities to the cloud rather than migrate the actual system*".

Participant C said, "*legacy systems don't lend themselves well to the cloud*" and that they explore hybrid options where some functions are moved to the cloud and these integrate back to the legacy application on-premise. They have experienced issues with this as "*some vendors would not support this hybrid approach to application deployment*". Participant G that Salesforce, which is the world's leading CRM platform, is a good example of an application that is only available in the cloud. This could be used to replace similar functionality from on-premise applications.

A different perspective was mentioned by Participant F who said "*some vendors not offering on-premise applications, they are pushing cloud versions, if you want our offering you need to go to the cloud*", this is forcing a migration to the cloud.

4.4.5 Migration criteria

Participants were asked which suitable criteria they use for evaluating legacy applications for migration to the cloud and the common criteria found were number of integration points, level of change required, data criticality and cost.

Number of integration points

The number of integration points or number of other applications the legacy application interfaces with was a key criterion for eight participants. Participant J told how they "*analysed a core banking application and found 50 integration points to other applications*", this resulted in the application not being migrated. Participant D believed "*you expect an application does one thing but then you discover it's connected to another legacy system*". Participant I noted "*integration is a major concern because organisations can have very complex landscapes that have evolved over decades*", and questions if related applications needed to be migrated at the same time or if not could a hybrid model work, where the migrated application in the cloud integrates back to the other applications on-premise. Participant F reported using the hybrid model where some capabilities were migrated to the cloud and these were integrated back to the legacy application on-premise, however, they expressed concerns about how the "*latency of this hybrid approach*" could impact on the legacy applications performance.

Level of change required

The level of change required to prepare an application for the cloud and the associated effort is also a key criterion. Participant I claimed, "*applications that do not require rework are the best candidates for migration*". Participant I contends "*if you have to rework your existing legacy application so that it moves to the cloud, and you have to spend a lot of money doing that, that can seem like a complete waste of time because all you are going to end up with is the same capability from a business point of view, but technically working differently. That achieves no business value, it's very much an IT driven project, let's prove we can do this*".

Criticality of data

The criticality of the application's data is one of the most important criteria according to the participants. Participant H, "*would not migrate any application with highly secure data as they believed the cyber controls required cannot be met by vendors at present*". Participant L was even stronger in this regard and stated: "*this organisation is very risk-averse, I can never see critical systems or data ever going to the cloud*".

Cost

While cost is a criterion, participant H believed "*cost is less of a driver, there are very few scenarios we see that going to the cloud will save us money, it just gives us different services or different tiered offering, or different functions, this is where we feel that the benefit lies"*. Participant F agrees with this as in his organisations experience the "*SaaS model is more expensive than on-premise licence model*".

Other criteria mentioned by participant C were "*are there issues with the application?*" or "*is it difficult to manage*", if the answer to any of these is yes then alternative solutions need to be sought.

4.5 Summary

This chapter presented details of the data analysis process carried out on the data collected during the research process and the resulting findings. The next chapter will present a summary of the findings, show how the research question was answered, outline research limitations and propose topics for future research.

5 Conclusion

5.1 Introduction

The previous chapter presented details of the data analysis process carried out on the data collected during the research process and the resulting findings.

This chapter will present a summary of the findings, show how the research question was answered and aims and objectives were met, outline research limitations and propose topics for future research.

5.2 Findings summary

This section will summarise the findings and compare them to the reviewed literature. The study was carried out using an interpretive philosophy, the research method was semi-structured interviews, and the findings were analysed using a qualitative approach combined with thematic analysis and inductive reasoning.

5.2.1 Legacy applications

All participants described legacy applications as old applications, possibly out of support, not fulfilling the business needs.

Seven participants described legacy applications as being 10 to 30 years old, this correlates with the study by Khadka et al. (2014) who described legacy applications as old applications, perhaps up to twenty or thirty years old. The age of the application may not always a negative aspect as having applications that have endured for 25 or 30 years testifies to the longevity of the application and these applications must be fulfilling a business function to have survived that long. This longevity implies that legacy applications are a proven technology as described by Erradi et al. (2006) who asserts that legacy applications have been developed, tested and have been in a production environment for years.

The participant's opinion on the support status of legacy applications varied from those who described them as out of support or sunset applications to those who said they may be still in support but are classified as legacy for other reasons. This factor did not feature in the literature which may be explained by a time factor, as time progresses legacy applications are more like to move out of support, particularly those sourced from 3rd party vendors.

Support status is less of an issue for in-house developed applications as once the organisation has the skills they can support the applications.

Three participants reported that some vendors are forcing their clients on to the cloud by only offering or supporting the latest version of their applications in the cloud. This approach is likely to increase over time and organisations who are not comfortable using cloud application will find their options decreasing.

It is essential that any application fulfils the business needs so it is unsurprising that this criterion rated highly with the participants in the research. An application not fulfilling the business needs alone is sufficient reason to search for an alternative, irrespective of other criteria. This finding agrees with Erradi et al. (2006) who states an application's business value contribution should be determined based on the application criticality in achieving business objectives and its ability to generate business returns both in terms of financial benefits and/or improved customer satisfaction.

A surprising finding, mentioned by two participants, is that an application could be classified as legacy if it is not capable of going to the cloud. This attitude, while it may not be prevalent, has a lot of implications for software vendors who are only providing on-premise applications. The implication here is that software vendors need to start offering versions of their applications that can be deployed in the cloud, failure to do this could result in their applications being classified as legacy. Garcia et al. (2015) agree with this finding, they state cloud computing is having a big impact on outsourcing vendors, who have had to develop new approaches to include cloud services as part of their offerings to keep up with profound changes in the IT service industry.

5.2.2 Issues with legacy applications

The findings identified several issues with legacy applications, these applications are difficult to change, lack documentation, there is a skills shortage and applications are out of support.

Five participants stated that legacy applications are difficult to change. The main reasons cited for this were a shortage of skills and lack of documentation. The skills required to support legacy applications are being lost due to resources moving on to more modern applications or retiring. Khadka et al. (2014) is in agreement with this finding and contends while legacy applications are critical to the business, they are also inflexible when it comes to supporting new business requirements. This necessitates a business manager checking with an application owner if a process can be changed rather than informing the application manager that a change is necessary to support the business. There is a hesitancy in changing legacy applications as they are so complex and lacking in documentation that the risk of causing an issue is so great that the safe option is not to allow the change. This can often result in a new requirement being carried out external to the core legacy application and then 'bolted' on, causing further layers of complexity.

Skills shortage is an issue which is worsening as time progresses, participant F believes that their current support staff for legacy applications will have retired in the next ten years and replacement staff will not be available as new graduates are not interested in working on legacy applications. This implies that sourcing alternative solutions for legacy applications is urgent and must be addressed soon, otherwise, these applications will not be supported into the future. This finding correlates with the views of Brodie & Stonebraker (1993), who assert that specialised skills are required for legacy applications as they are not developed in modern programming languages and that there is a lack of documentation of legacy applications leading to a scarcity of knowledge and legacy experts, developers must have the expertise to analyse the code to determine how functions should operate.

Participant K expressed concerns about legacy applications failing and how they were core to the organisation. While other participants did not explicitly mention that their legacy applications were vulnerable to failure they did have concerns about lack of documentation, skills shortage and difficulty changing these applications which imply a vulnerability. This ties in with research by Khadka et al. (2014) who state that as legacy applications are business critical, organisations cannot afford for them to fail. This contributes to a reluctance to change the application, the risk is that the change will impact the stability of the application and introduce a vulnerability to failure that did not exist previously. To mitigate against this risk failure organisations must look for alternative solutions.

5.2.3 Cloud strategy

The findings showed that the main benefits participants found from using the cloud were accessibility, ease of deployment, scalability and additional services.

Benefits

Nine participants rated accessibility or broader access as a key benefit to the cloud. While it is possible to access on-premise applications remotely, frequently the infrastructure is not in place to do this, with the cloud this infrastructure is available by default. This accessibility to applications allows employees to work from remote locations as if they were in the office. This finding corresponds to research by Pallis (2010) who states that the accessibility the cloud provides allows employees to be more productive and provides the capability to be able to access project information, contracts and customer documentation as and when they need it.

Six participants put ease of deployment as a key benefit from the cloud, this contrasts sharply with their experiences deploying systems on-premise which they say is becoming more and more difficult due to their organisation's internal policies and procedures. This is even the case when it’s a virtual machine that is required rather than physical hardware. The cloud vendors provide consumers with a self-service model where they have the ability to specify a system build and have it built and available within minutes as opposed to on-premise where this could take days or weeks or in some cases months. This matches the research from Buyya et al. (2008) who found that the provision of computing capabilities is done automatically by the consumer without requiring any interaction with the service provider. This is normally accomplished using templates provided by the cloud service provider accessed through a web browser over the internet.

Five participants rated scalability as an important benefit for cloud computing, as in the example given by Participant F, it allows an organisation increase the size of a system based on increased demand and then decrease it at other times. This links directly to the cloud payment model where resource usage is measured and charged accordingly. On-premise systems do not have this capability and must be sized for peak demand which is an inefficient use of resources outside of peak demand. These findings are similar to literature from Shawish & Salama (2014) who state that elasticity is often considered a core justification for the adoption of cloud computing, primarily as the ability to quickly scale up or down resource usage, is an important economic benefit as it transfers the costs of resource overprovisioning and the risks of under-provisioning to the Cloud providers.

Concerns

The findings from all participants were clear that the primary concern around using the cloud is security and data protection. The participants talked about the pressure they experience to ensure that the cloud vendors security is sufficient to meet their organisation's requirements. This is done at several levels, firstly the cloud vendors are asked to complete security questionnaires developed by the organisations information security teams, then the legal department insist on certain clauses in the contracts to ensure that roles and responsibilities are clear, finally audits are carried out to confirm the procedures and controls in place match those committed to by the cloud vendor. As participant H pointed out, this process is not always successful and there are times when the engagement with the cloud vendor ends during this process due to failure to meet the security terms required by an organisation. This matches the work of Kim (2009) who says that while it is nearly impossible to guarantee 100% security and privacy protection against all possible sources of violation, including the inevitable software bugs, the growing sophistication of the hackers, inadequate procedures and human errors. Cloud computing providers must adopt the most sophisticated and up-to-date tools and procedures, and strive to provide better security and privacy than is available for on-premises computing.

5.2.4 Legacy migration approaches

When the participants considered which approaches they would take to migrating legacy applications the findings show there were three approaches, which were, migrate, modify and migrate or replace. This compares favourably to the approaches proposed by Erlikh (2000) and Bisbal et al. (1999) which comprised of four options:

- Migrate
- Wrap (and Migrate)
- Retain
- Retire and Replace

The option to retain the application was not mentioned by any of the participants, however, this may be explained by the question which was "*What is your migration approach regarding legacy systems?*". The participants may have felt that the option to retain the application, which essentially means do not migrate, was not a valid response to this question. In reality what tends to happen is that the retain option is the default position until one of the other migration options is chosen. Legacy systems have been retained for up to 30 years and some will continue in operation.

Migrate

The findings showed that migration option is preferred when there is a definite upgrade path from the on-premise application to the cloud. Participant C pointed out that they first look for a SaaS model and if there is one then they go with it. This is helped by vendors providing cloud versions of applications which were previously on-premise only.

The preferred migration option according to two participants, is to look for a Saas model that can be utilised as a direct migration path for on-premise legacy applications. The example given by Participant C was to migrate from SharePoint on-premise to Office365 in the cloud. In the absence of a clear migration path to the cloud, the participants say that they are required to try and determine their own path. According to participant B, this can result in certain capabilities of the application being migrated as opposed to the complete legacy application. This agrees with the literature when Beserra et al. (2012) assert that following a decision to migrate the next stage is to define an adequate migration strategy.

Participant I talked about needing to maximise use of the facilitates in the cloud and that it was important not to build another legacy application in the cloud. This agrees with the work of Scandurra et al. (2015) who believe that the drivers behind a migration decision must be documented and any requirements and constraints (such as time, cost, and feasibility) detailed. The migration may be complicated by a need to extend the core functionality of the application to utilise additional cloud services to provide added value to the business.

Modify and migrate

Participant G spoke about wrapping the application with functions and services that work well in the cloud and then migrating the application. The functions that are wrapped around the legacy application will allow it be a better fit for migrating to the cloud and will provide additional services so that the application can appear like a SaaS solution. This approach corresponds to the thinking of Saeidi et al. (2013), who believe that the code can be changed to make the application more suitable to the cloud environment, however, they warn about taking care to ensure the stability of the application is not impacted on.

Replace

Participant B said that they would not migrate any legacy application, preferring instead to retire the old application and replace it with a cloud application. Participant C agrees with this approach as legacy systems do not fit well in the cloud and they also prefer to replace functions with cloud versions. This matches the work of Lewis et al. (2008) who stated it may not be possible to migrate a legacy application due to technical constraints stemming from the nature of the legacy system. Some scenarios where this would be the case is if the user interface layer is not distinct from the business or core function layer, this would require a large effort of rework to separate these layers and there is no added value from this effort. Another reason is that cloud applications operate on a request-response model whereas legacy systems can operate in batch mode and this would cause a conflict in a cloud environment.

Some applications are only available in the cloud, Participant G uses the example of Salesforce CRM. Participant I also mentions that features like machine learning and AI are only available in the cloud. Switching from on-premise applications to cloud application will give an opportunity to take advantage of these applications and features that only exist in the cloud. This matches the thinking from Lewis et al. (2008) who state that a reason to switch to cloud applications is to use technologies that may not exist in the legacy application.

5.2.5 Migration criteria

The criteria which the participants highlighted as being the most import when evaluating legacy applications for migration to the cloud were number of integration points, level of change required, data criticality and cost.

Number of integration points

Eight participants agree that applications that integrate with a lot of other applications are much more complex to migrate than applications with few integration points. Participant I believed that when multiple applications are integrated and one is migrated to the cloud then the question is do all of the related applications need to be migrated as well. If not then can the application that is in the cloud integrate with the applications that remain on-premise. This integration between the cloud and on-premise can add another layer of complexity to the applications. Participate J gave an example of identifying up to 50 integration points in a legacy application they analysed. This correlates well with the literature when Li et al. (2013) found that when migrating a legacy application to the cloud that the analysis should include the number of applications interacted with, the location of the applications and the frequency of the interaction and the amount of data or bandwidth consumed transferring data to and from the application. There is a danger that an application that performs well on-premise can perform poorly when deployed to the cloud solely due to the network latency impact of interacting with other applications which are not in the same environment.

Level of change required

The findings also highlighted that the level of changes required to prepare an application for the cloud was an important criterion. Participant I pointed out that applications where rework is not required are the best candidates for migration and believes there is little value carrying out major rework on an application to allow it migrate to the cloud if no additional value is included in the work. This matches with the literature when Lewis et al. (2008) state that a considerable amount of redevelopment may be required to separate functions such as the user interface that are tightly coupled with the business logic in a legacy application to prepare it for operation in a cloud environment which expects functions to be loosely coupled.

Criticality of data

All participants rated the criticality of data as being very important, some like participant L said that it would prevent them considering cloud for their critical systems. Others like participant H claimed the controls required for highly secure data could not be met by cloud vendors at present. Participant G commented on the levels of authorisation they need to go through to get their information security team to agree to put data on the cloud. However, the opposing viewpoint was expressed by participant K who thought that cloud vendors were capable of providing better security than an organisation could do on-premise.

The range of findings in this area shows that data security is a top factor when it comes to deciding to deploy an application to the cloud. This matches the research by Gorelik (2013) who state that business-critical applications, particularly in financial services and health care, will have strict requirements that may not be easily achieved in the cloud. Systems of record are almost always repositories for some of an organisation’s most sensitive information, including customer data and financial records. Regulatory compliance and governance best practices may prevent storage of this data in the cloud.

A similar view point is expressed by Mohagheghi & Sæther (2011) who believe that an organisation must understand exactly how the cloud provider vendor meets their particular security requirements. Applications that process private or proprietary data are highly sensitive and therefore more compatible with remaining on-premise.

Cost

Findings related to cost demonstrate that cost is not seen as a driver to migrate to the cloud, which was a view expressed by both participant H and participant F. The cost of initial entry to the cloud appears low but experience is showing that to operate a cloud application on higher than entry level systems over time can cost the same or even more than an equivalent on-premise application. The cost benefits with the cloud are the extra facilities and capabilities the cloud provides. There are some similarities to the work of Tak et al. (2011) who believe that is difficult to compare on-premise costs to cloud operating costs. They say that the costs of operating an on-premise application are often underestimated which results in an unfair comparison.

5.3 Answering the research question

This study set out to answer: What are the most suitable criteria for evaluating legacy applications for migration to the cloud?

In addition, the study had the following aims and objectives:

- Define legacy applications
- Consider issues associated with legacy applications
- Review possible solutions for issues with legacy applications
- Explore criteria for analysing legacy applications.

The study found that the definition of legacy applications varied by organisation, however, the common characteristics were, legacy applications are old, up to 30 years old, either out of support or difficult to support and struggling to fulfil the business requirements.

The main issues found with legacy applications is that they are difficult to change, this is compounded by a skills shortage and a lack of up to date documentation.

One possible solution to these issues identified was to migrate a legacy application to the cloud, which was acknowledged as being at best very difficult and perhaps impossible. Another option is to modify the application by wrapping functions around it to make it more compatible for migrating to the cloud. The most popular option was to replace the legacy system, this could either be a complete replacement by a cloud application or replace certain capabilities with cloud versions.

The criteria which the findings revealed as being the most important when evaluating legacy applications for migration to the cloud were the number of integration points, level of change required, data criticality and cost. Organisations typically based their migration decision on one of these criteria, for example if data criticality was the main priority then additional costs could be justified.

5.4 Research limitations

The findings of this research were based on semi-structured interviews with twelve participants and while this did produce a rich set of data, the study would have benefited from a broader set of data, perhaps the inclusion of a survey could have reached a broader participant group.

5.5 Future research

This study was based on participants who work with both legacy applications and cloud applications. The cloud is only one possible solution to legacy systems so a study that explores other approaches such as addressing issues with legacy applications through on-premise solutions would be worthwhile.

There would also be merit in researching what could be done with legacy systems to prolong their life and usefulness thus preventing the need to carry out extensive re-engineering or migrations. Narrowing the focus to include certain types of legacy systems would be interesting, for example, a case study on addressing mainframe legacy applications in the banking sector.

Whenever cloud applications are mentioned, security is very quickly brought into the conversation, the findings in this study indicate that securing cloud systems remains a major concern for organisations. A study on how cloud vendors could address the security concerns would be useful, with an aim of determining if the cloud vendors could provide answers to an organisations security questions before they ask them.

5.6 Summary

The study highlighted that the issues with legacy applications are likely to increase into the future, particularly given the skills shortage. Legacy applications are often core applications and having them prone to failure could have disastrous consequences for an organisation. These applications are already failing to fulfil some business requirements and given the frequency of changes required to secure applications and data the issues need to be addressed sooner rather than later. The study also questions the value of carrying out an evaluation of legacy applications to determine all the processes, features and functions they contain, the skills are lacking for such an exercise and it could take an inordinate amount of time. The preferred approach is to replace specific capabilities with cloud capabilities or functions and in this manner the legacy application can be gradually replaced which lessens the risk and impact on business operations.

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Appendix A Ethics application

School of Computer Science & Statistics
Research Ethics Application

Part A

Project Title: What are the best criteria for evaluating applications for migration to the cloud

Name of Lead Researcher (student in case of project work): James Maughan

Name of Supervisor: Noel Faughnan

TCD E-mail: me Contact Tel No.: 08

Course Name and Code (if applicable): MSc Management of Information Systems

Estimated start date of survey/research: 1st May 2017

I confirm that I will (where relevant):

- Familiarize myself with the Data Protection Act and the College Good Research Practice guidelines http://www.tcd.ie/info_compliance/dp/legislation.php;
- Tell participants that any recordings, e.g. audio/video/photographs, will not be identifiable unless prior written permission has been given. I will obtain permission for specific reuse (in papers, talks, etc.)
- Provide participants with an information sheet (or web-page for web-based experiments) that describes the main procedures (a copy of the information sheet must be included with this application)
- Obtain informed consent for participation (a copy of the informed consent form must be included with this application)
- Should the research be observational, ask participants for their consent to be observed
- Tell participants that their participation is voluntary
- Tell participants that they may withdraw at any time and for any reason without penalty
- Give participants the option of omitting questions they do not wish to answer if a questionnaire is used
- Tell participants that their data will be treated with full confidentiality and that, if published, it will not be identified as theirs
- On request, debrief participants at the end of their participation (i.e. give them a brief explanation of the study)
- Verify that participants are 18 years or older and competent to supply consent.
- If the study involves participants viewing video displays then I will verify that they understand that if they or anyone in their family has a history of epilepsy then the participant is proceeding at their own risk
- Declare any potential conflict of interest to participants.
- Inform participants that in the extremely unlikely event that illicit activity is reported to me during the study I will be obliged to report it to appropriate authorities.
- Act in accordance with the information provided (i.e. if I tell participants I will not do something, then I will not do it).

Signed: .... Date: 21/3/2017
Lead Researcher/student in case of project work

Part B

Please answer the following questions.		*Yes/No*
Has this research application or any application of a similar nature connected to this research project been refused ethical approval by another review committee of the College (or at the institutions of any collaborators)?		No
Will your project involve photographing participants or electronic audio or video recordings?		Yes
Will your project deliberately involve misleading participants in any way?		No
Does this study contain commercially sensitive material?		No
Is there a risk of participants experiencing either physical or psychological distress or discomfort? If yes, give details on a separate sheet and state what you will tell them to do if they should experience any such problems (e.g. who they can contact for help).		No
Does your study involve any of the following?	Children (under 18 years of age)	No
	People with intellectual or communication difficulties	No
	Patients	No

School of Computer Science and Statistics
Research Ethical Application Form

Details of the Research Project Proposal must be submitted as a separate document to include the following information:

1. Title of project
2. Purpose of project including academic rationale
3. Brief description of methods and measurements to be used
4. Participants - recruitment methods, number, age, gender, exclusion/inclusion criteria, including statistical justification for numbers of participants
5. Debriefing arrangements
6. A clear concise statement of the ethical considerations raised by the project and how you intend to deal with them
7. Cite any relevant legislation relevant to the project with the method of compliance e.g. Data Protection Act etc.

Part C

I confirm that the materials I have submitted provided a complete and accurate account of the research I propose to conduct in this context, including my assessment of the ethical ramifications.

Signed: .... Date: 20/3/2017
Lead Researcher/student in case of project work

There is an obligation on the lead researcher to bring to the attention of the SCSS Research Ethics Committee any issues with ethical implications not clearly covered above.

Part D

If external or other TCD Ethics Committee approval has been received, please complete below.

External/TCD ethical approval has been received and no further ethical approval is required from the School's Research Ethical Committee. I have attached a copy of the external ethical approval for the School's Research Unit.

Signed: .... Date: ....
Lead Researcher/student in case of project work

Part E

If the research is proposed by an undergraduate or postgraduate student, please have the below section completed.

I confirm, as an academic supervisor of this proposed research that the documents at hand are complete (i.e. each item on the submission checklist is accounted for) and are in a form that is suitable for review by the SCSS Research Ethics Committ

Signed: .... Date: 20th March 2017
Supervisor

Completed application forms together with supporting documentation should be submitted electronically to the online ethics system - https://webhost.tchpc.tcd.ie/research_ethics/ When your application has been reviewed and approved by the Ethics committee, hardcopies with original signatures should be submitted to the School of Computer Science & Statistics, Room 104, Lloyd Building, Trinity College, Dublin 2.

Ethics Application Guidelines – 2016

Appendix B Interview questions

TRINITY COLLEGE DUBLIN
INTERVIEW QUESTIONS

What are the most suitable criteria to use to analyse whether an application is suitable for migration to the cloud?

Background Information

- Describe your current Role
    - Do your current responsibilities involve managing cloud applications or evaluating applications prior to deployment to the cloud?
    - Have you previously migrated applications to the cloud?

Cloud Strategy

- Describe your organisations strategy for utilising cloud applications?
    - What is the motivation that led the organization to contemplate cloud migration?
    - What is the level of senior management buy-in to the cloud strategy?
- What stage is your organisation at with regards to deploying cloud applications?
- Have you identified any criteria to use when measuring the success of deploying applications to the cloud?
- Is your organisation expecting additional revenue by leveraging cloud technologies?
- Is your organization subject to any law or legal restriction on the physical location of its data and/or applications?

Application Evaluation

- Do we have an enterprise wide consolidated list of applications and their intended usage in place?
    - Do you have applications that could be classified as legacy?
    - How does your organisation define legacy applications?
- What is your migration approach regarding legacy systems?
    - If leave off cloud – What are the reasons?
    - If planned migration – What cloud attributes are you planning to take advantage of by moving to the cloud?
    - If mixed – describe the reasons?
- What criteria do you use when evaluating an applications' suitability for deployment to the cloud?

Application evaluation outcomes

- What are the possible out-comes of this evaluation?
- Describe the characteristics of any applications that you have decided:
    - Should be migrated to the cloud?
    - Should **not** be migrated to the cloud?