Towards a Flexible Cloud Architectural Decision Framework for Diverse Application Architectures

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Abstract

Most organisations moving their legacy systems to the cloud base their decisions on the naïve assumption that *public cloud always provides cost savings*, without sufficiently assessing the underlying application architecture, and the technical and financial constraints that it imposes on the chosen cloud architecture. This can lead to undesirable consequences including project delays, budget overruns, below-par performance, application instability and creation of technical debt. In this paper, we address the shortcomings of this assumption by proposing a structured yet flexible decision framework comprising models, guidelines, tools and calculators that enables IT and/or business practitioners to make the correct architectural decision between public, private and hybrid cloud, from a functional, non-functional and financial perspective, based on the application architecture. By treating the application architecture as a first-class citizen in the decision making process, our proposed framework ensures that business and technical stakeholders make the correct decision early on in the migration process, resulting in timely deployment and quality-assured provision of critical business functions, minimization of waste, and avoidance of rework. We use a sample scenario to illustrate the need and usefulness of such a decision framework.

Keywords: Cloud Computing Adoption, Cloud Migration, Private Cloud, Public Cloud, Application Architecture.

1 Introduction

The Australian Government's National Cloud Computing Strategy (NCCS) (Australian Government 2014) outlines a vision for cloud computing in which the Australian Government will lead the uptake of cloud services to achieve greater ICT efficiency and deliver better services to the public, while also encouraging Australian businesses, both big and small, to adopt cloud services. Efficient cloud adoption by both the public sector and the private sector will lead to significant cost savings, as well as energy savings and reductions in carbon emissions. Independent research backs this vision and predicts that by 2018, the Australian Government's ICT Budget will exceed $6.2 billion with cloud services accounting for a significant portion of it (Australian Government 2014).

Despite the push for cloud adoption, there are several challenges associated with it (Gholami et al., 2017; Holami et al., 2016). Any cloud migration methodology has to incorporate several aspects including requirements gathering, identification and understanding of constraints, tracing of constraints to architectural building blocks, and identification of infrastructure components. Failure to consider such aspects can result in project delays, budget overruns, below-par performance, application instability, poor customer experience and creation of technical debt. The *Pay-as-You-Go (PAYG)* philosophy of (commercial) public cloud further complicates the migration process making optimum application placement critical to the overall migration cost (Marcsova et al., 2017) and quality-assured provision of the migrated application.

However, most organizations adopting a cloud strategy tend to base their cloud migration decisions on the naïve assumption that *public cloud always provides cost savings* (Kavis 2014; Maresova et al., 2017), without sufficiently assessing the underlying application architecture and the technical and financial constraints that it imposes on the chosen cloud architecture. In this paper, we address the shortcoming of this naïve assumption by proposing a structured yet flexible decision framework with corresponding models, guidelines, tools and calculators to enable IT and/or business practitioners to make the correct cloud architectural decisions regarding public, private or hybrid cloud, from a functional, non-functional and financial perspective, based on the application architecture. The proposed framework treats the application architecture as a first-class citizen in the decision-making process and helps make the cloud architectural decision explicitly on a per application basis. The main benefit of doing so is that it ensures that the correct decision is made the first time resulting in timely deployment and quality-assured provision of critical business functions, minimization of waste, and avoidance of rework. We illustrate the need for and the applicability of our proposed approach through a sample scenario.

The rest of the paper is organized as follows. Section 2 presents related work on cloud migration frameworks and methodologies. Section 3 presents a sample scenario to motivate the need for a cloud architectural decision framework. Section 4 describes the research methodology used in our research work. Section 5 provides an overview of our proposed framework and illustrates its suitability by providing a sample scenario. Section 6 concludes the paper by providing a summary of the completed work and identifying areas of future work.

2 Related Work

The majority of research so far identifies cost savings as the primary reason for moving enterprise applications to cloud. In fact, most research reviewed so far assumes that *public cloud is less expensive than the legacy environment* hosting the applications (Kavis 2014; Maresova et al., 2017). Moreover, most assessments of public cloud do not include the implications of moving data into and out of a public cloud provider, except for calculators for public cloud pricing and identification of non-quantifiable costs of cloud computing (Maresova et al., 2017).

Some perceived benefits of cloud migration include reduction in energy consumption due to consolidation of applications (Basmadjian et al., 2012) and suitability for applications with cloud native architectures and dynamic workloads. Cloud native architectures are increasingly being utilised to gain competitive advantage, with advances in technology such as Network Virtual Functions (NVF) eliminating the need for dedicated hardware and enabling quicker deployment of software solutions (Bhamare et al., 2017). However, the corresponding impact of NVF on the application cost and performance, as compared with physical appliances, is yet to be clearly established.

Also, the regularity of cloud adoption seen with cloud-native architectures is still missing in legacy or monolithic architectures, and there is still a significant focus upon the need for guidance with regards to using the public cloud computing models including IaaS, PaaS and SaaS (Kavis 2014). However, as correctly identified in (Gholami et al., 2017; Reza et al., 2017), cloud migration is not simply a matter of replicating functionality in the cloud or porting an application to the cloud – it is also ensuring that the associated non-functional requirements will be matched or exceeded. The authors in (Gholamai et al., 2017) report that comparing an application's current environment to a 'standardised' cloud environment can be significantly complex when environments have not been kept up-to-date.

In Yangui et al. (2016), the authors recommend avoiding vendor lock-in when choosing a public cloud provider, hence, a focus on application portability is encouraged during the engineering of the application. They also recommends that enterprises should have a multi-cloud service strategy of public and private cloud models. Similarly, Lewis (2011) and Famideh et al. (2016) identify a number of considerations for the placement of functionality in a cloud platform, including cloud resource management, user authentication, performance, and security. Our research aims to extend, elaborate and incorporate these considerations in a decision support tool. In terms of Quality of Service (QoS) and Service Level Agreements (SLA) current research identifies that in a multi-tenanted environment this can be at risk as resources are shared and legacy means of offering application redundancy are not supported. In a cloud-native architecture of a 'shared nothing' principle, this has less of an impact if the application is able to create new instances when it reaches processing thresholds (Chorafas 2010; Holami et al., 2010).

Current research for requirements engineering when migrating to the cloud centres upon the TOGAF dimensions of architecture (The Open Group 2017) and IBM's Framework for IT Systems (Cook et al., 2013). Our research extends upon this thinking through examining the current requirements gathering work products and procedures, and identifying specific criteria that enable the architectural decision between public and private cloud. In reviewing current research, we have identified eight high-level concerns related to cloud migration that form a basis for identifying criteria for entry into a Use Case Model or Customer Wants and Needs artefact. These concerns are Business Wants and Needs (Kavis 2014), Business Requirements (Maresova et al. 2017), Migration Planning (Gholami et al., 2017), Application Architecture (Kavis 2014), Application constraints (Lewis, 2011), Public Cloud Platform (Kavis 2014), Private Cloud Platform/Service (Yangui et al., 2016) and Total Cost of Ownership (Holami et al., 2016). The authors in Zimmerman et al. (2011) propose an architectural decision-modelling framework and a reusable decision model for SOA. The framework emphasises that after making an architectural decision, it is imperative to enforce the decision and catalogue it to prevent revisiting the choice in future, but instead elaborate upon further criteria as applications are considered on a case-by-case basis. We take a similar approach in the context of cloud architectural decisions for diverse applications architectures.

The main advantage of our proposed framework is that it provides a set of models, guidelines, tools and calculators to assist users in making a more informed decision on the technical choice between public and private cloud, rather than relying on implied assumptions. It is suitable for use in any cloud migration scenario where a decision is required in the initial requirements gathering phase of the project lifecycle. It differs from The Open Group decision tree (Harding et al., 2011), which considers in-place contracts, spare in-house infrastructure and organisational control (common to our framework) to make the decision from a technical perspective only. Our framework provides additional criteria and a streamlined approach to make the decision from a financial perspective as well.

3 Sample Scenario

An enterprise reaches a point in time where its Contact Centre (application) infrastructure reaches its end of life and a need arises to consider alternative compute, storage and network infrastructure options. The Contact Centre application facilitates customer interactions providing customers with the choice of the device and method they wish to use to interact with their suppliers. Contact centres can be either multi-channel (multiple technology providers) or omni-channel (single vendor technology). They support inbound and outbound voice calls, SMS, web-chat, email and smart applications. In recent times, the number of web chats and SMSs have been increasing, while voice calls are decreasing across enterprises' contact centres. In order to provide contact centre agents with a good work life balance and to reduce overheads, enterprises are allowing many agents to work remotely, either from home or from branch offices. A key benefit for the enterprise is that agent churn, a large overhead, reduces when an agent can work remotely. The customer experience is paramount but not at the expense of agent utilisation and balancing this requires investment in current technologies as the enterprise accelerates into a digitally transforming experience.

As the platform and software require a significant upgrade - the first step often taken is to assess the migration effort onto the public cloud for an inexpensive hosting experience. Typically, IT practitioners have a preferred public cloud that they want to use, based on grooming via the marketing of public cloud vendors, and are under the impression that a 'cloud-enabled business model' offers them the least expensive option. However, this can be problematic in a PAYG model, and the cost of hosting on the cloud can become more expensive than buying and managing the infrastructure outright. The increased costs are typically due to the hidden costs that vendor calculators do not cover such as the cost of in-house employees that are required to fulfil dependencies placed upon the enterprises for public cloud. Additionally, from a commercial perspective, the public cloud PAYG business model is rarely a better fit for monolithic, static application workloads relative to buying and managing the infrastructure outright.

There are several other possible implications of making a sub-optimal decision. For example, additional data centre space may be required for components that are not cloud ready. This introduces additional data centre networking costs. Increased components in the setup lead to further complexity and cost of building and maintaining the system. Lastly, enterprises tend to carry out a migration exercise to an alternative platform, which can translate into further costs and delay in the release of the business functionality.

4 Research Methodology

The research work presented in this paper is guided by the design-science research paradigm proposed in Hevner et al. (2004), which is essentially a problem solving-paradigm with roots in engineering and science. As such, the key outputs of the research work are IT artefacts, which fall under one of four different categories – *constructs, models, mechanisms* and *instantiations*. We divide our research work into three main phases, namely Literature Review, Framework Design and Framework Validation.

- The literature review focusses on identifying studies related to the migration of applications to cloud and then examining the degree to which different criteria including application requirements and constraints are applied, identifying the reasons for moving applications to the cloud, and organising the criteria in each of the artefacts.
- In the design phase, we propose a framework that guides a business Subject Matter Expert (SME) from the step where he/she receives an initiative, right through to the architectural decision between private or public cloud. The proposed framework comprises models, guidelines, tools and calculators to support the decision-making process. On receiving the initiative, the business SME uses it to identify the *Customer Wants and Needs*. If the business SME is time or resourced constrained, the framework provides a *Basic Use Case Model (BUCM)* to aid the architectural decision between private and public cloud. Alternatively, if the business SME has time and/or resources available, the framework provides a *Detailed Use Case Model (DUCM)*. The framework also provides *High Level Guidelines* for making a cloud architectural recommendation based on DUCM. We intend to elaborate on the detailed guidelines for decision-making based on DUCM in future. The main idea behind the development of guidelines is to provide criteria that are sufficiently generic to apply to a variety of cloud migration scenarios, which can help make architectural decisions between public and/or private cloud for an application based on the business functions and quality of service required, and the application architecture being considered. Our framework also includes a financial calculator to determine an application's Total Cost of Ownership (TCO) in the target cloud platform to determine if the technical preference for either public or private cloud or 'Do It Yourself' is financially viable and practicable.
- In the validation phase, we intend to use different types of applications to validate our proposed framework.

5 Proposed Framework

The aim of the proposed framework is to support business users, business analysts and/or solution leads to choose between public or private cloud for their application, from both a technical perspective and a financial perspective.

5.1 Cloud Architectural Choices

The choices typically available to the decision-makers are – traditional IT, private cloud, public cloud or hybrid cloud. In the *traditional IT* approach, an enterprise deploys monolithic applications on traditional infrastructure in its own data centre. If using the *private cloud* approach, the private Infrastructure as a Service (IaaS) Cloud is located on the enterprise's own data centre, and managed by the enterprise. An extension of this cloud architectural choice is the *managed private cloud*, in which the private IaaS Cloud is located in the enterprise's data centre but the enterprise's partner manages it.

With the public cloud architecture, the enterprise uses the public cloud with a Pay As You Go (PAYG) business model to deploy applications that require temporary or seasonal compute/storage requirements or social applications that include collaboration, communities and other services. The last cloud architectural choice is the *Hybrid Cloud*, in which the enterprise uses a mix of on-premises, private cloud and public cloud services to deploy its applications.

5.2 Preliminaries

IBM's (Rasmussen, 2010) provides enterprises with prescriptive guidance on building cloud-based solutions using different cloud adoption patterns. It also provides a five-phase process for Client Value Assessment (CVA) for any cloud migration initiative (see Figure 1 below). The orthodox implementation of this process is time consuming and requires a high degree of expertise and sufficient resources within the enterprise to contribute to the process, with the cloud architectural decision typically made in the Develop phase. However, more often than not, enterprises are short of expertise and resources.

Figure 1 Five-phase process for Client Value Assessment of Cloud Adoption (adapted with permission from Rasmussen, 2010, p.2)

To address this shortcoming, we propose a flexible framework that can be applied in the Understand phase to make a technical decision on the appropriate cloud platform. Our proposed framework extends the IBM Unified Method Framework (Cook et al., 2013), which represents a standards compliant process for developing IT system solutions based on a set of reusable models. Any system developed using this approach comprises three key models, namely *Requirements* model, *Solution* model and *Validation* model, and associated work products as shown in Figure 2.

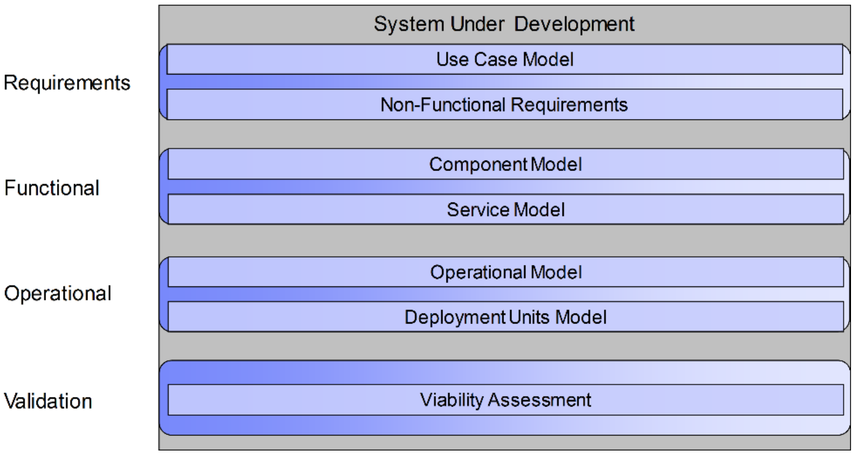

Figure 2 IBM Unified Method Framework - Artefacts that describe the complete system (Cook, Cripps & Spaas, 2007, p. 13)

- *Requirements Model* – This model describes what the system will do and includes the business, technical, functional and non-functional requirements. The typical elements of the Requirements model are the Use Case Model and the Non-Functional Requirements work products.
- *Solution Model* – This model describes the elements in the system and consists of two sub-models – *Functional* and *Operational*. The Functional Model describes the components and data in the system while the Operational Model describes where the components are placed.
- *Validation Model* – This model captures the criteria for viability assessment of the proposed system.

If using the traditional UMF approach, the cloud architectural decision captured in the Operational Model is reliant upon the work products above it. In our proposed approach, we allow the cloud architectural decision in the Operational Model (at the Operational Level) to be made at the Requirements Level based on the Use Case Model and Non-Functional Requirements work products, without the need to elaborate on the Component Model and the Service Model. The non-functional requirements identified in the requirement phase contribute to platform requirements sizing, project duration estimation, management and maintenance fees, network dimensions, professional services, and corresponding costs that help populate the cost calculator.

5.3 Our Approach

We propose a structured, yet flexible cloud architectural decision framework as shown in Figure 3. The aim of the framework is to enable business users, business analysts and/or solution leads to bring forward the decision whether to deploy their application/s on the cloud - public or private. At the start of the decision-making process, the business SME is presented with a business case for cloud migration and is required to make a choice from multiple alternatives – *traditional IT*, *private cloud*, *public cloud* or combinations of them.

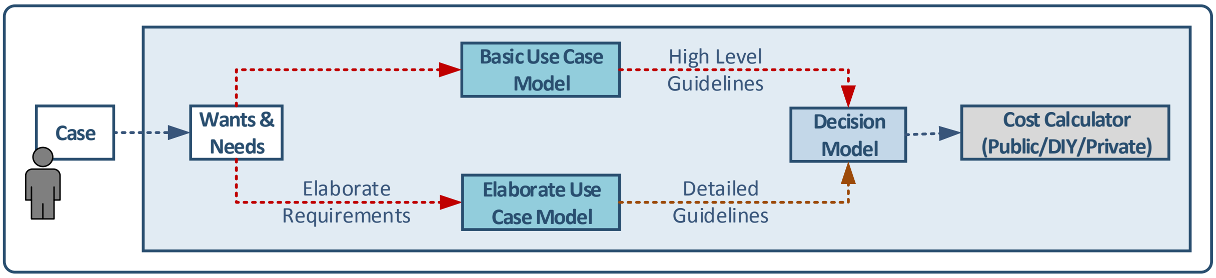

Figure 3 Cloud Platform Architectural Decision Framework

5.3.1 Wants and Needs

The first step in the decision-making process is to identify the key business drivers underpinning the migration initiative and corresponding decision. For example, in the use case scenario presented in Section 3, the enterprise – (a) Improve contact centre staff work-life balance through support for working from home in order to improve staff retention, (b) Use the large volumes of customer interaction data to predict the reasons why customers may contact in future

5.3.2 Streamlined Decision Process

Having identified the basic wants and needs, there are two alternative paths to the decision model. The recommended approach (Cook 2017) is to produce detailed work products in each stage of the solution element i.e. the component model, service model, operational model and the deployment units model (see Figure 2) in order to have a high level of confidence in the decision-making. However, in certain situations, it makes sense to use a streamlined approach and make the decision with a reasonable confidence level. Therefore, we propose a streamlined process for decision-making, which involves the development of a BUCM based on the *Business Wants and Needs,* and use of high-level guidelines to provide an indication of the cloud architectural decision with a reasonable level of confidence.

Basic Use Case Model

Our BUCM is a simplified extension of the existing TOGAF work product – Use Case Model (The Open Group 1995) with a set of essential criteria (Australian Government 2014; Konet et al. 2011) from each layer of the system architecture (see Table 1) that provides a means to make the cloud architectural decision confidently, despite the early stage in the lifecycle.

High-level Guidelines

Once the BUCM is developed, the next step is to make a decision on the appropriate cloud architecture. In the streamlined approach, we propose a set of high-level guidelines (as shown in Table 2) to provide an indication of the architectural decision. The streamlined approach is appropriate if resources in the enterprise are constrained or time is not available and a decision is required with a reasonable confidence level. An early decision may be required in the following business scenarios:

- In a digital era where disruptive business can arise to upset a business model, business are required to adapt quickly, hence for business initiatives that are required in response, business subject matter experts or IT practitioners can respond early using this framework.
- A business SME does not have access to an IT team; however, they have a credit card to buy cloud services; something that was not possible prior to cloud computing.
- Due to a business case being required to secure funding for a business initiative, the decision for public, private, DIY or a combination is required to inform the business case or to secure funding in the following financial year.

- Where a viability assessment is required for a business initiative, an early decision will be required to confirm the technical and financial viability.

Criteria	**Explanation**
Application Architecture	Which category of application architecture does yours fall into: Legacy, cloud native, cloud foundry, service-oriented?
Application Availability	What is the availability requirement? Does the application have a monolithic architecture that requires availability higher than 99.95% or a cloud-native architecture that requires 99.9-99.95%?
Application Usage	Is the application usage fixed all year round or variable?
Data Classification	Is the application data sensitive or publicly available?
Enterprise Control	Does the enterprise intend to control and manage the platform on which the business functions are deployed?
Regulatory Requirements	Does the application have any regulatory requirements such as Australian Government Information Security Manual (ISM) AS/NZS ISO/IEC 27001:2006, AS/NZS ISO 9000, FIPS 140-2 , Australian Earthquake Loading Standard AS1170, APRA certification and PCI Compliance
Technology Standardization	Does the application utilise commodity or prolific computing hardware and system software?

Table 1 Essential criteria for building Basic Use Case Model

Decision Criteria	**Enterprise (Non-cloud)**	**Private Cloud**	**Public Cloud**
Application Architecture	Monolithic	Monolithic	Cloud-Native
Application Availability	>99.95%	>99.95%	99.9% or 99.95%
Application Usage	Static	Static	Variable
Data Sensitivity	High	High	Low
Enterprise Control	Keep	Keep	Migrate
Regulatory Requirements	High	High	Medium
Technology Standardization	Low	Medium	High

Table 2 Basic Guidelines for Cloud Architectural Decision

5.3.3 Detailed Decision Process

If an enterprise has sufficient resources and time available, we propose a detailed decision process that helps to make a cloud architectural decision with a high level of confidence. The first step in this process, involves requirements gathering at the business, system, component and cloud platform layers. This is an iterative process where requirements from each category are refined as they are traced, workshopped, negotiated and agreed in a time-boxed activity. As part of our framework, we propose the following set of guidelines for detailed requirements gathering.

- **Business Requirements** – The business requirement is a statement of what is required to achieve the business objective. It describes the business need in a tangible and measurable manner and provides the scope of the project.
- **System Requirements** – The next step is to elaborate the business requirements into system requirements. A system requirement is a capability that specifies a required behaviour (functionality) that a system will exhibit in the solution to be developed. It is the top-level requirement for a product that contains multiple subsystems.
- **Component Requirements** – The next step is documenting component requirements for each system/sub-system. An example of a Component requirement is a software requirement that is generated to satisfy the system requirements allocated to a given component. This includes all non-functional, performance and integration requirements required to meet the system requirement.
- **Cloud Platform Requirements -** Finally, more component requirements in the form of Cloud Infrastructure requirements are documented to enable an architectural decision between public and private cloud. The infrastructure requirements need to extend from compute, virtualisation, ISV recommended configuration (if a package), storage, data centre network, MPLS network,

networking between data centres (all with estimates of network bandwidth requirements based on peak of peak transaction rates or average peak transaction rates).

Criteria	**Explanation**
Availability	What is the required availability?
Business Service Availability	What is the business service availability requirement?
Long running business process	Is the business process associated with the application long or short running? Is it variable?
Application Usage	Is the usage static or variable?
Regulatory requirements	Does the application have any regulatory requirements such as Australian Government Information Security Manual (ISM) AS/NZS ISO/IEC 27001:2006, AS/NZS ISO 9000, FIPS 140-2 , Australian Earthquake Loading Standard AS1170, APRA certification and PCI Compliance
Operating costs	Do the operating costs of the platform vary due to marketing campaigns or seasons?
Performance	What is the peak transaction rate? What is the reserved bandwidth requirement to meet the performance requirement?
Application Architecture	Which category of application architecture does yours fall into: Legacy, cloud native, cloud foundry, service-oriented?
Application Constraints	Bare metal, storage speed requirements, network bandwidth requirements at average peak of peak rate
Security	Physical appliances or Virtual appliances
Data security classification	Does the data used by the application have an Australian Government classification?
Network Global Load Balancing	Does your solution require Global Load Balancing outside the two cloud data centers?
Connectivity to a private MPLS network or internet VPN	Consider the charges associated with bandwidth of data transferring in/out of the Cloud Data Centre [28]
Hypervisor	Hypervisor version required by the application
Enterprise Control	Does the enterprise wish to control and manage the IT and network platform?
Data Classification	Is the data sensitive or publically available?
Technology Standardisation	Does the application utilise commodity or prolific computing hardware and system software?

Table 3 Detailed criteria for building Elaborate Use Case Model

At the end of this process, a DUCM with an associated set of guidelines is developed to help make the architectural decision. The criteria shown in Table 3 extend the TOGAF Use Case Model (The Open Group 1995) to include those that have been identified in (Australian Government 2014) (Konet et al., 2011) (Fahmideh et al., 2016) and through extensive industry experience. The next step is to make the cloud architectural decision based on a set of detailed guidelines. While we have elaborated on the high-level guidelines for the streamlined decision process, we intend to elaborate on the guidelines for the detailed decision process in future work.

5.3.4 Cost Calculator

Subsequent to making the technical decision, it is necessary to evaluate its financial implications. The last step in our framework deals with evaluating the cost effectiveness of the proposed decision. To support this, our framework includes calculators for public and private cloud as well as DIY options. As mentioned in Section 5.2, non-functional requirements identified at the Requirements Level contribute to populating the cost calculator with the different costs associated with the cloud architectural decision. This includes costs related to professional services, production infrastructure, disaster recovery infrastructure, monitoring & management services, and data centre and platform lifecycle management. After providing this input, the user can view the cost summaries across all options and validate their technical decision. The calculator provides the perfect vehicle to verify that cloud economics work out as perceived for the application under consideration. It allows users to compare the costs across private, public and DIY options and helps assess the viability of the cloud architectural decision.

To derive the private cloud calculator, we used the VCE calculator (Forrester, 2016) and added additional costs that directly affect the enterprise, notably data network connectivity to a private network from a data centre facility, monitoring and maintenance and backup. We did not capture Data Centre costs, as these are relative for DIY and Private Cloud. Similarly, for public cloud, we used the calculators provided by public cloud providers such as Amazon and Microsoft and augmented this with High Level Design and Detailed Design of the infrastructure solution, data network connectivity to a public cloud from a data centre facility, ingress charges and backup.

5.4 Illustration of the framework using sample scenario

We use the sample scenario from Section 3 to demonstrate how our proposed framework helps with the cloud architectural decision. The streamlined decision process based on the essential criteria listed in Table 1 and the guidelines listed in Table 2 selects private cloud as the best choice. Using our calculator, we find that (a) the private cloud is 69% cheaper than the public cloud for the Avaya Contact Centre, (b) the private cloud is 15% lower than DIY, and (c) in fact, as the private cloud becomes the chosen platform and uses 3x the capacity in the converged infrastructure, the economies of scale improve further.

Decision Criteria	**Private Cloud**	**Explanation**
Application Architecture	Monolithic	Legacy application architecture
Application Availability	>99.95%	99.97%
Application Usage	Static	Static (average number of calls per day is 1,400)
Data Sensitivity	High	High (Client and payment data)
Enterprise Control	Keep	Keep (only channel available to customers)
Regulatory Requirements	High	High (PCI compliance required)
Technology Standardization	Medium	Medium (most components can be virtualized)

Table 4 Cloud Architectural Decision Model

The DIY model entails a number of costs that are not applicable in converged infrastructure for a private cloud [26 including costs related to the development of a reference architecture for the DIY setup, a solution design based on the reference architecture, and the procurement of data centre components and space. Additionally, there are costs related to the management and maintenance of the bespoke solution. As a simple illustration, if an enterprise was to accept this task and each support staff with appropriate skills cost $200K per annum, then the total cost of a team of three employees over a five-year term equates to $3,000,000 to sustain a DIY platform (Gartner 2014). Alternatively, private cloud has the following advantages including shorter time to value, low cost of operations and mitigation of support risk (Messmer 2012). 50 days from purchase, a physically configured private cloud system that will be deployed to the enterprise data centre. As part of the 24/7 ITIL-based managed service, the private cloud service provider who is responsible for renewing the platform and keeping it evergreen, takes a known, pre-tested, pre-validated set of patches from the Release Certification Matrix to deliver periodic low risk software/firmware updates to the platform (Durkee 2010).

6 Conclusion and Future Research

This paper introduced a structured, yet flexible cloud architectural decision framework for diverse application architectures. The main purpose of the framework is to assist enterprises looking to migrate their applications to the cloud, in making a cloud architectural decision that considers the application architecture as well as technical, financial, regulatory and quality requirements. Our framework comprises models, guidelines, tools and calculators that assist with the decision-making process and its financial validation. As part of the framework, we proposed a *streamlined approach* for making cloud architectural decisions based on a basic set of decision criteria. We defined the relevant criteria for building a Basic Use Case Model and provided the high-level guidelines for making a subsequent cloud architectural decision. We also identified a more detailed set of criteria for building a Detailed Use Case Model. The next step is to build a set of detailed guidelines associated with these criteria for making the cloud architectural decision. We also plan to work on the qualitative evaluation of the framework in various 'Use Case Models' and 'Customer Wants and Needs' scenarios. Future work will also focus on 'Hybrid Cloud' outcomes where some components of the end-to-end architecture may reside in co-location (e.g. physical appliances), while others are deployed across public and private cloud.

7 References

[1] Greverie, F. (2017). "Cloud Native Comes of Age", Cap Gemini, 12-14

[2] The Open Group. (1995). "The Open Group Framework Method v9 Template - Business Principles - Goals – Drivers", The Open Group

[3] The Open Group. (1995). "The Open Group Method Framework, TOGAF 9 Template – Use Case Model", The Open Group

[4] Basmadjian, B., De Meer, H., Lent R., and Giuliani, G. (2012). "Cloud Computing: Advances, Systems and Applications Advances, Systems and Applications", Licensee Springer, DOI: 10.1186/2192-113X-1-5

[5] Bhamare, D., Samaka, M., Erbad, A., Jain, R., Gupta, L., & Chan, H. A. (2017). "Optimal virtual network function placement in multi-cloud service function chaining architecture". Computer Communications, 102, 1-16.

[6] Gholami, M. F., Daneshgar, F., Beydoun, G., & Rabhi, F. (2017). "Challenges in migrating legacy software systems to the cloud—an empirical study". Information Systems, 67, 100-113.

[7] The Open Group. (2011). "The Open Group Framework Method - TOGAF® v9.1", Open Group Standard (G116), The Open Group

[8] Kavis, M. J. (2014). "Architecting the cloud: design decisions for cloud computing service models (SaaS, PaaS, and IaaS)". John Wiley & Sons.

[9] Yangui, S., Glitho, R. H., & Wette, C. (2016). "Approaches to end-user applications portability in the cloud: A survey". IEEE Communications Magazine, 54(7), 138-145.

[10] Chorafas, D. (2010). "Threats and Opportunities of Cloud Computing", Cloud Computing Strategies, 109–131

[11] Zimmermann, O. (2009). "An architectural decision modeling framework for service oriented architecture design".

[12] Lewis, G. (2011). "Architectural Implications of Cloud Computing". CARNEGIE-MELLON UNIV PITTSBURGH PA SOFTWARE ENGINEERING INST.

[13] Cook, D., Cripps, P., & Spaas, P. (2007). "An introduction to the IBM Views and Viewpoints Framework for IT systems". IBM developerWorks.

[14] Maresova, P., Sobeslav, V., & Krejcar, O. (2017). "Cost–benefit analysis–evaluation model of cloud computing deployment for use in companies". Applied Economics, 49(6), 521-533.

[15] Reza Bazi, H., Hassanzadeh, A., & Moeini, A. (2017). "A comprehensive framework for cloud computing migration using Meta-synthesis approach". Systems and Software, 128, 87-105.

[16] Australian Government. (2013). "Department of Broadband Communications and the Digital Economy", Australian Cloud Computing Strategy

[17] Harding, C., Members of The Open Group (2011). "The Open Group - Cloud Computing For Business", The Open Group

[18] Pamela K Ison, Members of The Open Group - Cloud Work Group. (2011), "Strengthening Business Case Using Cloud", The Open Group

[19] Von Alan, R. H., March, S. T., Park, J., & Ram, S. (2004). "Design science in information systems research". MIS quarterly, 28(1), 75-105.

[20] IBM Cloud Garage Method. (2017). "Cloud adoption and transformation framework", IBM

[21] IBM Corporation. (2014). "Cloud Computing Reference Architecture (CCRA) 4.0 Overview", IBM

[22] Forrester. (2016). "A Practical Guide for Evaluating the Value of VCE Converged Infrastructure for Data Centre Modernisation", Forrester

[23] Zheng, L., Hu Y., Yang C. (2011). "Design and Research on Private Cloud Computing Architecture to Support Smart Grid", In Intelligent Human-Machine Systems and Cybernetics (IHMSC), 2011 International Conference on (Vol. 2, pp. 159-161). IEEE.

[24] Messmer, E. (2012). "Calculating cloud ROI' gives IT managers the math to argue for cloud budget". *Network World (Online),* 22.

[25] Durkee, D. (2010). "Why Cloud Computing Will Never Be Free". Queue 8, 4, 20 (April 2010),

[26] Gartner. (2014). "Data centre Economics – What you need to know before investing millions of dollars in your data centre", 14

[27] Rasmussen. (2010). "Modeling in IBM – A Practitioners View", IBM, 2