CLOUD COMPUTING FRAMEWORK FOR AGILE DEVELOPMENT

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Abstract
The emergence of cloud computing is influencing how businesses develop, re-engineer, and implement critical software applications. The cloud requires developers to elevate the importance of compliance with security policies, regulations and internal engineering standards in their software development life cycles. Cloud computing and agile development methodologies are new technologies that have come with new approaches in the way computing services are provisioned and development of quality software respectively. However, the synergy between the two is bonded with technical and non-technical challenges. In this paper, a conceptual framework is proposed to support the process of migration of South African small, medium and micro enterprises (SMMEs) who are using agile software development methodologies to cloud computing environment. The framework is also analysed based on critical cloud computing adoption factors as recommended from previous studies on SMMEs adoption practices.

Keywords: Cloud Computing, Agile Development Methodologies, SMMEs.

1. INTRODUCTION
Cloud computing is trending within social and corporate realms and experts believe that it will reshape information technology processes in the next few years (Armbrust et al., 2009). Cloud computing affords traditional and ubiquitous smart end user devices such as PCs, tablets and mobile smart phones to access computing services that include software applications, storage facilities, processing and application development by connecting to the Internet through Web 2.0 (Buyya, Yeo, Venugopal, Broberg, & Brandic, 2009). These resources are provided and kept by providers who are remotely situated. There are generally four cloud deployment models: private cloud - the company owns and controls its infrastructure and applications running behind a firewall with virtualization, tools and policies including deployments; public cloud - resources and applications are offered as services on a subscription basis by providers; hybrid cloud – a mix of public and private clouds and Community cloud provides an infrastructure shared by more than one organisation. Each of these deployments have advantages and disadvantages associated with them (Marinescu, 2012; Mell, Grance, & Grance, 2011).

The whole cloud computing model is attractive to users of different needs as it provides the following benefits: cost saving in operation, development and fast deliveries; resources such as data, applications and tools can be accessed anywhere and by any Internet ready device with Web 2.0; offer customized computing infrastructure with convenient task-centric, on-demand way of sharing configurable shared pool of resources; facilitates collaboration and provides good conditions for green computing (Buyya, Yeo, Venugopal, Broberg, & Brandic, 2009; Marinescu, 2012).

Despite being endowed with benefits, cloud computing has challenges such as security concerns; data ownership concerns; lock-in and interoperability concerns; enterprise Support and Service Maturity; requirement for online connectivity and; anxiety among developers about a new cloud computing platform without appropriate guidance and understanding of how to effectively utilize cloud computing standard architecture (Conway & Curry, 2012; Venkatraman & Wadhwa, 2012).

In spite of significant challenges that the technology platform faces, many users, vendors and industry observers predict an optimistic future for cloud computing (Buyya et al., 2009). Worldwide, some agile developers have migrated to cloud computing environment. For instance, the R&D of Salesforce motivated migration of all software development to the cloud environment (Salesforce, 2008). However, it is evident that this migration to private cloud has mainly involved large scale companies that have the capability to create private cloud infrastructures of their own with easy access to resources and tools. Small, medium and micro enterprises (SMMEs) on the other hand have challenges in adopting private cloud computing for reasons such as lack of capital base for investing in cloud infrastructure that will accommodate all resources needed for their development activities. This leaves them with the option of subscribing to

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public clouds only. This puts them at a disadvantage and subjected to the challenges of cloud computing associated with public clouds.

The South African Government currently considers SMMEs as vital enterprises for the economy (Berry et al., 2002). They contribute 56% of private sector employment and 36% of gross domestic product (Fatoki & Smit, 2011). According to the National Small Business Act (1996), an SMME in South Africa’s finance and business services sector is an organisation of micro-business which employs up to 5 employees, or a very small business employing of up to 10 employees, or a small business employing up to 50 employees, or a medium sized business employing up to 100 employees.

A significant adoption of cloud computing solutions in South Africa especially for business owners who are technologically proficient has been observed. These adoptions have mainly been in web hosting and ecommerce (94%), email hosting/archiving (75%), customer Relationship Systems (58%), configuration and data backup (58%) and application development with 40% (Hinde & Van Belle, 2012). It will be interesting to investigate application methodologies, programming environments and tools used by these organisations who have adopted cloud computing as it was not part of Hinde & Van Belle (2012)’s study. Reason being that, certain development methodologies such as agile emphasize specific practices that may bring about issues in the form of non-technical and technical problems associated to cloud computing environment. User/developer communication limitations and programming environment lock-in are examples of non-technical and technical problems respectively (Khajehhosseini, Greenwood, Smith, & Sommerville, 2012; Sillitti & Succi, 2004).

It is against this background that this research paper aims at proposing a framework based on apparent characteristics, practices and contexts that are critical in agile development processes in order to determine successful migration to cloud computing specifically for SMMEs in the South African context. According to Sahandi, Alkhalil, and Opara-Martins (2013), a global phenomenon of cloud computing adoption in the SMMEs sector is evident; however, this research is specific to the South African context due to its unique standards and regulatory frameworks that guide Internet use.

It is envisaged that the framework will contribute to; 1. Theoretical knowledge and perceptions of technological innovation adoption frameworks as applied to agile development methodologies and cloud computing environment; 2. Determine effective interactions among the factors that contribute to successful migration; 3. Will provide guidelines to SMMEs in South Africa who are using agile development methodologies in effective transition into use of cloud computing without compromise on software quality.

The rest of this paper is organized as follows: Section 2 reveals the available literature on cloud computing environments and software engineering with a focus on agile development methodologies. In Section 3, an analysis of problems arising from developing on the cloud environment are discussed. Section 4 proposes a framework. Finally, the paper ends with a conclusion and recommendation for future work.

2. BACKGROUND

Cloud computing has over the last decade been a catchword in the computing circles and has escalated promises of a new paradigm shift in the manner in which computing services are provisioned to users individually as well as an organisation computing (Buyya et al., 2009; Pallis, 2010). Its use currently involves users using services on different levels of its architecture computing (Buyya et al., 2009; Marinescu, 2012; Mell et al., 2011). Users get access to services that include storage, access to application software, processing and application development by using various devices such as smart phones, laptops, personal computers etc. (Buyya et al., 2009). In addition to this, there are other benefits such as cost savings, increased capacity and capabilities to Information Technology departments.

While there has been apparent significant benefits in the use of cloud computing, adoption of cloud technologies is still faced with doubts by many would-be users due to some challenges such as those of security, privacy, lock-ins and uncertainties in the regulatory frameworks (Conway & Curry, 2012; Venkatraman & Wadhwa, 2012). However, there has also been substantial research in this area especially addressing challenges of the technology offerings as it will be discussed in this literature review.

2.1 HISTORICAL PERSPECTIVE AND DEFINITION OF CLOUD COMPUTING

The dawning age of cloud computing spans long before the advent of the Internet where researchers had a vision of what was termed as computer utility. For instance, in 1961, Professor John McCarthy predicted that computing would in future be structured like any other public utility such as telephone or electricity (Arutyunov, 2012). The cloud computing ideology can also be traced back to Advanced Research Projects Agency Network (ARPANET) in 1969 when Joseph Carl Robnett Licklider visualized a network of data and programs interconnected for everyone to use globally (DARPA, 1981). All these ideas had a theoretical concept of commoditizing computing services by providers who would make available services according to user requirements.
The philosophical ideas of the 1960s were introduced in the mainframes or datacentres managed by computer companies such as IBM from single installations. These were characterized by “dumb terminals” that never had any processing capacity but totally dependent on connectivity with the mainframe or minicomputer (Marshall, 1990). The target users were mainly corporate or Government institutions who also actually set them up internally due to the complexity and huge cost of maintaining them.

However, during the early 1980s, most organisations started acquiring personal computers and workstations which emerged within affordable levels. This technological landscape was perceived as bringing to an end the original utility computing philosophy. The personal computers brought about the second wave of computer revolution that focussed on digitalization where users were increasingly using computers for documents, spreadsheet and databases (Barnatt, 2010). By the 1990s, as digitalization extended to storage of pictures, company documentation, music, video etc., it started to become almost impossible to store these forms of digitized information on stand-alone computers. This led to traditional systems of client-server architectures that accommodated a dedicated storage or application server of which individual PCs would connect to and access required information (Berson, 1996).

Since the beginning of the new millennium, a new wave of computer revolution started to emerge. This new revolution calls for “atomization” and “ubiquitous computing”. Atomization is the opposite of digitalization that entails digital content to be turned back into atoms that can be realised by vision, touching and hearing. Ubiquitous computing involves development of non-traditional computing devices that promote atomization Barnatt, 2010. For instance, smart phones and iPods are ubiquitous computing devices.

This type of requirements has led to the rise of cloud computing which in a way also has evolved through a number of stages that includes grid and utility computing, application service provision (ASP) and Software as a Service (SaaS) (Marinescu, 2012; Desai & Currie, 2003).

Cloud computing creates a situation where a user application accesses computing resources through a type of service and not necessarily directly by talking to the specific CPU for processing or hard drive for storage. A precise definition of cloud computing can be difficult to define due to the fact that different technology specialists would go for different emphasis in their definition rather than most end-users. Gartner defines cloud computing as a style of computing where massively scalable IT related capabilities are provided “as a service” across the Internet to multiple external customers while Forrester defines it as a pool of abstracted, highly scalable, and managed infrastructure capable of hosting end-customer applications and billed by consumption (Gartner, 2013); while IBM states that it is an emerging computing paradigm where data and services reside in massively scalable data centres and can be ubiquitously accessed from any connected devices over the internet (Gartner, 2013; Staten, 2008).

The world’s developer of international standards, The International Organisation for Standardization (ISO) is still crafting cloud computing definition paradigms (ISO/IEC JTC 1/SC. 2011, August). Currently, The National Institute of Standards and Technology (NIST) offers a succinct definition which describes cloud computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Mell et al., 2011). Building on this, the user’s perspective can in this manner mean cloud computing being dynamically scalable, device-independent and provides task-centric resources that are accessed from the internet at a charge as per use basis from service provider’s infrastructure (e.g., Google Apps, Amazon EC2, or Salesforce.com).

With the evolution of the web to 2.0, it is prudent to speculate that cloud computing technology is geared to achieve the philosophical objective of making computing services as the 5th utility after water, electricity, gas and telephony computing (Buyya et al., 2009). It entails a radical move from the traditional client-server architecture into web service.

Figure 1 below shows the difference between a traditional computing (client-server) model and the cloud computing model. The first part (1a) in Figure 1 shows traditional client-server settings where local software is installed and data stored on personal computers. Users of these personal computers have access to enterprise applications, data storage including processing power from corporate servers (data centres). In case of software development, all the development tools and necessary databases are either stored on the local server or personal computers. The Internet is not a critical requirement until deployment time or only if there is need to access some websites and communication in terms of emails.

The second part (1b) of Figure 1 shows the cloud computing model. In this scenario, software applications and data are not stored on user’s or corporate computing devices but in the cloud. In this case, Internet connectivity is critical to have access to the required resources. Unlike in the traditional architecture, the cloud computing model requires third parties in order to facilitate access to resources. That is, you need an Internet service provider and a cloud

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services provider. Challenges of cloud services provision emanate from around these third parties (Ren, Wang, and Wang, 2012). For example; trust on how secure a connection is and not to allow intrusion.

Figure 1. Comparison of Traditional and Cloud Computing Models

Cloud computing has essentially five characteristics that are supposed to be available in its infrastructure, namely; on-demand self-service, broad network access, resource pooling, rapid elasticity and; measured service (Sitaram & Manjunath, 2012).

2.2 CLOUD DEPLOYMENT MODELS

There are four different ways in which cloud services can be deployed depending on the structure of an organisation and the provisioning location. Mell et al. (2011) defined cloud computing deployment models as private cloud, public cloud, community cloud and hybrid cloud.

Private cloud is the most secure and risk-averse cloud that has the whole cloud infrastructure belonging only to a single organisation (Armbrust et al. 2010). Normally, private clouds are considered a step to the growth of a corporate data centre where the organisation shares in-house infrastructure for cloud services. Mainly targets virtualization solutions for mission critical applications with demands for high security and low latency, and custom service levels. The main advantage is that the organisation has full control over its data, security aspects and performance. Ideally, the cloud user owns this infrastructure. This implies that such organisations should have the necessary capital outlay to host such infrastructures which in some cases result in poor economies of scale. Usually SMMEs do not have such capability, making this option unfeasible for them.

Public cloud are in real sense the early manifestation of cloud computing. The cloud infrastructure owned by a service provider that offers cloud services to the public on commercial basis, available through a public network; the Internet. Cloud services are usually sourced from very large resource pools that are shared by many other clients specializing in elastic workloads such as software development and testing application. They are synonymous to plants or factories that cater for services or utilities to clients on as demand with size of requirement arises. Structurally, they are distributed systems consisting of one or more data centres. They are normally considered an attractive option for SMMEs because they provide an economical plan for organisations to reduce IT costs and capital expenditure. SMMEs are capable of starting up or running a business with a rent an infrastructure option without an upfront capital investment in IT services. However, since public clouds are meant to serve many users on the same infrastructure, a multitenancy characteristic is created. A number of issues such as security, QoS performance management etc. are associated to this multi-tenancy effect (Ren et al. 2012). Other concerns evident in the public cloud are issues of data ownership, lock-ins, interoperability, support maturation and connectivity (Sitaram & Manjunath, 2012). Most popular public cloud providers are proprietary overlooking the challenges mentioned due to lack of cloud computing standardization.
Examples of some well-known public clouds are the Amazon Web Services (AWS) comprising of the Elastic Compute Cloud (EC2) and the Simple Storage Service (S3) which form an IaaS cloud offering and the Google App Engine which offers PaaS to its clients.

Community cloud provides an infrastructure shared by more than one organisation that have similar interests for serving a particular community. Interests can be of an industry or a business sector nature. According to NIST, "the infrastructure is shared by several organisations and supports a specific community that has shared concerns (e.g. mission, security requirements, and policy or compliance considerations). It can be managed by organisations or third parties and may exist on premise or off premise". It differs from public cloud in the sense that cloud services are provided for a certain need of end users rather a multitude of needs to different users as in the public cloud. It also differs from the private cloud due to the fact that cloud services are not provided and owned by one organisation. Architecturally, community clouds are usually implemented over various administrative domains. An example of a community cloud would be a scientific research community sharing a large distributed infrastructure. Another example would be a community of SMMEs sharing common infrastructure in application development. However, the problem is that community clouds would require hosting standard software which may not be appropriate for organisations with different approaches to software development.

Hybrid clouds are a combination of different deployments (Armbrust et al. 2010). For example, a company may decide to run its software applications on a public cloud but make storage on its private cloud. This arises in cases where private clouds are unable to meet user's quality of service requirements. They allow organisations to exploit their own IT infrastructure for maintaining sensitive information within locations at the same time be able to grow and shrink by provisioning external resources which they are able to release when not needed. Common workloads are those of regulated data that require elasticity and agility such as Business Intelligence solutions. They are sometimes referred to as heterogeneous cloud due their heterogeneity nature in distributing integrated services or resources from one or more clouds (Buyya, Vecchiola & Selvi, 2013). Being hybrid make them inherit problems of associated deployment models.

In this study we focuses on public clouds as SMMEs do not have capacity to invest in private clouds.

2.3 Cloud Technologies

In order to replace the traditional client-server approach with cloud computing, there are basically three options or service types in which services can be provisioned. These are: 1. Software as a Service (SaaS); 2. Platform as a Service (PaaS) and; 3. Infrastructure as a Service (IaaS) (Marinescu, 2012).

Figure 2 shows the services types and their relationships. SaaS is designed to provide applications as a service to end users. The approach is to provide off-the-shelf and existing web applications. Users can access the applications and still be able to customise it to their conditions and requirements. In case of off-the-shelf application not being present in the cloud infrastructure, then the SaaS becomes unsuitable. Then the user may have to use other service types that allow application development. SaaS is currently the most noticeable and used in the cloud as it mostly deals with end user software packages such as word-processing and spreadsheets. Example SaaS services are those from Google Docs and email services such as Gmail, Hotmail and Yahoo mail (Barnatt, 2010; Sitaram & Manjunath, 2012).

PaaS is designed to provide a platform service mainly for online application deployment for developers. The platform entails the operation system and the hardware associated with it. An environment is created to allow software development including test runs using development tools that are present within that particular service provider’s cloud infrastructure (Barnatt, 2010; Sitaram & Manjunath, 2012). It also facilitates speed of programming by automating some coding tasks and allows programmers to work on their programming languages and associated tools. Hence, technical programming knowledge and skills are necessary for most use of PaaS offerings. Therefore this service type is suitable for companies that choose to cloud compute or development of software although it can be restrictive in terms of resources provided by the cloud provider leading to the problem of vendor lock-in. A vendor lock-in is a situation created when a user of a service or product fails to easily change to another competitor’s service or product due to incompatible proprietary technologies. An example of PaaS is the App Engine offered as service by Google which can allow any user to write new cloud applications and be able to deploy them to the web using the Google’s cloud infrastructure (Barnatt, 2010; Sitaram & Manjunath, 2012).

The IaaS service type is a major cloud computing development meant for IT operators. It has a capability of offering services of processing, storage, networks and many other vital computing resources where a user is able to deploy and run arbitrary software (Mell et al., 2011). It includes services such as operating systems and applications. Without control of the underlying hardware in the cloud infrastructure, the user has control over the operating systems, storage, deployed applications and some limited control over networking components. Cloud providers of this service rent out servers using a process called virtualization. Server virtualization involves masking and
pooling of server resources. For example, one physical server may be configured using a special administrator software into multiple virtual servers (machines) and each acts like a distinctive physical device, capable of running its own operating system (Barnatt, 2010). In cloud computing, these virtual servers are mostly referred to as instances. The IaaS service provider can either offer dedicated physical servers or virtual server instances. Although, these two services can perform the same functions, virtual instances are sometimes regarded as insecure especially by users who do not want to share server hardware with others. For this reason, some customers may choose to use specific deployment models like private cloud only or a combination depending on the security requirements of their services or products. One example of IaaS vendors is the Amazon Web Services (Barnatt, 2010; Sitaram & Manjunath, 2012).

Figure 2. Relationships between Service Types

![Diagram of Service Types]

Source: (Barnatt, 2010; Sitaram & Manjunath, 2012).

2.4 CLOUD TECHNOLOGIES.

Considering current demand from work and personal needs for online engagements and growth of the web, cloud computing could be a manifestation of a new paradigm of a large-scale distributed computing utility for business and society solutions (Pallis, 2010).

The South African e-government initiative strongly supports IT research in development of solutions that are directed to the future IT trends and offering (Department of Public Service and Administration-Republic of South Africa, 2001). Research studies on SMMEs using cloud computing have been conducted widely in South African and at an international level. We reviewed a few studies and decided to cite two local studies mainly because most of the studies had a common approach and presented the similar results although in different contexts.

The first local study was conducted by Hinde and Van Belle (2012) on cloud adoption by SMMEs in South Africa. The study showed a potential growth in cloud computing and that slightly over 52% of respondents accepting cloud adoptions. In the same study, 65% were aware of cloud computing existence, 25% thought it was for bigger companies and 34% had an adoption model in place.

The second study by Schofield (2013) conducted with the research team of Johannesburg Centre of Software Engineering (JCSE) summed up surveys conducted in the last two years of the study which included SME Survey 2012 (Goldstuck, 2012) involving 2,000 respondents; Microsoft SMB Cloud Adoption Study 2011 (Microsoft, 2011) involving 3,258 respondents and IDG Cloud Computing Survey 2013 (IDG Enterprise, 2013) involving 1,358 respondents. The majority of companies considered in these studies belonged to the SMME category (employing up to 100 employees).

The study results agreed with Hinde and Van Belle (2012)’s findings on cloud computing adoptions. The study concluded that company owners, who were technologically capable, appreciated the value of cloud computing in usage as well as economical use as compared to those who did not understand it. Further, challenges of cloud computing such as security, bandwidth connections were also highlighted as impediments to making adoption decisions.

Going further, a study based in UK showed that SMMEs stand to benefit in reducing, costs, improving flexibility and scalability when they decide cloud computing migration. However, issues relating to security, vendor lock-in, and technical hitches with data privacy and data protection need attention (Sahandi et al. 2013). In another report, The European Commission technical report on ICT – Information and communication Technologies - Work programme 2013, a recommendation was made to strengthen software and services technologies by exploiting Internet-based services such as cloud computing. It also recommended that adoption of cloud computing should be taken with careful consideration of legal, socioeconomics and technical issues. In conclusion, the report indicated that the potential of cloud computing and its models has not yet been fully exploited in terms of development and research to the degree of full utilisation by stakeholders (European Commission, 2013).

Based on industry commentaries, it is interesting to note that although South African organisations have approached adoption of cloud computing with scepticism, South Africa has however taken a critical role in cloud computing adoptions in Africa. This is according to Sudarshan Roongta, vice-president of Oracle’s Industry Strategy and Insight programme for Europe, the Middle East and Africa (EMEA) (itWeb, (n.d.).)

SMMEs have taken a leading role in adoption followed by large enterprises. Roongta reported that 66% of enterprises in South Africa have shown “very high” confidence in the security aspect of the cloud services and only one in 10 of the decision-makers have no trust in cloud
security. This has made the security concern dropping to the third on the list of other challenges. The recent investment in the Telcos and access to international bandwidth has improved the reliability of cloud computing. He noted that by end of 2014, adoption rate in South Africa will increase from the current 56% to 66% being led by the retail and mining sectors. According to him, the Compound Annual Growth Rate (CAGR) of 35% and an investment worth $215 million would be realized in 2017. Some other useful statistics that Roongta also reported are:

- Globally, cloud computing is taking the mainstream with 82% adoptions in SaaS; 52% cloud storage; 36% IaaS; and 21% adopting hybrid cloud;
- In terms of cloud usage, most organisations (57%) are using it for human resources; 54% for e-mail collaboration; 52% for sales and marketing; 51% for customer care; 42% for supply chain; 41% for finance; 36% for sourcing; and 35% for operations management.
- 70% of the respondents indicated that cloud computing is providing tangible cost savings.

On an international arena of industry analysis, statistics from North Bridge (2013), an active partner for early-stage entrepreneurs providing seed-to-growth financing for innovative companies looking to disrupt big markets in America, indicated that SaaS has taken the main role in cloud computing adoptions although the fastest in terms of growth is the IaaS. This implies providing way to growth in the PaaS. The report indicates that SaaS is the most popular with current (year 2013) 63% from 55% a year before. However, IaaS recorded a 29% annual increase making it the fastest while PaaS is forecasted to grow fastest in the next five years. A growth in IaaS or PaaS indicates application development activities.

[44] predicts IT cloud services will have a CAGR of 23.5%, five times that of the IT industry as a whole over the 2013–2017. Another study on current actual adoption rate from a study by TheInfoPro (2013), a service entity of 451 Research, predicts an average growth rate of 36 % from this year until 2016. This study was conducted during the first six months of 2013 and involved IT management and primary decision makers of medium sized to large organisations in Europe and North America. Some notable findings in this study were:

- That sixty percent respondents believe that cloud computing is a natural evolution of IT service delivery and do not need to allocate a budget it. Out of those with a separate budget for cloud computing also believe that their spending will increase in 2013 and 2014 as compared to previous years.
- IaaS and SaaS activity has doubled to levels between 35% and 33% on projects declared, with 35% respondents indicating that private cloud activity are dominating.
- Despite increased cloud computing activity, 83% of the respondent have challenges in deploying their cloud computing initiatives. Mostly the challenges are non-technical but lie with the domain of processes, people, policy and organisational issues.

Jacobs (2013) of ITWeb, indicated that Gartner’s predictions has positioned cloud computing to number four out of the top ten technological trends for 2014 with a bulk of new IT spend in 2016.

Considering Schofield (2013), Hinde and Van Belle (2012) and Roongta’s report, we can confidently conclude that there is a positive trend in the growth of cloud computing in the South African context. However, we still not clear on the levels of cloud adoption of PaaS services specifically for software development purposes.

Some of the reasons or benefits that have led organisations migrating to cloud computing are:

- Cloud computing is being perceived as a new paradigm or next generation platform for future practices and philosophy of computing.
- Cost savings in operation, development and fast deployment of software with less failovers. There is no consideration for hardware or software for cloud services.
- Resources such as data, applications, tools and web services can be accessed from anywhere on the Internet and offers a one-stop facility for software development. It also offers easy integration of these resources with other enterprise solutions.
- Offers highly customized computing infrastructure online using the Web 2.0 strategy. These are provisioned in a convenient, task-centric, on-demand manner to a shared pool of configurable computing resources such as networks, servers, storage and applications.
- Cloud computing is collaborative, facilitating software development practices such as those of agile development methodologies.
- Cloud computing offers legal and good conditions to use less energy and waste fewer resources computing (Buyya et al., 2009; Marinescu, 2012; Mell et al., 2011).

Certain drawbacks that are associated to cloud computing especially in the absence of a cloud computing adoption framework are as follows:

- Security concerns
- Data ownership concerns
- Lock-in and interoperability concerns
Enterprise Support and Service Maturity
- Requirement for online connectivity
- Anxiety within developers about a new cloud computing platform without appropriate guidance and understanding of how to effectively utilize cloud computing standard architecture (Conway & Curry, 2012; Venkatraman & Wadhwa, 2012).

Generally, technology innovation adoption models and frameworks have been thoroughly invested and applied in information technology projects. For instance, the Technology, Organisation and Environment model (TOE) (Tornatzky, Fleischer & Chakrabarti, 1990; Hage, 1980), Diffusion of Innovation (DOI) (Rogers, 1995) and the Technology Acceptance Model (TAM) (Wixom & Todd, 2005). These models have also been combined in certain adoptions just to meet the requirement of the technology situation (Oliveira & Martins, 2011).

In most of these models, an element of social context has been considered very critical (Tornatzky et al., 1990). More recently, Werfs, Robert, Baxter, Allison and Sommerville (2013) considers that adaptive social-technical issues can inform adoption processes of disruptive technologies such as cloud computing. These involve complex interaction among humans, technology and the environment.

With specific reference to cloud computing, we found a wealth of literature on cloud computing adoptions of which may also be applicable to SMMEs in the South African context. We reviewed the Cloud Computing Toolkit by Khajeh-Hosseini et al., (2012) which has not yet reached maturity, the cloud adoption Goal-Oriented Requirements Engineering Approach (GORE), an interactive process of adoption (Zardari & Bahsoon, 2011), Bidgoli (2011)’s six step process model that does not pay much attention to organisational issues and finally the Alshamaila and Papagiannidis (2013) analysis of the TOE based on the SMEs in the UK.

In this research we, consider the cloud computing adoption using Alshamaila and Papagiannidis (2013) analysis. The reason for this choice is motivated by the fact that it is more recent, involved SMEs and the process framework addresses most of issues associated to information technology companies. The main factors which were found to be playing a critical role in the adoption process were relative advantage, uncertainty, geo-restriction, compatibility, trialability, size, top management support, prior experience, innovativeness, industry, market scope, supplier efforts and external computing support.

Those that fall in the technology context are as follows:

- **Relative advantage**: refers to as: “the degree to which an innovation is perceived as being better than the idea it supersedes” (Rogers, 2003). It is considered as a central indicator to adopting a new technology in information systems innovation. The probability of adoption is enhanced when a business realizes a relative advantage in an innovation (Thong, Yap & Raman, 1994; Lee, 2004).
- **Uncertainty**: referred to as “the extent to which the results of using an innovation are insecure” (Fuchs, 2005). This indicates knowledge deficiencies on an innovation by stakeholders. In the case of cloud computing lack knowledge expertise in areas such as security, privacy and lock-in are evident especially for SMMEs.
- **Geo-restriction** is the uncertainty factor about data location. There is a possibility that consumers may not be able to know the exact location where their data is stored and processed. Depending on need, consumers should be allowed to sign SLAs with an option of knowing about data location.
- **Compatibility**: Refers to: “the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters” (Rogers, 2003). Compatibility is considered an important factor of an IT innovation (Rogers, 2003).
- **Trialability**: Refers to: “The degree to which an innovation may be experimented with on a limited basis” (Rogers, 2003).

The organisation context has the following factors:

- **Organisation Size**: this refers to the organisational size (Alshamaila & Papagiannidis, 2013). Small businesses are more motivated to adopt cloud services.
- **Top management support**: Refers to: the plan of action that dedicates time for ICT program in relation to cost and potential, plan reviews, results follow-ups and coordinating integration of ICT with management processes of business (Young & Jordan, 2008).
- **Prior technology experience**: Refers to “the extent of a user’s experience with previous similar technologies” (Lippert & Forman, 2005).
- **Innovativeness**: Refers to: “the extent to which a client adopts innovations earlier than other members of the same social context” (Rogers & Shoemaker, 1971).

Finally, the environmental context involves the following factors:

- **Industry**: Refers to: “the sector to which the business belonged” (Goode & Stevens, 2000).
- **Market scope**: Refers to: “the horizontal extent of a company’s operations” (Zhu, Kraemer & Xu, 2003).
• Supplier efforts and external computing support: Refers to: “the supplier activities that can significantly influence the probability that an innovation will be adopted “(Frambach, Barkema, Nooteboom, & Wedel, 1998).

2.5 SOFTWARE ENGINEERING AND AGILE DEVELOPMENT METHODOLOGIES

Software can be classified as a product of a design process by software engineers. It is a systematic amalgamation of programs that are made to run within a computer system that can be of any size, and architecture. Today’s business can hardly optimally be operational without a presence of software in their systems. The choice of software by companies varies depending on the requirement which has a direct influence in the way software is created. Pressman (2010) gives a textbook definition of software as one that consists of three pillars as follows: 1. instructions consisting of programs that when executed provide function and performance, 2. data structures that enable the programs to adequately manipulate information, and 3. documents that describe the operation and use of the programs. However, it is paramount to understand software when you consider its characteristics. The basic characteristics are that software systems are abstract and intangible. As a product, it is developed, does not wear out and mostly it is custom built. These characteristics are varied from those of hardware engineered products. It is usually developed for a particular customer even when concepts such as re-usability are encouraged.

The early software applications until the 1960s were largely developed devoid of an explicit information system development methodology. These practices brought about a number of challenges in user satisfaction ranging from cost, time and scope perspective. After this era a number of thoughtful efforts such as Systems Development Life Cycle (SDLC) have been made to understand the software development process. These efforts were mainly done in order to improve the quality of software during and after its development by addressing challenges of the previous unconventional era (Avison & Fitzgerald, 2006).

The result of these efforts has been value addition to the final software product and improvement in delivery times. However, these achievements could not preclude technical challenges as well as development process skills that continue to affect the SDLCs (White & Leifer, 1986). In South Africa, it is common to find problems within developing organisations such as software failures, budget over runs and late delivery to satisfy clients who are in need of quality software due to problems that are everywhere within the development environment. Mostly, these are associated with incomplete user requirements.

Newer approaches such as agile methodologies were introduced to software development in order to address issues of software quality although the quality aspect has been and continues to be subject of research in the software engineering domain. In agile development, the quality aspect is inherent in the development process. Agile methodologies are an alternative to traditional waterfall approach of software development. It can be defined theoretically as a group of software development processes that are iterative, incremental, self-organizing, and emergent (Keith, 2002).

With agile methodologies, prescribed values, principles and practices are recommended for successful software project implementation (Keith, 2002). Agile development requires distinctive tools such as feedback, transparency in communications, and time-boxing. Therefore, organisations that adopt agile methodologies need to implement an environment with an integrated toolset comprising tools for measurement, bug tracking, design, analysis, testing, coding, business intelligence and critiquing, just to mention a few. In addition, open source tools and proprietary tools need to be carefully coordinated to deliver successful projects (Sillitti & Succi, 2004). Success in this context means delivering a software product within the agreed time and budget constraints and at the same time meeting the anticipated user requirements from the project sponsor (Mnkandla, 2008).

In principle, cloud computing environment facilitates speedy provision of tools and infrastructural resources to agile development teams who also add value by continuous development of a software product through iterations and incremental approach. However, Werfs et al. (2013) classifies cloud computing among disruptive technologies. They further claim that when making decisions to adopt cloud computing, careful analysis should be made in light of 1. The type of cloud that is intended for use; 2. How the product’s functionality will be offered; 3. The cloud service provider to use and; 4. The pricing structure to be used for the services and products. As much as one would be keen to make decisions of cloud exploitation, a decision making process based on the above could complex depending nature of activities or services required.

Research shows an increase in the adoption of agile methods by developers in South Africa. However, there is little evidence to show which specific agile methodology is being adopted. The development platform has mostly been on stand-alone and traditional client-server architectures. However, as observed from Hinde and Van Belle (2012), application development within the cloud environment by SMMEs within South Africa is evident but it is not clear that these adoptions involve agile methodologies. Worldwide agile development in cloud environment has been successful although these experiences are only for large
Exploration and innovation within a team by trying new ideas on server working environments (Brynjolfsson, Hofmann & Jordan, 2010).

While cloud computing has the capability of facilitating agile development practices in theory, the actual practical aspect has some challenges arising from non-technical and technical assumptions and constraints. Some challenges as depicted from an industry expert include non-technical problems such as inadequate training, poor leadership, and rigid adherence to agile principles that do not fit into the project (Stafford, 2013). Technical problems arise from Internet access and its assumptions about co-locations, latency, and errors cannot be easily made. As a result, problems such as not having required meetings, inadequate documentation and issues related to short iterations are experienced. In addition, due to the fact that computing resources can shrink and grow on demand requires proper planning if the benefit of cost saving are to be realised while keeping good qualities of service, otherwise this may affect development processes (Armbrust et al., 2009).

Ramesh, Cao, Mohan and Xu (2006) also identified five specific challenges that apply to agile distributed software development as follows: 1. Communication need vs. communication impedance, 2. Fixed vs. evolving quality requirements, 3. People- vs. process-oriented control, 4. Formal vs. informal agreement, and 5. Lack of team cohesion. Distributed software development is modelled around IT development teams spread out geographical locations but collaborate with each other on applications through mini-projects in order to develop final software. Modern web based techniques and tools such as cloud computing facilitate smooth running of activities in a distributed manner.

**Communication need vs. communication impedance.**

As indicated earlier, agile development methodologies do not depend on formal documentation but informal interactions within the team of developer and users. The distributed software development environment however requires that formal mechanisms such as designs are put in place for geographically separated locations. This raises a question on how you can balance formality of communication in agile distributed software development platforms.

**Fixed vs. evolving quality requirements.**

Distributed software development will normally require fixed and upfront agreements on quality requirements because of limited capability to control activities of distantly located teams. On the other hand agile requires an ongoing negotiations environment between developers and users as in the process of arriving at acceptable levels of quality on different phases of development. The issue of balancing between fixed and evolving quality requirements need to be addressed in these circumstances.

**People- vs. process-oriented control.**

The question of concern here is how you apply a suitable balance between people and process-oriented control in agile distributed development. The reasoning behind this question is based on the nature of distributed environments that are process oriented while agile is more of people oriented through informal processes and practices.

**Formal vs. informal agreement.**

Agile development environments normally involve informal contracts while distributed development requires formal agreements especially on targets, milestones and requirement specifications. This situation requires a balancing act between levels of contract formality appropriate in the agile environment.

**Lack of team cohesion.**
Team cohesion in distributed development where developers and users are in different locations is not as binding as in co-located environments. This even makes it worse when agile development processes are used because they emphasise on continuous collaboration on all stages and aspects of the development project.

Some guidelines in form of a framework on migration are necessary to aid these SMMEs in making decisions on how to maximize benefits and optimize usage of cloud environment.

3. ANALYSIS

The current rate of emergence of cloud computing poses a big challenge for the need to embrace it. For many reasons outlined by computing (Buyya et al., 2009; Conway & Curry, 2012; Venkatraman & Wadhwa, 2012; Pallis, 2010; Arutyunov, 2012; European Commission, 2013; Brynjolfsson et al. 2010; Armbrust et al. 2010; (Vaquero et al., 2009), it is an indication that we are sitting at a critical stage of the most significant trend in information technology industry. Despite the explosion, there has been no clear contextual definition of cloud computing while at the same time it is crucial to understand the requirements and challenges of cloud applications if one has to fully benefit from its environment (Pallis, 2010). This is a problem, for instance, agile development proponents would like to emphasize certain characteristics of cloud computing to meet their goals. Hence the need to define its own cloud computing framework within their requirements and use.

Without a framework and specific cloud computing description, there are a number of challenges that are likely to be experienced especially by SMMEs as they decide to migrate to the cloud environment such as anxiety within developers about a new cloud computing platform without appropriate guidance and understanding of how to effectively utilize cloud computing standard architecture. These problems are likely to emerge from the perspective of technical and non-technical limitations (Hinde & Van Belle. 2012; Sillitti & Succi, 2004). Literature has shown that there are several frameworks and decision models for cloud migration (Oliveira & Martins, 2011). However, agile migration is the most desired and concerns raised by the researchers are on some critical aspects associated to agile that are lacking in current frameworks.

4. PROPOSED FRAMEWORK

Based on literature surveyed in this research on current trends in cloud computing and agile software development practices, we propose to develop a framework that addresses the following problems:

- Determine effective interactions among the factors that contribute to successful migration; and
- Provide guidelines to SMMEs agile developers in South Africa for effective transition into use of cloud without compromise on software quality.

In order to achieve the above, an innovative approach is required to leverage all the benefits of cloud when used with agile software development so as to mitigate technical and non-technical challenges. We therefore hypothesize framework building with the following considerations:

- Important factors to consider in migrating agile development methodologies to cloud computing.
- Management of the process of migrating agile development methodologies to cloud.
- Roles of different stakeholders within and outside the organisation in ensuring successful migration.

Table 1 shows a framework exposition that addresses proposed activities and information required for the framework in order to address envisaged challenges during the migration process.

Table 1. Activity Versus Information Requirement for Framework

<table>
<thead>
<tr>
<th>Activity</th>
<th>Information Required for Framework</th>
<th>Variable(s) and/or Relationships measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>DETERMINE EXISTING ENVIRONMENT</td>
<td>Agile methodology in use</td>
<td>These will be identified through the coding of interviews transcripts, observation schedules. Literature and document reviews.</td>
</tr>
<tr>
<td></td>
<td>Cloud computing services in use/required</td>
<td>Tests; Content Analysis and Correspondence Analysis</td>
</tr>
<tr>
<td></td>
<td>Type of applications and tools in use/required to develop software in cloud computing environment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Perceptions held by agile software developers with respect to cloud computing</td>
<td></td>
</tr>
</tbody>
</table>
Based on literature, we analyze each activity in the proposed framework in order to give further information and clarity as in Tables below:

Table 2.1 shows the approach to determine existing environment.

Table 2.1 Existing Environment

<table>
<thead>
<tr>
<th>Information Required for Framework</th>
<th>Possible factors for analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agile methodology in use</td>
<td>Extent to which an agile methodology such as scrum/Extreme Programming is used</td>
</tr>
<tr>
<td>Cloud computing services in use/required</td>
<td>Extent to which developers use PaaS, IaaS Service Types</td>
</tr>
<tr>
<td>Type of applications and tools in use/required to develop software in cloud computing environment</td>
<td>Extent of programming experience with programming tools in the cloud</td>
</tr>
</tbody>
</table>

Table 2.2 shows the approach to evaluate conditions for successful migration. It addresses information required for factors responsible for success in migrating organisation’s agile development to cloud computing with specific reference to technology factors.

Table 2.2 Technology factors

<table>
<thead>
<tr>
<th>Information Required for Framework</th>
<th>Possible factors for analysis (Alshamaila &amp; Papagiannis, 2013)</th>
</tr>
</thead>
</table>
| Factors responsible for success in migrating organisation’s agile development to cloud computing | - **Relative advantage:**  
  o The degree to which an innovation is perceived as being better than the idea it supersedes.  
- **Uncertainty:**  
  o The extent to which the results of using an innovation are insecure.  
- **Geo-restriction:**  
  o The degree of uncertainty about data location.  
- **Compatibility:**  
  o The degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters.  
- **Trialability:**  
  o The degree to which an innovation may be experimented with on a limited basis. |

Table 2.3 shows the approach to evaluate conditions for successful migration. It addresses information required for factors responsible for success in migrating organisation’s agile development to cloud computing with specific reference to organisational factors.
Table 2.3 Organisational factors

<table>
<thead>
<tr>
<th>Information Required for Framework</th>
<th>Possible factors for analysis (Alshamaila &amp; Papagiannidis, 2013)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Organisation Size:</td>
<td>o The size of a business in terms of:</td>
</tr>
<tr>
<td></td>
<td>➢ The market share of the business;</td>
</tr>
<tr>
<td></td>
<td>➢ The level of sales turnover</td>
</tr>
<tr>
<td></td>
<td>➢ The number of employees.</td>
</tr>
<tr>
<td></td>
<td>➢ The value of the business</td>
</tr>
<tr>
<td></td>
<td>➢ The value of capital employed</td>
</tr>
<tr>
<td>• Top management support:</td>
<td>o The degree of support from management on:</td>
</tr>
<tr>
<td></td>
<td>➢ The plan of action that dedicates time for ICT program</td>
</tr>
<tr>
<td></td>
<td>in relation to cost and potential,</td>
</tr>
<tr>
<td></td>
<td>➢ Plan reviews,</td>
</tr>
<tr>
<td></td>
<td>➢ Results follow-ups and coordinating integration of</td>
</tr>
<tr>
<td></td>
<td>ICT with management processes of business.</td>
</tr>
<tr>
<td>• Prior technology experience:</td>
<td>o The extent of a user’s experience with previous similar</td>
</tr>
<tr>
<td></td>
<td>technologies.</td>
</tr>
<tr>
<td>• Innovativeness:</td>
<td>o The extent to which a client adopts innovations earlier</td>
</tr>
<tr>
<td></td>
<td>than other members of the same social context.</td>
</tr>
</tbody>
</table>

Environmental Factors

<table>
<thead>
<tr>
<th>Information Required for Framework</th>
<th>Possible factors for analysis (Alshamaila &amp; Papagiannidis, 2013)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Industry:</td>
<td>o Determine a business sector within software development.</td>
</tr>
<tr>
<td>• Market scope:</td>
<td>o The horizontal extent of a company's operations.</td>
</tr>
<tr>
<td>• Supplier efforts and external computing support:</td>
<td>o Determine supplier activities that can significantly influence the probability that an innovation will be adopted.</td>
</tr>
</tbody>
</table>

Table 2.4 shows the approach to evaluate conditions for successful migration. It addresses information required for factors responsible for success in migrating organisation’s agile development to cloud computing with specific reference to environmental factors.

Table 2.4 Environmental factors

<table>
<thead>
<tr>
<th>Information Required for Framework</th>
<th>Possible factors for analysis (Alshamaila &amp; Papagiannidis, 2013)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Industry:</td>
<td>o Determine a business sector within software development.</td>
</tr>
<tr>
<td>• Market scope:</td>
<td>o The horizontal extent of a company's operations.</td>
</tr>
<tr>
<td>• Supplier efforts and external computing support:</td>
<td>o Determine supplier activities that can significantly influence the probability that an innovation will be adopted.</td>
</tr>
</tbody>
</table>

Table 2.5 shows the approach to evaluate conditions for successful migration. It addresses information required for assessing difficulties and weaknesses for the framework.

Table 2.5 Difficulties and weaknesses

<table>
<thead>
<tr>
<th>Information Required for Framework</th>
<th>Possible factors for analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulties or weaknesses encountered during the process of migrating to cloud computing</td>
<td>The extent of system weaknesses and difficulties in the migration process.</td>
</tr>
<tr>
<td>Factors responsible for the difficulties and weaknesses during the process of migrating to cloud computing</td>
<td>Decode from the weaknesses identified earlier.</td>
</tr>
<tr>
<td>Difficulties or weaknesses encountered during the process of migrating to cloud computing</td>
<td>Decode from the difficulties identified earlier.</td>
</tr>
</tbody>
</table>

Table 2.6 shows the approach to evaluate interactions of successful factors for the framework.
Table 2.6 Interaction of Success factors

<table>
<thead>
<tr>
<th>Information Required for Framework</th>
<th>Possible factors for analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction between factors that are responsible for success in migrating to cloud computing</td>
<td>Analysis of interactions of identified factors in “Factors responsible for success in migrating organisation’s agile development to cloud computing”.</td>
</tr>
<tr>
<td>Interaction between factors that are responsible for the difficulties/weaknesses in successful migration</td>
<td>Analysis of interactions of identified factors in “Factors that are responsible for the difficulties/weaknesses in successful migration”.</td>
</tr>
<tr>
<td>Relationship between factors that account for success and those that account for difficulties and weaknesses</td>
<td>Analysis of relationships of identified factors in “Factors that account for success and those that account for difficulties and weaknesses”.</td>
</tr>
</tbody>
</table>

5. CONCLUSION/FUTURE WORK

Developing software in a cloud computing environment differs from the traditional approach. It makes it even more challenging when methodologies such as agile are used due to the fact that there is great need for interaction both technical and non-technical (such as sharing applications or development tools, communication and coordination) during development and deployment processes.

In this paper, a conceptual framework is proposed yet to be tested empirically through further investigation. The main thesis of this paper is that the migration process to cloud computing by SMMEs should be guided by a framework in order to mitigate all the challenges that are associated to cloud computing environments.

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7. REFERENCES


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