Migrating Agile Development into the Cloud Computing Environment

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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.

Keywords-Cloud Computing, Agile Development Methodologies, SMMEs

I. 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 [1]. 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 [2]. These resources are provided and kept by providers who are remotely situated. There are generally three 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; and ***hybrid cloud*** – a mix of public and private clouds. Each of these deployments have advantages and disadvantages associated with them [3].

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 [2]-[3].

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 [4]-[5].

In spite of significant challenges that the technology platform faces, many users, vendors and industry observers predict an optimistic future for cloud computing [2]. 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 [6]. 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 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 [7]. They contribute 56% of private sector employment and 36% of gross domestic product [8]. According to the National Small Business Act (1996), an SMME in South Africa's finance and business services sector is an organization 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

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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% [9]. It will be interesting to investigate application methodologies, programming environments and tools used by these organizations who have adopted cloud computing as it was not part of [18]'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 [10]-[11].

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. A global phenomenon of cloud computing adoption in the SMMEs sector is evident [12]; however, this research is specific to the South African context due to 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.

II. 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 organization [2] & [13]. Its use currently involves users using services on different levels of its architecture [2] - [3] & [14]. 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. [2]. 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 [4]-[5]. 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.

A. 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 [15]. 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 [16]. 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 [17]. 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 organizations 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 [18]. 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 [19].

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 digitization 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 [18]. 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) [3] & [20].

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 [21].

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 [14]. 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 [2]. It entails a radical move from the traditional client-server architecture into web service.

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 [22].

On-demand self-service aims to reduce the configuration tasks from the user's point of view where resources such as the compute, storage or platform are self-provisioned or automatically configured. Other than creating accounts on a service provider, a user may not interact physically with the service provider's staff to have access to resources. Broad network access is a ubiquitous characteristic that allows access to resources using any device such as phones, PCs etc. as long as it is connected to the Internet and running a web browser. Resource pooling implements virtualization and multi-tenancy by supporting many concurrent users. Rapid elasticity creates a service platform or resource that increases or decreases according to user requirements. It is possible to declare the number of servers that one needs. This significantly aids cost saving in capital investments where organizations would not invest in computing resources that are often idle. Measured service is a "pay as you go" facility that literally removes the element of computing equipment being a fixed cost [18] & [22].

B. Cloud Deployment Models

[14] also defined cloud computing deployment models as follows: Private cloud –This is the most secure and risk-averse cloud that has the whole cloud infrastructure belonging only to a single organization; Community cloud is a cloud infrastructure shared by more than one organizations that have similar interests for serving a particular community; Public cloud is a cloud infrastructure owned by a service provider that offers cloud services to the public on commercial basis and the Hybrid clouds which are a combination of different [3]. For example, a company may decide to run its software applications on a public cloud but make storage on its private cloud. This research however, focuses on public clouds as SMMEs do not have capacity to invest in private clouds.

C. 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) [3].

Figure 1 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 [18] & [22].

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 [18] & [22]. 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 [18] & [22].

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 [14]. 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 [18]. 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 [18] & [22].

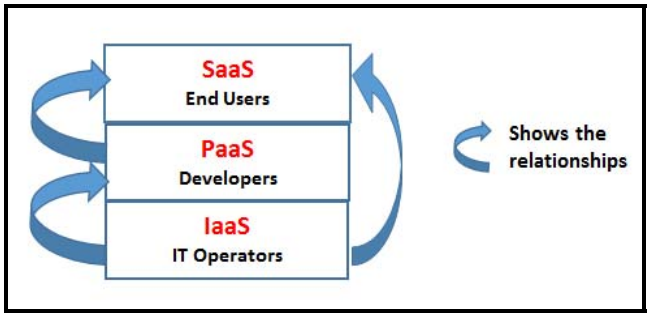

Figure 1: Relationships between Service Types (Adapted from [22])

D. Cloud Computing Adoption and Growth

The European Commission technical report on ICT – Information and communication Technologies - Work programme 2013 suggested building industrial strength in software and services technologies by exploiting Internet-based services such as cloud computing. It also recommended adoption of cloud computing at the same time taking into account of legal, socioeconomics and technical issues. The report generally concluded 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 [23].

The South African e-government initiative strongly supports IT research in development of solutions that are directed to the future IT trends and offering [24]. Although there are elements of scepticism, cloud computing, an emerging technology, has in the recent past entered the mainstream industry due to its competitive edge [25]. 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 [13].

In contrast to utilities such as electricity, cloud computing is still in the limelight of innovative research from service provision to technology developments. This contributes to a problem of identifying appropriate tools and practices in cloud environments [13] & [25]. Some companies that adopted cloud computing without much consideration have ended up losing out on some benefits such as those of new technology for reasons such as lock-ins. With cloud computing, there are opportunities and risks that need careful analysis [25].

Apart from giant development companies such as Google and Microsoft moving their application and services into the cloud, the academic community has recently been very active with a number of research work in the area of cloud computing as a multi-disciplinary research field. It is regarded as multidisciplinary because it is an amalgamation of several independent computing aspects and trends such as Internet delivery, utility computing "pay-as-you-go", elasticity, virtualization, grid computing, distributed computing, storage, security, Web 2.0 and content outsourcing [13]. The study by [9] on cloud adoption by SMMEs in South Africa showed 53% respondents used the service type of PaaS and IaaS; and 40% were adopting cloud computing for application development. It is also thought-provoking to note [26] prediction that cloud computing will grow and that application developers should start to consider its offerings at all levels.

Statistics from [27], 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.

Some of the reasons or benefits that have led organizations 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 [2] - [3] & [14].

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 [4] - [5].

E. Software Engineering and Agile Development Methodologies

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 [28].

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 [29]. In South Africa, it is common to find problems within developing organizations 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 [30].

With agile methodologies, prescribed values, principles and practices are recommended for successful software project implementation [30]. Agile development requires distinctive tools such as feedback, transparency in communications, and time-boxing. Therefore, organizations 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 [11]. 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 [31].

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.

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 [9], application development within the cloud environment by SMMEs within South Africa is evident but it is not clear that these adoptions involve agile methodologies. World-wide agile development in cloud environment has been successful although these experiences are only for large companies [32].

Considering the benefits of cloud computing, SMMEs agile software development adopters can enjoy faster, production, improved quality and more flexible and collaborative processes that embrace change. Some benefits include the following:

- Automated build in the cloud. Development organizations would reduce costs by using virtualization in accelerating their work through existing images residing on multiple platforms. This reduces utility pricing on servers as compared to the use of dedicated servers.
- In the cloud environments, access to production environments is quicker and supports automated production deployment. This results in reduction of feedback cycle within the technical team and business owners.
- Development teams are able to use virtualization aspect of cloud computing for unlimited number of servers and be able to do parallel work within the agile philosophy. Successful Agile development projects depends on strong and extensive communications.
- The virtualization aspect of cloud computing will facilitate quicker provisioning and testing of code while at the same time developing and testing a new version. Cloud testing allows substantial advances in speed and agility by using multi-platform testing on virtual images. Unit tests can be done in parallel on cloud machines which also results in cost serving as compared to using dedicated servers.
- Exploration and innovation within a team by trying new ideas on server working environments [25].

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 [33] include non-technical problems such as inadequate training, poor leadership, and rigid adherence to agile principles that do not fit into the project. 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 [1]. 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.

III. ANALYSIS

The current rate of emergence of cloud computing poses a big challenge for the need to embrace it. For many reasons outlined by [2], [4]-[5], [13], [15]; [23], [25]-[26] & [32], 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 [13]. 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 [9] & [11]. Literature has shown that there are several frameworks and decision models for cloud migration [34]. 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.

IV. 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:

- Identify factors necessary for successful migration of SMMEs that are using agile development to cloud computing;
- 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 organization 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.

Activity	Information Required for Framework	Variable(s) and/or Relationships measured
DETERMINE EXISTING ENVIRONMENT	Agile methodology in use Cloud computing services in use/required Type of applications and tools in use/required to develop software in cloud computing environment Perceptions held by agile software developers with respect to cloud computing	These will be identified through the coding of interviews transcripts, observation schedules. Literature and document reviews. **Tests ;** Content Analysis and Correspondence Analysis
DETERMINE AND EVALUATE CONDITIONS FOR SUCCESSFUL MIGRATION	Factors responsible for success in migrating organisation's agile development to cloud computing Difficulties or weaknesses encountered during the process of migrating to cloud computing Factors responsible for the difficulties and weaknesses during the process of migrating to cloud computing	These will be identified through the coding of interviews transcripts, observation schedules. Literature and document reviews. **Tests ;** Content Analysis and Correspondence Analysis
DETERMINE ACTION/INTERACTION BETWEEN MIGRATION SUCCESS FACTORS	Interaction between factors that are responsible for success in migrating to cloud computing Interaction between factors that are responsible for the difficulties/weaknesses in successful migration Relationship between factors that account for success and those that account for difficulties and weaknesses?	These will be identified through the coding of interviews transcripts, observation schedules. Literature and document reviews. **Tests ;** Content Analysis and Correspondence Analysis

Table 1: Activity versus Information Requirement for Framework

V. 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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