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LEAN CONFIGURATION MANAGEMENT SYSTEMS IMPLEMENTATION FOR THE GOVERNANCE: A CLOUD COMPUTING CASE STUDY

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ABSTRACT

With the shift of computing paradigm from standalone, to parallel, to distributed, to grid, and now "Cloud Computing", came new waves of issues, concerns, and challenges and a need to explore more innovative ways to govern software development activities. At present there is a lack of studies in the area of governance in cloud computing and its impact on the software development activities. This paper presents an adaptable management systems model formulated for this purpose as a result of a longitudinal case study in a large Australian IT program. The case study environment involved various agile and plan driven software development teams collaborated with each other using various lean strategies, to develop and deliver a consolidated software system in a hybrid cloud computing environment. This paper will contribute an empirical study towards literature of lean thinking, governance, and traceability models and practical guidelines for process engineers to implement governance.

Keywords: Cloud Computing, Adaptable Management Systems, Software Configuration Management, Lean, Lean Thinking, Traceability, Governance, Process, Model

INTRODUCTION

Cloud computing is emerging as a novel computing environment, where computation and storage resources are provided as services [1]. It is considered "as a type of parallel and distributed system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources(s) based on service-level agreements established through negotiation between the service provider and consumers" [2].

Cloud computing on one hand provide benefits, such as, cost effectiveness, real time provisioning and pay-as-you go services [3, 4], and on the other hand, present concerns and issues in terms of security, privacy, performance, availability, integration and governance [1, 5-7]. Such environments raise number of challenges to the classical software engineering processes, such as Software Configuration Management (SCM), especially in a highly regulated and audited environments [8].

According to Guha and Al-Dabass [7], existing software process models and framework activities are not adequate for cloud computing environments, unless additional measures are taken to make it compatible with cloud computing environment. At present, there is a lack of empirical and academic studies which may provide adaptable governance solutions to implement classical software engineering processes, such as, SCM process through lean principles, and strategies and considering cloud privacy and security requirements [9-14].

Motivated to investigate hybrid cloud computing environment and its governance through SCM process and associated management systems solution, we performed a longitudinal case study of a large Australian IT program, where Agile and Plan driven software development teams, coexisted to deliver a consolidated software system, and management was concerned about the governance of software development activities in cloud computing environment. This paper contribute an empirical study towards literature on lean thinking, cloud computing, and governance, and also present a traceability model for the practical guidelines of IT practitioners, in general and process engineers, in particular.

This paper is structured as follows: In next section, we will provide the background and the related work associated with the research. Proceeding section will then formulate an adaptable management systems model called as Software configuration Lean Agile Management (SLAM). It will then followed by a section describing the research methodology adopted for the case study. Next section will then present the case study background including description of technical cloud computing environment of the case. Next section will discuss the findings of the case study. In the last section, we will present the conclusion, implication, and the future research direction.

BACKGROUND

Theory of Lean Thinking and the associated properties

Lean thinking represents a culture where all employees continuously look for ways to improve the process with the philosophy of eliminating all non-value added activities, encompassing wasted time, activities, inventory, and space – and create processes that flow and are initiated by customer demand [15, 16].

There are two pillars that support this system, "continuous improvement", and "Respect for People" [11]. Continuous improvement also called as "kaizen" emphasizes on "Challenging everything" by creating an atmosphere of continuous learning and embracement of change [17]. Such an environment can only be created where there is a respect for people [11, 18].

In addition, five associated principles that facilitate the above mentioned pillars are: 1) definition of product that precisely meets customer requirement, 2) identify the value stream for each product, 3) allow value to flow through the value stream without delays or barriers, 4) allow the customer to pull value, and 5) pursue perfection and practice continuous improvement [12]. These principles, along with others, when applied appropriately can provide an adaptable environment through which various software engineering practices and collaborative management systems can prevail to deliver value [9, 10, 18-20].

In the scope of this paper, we used of a subset of lean tools selected based on the goals of the case study and listed in Table 1. We also presented the implementation of these lean tools in the context of the case study and illustrated in Figure 1.

Table 1: Lean tools for the SLAM model implementation

Lean Tools	Meaning
Sustaining continuous flow (Heijunka, Takt Time)	Creating flow and eliminating waste
Jidoka	Continuous integration and intelligent automation
Kanban	Visual management and pull system
Kaizen	Continuous improvement ("change for the better")
Yokoten	Best practice sharing across everywhere
Gemba	The real place (Go and see the work)

Cloud Computing Environments and Governance Challenges

Many studies have been performed in an attempt to define cloud computing and to identify, and describe the key characteristics of cloud computing [3, 4, 21, 22]. As stated by Armbrust, et al. [23], it refers to both applications delivered as a service over the internet and the hardware and systems software in the data centers, through the use of different virtualization technologies by defining images of operating systems, middleware, and applications to represent physical machines and are usually pro-allocated to an available server [24].

Research studies in the past have identified various advantages and benefits of using cloud computing, such as, cost effectiveness, real time provisioning and pay-as-you go services etc.[3, 4]. On the contrary, it has also presented different challenges, issues, vulnerabilities, and complexities, such as, security, privacy, performance, availability, integration and governance [5, 7, 21, 25-28].

According to Guha and Al-Dabass [7], the existing software development process models and frameworks are not adequate from the cloud computing aspects, and the suggestion was made to involve cloud service providers during the software development lifecycle for the establishment of different processes (such as, cost and schedule estimations, risk management, configuration management, change management, and quality assurance) and the provisioning of different project related environments .

In the scope of this paper, in later section, we will discuss and illustrate the deployment of various management systems for the governance of software development activities in the cloud computing environment and the role of different stakeholders.

FORMULATION OF THE ADAPTABLE MANAGEMENT SYSTEMS MODEL

Adaptable management system in Figure 1 shows a high-level view of a SLAM model [20] with its basis on lean principles and associated lean tools [11, 12, 18, 29, 30].

From structural aspect, SLAM model comprises of six collaborative management systems established through a principle defined for this research as, "the level of tool and technology sophistication and the formality of the process and practices associated with each management systems should be directly proportional to change traceability granularity expected by the customer, and should be aligned with the business goals and customer requirements to deliver value" [20].

The process and tool control arrows, which we called "Volume Adjustment Monitor (VAM)" is associated with each of the management systems and facilitate in the application of lean principles for pragmatic implementation of sound SCM principles to serve the need of the business [9, 10, 31]. VAM represent the pre-assessment tasks executed at the operational level of the organization to review business goals and the assess change traceability granularity required. Consideration should be made to add nothing but value (eliminate waste), center on the people who add value, flow value from demand (delay commitment), and optimization of the target management system across the organization [19, 32].

As illustrated in Figure 1, "upstream components" or "manufacturing components" of SLAM model comprises of Change/Requirement management system, and defect management system. These management systems are linked with the "Production KANBAN" representing a "pull" system to avoid overproduction [18]. Once a requirement is recorded through the upstream component, project development team members gets their assigned workload through the established workflow channel (such as, Kanban stand-up meetings, and/or email notification of assignment through management systems etc.) and software changes gets released through a "Sustainable Continuous Flow" and stored under the "version control management system" [18].

Once the software changes are stored inside the version control system, it waits for the "Withdraw Kanban"; a pull event which represents a "wish" of a target environment owner to deploy selective changes into the relevant managed environments [18].

The role of "downstream components" or "distribution components" starts from this point and comprises of Build management system and the Release & Deployment management system. Build management system pulls as a result of "Withdraw Kanban" all the software changes represented by a particular "baseline/snapshot/tag" and package the changes as per build instructions. Release & Deployment management system gets trigger at a defined regular interval of time for the collection of "release package" and deploys in the target managed environment through a "continuous integration (Jidoka)" process.

Software changes once deployed in the managed environment, goes through a "customer acceptance criteria" and the "production Kanban" gets updated accordingly to reflect the updated state of the requirement and hence another trigger of a pull event for the upstream component.

Since collaboration between different management systems is the basis of a SLAM model, the content management system which performs the role of centralized reporting system should be kept up-to-date (automatically or manually etc.) to reflect the progress of all the tasks mentioned above, and should be made readily available to the relevant stakeholders for further analysis and hence the contribution towards continuous improvement "Kaizen" to pursuit perfection and conveyed in the constant "change for the better" [18, 29]. The basis of Kaizen is relentless reflection which pursuit this perfection, continuously and iteratively and VAM is the control tool which also facilitate Kaizen in this improvement process.

In section 5 of this paper, we will illustrate how we deployed the management systems as proposed by the SLAM model in the context of case study using different lean strategies.

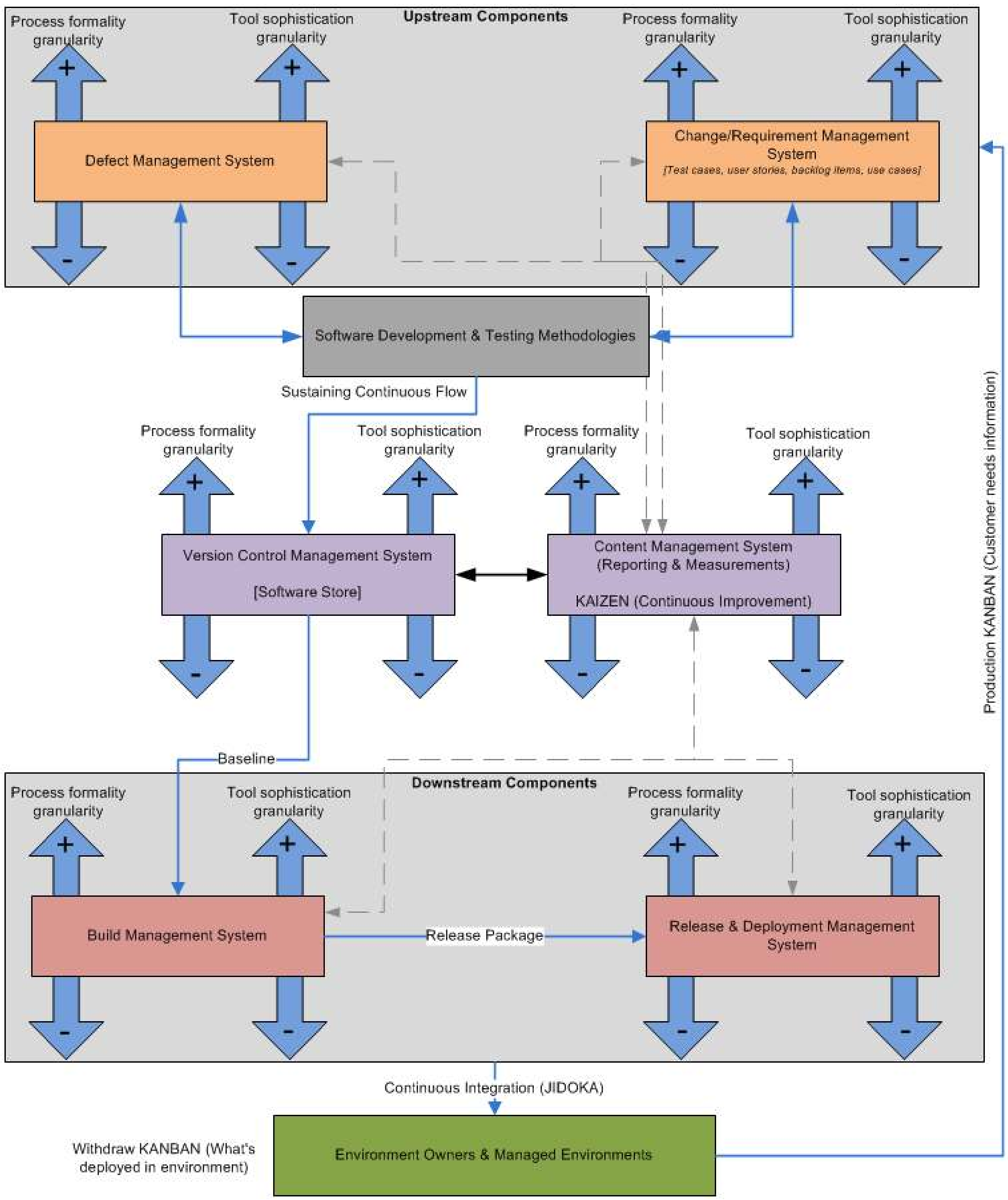

Figure 1: SLAM model

RESEARCH METHODOLOGY

Following Eisenhardt [33], a qualitative and single case study approach for this phase of the research was chosen primarily to provide rich data to other researchers and an opportunity to analyze management decision processes of deciding how, what, and when to apply SCM process facilitated by an internal cloud service provider.

The case study was unique and complex because of the coexistence of parallel operational levels, such as, program, platform and vender etc. with their own associated management systems. Also the involved software venders' teams were using different software development methodologies such as, Agile and Plan driven. The challenge was to maintain this parallel operational momentum with hybrid venders to deliver an integrated product as per defined project milestones. Thus, in order to understand what strategies were taken by each operational level managers to establish governance through SCM in a cloud computing environment, it was deemed essential to pursue an in-depth look into why and how of the phenomenon [34].

After selecting the site and gained access to the case study environment, we developed our research protocol, entered the field, analyzed the data, and enfolded the literature until closure was researched. Data was collected using multiple methods, including semi-structured interviews, kanban meeting observations, inspection of internal documents, and archival of project data [33, 34].

During the case study, we interviewed SCM resources, developers, project managers, business analysts, and program level executives. We developed an interview protocol (available from the authors on request) prior to entering the field. We derived this protocol by devising questions about various management systems (as shown in Figure 1), their perceived importance for governance, and applicability of lean principles and associated lean tools in the case study context [11, 12, 18, 19, 30, 32, 35]. We also used a Delphi technique to received feedback and enhancements regarding protocol from our case study colleagues [36].

Semi-structured interview format was followed to produce consistent information across the participants while also remaining open to explore each interviewee's unique perspective. These interviews lasted between 15 to 45 minutes, and were either recorded during the session or extensive notes were taken after the interviews.

Along with the interviews, we also attended multiple daily kanban meetings, weekly platform status review meetings, and monthly program status meetings. The observations from these meetings helped to increase our understanding of lean principles and associated tools implementation in the case study environment. During and after interviews, we also gathered supplementary material including program technical implementation plans, software configuration management plans etc. explaining various case study policies, principles and processes.

At defined milestones in the case study, we continuously kept categorizing the collected data, based on the lean principles, associated lean tools, and linking it with management systems as proposed by the SLAM model (Figure 1). Such an iteration between field data and data analysis is consider important for the case study research process [33, 34]. Such a recursive process permits researchers to empirically ground their observations and identify anomalies to advance the theory-building process [37].

THE CASE STUDY: PROGRAM B

Program B, a coded name for the actual program, was established to build and operate new infrastructure, to enable advanced super-fast digital services nation-wide. The program's rollout commenced in 2010 and was comprised of design, development, implementation, and ongoing support and enhancement services of the business and operational support systems required for the processes of activating, assuring and billing services.

The Program B's technical environment was based on infrastructure using virtual servers in a hybrid cloud computing environment (as shown in Figure 2). Before the actual provisioning of the cloud infrastructure, platform and related software (management systems etc.), appropriate measures were taken regarding privacy, trustworthy computing, and auditing compliance [13].

The virtual servers were created by Program B Data Centre (DC) Engineers (Cloud Providers) on the demand of the program manager who specified the requirements in an Infrastructure Service Request. Servers were created by specifying characteristics such as CPU cores, memory and disk space as well as by service level categories as defined in the DC Service Catalogue. Other Services were also requested for databases, network services and user provisioning. All management systems as proposed in section 3 and illustrated in Figure 1 were placed under Program B Data Centre – Trusted Cloud Zone (as shown in Figure 2). These management systems were accessible to the relevant stakeholders via Citrix gateway using Citrix virtual desktops.

Consistency among various managed cloud computing environments was maintained by adhering to the agreed high-level SCM standard (as documented in Program SCM Plan) at all operational levels of the program using different management systems. There were however few exceptions to the environment specific properties changes that required direct access to the deployed solutions in a target cloud computing environment using Citrix XENAPPS client SW.

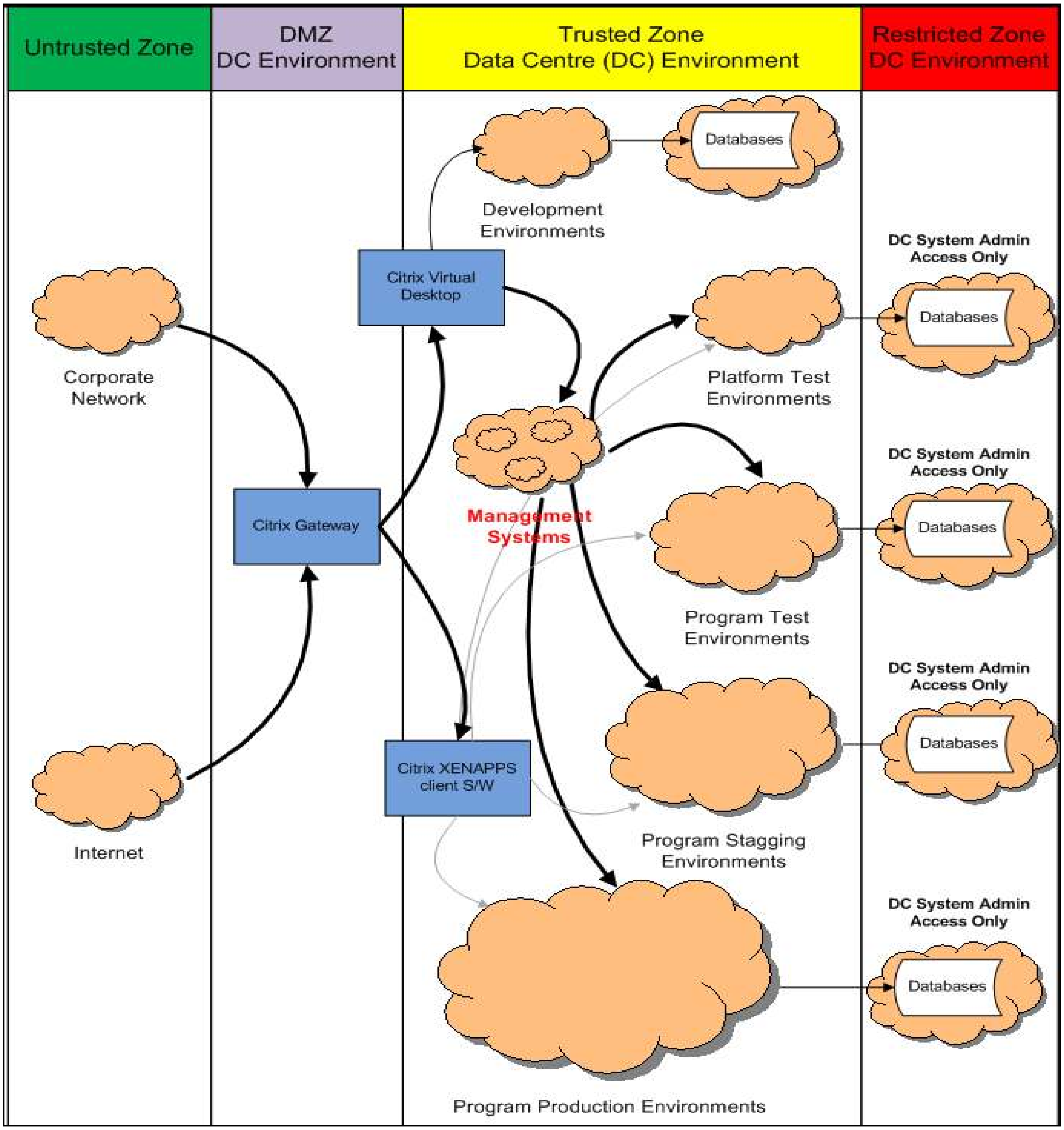

Figure 2: Hybrid cloud computing implementation in Program B

RESEARCH FINDINGS

In this section, we discuss the findings with the help of the research investigation tools as discussed in the research methodology section. The findings that emerged from the analysis of the data were categorized into process-based and role-based perspectives.

Process-based perspective

In order to implement the end-to-end traceability for the Program B, "Program Delivery Framework" was used as a reference model to create an enterprise-level SCM framework, which was then enacted by the vendor and platform delivery teams. Each of the teams had taken a value-based approach for the customization of their SCM process by adjusting the process complexity and tool sophistication according to the traceability requirements defined by the "Program Delivery Framework" [9-12, 19].

Following were the three key lean strategies taken:

- **Empowering teams:** Team empowerment has been recognized as an effective way of helping organizations to respond rapidly to environmental changes, such as those initiated by customers [38]. This strategy in our case study helped in building the confidence of the delivery teams as well as the integration teams and created a culture of mutual respect within the program team. It also facilitated in the successful migration from a vendor and platform defined SCM process to an enterprise level SCM process in a short span of one year and without delaying any program milestones.
- **Designing simple solution:** The emphasis was made to keep information flow simple within the identified value stream [39], which for this case study was, the flow of information between various management systems to ensure end-to-end software change traceability. It was recommended to use existing processes and tools [17] in the environment and categorize them into management systems. Each of the management systems varied in terms of it process formality and the level of tool sophistication, but it was built though value-based mind-set aligned with the goals of the required operational level and associated software development methodology and target cloud computing environment.
- **Continuous improvement of the existing capabilities**: In our case study, during the initial phase R1, all associated work products and software changes were delivered through the management systems capabilities already existed in the environment [17]. This process was continuously improved during R2, R3A, and R3B through the inputs from different stakeholders and measures were taken to develop a fully automated, end to end traceable SCM solution defined at the enterprise level. One important point is that vendor and platform teams continued to use their relevant SCM processes at the operational level, because of its alignment with program goals. Most importantly SCM process was delivering value to immediate stakeholders. Improvements were made horizontally with in each operational level to automate practices internally, as well as, vertically to integrate their outcome with other operational level SCM processes.

Role-based perspective

In Program B, the consultants responsible for the implementation of the SCM process had to work closely with the enterprise, platform and vendor level teams to understand their existing SCM capabilities and the tools they used to perform various tasks. Similarly, close coordination was also kept with the Program B Data Centre representatives for the provisioning of new hybrid cloud computing environments and its placements in different zones as presented in Figure 2.

From the cloud computing perspective, the key difference for the implementation of SCM process was the coordination and sharing of various administration activities and the provisioning of managed cloud computing environments with the cloud providers (Program B Data Centre team). Using their services, all the management systems were provisioned under Program B trusted zone (Figure 2) and platform and hardware maintenance responsibility (PaaS, IaaS etc.) was given to them. Vender, platform and enterprise level application (SaaS) authentication and authorization was handled by the associated SCM or management representative.

CONCLUSION, IMPLICATIONS, AND FUTURE RESEARCH

Having discussed the findings of the case study, we now examine their relevance using the theory of lean thinking. We provide the analysis of the theoretical underpinnings behind the lean strategies taken for the application of SLAM model in the Program B's hybrid cloud computing environment. Finally, we will discuss the implication of our findings in light of changing role of SCM Enabler and the adaptable management systems in the cloud computing environment.

As shown in Table 2, theory of lean thinking is able to comment on the strategies taken by Program B for the implementation of SCM process in a cloud computing environment.

Table 2: Theoretical Bases for case study findings

Category of Findings	Benefits/Motivators	Initial/Current Concerns	Lessons from Theory
Role of SCM Enabler in Cloud Computing	The role provide the SCM domain knowledge and implementation of management systems	Physical security of management systems in cloud service providers premises and the application level security settings by the SCM Enabler	Lean thinking can comment in this area where SCM Enabler need to work closely with different stakeholders to identify the value stream and then proposed appropriate measures to address the security concerns
Designing simple solution	Migration of management systems from vender, and platform operational levels to enterprise level in last phase	Too many differences in the operational levels such as, configuration items naming conventions, baseline conventions, release packages names etc. may makes migration difficult	Lean Thinking can comment on this value based mind-set which was applied to define the information flow between different management systems. Simple and consistent naming conventions were used to define configuration items, baselines and release packages across all operational levels.
Empowering teams	Every team knows their internal capabilities more than other and it needs to be respected	External influence on the delivery team to make changes to their process for the Program B may affect their capability to deliver on time	Theory of lean thinking emphasize on respect of people which also comments on giving empowerments to the teams to perform their tasks under guiding principles given by the project. It builds a confidence and a culture of mutual respect in a project environment
Continuous Improvement of the existing capabilities	Rather than introducing new processes, tools and technology immediately in the environment it is better to refine the existing capabilities and introducing small pieces of improvements	Too many immediate and new changes may affect the project delivery deadlines	Lean thinking can address that through "kaizen" which emphasizes on "Challenging everything" by creating an atmosphere of continuous learning and embracement of change.

The implication of this paper leads us to consider more theoretical perspectives, such as, dynamic capabilities theory, theory of constraints, capabilities learning loop, to look into similar case studies [7, 17, 40], existing software process models and framework activities are not going to be adequate unless additional roles, such as, cloud providers and SCM enablers as suggested by this case study are included in the process to establish governance. This case study also suggests the need to develop adaptable management systems through application of lean thinking and possibly through other theoretical underpinning. Thus, our future research will be directed towards more case studies on adaptable management systems which may facilitate in the implementation of governance especially in different cloud delivery models.

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