LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
LUT School of Business and Management
Master Degree Program in Computer Science

Alejandro Antillon Lopez Salinas

Measuring the adoption of cloud computing in technology companies through a Cloud Maturity Model

Examiners:	Professor	Ajantha Dahanayake
	M.Sc.	Niko Päivärinta

ABSTRACT

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Cloud computing has emerged in the market delivering promises held since decades ago by movements like "grid computing" or "utility computing". Nevertheless, research on cloud computing has typically had a focus on the technology around cloud computing, leaving a gap between technology related research and holistic research that includes business and socioeconomic aspects. Such gaps in knowledge are reflected in the challenges organizations face when they begin to adopt cloud computing. There is a need for tools that allow organizations to assess their cloud readiness and devise a roadmap towards an effective use of cloud computing. This work proposes a simplified maturity model to assess cloud readiness in enterprises. The simplified maturity was tested during a study in which a set of technology companies participated to assess their cloud maturity. The results obtained validate the simplified maturity model, and provide insight into the status of cloud adoption.

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The years at LUT were pivotal in my life, they marked a great change in my life that I am sure will continue to unfold in the future.

Finally, I want to express my love and gratitude to all my family.

Helsinki, December 2017.
Alejandro Antillon Lopez Salinas

CONTENTS

LIST OF ABBREVIATIONS

CC	Cloud Computing
IaaS	Infrastructure as a Service
PaaS	Platform as a Service
SaaS	Software as a Service
CMM	Cloud Maturity Model
SEI	Software Engineering Institute
ODCA	Open Data Center Alliance
VM	Virtual Machine
OS	Operating System

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1 Introduction

Cloud computing (CC) is a revolutionary computing model that certainly has gained a lot of attention in the last decade from both academy and industry professionals. Although, due to the rapid growth and evolution of CC it remains challenging for the community to rely on a single definition to capture everything CC is.

The following definition offered by N. Antonopoulos [1] captures the essence of CC:

> *"A new model of computing, in which data and computation are operated somewhere in a "cloud," which is some collection of data centers owned and maintained by a third party"*

In order get a holistic view of CC, it is not only necessary to understand what it means, but also it is necessary to understand the impact of CC in the industry. Moreover, CC is not only relevant for those organizations (or departments) that deal directly with technology and IT systems, in fact, CC is of great importance for management disciplines as well. For this reason, many researchers such as Marston [16], have shifted the perspective of their research from technical to a business perspective.

1.1 Development of cloud computing

Cloud computing is not an isolated concept, on the contrary, it is closely related to many other visions held decades before, especially to those of *"utility computing"* and *"grid computing"*. In fact, some researchers and professionals, such as Foster [4] argue that cloud computing and grid computing may even be the same concept.

In fact, CC and these other computing paradigms, are not only related but rather entangled, since confusion remains in the community regarding what cloud computing exactly is, and how it is different from the other paradigms, as pointed out by Armbrust [15].

Weather there are differences between cloud computing and the previous utility computing models, is that cloud computing made a breakthrough from being just a concept, and *"emerged as a commercial reality"* as stated by Armbrust [40].

Armbrust [40] compares the disruption cloud computing can bring to IT in the next years, to what happened with silicon chips fabrication not too long ago. When the cost of a silicon production line was over 3 billion dollars, owning and operating one of these production lines was something only large companies could afford, such as Intel. But then, a type of company emerged that offered silicon manufacturing services to their customers, this enabled small companies that otherwise could not afford building and operating their own silicon production line to manufacture their chip designs, to be able to outsource their manufacturing process, while adding value to their products with innovation in the design of their products. These silicon manufacturing companies are called *"foundries"* and the companies that utilized their services are called *"fab-less"*, where *"fab"* stands for fabrication. These foundries relied on manufacturing different products for different customers in order to offset the large investment of operating a silicon production line.

In a similar way, Armbrust [40] claims that companies large enough to own and operate datacenters with the cloud scale, such as Microsoft and Amazon, can profit by offering a wide variety of cloud services to smaller companies that would otherwise not be able to build and operate their own datacenters at the same scale. Conversely, smaller companies can have access to on-demand cloud services of large scale.

Additionally, Armbrust [40] points out the change in trends and business models occurred in the last decade, have contributed to cloud computing finally arriving to the market. Examples of this trends are the Web 2.0, IoT and mobile technologies.

Nevertheless, although cloud computing has emerged on the market, multiple researchers (Foster [4], Dillon [12]) and industry leaders have pointed out the next challenges related to cloud computing that need to be addressed in order to continue its widespread and adoption. To this, Dillon [12] lists the following as the core challenges in the next stage of cloud computing: standardization, interoperability, security, privacy and adoption.

1.2 The problem

The problem addressed by this work is the lack of tools that aid enterprises to assess their cloud readiness and design a roadmap to incorporate cloud computing into their current architecture. Having such tools is of great value especially when an organization is relatively new to cloud computing and lacks expertise in the domain.

This research aims to provide a tool to assess the adoption of cloud computing by an organization, that is balanced between simplicity and detailed. The tool mentioned is in fact a maturity model designed specifically to assess cloud maturity in an enterprise context.

The challenges faced by enterprises when moving into cloud computing have already been studied by researchers (Vaquero [28], Dillon [12]), and are explored in more detail in the literature review section. However, at this point is important to understand that challenges do exist for enterprises adopting cloud computing, as stated by Foster [4], *"Cloud Computing is still in its infancy…"*.

Therefore, the need to generate more knowledge and tools to assist organizations in harnessing the power of cloud computing effectively, such as the cloud maturity model designed on this work. One more very important fact introduced by Yang et. al [10] is that most of the research done in cloud computing, is done with a focus on technology, leaving other aspects that are also relevant unattended, such as business and organizational impact.

The current work applies the concept of maturity models to bring a systematic process to model adoption of cloud computing in enterprises. Although, it is important to mention at this stage, that maturity models have already been applied to the domain of cloud computing. A few researchers have already done work incorporating maturity models to assess the integration of cloud computing in organizations. McGeogh [38] conducts a very relevant study within a company to understand the adoption, another example is the cloud maturity model designed by the Open Data Center Alliance (ODCA).

Nevertheless, what makes the cloud maturity model introduced in this work different from previous work is that it aims to balance the level of detail and simplicity. The balance between these features is to make it a viable first step for organizations looking to make a preliminary assessment of their cloud maturity.

The maturity models found in the literature review (i.e. McGeogh [38] and ODCA's maturity model) could result difficult for organizations with little experience to implement, because they are fitted very specifically to a particular type of organization, or incorporate a high level of detail.

1.3 The research questions

Despite the commercial and technical development of cloud computing as pictured by Armbrust [40], Foster [4] summarizes the challenges that still remain, and states that *"Cloud Computing is still in its infancy.*

Therefore, this work addresses the following research questions:

a) How can enterprises with little expertise in cloud computing assess their cloud capabilities and prepare to move forward with cloud computing?
b) What are (or could be) the maturity levels of an organization for cloud adoption in a simplified cloud maturity model?
c) What are the challenges associated with cloud adoption in this simplified maturity model?

Answering such questions can lead to identify how organizations can start diving into cloud technologies, how they can assess their expertise and maturity levels, and how they plan a roadmap towards the desired maturity level.

1.4 Methodology Overview

Research methods have been for long time divided into qualitative and quantitative, although as pointed out by Creswell [39], they should not be seen as different or exclusive categories, but Creswell suggest thinking about them as *"opposite ends of a continuum"*. Similarly, Creswell [39] suggests the importance of mixed methods that imply the combination from both quantitative and qualitative approaches.

Creswell [39] argues that a study is not pure quantitative or qualitative, it simply tends to be more qualitative than quantitative, or vice versa, and that similarly, mixed studies are situated right in the middle of this continuum.

The data collection stage is a vital process for every study, Creswell [39] provides a wide variety of data collection alternatives, such as open-ended versus closed-ended questioning, and how these different approaches have a numeric (close-ended) versus a non-numeric (open-ended) focus. Along with this same idea, Creswell states that the suitability of these two different approaches for data collection depends on the nature of the subject of study.

Another important concept mentioned by Creswell and his sources is that all data collection techniques will inherently have a bias, therefore it is wise to combine qualitative and quantitative data to offset these biases.

Based on the previous foundation laid by Creswell [39], a mixed method is proposed to carry out this study based on the following reasoning.

First, given that the research questions in this study attempt to, understand how cloud adoption occurs (or doesn't) in organizations, and to design a simplified maturity model, as a systematic approach to help describe and analyze the adoption process. A qualitative approach has been useful to first bring understanding about the adoption process through consulting literature.

Second, quantitative phase surveys are conducted among individuals and/or organizations with experience on the use of cloud services, and on how to incorporate cloud services into an organization's IT systems. This quantitative study aims to first validate the model proposed in the first stage, and second to identify the challenges faced in the adoption process when following this simplified maturity model. These challenges specific to the constructed maturity model, could be considered as the risks in the model.

One noteworthy aspect mentioned by McGeogh [38], about the quantitative studies, such as the one proposed in this mixed method, which intends to collect data from subjects through surveys and interviews as data collection instruments, is that the nature of close-ended questions with predefined answers, tend to limit the freedom in which the subjects can comment about the subject, therefore inhibiting the possibility of bringing up new questions previously not considered. While open ended questions and semi-structured interviews allows for the subject to explore the subject with more freedom, and provide more diverse information which can lead to new questions or different viewpoints on the subjects that are unknown before.

Nevertheless, this study is limited to simple surveys with close ended questions, for the sake of simplicity for the subjects. Given the difficulty to find participants, the survey is designed to be simple and not too long to maximize the chances of getting participants, and minimize the chance of participants from failing to finish the survey.

2 Literature review

2.1 Many definitions of Cloud Computing

Cloud computing (CC) is a revolutionary model of computing that promises many advantages but also poses multiple challenges for effective adoption and further development. Among the advantages promised by CC are on-demand computing resources and opening new business models for companies. Within the challenges are transitioning of legacy systems, and security and privacy, to name a few.

Despite the popularity of cloud computing in both academia and industry, there has been an ongoing discussion regarding the exact definition of the concept, and how it differs from previous computing models that offer similar features.

Additionally, Dillon [12] compared cloud computing with previous computing models, such as grid or service computing, which in fact has multiple similarities with cloud computing, up to the point that some of them claim that cloud computing and grid computing are the same concept [4].

Since the concept of cloud computing was introduced, to the current day, multiple definitions of cloud computing have been developed by researchers, as well as studies that condense the evolution and state of the art of cloud computing. Along this line Zhang [13] and Yang [10] provide holistic reviews of cloud computing in two different points in time. However due to the rapid evolution of cloud computing and the growth it has seen in the last decade, it remains challenging to capture what cloud computing is in a brief yet as a concrete definition.

There is really no need to develop yet another definition of cloud computing in this work, because there already exist multiple definitions offered by previous researches, as mentioned previously. However, it is convenient to consider multiple definitions with different angles that help capture a modern and holistic view of cloud computing.

N. Antonopoulos [1] offers a simple but accurate definition of cloud computing as:

"A new model of computing, in which data and computation are operated somewhere in a "cloud," which is some collection of data centers owned and maintained by a third party"

Mei [3] offers another definition of cloud computing as *"Cloud computing is a paradigm that focuses on sharing data and computations over a scalable network of nodes"*, which mentions the concept of "scalability", which is a key feature of cloud computing as described later, and calls an application developed and deployed in a cloud, a "cloud application".

Yet another, rather well-rounded definition is offered by Foster [4], and introduces some features that are key for this research:

A large-scale distributed computing paradigm that is driven by economies of scale, in which a pool of abstracted, virtualized, dynamically-scalable, managed computing power, storage, platforms, and services are delivered on demand to external customers over the Internet.

The above definition extends the scope of cloud computing, from providing only (or mainly) "computing" to include also storage, platforms and services. This addition to the classical definition of cloud computing is key in understanding the status and direction of cloud computing.

Another important aspect of cloud computing pointed out by Zhang [13] is that despite the exponential growth and popularization it has achieved in the last decade," the *development of cloud computing technology is currently at its infancy"*.

Finally, it is also useful to define the counterpart of cloud computing (or software), which is called "on-premise". On-premise means that applications and/or data "reside within the enterprise boundary, subject to their policies" as stated by Subashini [20], which implies that the enterprise is responsible for all aspects of development and maintenance of the applications.

2.2 Cloud computing in a business context

The definitions offered above, although they are accurate to some extent, have the same technical focus, are written by, and addressed to, technical people with a background in IT or computer science, but are missing another key angle of cloud computing, which is the impact it has in a business and/or organization.

Yang et. al [10] provided an early mapping of the cloud landscape on 2012, in which they not only document the existing research at the time, but also point out that most of the research around cloud computing has a technical focus, and there is a need for more research with a business and organizational focus on cloud computing. Since the ultimate goal of cloud computing is to enable organizations and enterprises to achieve their goals in a more efficient way, it is also necessary to study cloud computing from a business and organizational context.

Fewer researchers have answered the call of research focused on the business perspective of cloud computing, in this regard Marston [16] provides an in-depth analysis of cloud computing within a business context. In his research several points are made regarding economic motivators for cloud computing, such as the common under-usage of on-premise IT assets. According to a study referenced by Marston [16] "most of the servers are using just 10–30% of their available computing power" and the fact that the cost associated with maintenance and support amounts to 60% of the IT budget.

These, and other challenges that organizations face in order to become more efficient and agile in their IT business can be addressed by adopting cloud computing. However as described in the following section, cloud computing is not to be interpreted as a generic solution for all IT problems. As all paradigm shifts in technology, it poses challenges and trade off's. The key is that organizations should be aware of them, and have all the necessary information as well as a comprehensive roadmap that guides them into the new arena of IT and cloud computing.

2.3 From On-Premise to Cloud

Although cloud computing offers multiple advantages over the traditional on-premise model, it is of vital importance to be aware of the challenges associated with adopting cloud computing, Dillon [15] has identified important challenges from a technical perspective. Conversely Hoberg [21] and Boillat [22] have explored the business and organizational challenges that can arise.

Additionally, Khajeh-Hosseini [23] provides a practical case study on the migration of an existing IT solution, which highlights the benefits of adopting cloud computing in the particular domain of the case study, which are mainly technical gains. But at the same time, the study reveals risks and impact to stakeholders in the organization-wide context (beyond technical staff). Thus, Khajeh-Hosseini [23] call for a thorough and comprehensive analysis of the implications of adopting cloud computing to *"avoid implementing local optimizations at the cost of organization-wide performance"*.

The challenges associated with moving on-premise assets to the cloud are in the main inhibitors of cloud computing adoption, more on this later. Organizations need to identify these challenges and plan a roadmap to guide them step by step in overcoming those challenges.

Previous research has focused on the transition process for organizations moving into the cloud, Ruparelia [17] explores such process and points out at the importance of having a comprehensive roadmap on hand for the transitioning process. Additionally, Ruparelia [17] stated that transitioning to the cloud *"gives you a good opportunity to redesign your business processes in order to make them more efficient"*.

2.4 The three layers of cloud computing

Cloud computing is divided in three layers, as pointed out by Lv [24], these layers are:

- Infrastructure as a Service (IaaS)
- Platform as a Service (PaaS)
- Software as a Service (SaaS)

Lv [24] and Boillat [22] mention the appearance of the first cloud services being SaaS. Afterwards, Lv [24] points out that with the development of virtualization technology and the vision of cloud computing became more mature, the need for infrastructure and platform services became clearer.

2.4.1 The first layer of the cloud - IaaS

Infrastructure as a service, is defined by Bhardwaj [25] as "the delivery of hardware (server, storage and network), and associated software (operating systems virtualization technology, file system), as a service".

Additionally, Khajeh-Hosseini [23] states the IaaS layer could be seen as the most viable option for enterprises that already have on-premise systems and wish to migrate these to the cloud. Since cloud infrastructure is relatively the same as physical infrastructure, the same on-premise architectures can be migrated to cloud infrastructure without the need of changing the application components.

Amazon EC2 is a popular example of IaaS. EC2 is studied and defined by Wang [26] as a service that allows users "to rent computers to run computer applications in the Amazon EC2 data center". These computers are in fact virtual machines called "instances" hosted in physical servers. EC2 instances are offered in a variety of specifications of computing power.

The benefits of utilizing IaaS identified in a study on this particular area by Bhardwaj [27] are:

- "Pay-as-you-go" for the service, this means that enterprises no longer have to make large up-front payments for infrastructure assets.
- Delegating the task of keeping the infrastructure running and operational to the service provider.
- Automation of some administrative tasks, related to deployment and monitoring.
- Dynamic scaling of the infrastructure, which means the possibility to request more instances. Although this does not directly translate into application scalability (more on this later)

2.4.2 The second layer of the cloud - PaaS

The PaaS layer is a platform for development and deployment of software in the cloud. Platform services manage the full life-cycle of software, as Dillon [12] points out.

The same concept of "full life-cycle" management is supported by Yang [10], who describes PaaS as a *"design, development, testing and deployment"* environment. Yang [10], mentions as benefits of PaaS a dramatic reduction of the system administration burden, and that developers can focus on more productive tasks. At the expense of less control over the underlying infrastructure. Additionally, some providers offer extra features to monitor the applications hosted in the platform (Yang [10]).

In this topic, Kibe [29] provides an overview of existing PaaS providers and their offering, focusing on the diversity across different providers and the architecture of popular platforms such as the ones offered by Google, and Microsoft.

The drawbacks of PaaS come as direct consequences of the benefits introduced by the platform. As the definition above point out, platforms aim to provide pre-configured environments, which are more managed and automated as pure infrastructure. However, this implies that developers must accept the restrictions imposed by the provider in terms of supported architectures, languages, etc. as pointed out by Foster [30].

2.4.3 The third layer of the cloud - SaaS

Software as a Service, or SaaS, is the third layer of cloud computing defined in research. Foster [30] defines it accurately as *"delivers special-purpose software that is remotely accessible by consumers through the Internet with a usage-based pricing model"*.

Similarly to Dillon [18], they both mention Salesforce as one of the pioneers in the SaaS area, which was the first company to provide a full featured CRM (Customer Relationship Management) solution over the internet, in a time when all other CRM solutions operated under a licensing business model, and ran locally installed in the user's on-premise machines.

With the difference of PaaS and IaaS, consumers of software services do not have any control over the infrastructure that hosts the services, as supported by Dillon [18], which makes these services.

In addition to the example of Salesforce, Dillon [18] mentions other common examples of SaaS, these include Google Mail, which is email service, and Google Docs. The former one being an online text processor, like Microsoft Word.

An important remark made by Qian [31] about SaaS is that the consumers of these services are in fact the end users of the software, whereas the consumer of IaaS and PaaS services are developers, which in turn build applications (often SaaS) on top of them.

2.5 Scalability in cloud computing

Garcia [32] defines two models in which an application can scale. Additionally, Garcia [32] carries out experimental work with both models, and presents his results on how they impact the performance of an application server.

One is "vertical scalability", which is when application performance can be enhanced by adding resources to the existing computing nodes, such as processors, memory or disk.

The second scalability model described by Garcia [32] is "horizontal scalability", which is when application performance is enhanced by adding more computing nodes to a cluster. In this case, the workload is distributed evenly among all the nodes in the cluster.

Both scalability models have strengths and weaknesses. Starting with vertical scalability, it is certainly simpler, and does not require application modification. But, there is a limit to how much power can be added to a single computing node. Additionally, vertical scalability is much less dynamic, since it is not possible to add or remove resources from a node as the workload fluctuates without interrupting the service.

Conversely, horizontal scalability theoretically does not have a strict limitation to how many computing nodes can be added to a cluster. However, applications need to be designed for compatibility with horizontal scalability. One of the main challenges in designing such applications, are state management, as mentioned by Armbrust [15], and the database layer, which *"is more difficult to scale"* according to Garcia [32].

2.5.1 Scalability in IaaS

Although, Bhardwaj [27] mentions scalability as one of the advantages of IaaS services, Armbrust [15] clarifies that in the context of IaaS, scalability refers specifically and only to scalability of infrastructure. Which means that users have the possibility to request more resources from an apparently "infinite" resource pool.

However, the last concept of scalability, does not directly translate into application scalability (either horizontal or vertical).

Armbrust [15] explains this using the case of Amazon's EC2 virtual machine instances, where the user has complete control of the software stack, from the kernel upwards. However, this "control" comes with responsibility of maintaining, and provisioning each instance. Thus, Armbrust [15] also discusses the counterpart of this condition, stating that:

"This low level makes it inherently difficult for Amazon to offer automatic scalability and failover because the semantics associated with replication and other state management issues are highly application-dependent"

In order to achieve application scalability with IaaS, applications must be designed with this purpose in mind, and be compatible with the "horizontal scalability" model described above.

2.5.2 Scalability in PaaS

Scalability is one of the main aspects of the platform layer of cloud computing. Armbrust [15] mention of this (and compares it to IaaS) by providing an example to Google's App Engine, which is a platform that enforces traditional web development architectures, and *"clean separation between a stateless computation tier and a stateful storage tier"* and in exchange, offers users automatic and powerful scaling, as well as failover recovery.

Although, it is important to acknowledge that the scalability provided by PaaS services like Google App Engine, is limited to the computing layer where the business logic of an application is contained. The challenge in storage and database scalability introduced by Garcia [32] remains open in this context.

2.6 The challenges of cloud computing

Although, the tone of the resources mentioned previously is positive towards cloud computing, it is also imperative to pay attention to the trade-off that exist, and also the risks that organizations run when moving to the cloud.

Dillon [12] does a thorough analysis of the challenges of cloud computing, especially from the adoption point of view. The challenges defined by Dillon [12] are the following:

Security

Being the main cloud adoption inhibitor stated by Dillon [12], he states that:

“Without doubt, putting your data, running your software at someone else's hard disk using someone else's CPU appears daunting to many”

Which is very logical statement, given that data and software are among an organization’s most valuable assets.

Cost Model

The cost model of cloud computing is very different to on-premise computing, with the first CC being provided on-demand and as a service, and the former (on-premise) being purchased all up-front and acquired as an asset.

While the infrastructure cost may be reduced by using IaaS services, Dillon [12] argues that other costs are elevated, such as data transfer and communication. Also, Dillon [12] points out that *“transactional applications such as ERP/CRM may not be suitable for cloud computing”*.

Charging Model

The charging model argument is the analogue of the cost model introduced by Dillon [12]. This is focused to those that are cloud providers (not consumers), and the challenges they face to perform an effective cost analysis of their operations in order to charge their products or services. Dillon [12] claims that an effective cost analysis should not be based on solely on the virtualized resources, but also on the underlying infrastructure.

Service Level Agreement

Dillon [12] argues that, regardless the fact that users do not have access to the physical infrastructure that host their services, they do need to have the certainty that the resources will be available and with the expected quality and performance.

These guarantees of availability, as well as quality of service and performance are offered by the provider in what is known as Service Level Agreements (SLAs). Also, Dillon [12] addresses the issue of defining an effective SLA, and points out that it should have the right grade of "granularity". Dillon [12] accurately explains this granularity level in SLAs as:

"the tradeoffs between expressiveness and complicatedness, so that they can cover most of the consumer expectations and is relatively simple to be weighted, verified, evaluated, and enforced by the resource allocation mechanism on the cloud."

Interoperability

The issue of interoperability is also extensively addressed by Dillon [12] and Satzger [5], as one of the main challenges of cloud computing. Dillon [12] defines the states that each cloud vendor "*has its own way*" of designing and providing the services offered, including interfaces, protocols, etc.

This growing diversity without standardization efforts, has led to very reduced interoperability between cloud providers. Therefore, consumers are forced to choose and consume services from only one provider. This condition is called *"vendor lock-in"* by Dillon [12].

Satzger [5], Also draws attention to the current problematics of cloud computing, being vendor locking one of the major concerns. Vendor locking is a condition in which a user or organization become dependent on a particular cloud provider to deploy their IT assets, and are subject to the provider's prices, rules and quality of service.

On the same topic, Satzger [5] recommends organizations to watch their dependency on cloud service providers and always to have a change strategy if they encounter problems with their operations and their service providers.

However, Satzger [5] also acknowledges that moving an IT architecture from one vendor to another is not a simple task and it is *"far from trivial"*, and points out that while some of the services offered by various vendors are similar *"in concept"*, others are completely different. Even those that are conceptually similar, have completely different implementations.

3 Maturity Models

3.1 Capability Maturity Model

A cloud maturity model will be the backbone of the field study and the analysis of the data collected to assess the adoption and effectivity with which organizations utilize cloud computing.

Before proceeding to describe what a cloud maturity model is, it would be convenient to describe a more generic concept from which our cloud maturity model is derived from, the **capability maturity model**.

A Capability Maturity Model is a rather established framework, dating from the decade of the 1980's as stated by Paulk [8]. Originated from the need to manage and improve software processes. This means any software development or maintenance process, whereas software that uses cloud computing of any kind, is a subcategory of software development.

Capability maturity models start by making the distinction between immaturity and maturity in software development. Paulk [8] describes an immature organization as *"reactive"*, which means that developers and managers improvise the tasks as they see fit during the development process. And there is a lack of understanding by managers and developers of the whole process, which causes that schedules and budgets are often exceeded and/or quality of the software is compromised.

On the other hand, Paulk [8] describes a mature organization as one that has "organization-wide ability to manage development and maintenance. Managers can accurately communicate the software process to staff and new employees, and work activities are carried out according to the planned process".

With both ends of the capability maturity model defined, immature at one end and mature at the other end, the next and most important piece of this model are the stages or levels in between these ends. Each level of the maturity model is characterized by a set of qualities and measures, and provides guidelines to bring the process to the next level by pointing out and prioritizing which activities or issues have to be addressed first.

The first capability maturity model developed by the Software Engineering Institute (SEI) in the decade of the 1980's [3] shown in figure 1 consists of five levels:

- **Initial**: Characterized by an Ad-Hoc behavior, developers and teams react to the situation and improvise the activities to carry the project forward, there is no systematic approach, or processes in place.
- **Repeatable**: In this level organizations have processes to develop and manage a software project, allowing the organization to repeat the process using earlier experiences as baseline, although in this level processes still vary slightly from project to project.
- **Defined**: In this level, policies and processes are documented and followed throughout the organization, including both development and management.
- **Managed**: In the managed level the organization is able to quantitatively measure various aspects of their products and processes.
- **Optimizing**: In the optimizing level the whole organization has not only established a well-defined and managed process, but they are also focused on constant improvement of this process, which ultimately translates in software improvement.

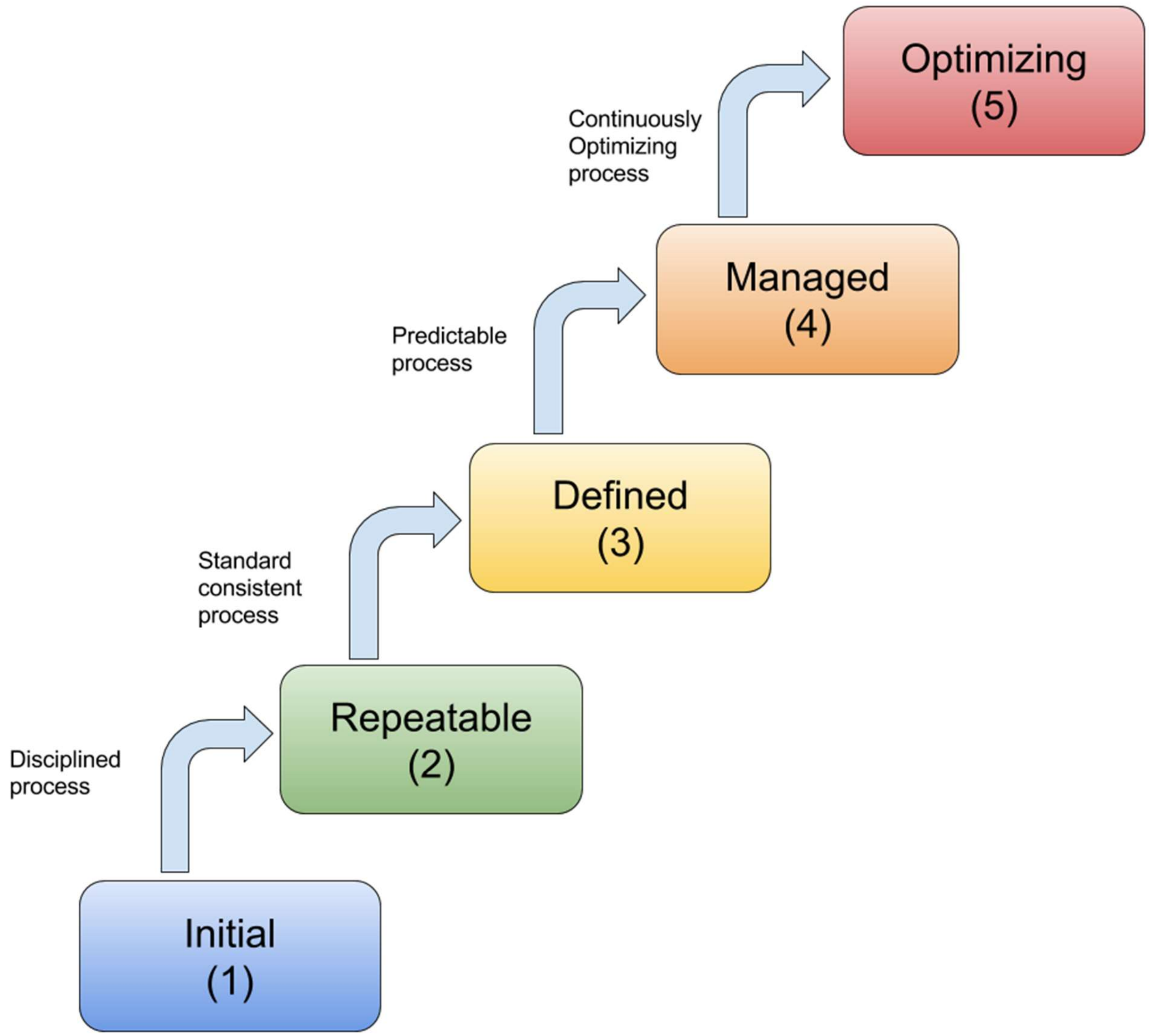

Figure 1. SEI Capability Maturity Model

3.2 Previous Cloud Maturity Models

The concept of maturity model has been applied to the context of cloud computing by previous researchers in different ways. Müller [35] uses the concept of maturity model to assess the benefits and define best practices of cloud computing. Similarly, Duarte [34] and Weiss [36] provides examples of a cloud maturity model to measure adoption and proficiency of cloud computing by organizations, as well as devise roadmaps for adoption.

A cloud maturity model, is based on the same foundation as the traditional capability maturity model, but it is focused to assess the maturity of an organization *"in specific domains and across cloud service models"*, as stated in the model proposed by the Open Data Center Alliance [33].

The model proposed by the Open Data Center Alliance [33], or ODCA by its initials, is of great help to this work since it already provides a suitable framework to define the metrics and qualities to be observed in the particular cases, as well as assessing the maturity level of the individual s cases. ODCA's maturity model is shown in figure 2.

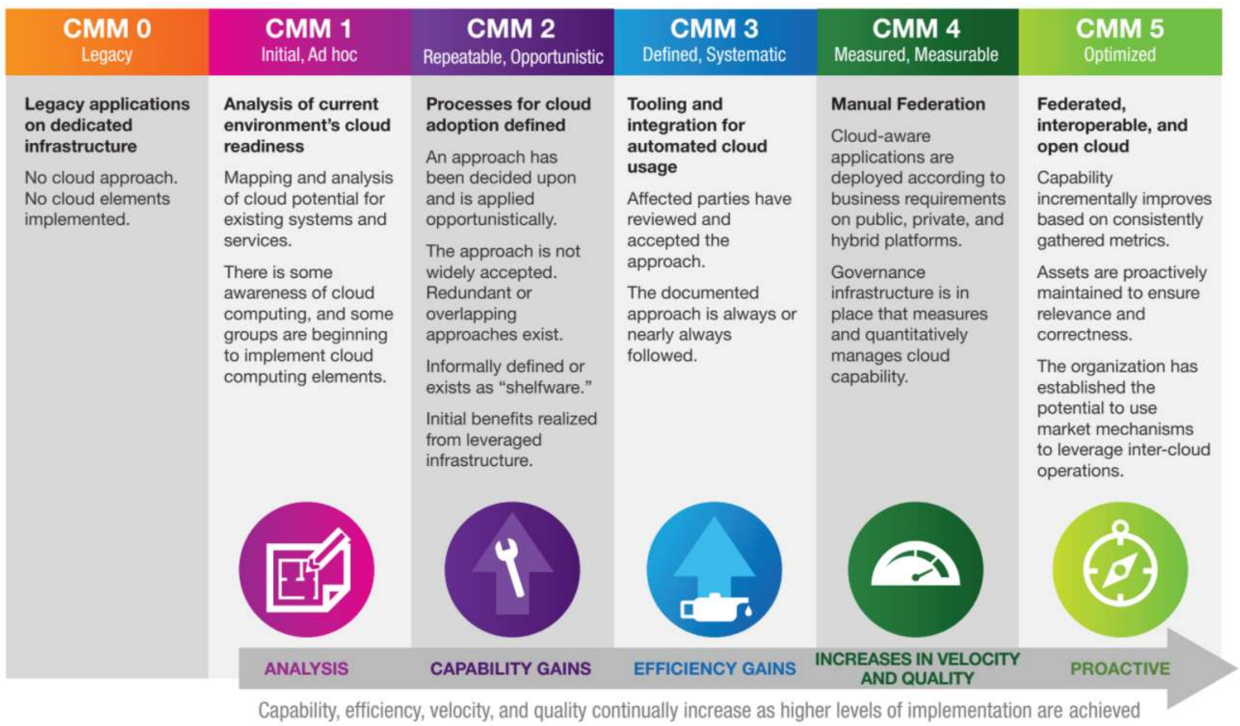

Figure 2. ODCA's Cloud Maturity Model

ODCA's model is generic by design, this means that it does not go into the particularities of a project, domain, or a particular cloud, in order to remain relevant and applicable for a wider range of cases.

However, ODCA's maturity model, perhaps due to its generic nature, may be cumbersome to apply to a specific domain, since it is needed to be interpreted and put into the organization's context to proceed with the maturity analysis.

Another cloud maturity model based on ODCA's is presented by McGeogh [37] for a case study within an organization, for which a custom maturity model is created fitted to the specific activities and business goals of the organization.

Finally, Abubakar [36] previously carried out an adoption in a particular geographical region, with very interesting output results about the adoption trends as well as the challenges faced by organizations who desire to adopt CC, not only from a technical perspective, but also taking in account management concerns and policy making.

3.3 The Simplified Maturity Model

The aim of this work is to provide a simplified maturity model that is still generic enough to offer organizations a quicker way to start assessing their maturity level and outline a roadmap to their target level. This simplified roadmap can be then expanded into ODCA's or other cloud maturity model.

The model proposed in this work, the model is modified to merge levels 4 and 5 in order to simplify the analysis. Figure 3 shows these levels in sequence.

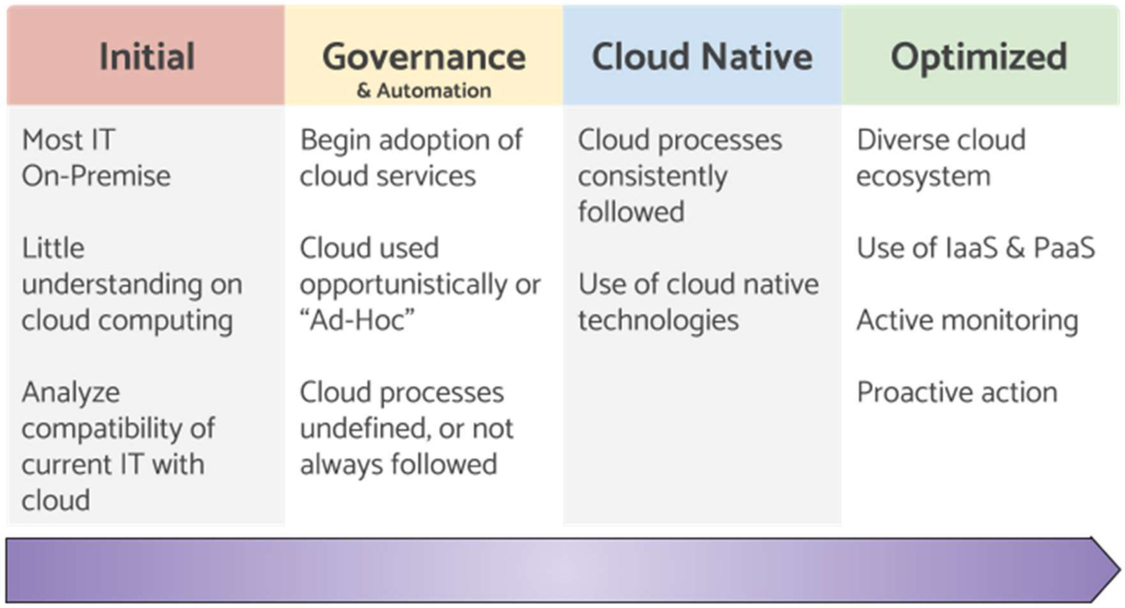

Figure 3. Proposed Simplified Cloud Maturity Model

This cloud maturity model will be the reference to map the organizations studied into maturity levels, also to point out what are the steps to move to the next level of maturity. Although upon more detailed revision the possibility to customize this cloud maturity model will be considered.

Level I - Initial

Most of the current IT is On-Premise, however there is some understanding of cloud technologies and it has been analyzed how the current On-Premise systems could in the future be moved, totally or partially, to the cloud to leverage from the benefits of cloud services.

Level II - Governance & Automation:

Cloud services have started being adopted in the current IT architecture, however there are no defined guidelines or best practices regarding the use of cloud services, or if there are, they are not being actively followed consistently across the organization. Cloud services are used opportunistically, in an *"ad-hoc"* fashion. Also, organizations have automated tasks related to management of their cloud assets.

Level III - Cloud native

Architects and developers begin to incorporate cloud native technologies in their systems, such as managed databases or application containers (e.g. AWS Beanstalk), stepping away from infrastructure maintenance and focusing on solving specific business problems leveraging cloud native technologies. Also, at this point there is a cloud strategy that is consistently followed across the enterprise.

Level IV - Optimization

The last stage is where enterprises incorporate diverse cloud services, from both IaaS and PaaS, have a defined cloud strategy and carry out monitoring and measuring of their cloud assets to proactively correct points of weakness, prevent issues, and have a swifter mitigation of the issues that arise during their operations.

4 Field study

4.1 Introduction to the field study

This section explains the methodology followed to conduct the field study, which consists of a series of surveys presented to a group of participants in order to obtain the data that later be analyzed to assess the overall cloud adoption of the participants and validate the cloud maturity framework proposed.

The relevant aspects of this section are the exploration of different research methods, and the rationale that lead to the selection of the method used to carry out the research work. The definition of a research method basically defines the direction and the next steps of the study.

Early on the introduction and literature review section, several similar studies that aim to generate knowledge and understanding of the current state of cloud computing are referenced, and will continue to be in the remainder of this work. These studies explore cloud computing not only as a technology, but also from a business and organizational context.

Nevertheless, as pointed out by Yang et. al [10], most of the research in cloud computing has been focused on the technical aspects, and only lately attention has been paid to the business and organizational impact of cloud computing. However, a gap of knowledge still exists between the technical research on cloud computing, and the business and organizational counterparts.

This study is in fact similar to those introduced earlier, in a similar way to Duarte [34] and McGeogh [38]; the goal is to study “adoption” of cloud computing in enterprises, find out the challenges that inhibit adoption, and finally to propose a tool to assess maturity, in the form of a cloud maturity model. These goals are, for the most part, located in a business and social context, rather than a purely technical one.

Despite the existence of previous studies that approach similar research questions, such as the adoption of cloud computing and cloud maturity models, by Duarte [34] and McGeogh [38], there is still room for more research it this area, based on the fact that most of the research done in cloud computing is from a purely technical focus and research from a business and organizational context has not yet caught up (Yang et. al [10]). Additionally, cloud computing is still a quite unexplored topic for the vast majority of enterprises that rely on On-Premise legacy systems, and for such enterprises, a simple and comprehensive tool to assess their current capabilities and a roadmap to explore cloud solutions is of high value, especially a simplified framework, that lowers the entry barrier for newcomers into the cloud.

4.2 Methodology of the study

Research methods have been traditionally divided into *"qualitative"* and "*quantitative"*, although as pointed out by Creswell [39], this division or categorization, is not meant to be binary, meaning that different research methods should not be thought of as purely qualitative or purely quantitative. Creswell [39] instead proposes the idea of a continuum where qualitative and quantitative are at both ends, and different research methods lay somewhere in this continuum, being either more qualitative than quantitative, or vice-versa, but always keeping elements of both.

Similarly, Creswell [39] states that the so-called *"mixed methods"* lay in the middle of such continuum, holding features from both qualitative and quantitative approaches in balanced quantities, not belonging to either end.

The methodology followed in this study is in fact a mixed methodology, that brings together elements from both qualitative and quantitative research. More specifically, the study consists of the following two stages, which belong to the different ends of the *qualitative-quantitative* continuum proposed by Creswell [39]:

1. The development of a Cloud Maturity Framework, through literature review of relevant research in the area of cloud computing. This would be the qualitative part of the research work
2. A field study, in which a series of interviews are conducted with professionals in the industry, who are using cloud services to support their business operations. The aim of this field study is twofold: One being to validate the cloud maturity framework developed in the first stage, and second to collect more information about the current status of adoption of cloud computing by the industry. This field study collects information in the form of close ended questions, with a numeric approach to manage the information, therefore making it the quantitative stage of the work.

4.3 Design of the study

Explain the study, shape/form approach, limitations and how it is implemented and conducted. Make a specific focus in the constraints of getting participants, and why the pool is relatively small.

The field study that builds the second part of this research work comprehends a series of surveys with a group of companies or individuals in the technology field, with experience in IT architectures, and cloud systems.

This survey is designed to validate the maturity model developed in the first stage of this study, which is a simplified model that originated from similar research, such as McGeogh [38] and also Open Data Center Alliance (ODCA) approach to assess cloud maturity in organizations.

Additionally, this survey is meant to provide a quantitative instrument for data collection, in the form of a closed-ended questionnaire, that will enable analysis of the data using traditional tools such as spreadsheets.

An open-source electronic surveying tool is used to build and deploy the survey to the participants. This tool provides a number of advantages over other approaches to carry out similar studies. Among these advantages are a comfortable user experience, leverage on an existing framework to create and manage surveys, with a streamlined process from the design and creation of a survey, and the delivery of the survey via a web URL or by email, as well as management of participants and answers.

4.4 Survey participants

The survey participants are selected from a small network of contacts, and from approaching companies with a suitable profile from online listings. The suitable profile mentioned, is the one of a small to medium sized company in the technology sector, with an address in Helsinki where it can be reached for their participation.

Several company listings are found online, given the strong entrepreneurship, and the dynamic ecosystem the city of Helsinki, and Finland in general, provides for startups and innovation.

However, after finding those companies that met the profile, approaching them is a different and challenging task, since they all have different locations, policies, and different levels of interest in participating in such projects. Nevertheless, it has been possible to find 12 companies willing to participate in this study.

Moreover, some of these participants are even eager to share more about their opinions and concerns with cloud services, other than the specifically stated in the questionnaire, and also what plans they have for the future of their IT systems. This information is of great value because it can offer insights into topics that are not addressed by the survey’s original questions, and serve as additional information to adjust the study, and broaden the scope of the study in directions that are relevant for the community.

This particularity of free-form interviews, offer the chance for the subject to elaborate about the topic in his own perspective and provide information that is not bounded to a fixed scope, as in the case of close-ended questions. This is an interesting fact already discussed and mentioned by McGeogh [38], that is also observed during this study.

The participants in the study were:

- Inline Market
- Yousician
- Nitor
- Zen Robotics
- Kaikuhealth
- Blancco
- Claudia
- Happy Signals
- Independent consultant 1
- Independent consultant 2
- Independent consultant 3
- Independent consultant 4

4.5 The interview process

After a group of potential participants is generated from various online listings of companies and startups that fulfilled the requirements (i.e. small-mid-sized companies, in the technology sector with an address where they could be reached in Helsinki), the next step is to visit them, and explain as clearly as possible, but also being brief and practical, about the study and the goals, and how they could participate in it.

There are many factors that influence the outcome of each of these encounters, from the size of the company, the internal policies they have about sharing information, or their busy schedule. All these factors may distract the potential participants from taking up the survey. In order to make a more significant introduction of the project, the physical visit to their site became the most effective alternative.

It is also observed that larger organizations tend to have more filters and layers that information has to go through to reach the right person to participate. For example, reception and front desk personnel can result into more difficulties when approaching larger companies. On the other hand, small companies are more straightforward when addressing requests, since they typically consist of only few people, it is not difficult to quickly find the right person for an inquiry.

When visiting the site of any of the prospective participants, it is of vital importance to introduce the topic in a practical manner, while providing just enough information to understand the subject, but also without becoming overwhelming. This proved to be challenging, since it is required to find the right balance of detail and generalization to introduce the topic to a prospective participant. It is definitely a task that requires some practice, and indefinitely variate from person to person.

4.6 Face-to-face and online survey

All the participants are approached in the first instance in person at their site, and asked for a few minutes to introduce the study and then asked to participate in the study right on that moment using a handheld device.

The average time to complete the survey is 5 minutes, therefore completing the survey at the moment of the first visit is a convenient option for the participants to quickly participate without the need to schedule further appointments.

Alternatively, some of the potential participants preferred to be contacted and have the survey delivered by email, which is in reality no different than taking the survey from the handheld device in the first visit. However, as it can be guessed contacting the participants online tends to be less successful than personally. Additionally, when the survey is taken online, there are less channels open to ask, clarify, and discuss related topics that are not included in the survey.

4.7 Survey questionnaire

The simplified maturity model proposed for this study is a model with 4 levels that allow enterprises to quickly perform an assessment of their cloud maturity, and then experiment with the larger models available for more specific assessment or roadmap planning.

The questionnaire designed for this study has the purpose of collecting data that allowed to directly map the participants into this simplified model. The questionnaire consists of 18 questions which are aimed to measure key areas of one of the levels in the maturity model and extract quantifiable information about these key areas to finally rank the skills of the enterprise on each of the levels.

As introduced in the 3rd chapter the cloud maturity model consists of the following four levels and the 18 questions are distributed in these 4 levels accordingly:

1. **Initial:** Questions 1 to 4. Focuses on assessing the organization's overall knowledge of cloud computing and if they have considered cloud services as part of their IT strategy.
2. **Governance & Automation:** Questions 5 to 8. Focuses on assessing the maturity of the organization's cloud practices, whether any best practices exist, and if are known and followed consistently in the organization.
3. **Cloud native:** Questions 9 to 12. Focuses on assessing the organization's domain on cloud native technologies, to inquire on the organization's position when it comes to using infrastructure services or platform services, IaaS vs PaaS.
4. **Optimization:** Questions 13 to 16. Focusses on assessing the organization's ability to monitor and manage their cloud assets, also of proactively identify weaknesses and swift mitigation of cloud related issues.

The full list of questions is located in the Appendix A section.

The last two questions are not related to a particular level of the cloud maturity model, but they are included in the questionnaire to obtain information about what are the motivators and inhibitors of adopting cloud services. These questions are derived from the main challenges of cloud computing identified in Dillon [12] and Duarte [34].

5 Data analysis

5.1 Background

The data collected through the field study enables the following analysis with the goal of finding insights that reveal the current status and trends in cloud computing, to also, help understand the current landscape.

The study conducted, and described in the previous sections, comprehends a survey in which 12 participants took part. The survey was designed to measure the maturity levels in key areas of cloud computing in order to assess the overall maturity of an enterprise.

The following section discusses the analysis of the data collected and possible ways to interpret the data to draw conclusions from it. Although, it should be noticed that the metrics and analysis do not represent the entirety of the possibilities to interpret the data. The same data can be reused for different purposes and merged with other sources to gain new insights.

5.2 Derived metrics and charts

As the survey results show, all 12 participants are familiar to some extent with cloud computing, however, they do differ in their levels of usage and adoption. The following metrics are drawn from the data to interpret and gain insight from the results of the survey.

Cloud deployments

The first chart composed from the data compares those organizations that already use cloud services, in any of its possibilities. Figure 4.

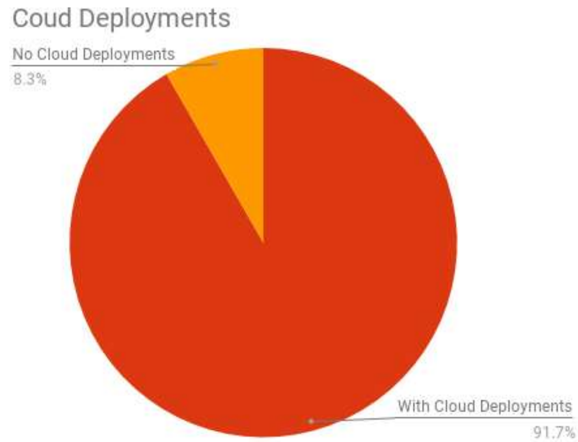

Figure 4. Organizations using CC

Note that figure 4 represents a comparison between those companies that already use cloud services in any way, however figure 4 does not provide any insight in the level of usage of cloud services.

The metric drawn from figure 4 suggests that most organizations have already started using cloud services, in one way or another.

Type of cloud deployments

The next visualization of the data is a comparison of the type of usage of cloud services across the participants. The categories included were: Experimental, QA/Test and production. Figure 5.

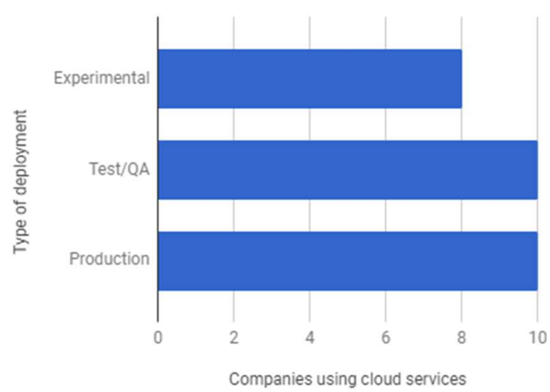

Figure 5. Comparison of types of CC usage

Figure 5 shows that most of the participants have used cloud services for different purposes already. This is a good sign about the adoption of cloud services among the participants.

Average of PaaS vs IaaS usage

This metric compares the use of cloud services per category, accounting only for IaaS and PaaS services. This metric shows a preference still for IaaS services. Figure 6.

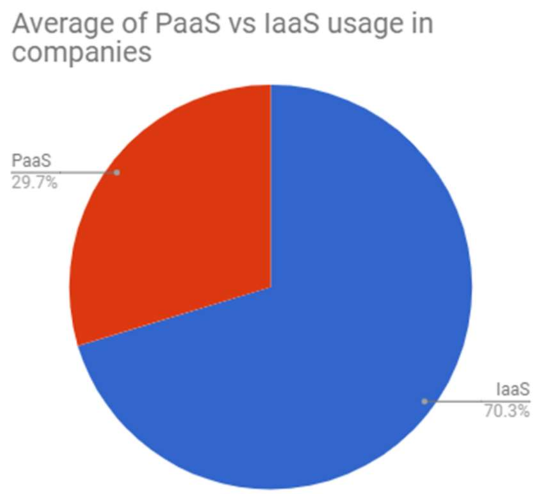

Figure 6. Comparison of PaaS vs IaaS

The metric from figure 6 shows that IaaS services are far more popular that PaaS services within the pool of participants, also suggests that IaaS is more popular in general with cloud services consumers.

Cloud native technologies

The cloud native technologies chart compares the use of cloud native technologies. Cloud native technologies belong to the PaaS layer, and enable companies to develop and deploy solutions rapidly greatly reduced infrastructure management requirements.

This chart only aims to compare those participants that are currently using any cloud native technologies. Figure 7.

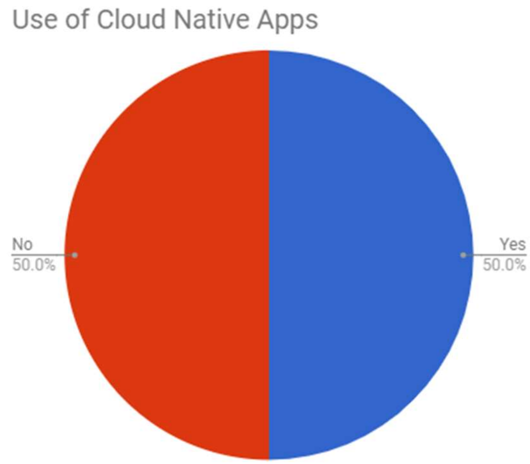

Figure 7. Usage of cloud native technology

Figure 7 shows that cloud native technologies are not used by about half of the participants. However, this metric does not indicate dominance of either of them.

Control vs Agility

The next chart compares the preferences between agility and control of the participants. This is an important metric, since IaaS are characterized for offering absolute control over the infrastructure, while PaaS services are characterized for reducing maintenance requirements at the expense of limiting the control over infrastructure, which typically remains hidden from the service consumer. Figure 8.

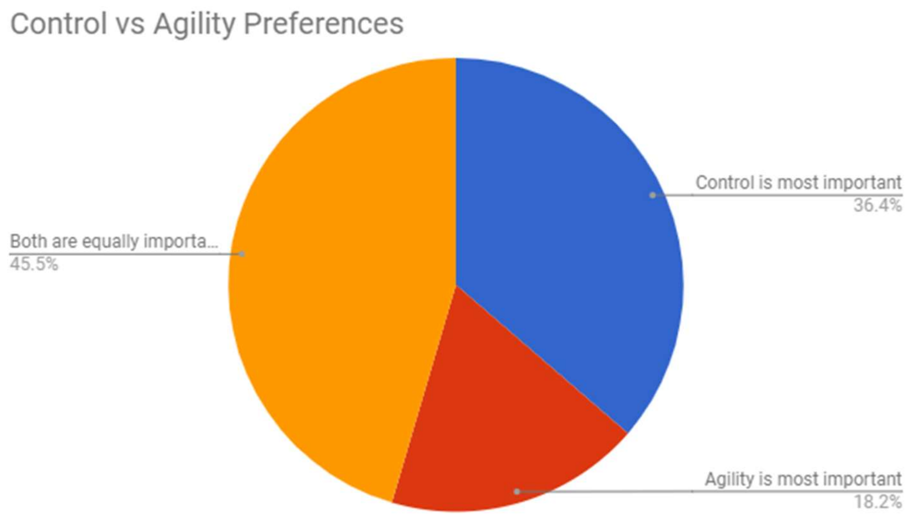

Figure 8. Infrastructure control versus agility

The metric shown in figure 8 shows that both control and agility are priorities for developers, a fraction of the participants pointed out that control is more important alone, with agility being at the bottom of the priorities.

This idea also supports the preference for infrastructure services over platform services, IaaS over PaaS, stated in figure 6.

5.3 Maturity indexes

The data collected through the questionnaire is useful to map the capabilities of each of the participants into the simplified maturity model introduced in chapter 3.

As introduced in chapter 3, the simplified maturity model used to assess the cloud capabilities of the participants consists of 4 levels. In a similar way, the questions in the study aim to collect information to make an individual assessment of each of the levels per participant.

The results of individual maturity levels reveal the areas in which an organization should focus resources to become more proficient, therefor mature in their cloud capabilities.

Ideally, an organization would approach cloud maturity starting from the first level through the fourth one. However, it is also possible for organizations to start working on the next level without achieving optimal maturity in the previous level.

The maturity indexes are calculated based on a short assessment of the answers to questions related to each level. The maturity levels of the participants are shown in table 1, without the names of the companies associated to the results.

Figure 9 shows a sample of three of the maturity levels from table 1. The chart in figure 9 displays only a subset of the data in table 1 to provide a visualization of the same data, however including too many series makes the chart unintuitive. Both table 1 and figure 9 are different representations of the same data.

	Maturity Level Indexes by respondent			
Company	Level 1	Level 2	Level 3	Level 4
Company 1	1	1	0.8	0.75
Company 2	0.5	0	0.2	0
Company 3	0.5	0.6	0.4	0.5
Company 4	1	1	0.8	0.75
Company 5	1	0.6	0.8	0.75
Company 6	1	0.8	0.4	0.5
Company 7	0.5	1	1	0.75
Company 8	1	0.8	0.6	0.5
Company 9	1	0	0.2	0
Company 10	1	1	0.8	0.25
Company 11	1	1	1	0.25
Company 12	0.5	0.6	0.6	0.25

Table 1. Sample of maturity indexes

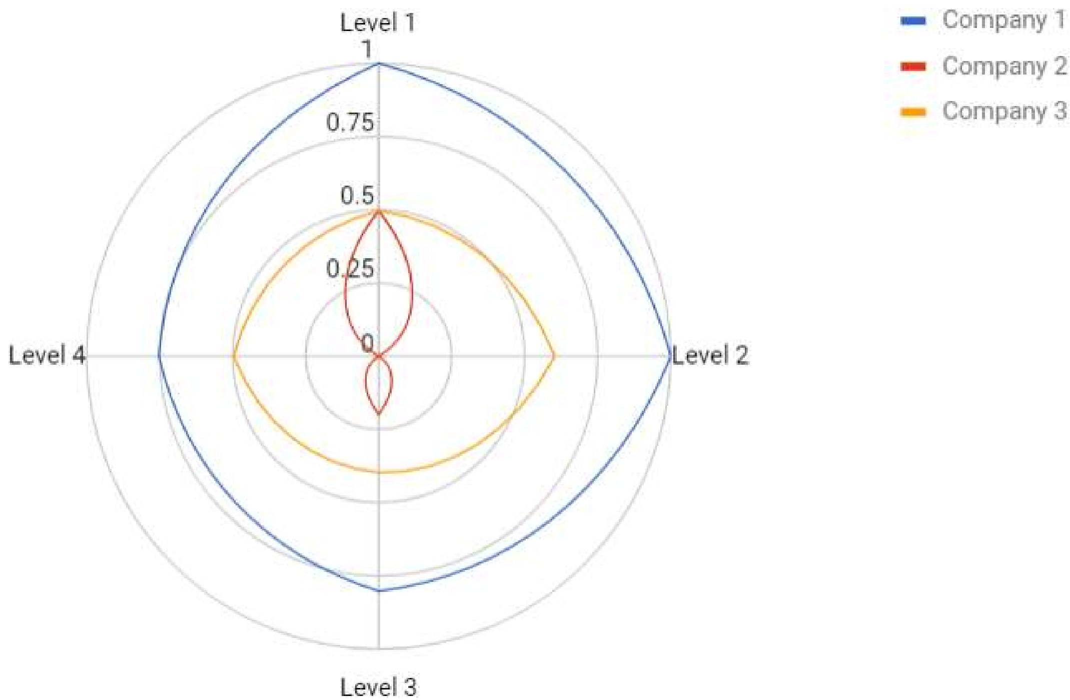

Figure 9. Polar representation of a sample of maturity levels

The three companies displayed in figure 9, and their maturity indexes on each of the maturity levels, are a good exemplification of the difference in the participant's maturity. It can be observed in figure 9 that one of the participants (labeled as company 2) has low maturity indexes in all levels. Another participant (labeled as company 3) has an intermediate performance across all levels, and the last one (labeled as company 1) has higher maturity indexes.

Another important aspect of the maturity levels that can be observed in figure 9 is that typically a company will have greater maturity indexes in the first levels of the model, and the value of the indexes is expected to decrease the higher the level.

5.4 Related findings

Aside from participating in the study by answering the survey, multiple of the subjects that participated in the study were open to share their view and concerns regarding cloud computing. This provided an opportunity to openly discuss other issues not directly addressed by the questions. As McGeogh [38] stated, free interviews are a valuable method to uncover issues or questions not considered originally in the study.

5.4.1 Motivators and inhibitors

Although the factors that motivate and inhibit adoption of cloud computing in the industry have already been addressed in the literature review, such as the research conducted by Dillon [12], the field study presented an opportunity to measure again these factors.

Figure 10 shows the summarizes the opinions of the participants about which are their main concerns with cloud services.

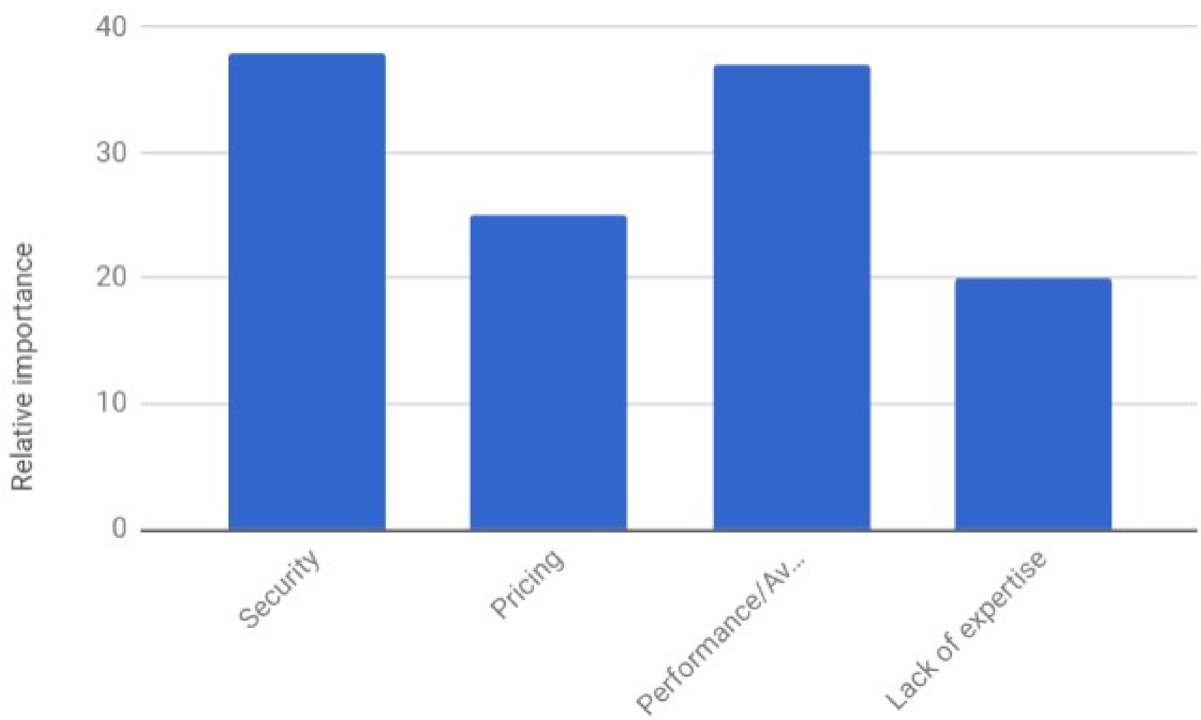

Figure 10. Relative importance of factors that inhibit cloud computing.

Analogously, the factors motivate the adoption of cloud computing among the participants of the study are shown in figure 11. Note that the factors included in figure 11, are not the only advantages of cloud computing that could be motivating users.

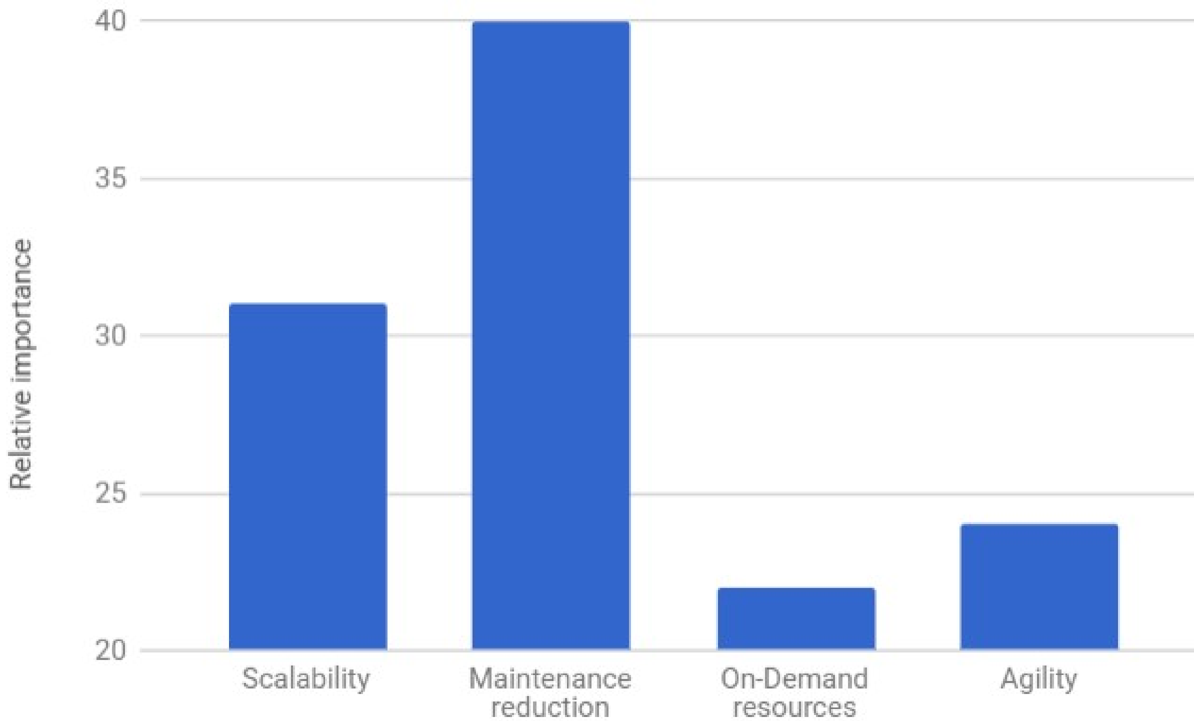

Figure 11. Motivators of cloud computing

5.4.2 Containers

During the interviews an important topic came up, which was not considered initially, but is certainly important to consider in the future. This topic was *"containers"*, and the technologies for creating and managing containers, such as Docker and Kubernetes.

Containers are a technology growing in popularity, a Docker container is defined at Docker's official website (docker.com) as "a lightweight, stand-alone, executable package of a piece of software that includes everything needed to run it: code, runtime, system tools, system libraries, settings".

Containers are often compared with virtual machines (VM), since the core ideas behind both technologies are somewhat similar. For instance, Preeth [40] analyzes and compares both technologies.

The main difference pointed out by Preeth [40] is that VM’s rely on virtualized hardware on which a whole guest OS is created, which can lead to unnecessary overhead and inefficiency. On the other hand, containers run within the host OS making a more efficient use of the infrastructure.

Joy [41] summarizes the benefits of containers, and why they are interesting and attractive for enterprises into: Portability, fast delivery, scalability and efficiency.

Portability comes from the fact that applications packaged along with dependencies can be deployed on any server.

Delivery of applications is also simplified, because development and deployment become separated and independent tasks, since developers can focus only on application development and packaging into a container, and administrators can safely deploy these containers without running into provisioning or compatibility issues between the development and the production environments.

Scalability is another feature of containers, since containers can be deployed on any server, regardless if it is on the cloud or an on-premise datacenter. Additionally, containers can be started and stopped very quickly.

Finally, Joy [41] labels efficiency as *“Higher workloads with greater density”*, which means since containers are more lightweight than VMs, more containers can run per physical server, utilizing host hardware and OS more efficiently.

During the interviews many participants mentioned containers into their roadmap, since they provide an attractive option to achieve scalability, portability, while reducing management and maintenance overhead.

6 Conclusions

Based on the findings of the literature review done in chapter 2, two remarks can be made about the status and direction of cloud computing. The first is the emergence of cloud computing as a reality that had long been promised by earlier paradigms (i.e. grid computing). And the second is that there are still several challenges to address regarding cloud computing.

Cloud computing has emerged on the market thanks to the technology advances in technology, but also thanks to the lessons learned in previous computing revolutions, i.e. utility computing and grid computing.

A very important issue with cloud computing is the one pointed out by Yang [10], which is that most of the research done in cloud computing, is focused on the technical, while organizational and business issues related to cloud computing are studied less depth. Although later research has addressed these knowledge gap.

The analysis performed in chapter 5 shows a preference for infrastructure services over platform services, despite of the efforts done by vendors to draw more users to their PaaS services. It seems users of cloud services are not willing to incur into the limitations of PaaS.

In a similar way, it was suggested by the field study that having absolute control over the infrastructure is still a top priority for users, which contributes to the slower adoption of PaaS services.

The use and growth of container technologies (such as Docker) may be attributed to the same issue with IaaS being the preferred type of service by enterprises. Since containers allow developers and architects to build custom applications without the limitations of PaaS, while allowing them to use IaaS services like a platform to deploy their applications in a more streamlined fashion.

The simplified maturity model presented in chapter 3 and analyzed more thoroughly on chapter 5 was applied to measure the maturity on the participants of the field study, and proved to be satisfactory to perform a quick assessment for enterprises with limited experience on cloud computing.

Similarly, the simplified maturity model allows enterprises to identify areas of maturity in which resources could be focused to achieve a higher maturity level.

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Appendix A

List of questions

1. Are you familiar with the three main layers of CC (IaaS, PaaS, SaaS)?
    - **Objective**: To assess the awareness of the cloud layers of the respondent
    - **Question type**: Single choice.
    - **Options**: Yes, No, Not sure.
    - CMM Target: 1
2. Do you currently have any cloud deployments (IaaS or PaaS)?
   Note: Of any kind and maturity, tests, isolated features, etc.
    - **Objective**: To inquire if the organization has already experimented (to any degree) with CC
    - **Question type**: Single choice.
    - **Options**: Yes, No, Not sure.
    - CMM Target: 1 - 3
3. Have you analyzed how your current infrastructure is compatible with the cloud?
    - **Objective**: To assess if the organization has evaluated how their current systems can be migrated to the cloud.
    - **Question type**: Single choice.
    - **Options**: Yes, No, Not sure.
    - **Condition**: If answered “No” in question 2.
    - CMM Target: 1
4. What type of cloud deployments exist in your organization?
    - **Objective**: To assess the maturity of their deployments and the cloud usage for existing systems.
    - **Question type**: Single choice.
    - **Options**: Experimental, Test/QA, Production, Not sure.
    - **Condition**: If answered “Yes” in question 2.
    - CMM Target: 2-3

5. Do you have any best practices and/or documentation regarding the use of cloud services?
    - **Objective**: To inquire if the organization has developed and communicated
    - Question type: Yes/No
    - **Condition**: If answered “Yes” in question 7.
    - CMM Target: 3
6. Are the different involved parties (managers, developers, end users) aware and consistently following the cloud practices of the organization?
    - **Objective**: To know the level of established governance in the company
    - Question type: Yes/No
    - **Condition**: If answered “Yes” in question 7.
    - CMM Target: 4
7. Do you have any processes and/or automation to create and provision cloud services?
    - **Objective**: To assess if the organization has evaluated how their current systems can be migrated to the cloud.
    - **Question type**: Single choice.
    - **Options**: Yes, No, Not sure.
    - **Condition**: If answered “Yes” in question 2.
    - CMM Target: 2-3
8. Do you have any integration of SaaS with internal systems?
    - **Objective**: To inquire if the organization has integrated a cloud service with another cloud service or on-premise system
    - **Question type**: Single choice.
    - **Options**: Yes, No, Not sure.
    - **Condition**: If answered “Yes” in question 2.
    - CMM Target: 2-3
9. Have you experimented with any “cloud native” services (using PaaS, managed DB’s, cloud storage, messaging, etc.)?
    - **Objective**: To inquire if the company has interest or has experimented with cloud native technologies.

- **Question** type: Single choice.
- **Options**: Yes, No, Not sure.
- **Condition**: If answered “Yes” in question 2.
- CMM Target: 2-3

10. Do you have any cloud native applications used in production?
    - **Objective**: In case the company has experience with cloud native technologies, to assess the maturity of their use.
    - **Question type**: Single choice.
    - **Options**: Yes, No, Not sure.
    - **Condition**: If answered “Yes” in question 2, and Yes in 9.
    - CMM Target: 3-4
11. From your current deployed solutions, which percentage is in each layer?
    - **Objective**: To assess the organization’s usage and preference for services across the different layers.
    - **Question type**: Sum of percentages
    - **Options**: IaaS, PaaS
    - **Condition**: If answered “Yes” in question 2.
12. Between the control offered by IaaS, and the agility of PaaS, what is the optimal balance for your organization?
    - **Objective**: To inquire on the organization’s interest in controlling low level infrastructure versus agility in deployment and maintenance.
    - **Question type**: Single choice.
    - **Options**: “Control is most important”, “Both are equally important”, “Agility is most important”
13. Do you have a provider change strategy to migrate existing solutions to a different cloud?
    - **Objective**: To inquire if the organization has a strategy to switch providers.
    - **Question type**: Single choice.
    - **Options**: Yes, No, Not sure
    - CMM Target: 4-5

14. Do you currently use a combination of two, or more, cloud providers and on-premise infrastructure to support your operations?
    - **Objective**: To inquire if the organization is mature enough to combine multiple clouds with on-premise to support their daily operations.
    - **Question type**: Single choice.
    - **Options**: Yes, No, Not sure
    - CMM Target: 4-5
15. Do you carry out active monitoring of your cloud services?
    - **Objective**: To know more about the governance framework of the organization
    - Question type: Yes/No.
    - CMM Target: 4
16. Do you collect any metrics about your cloud services?
    - **Objective**: To know more about the governance framework of the organization
    - Question type: Yes/No.
    - CMM Target: 4
17. What were the main motivators to move to CC?
    - **Objective**: To inquire on the organization's main drives to go into the cloud.
    - **Question type**: Multiple choice
    - **Options**: List all benefits of CC
    - CMM Target: NA
18. Which of the following risks is your organization more concerned about?
    - **Objective**: To inquire on the organization's view on the weaknesses of CC
    - **Question type**: Multiple choice.
    - **Options**: List the risks or weaknesses of CC
    - CMM Target: NA