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Applicability of IT service management in the migration to cloud computing

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Thesis

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RESUMO

O paradigma da computação em nuvem está a transformar a forma como os serviços de Tecnologia de Informação estão a ser disponibilizados, convertendo os produtos de TI em serviços. De modo a que as organizações consigam uma migração bem-sucedida para este paradigma necessitam de uma compreensão profunda das suas tecnologias de informação bem como o conhecimento da dinâmica da computação em nuvem. Neste sentido, foi desenvolvido um framework que agrega as atividades que devem ser realizadas na migração em dois grandes conjuntos: o "on-premise" e o "off-premise". Estes agregam as atividades que devem ser realizadas para migrar os serviços de TI de um ambiente tradicional para a computação em nuvem. O grupo "on-premise" engloba as atividades que devem ser realizadas pela organização, tais como o desenvolvimento de um plano estratégico, a descrição pormenorizada dos serviços e processos existentes bem como a definição do que deve ser migrado para a computação em nuvem. As atividades realizadas em colaboração com os provedores de serviços são englobadas no grupo "off-premise". Este engloba atividades tais como, a elaboração de uma lista detalhada dos serviços fornecidos pelos fornecedores de serviços, a identificação dos detalhes das tecnologias utilizadas e condições dos níveis de serviço.

Por outro lado, existe um grande número de recomendações relacionadas com a gestão de serviços e governança de TI em geral, tais como a ITIL e o COBIT, que, no entanto, não cobrem por completo o paradigma da computação em nuvem. Reconhecendo este problema, paralelamente com o facto do objetivo da computação em nuvem ser os serviços, o grande número de organizações que utilizam a ITIL para gerir os seus serviços de TI, a ITIL ser reconhecida como um conjunto de boas práticas mundialmente utilizadas decidiu-se estudar a aplicabilidade da gestão de serviços, nomeadamente a ITIL, à migração de serviços para a computação em nuvem.

A motivação para este estudo prende-se com a vantagem que as organizações podem usufruir do trabalho já realizado, da informação reunida e da gestão de serviços obtida aquando da implementação e utilização da ITIL. Adicionalmente, se o cliente e o fornecedor de serviços utilizarem a ITIL, a comunicação entre eles é também facilitada. De modo a res-

ponder às questões levantadas pela migração para a computação em nuvem e a aplicabilidade da ITIL a esta migração, foi desenvolvido um framework para suportar as organizações no processo de migração para a computação em nuvem e os processos deste framework mapeados na ITIL.

Palavras-chave: Computação em nuvem, ITIL, governação de TI, migração para a computação em nuvem.

ABSTRACT

The cloud computing (CC) paradigm is transforming the way Information Technology (IT) services are provided by converting IT products into services. This modification allows the delivery of IT services to end users in a way the customers stop purchasing products and start purchasing services instead. The successful migration to this paradigm by an organization requires a deep comprehension of its own IT as well as the dynamics of CC. To this purpose, a framework aggregating the activities that must be undertaken in two groups, the on premise and the off premise, was developed. The on premise group includes the actions developed by the customer, such as the development of a strategy plan, the attainment of a detailed definition of the organization processes and services and the definition of what to migrate to the cloud. The activities developed with the support of the candidates and selected CSPs are in the off premise group. This group encompasses activities such as the providers services', the details 'identification of the technologies related to the implementation of the organization processes into the cloud and the analysis of the conditions of service level agreement and the contract.

Furthermore, there is already an extensive set of recommendations for IT management and IT governance in general – such as the Information Technology Infrastructure Library (ITIL) and the Control Objectives for Information and related Technology (COBIT) recommendations. However, the field of CC remains poorly covered. Acknowledging this state of affairs and adding the fact that CC is concerned with IT services, not to mention the number of organizations using ITIL in order to manage their IT services, the fact that ITIL is being recognized as a set of good practices, led to the decision of studying the applicability of service management, namely ITIL, to the migration of IT services to CC. The motivation of this study is related to the circumstance that organizations can take advantage of the work already carried out, the information gathered and the management of services when implementing ITIL. Additionally, if the customer and the supplier implement ITIL, the communication between them is also improved. Accordingly, a framework to migrate IT services, applications data and infrastructures to CC has been developed and the processes of this framework have been mapped to the ITIL's framework.

Key words: Cloud computing, ITIL, IT governance, cloud computing migration

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ACRONYMS LIST

In this thesis acronyms of common names and organizations are used. To dispel any misunderstanding that may arise concerning what is meant by each of the abbreviations we present the list of abbreviations followed by their names.

AMI	Amazon Machine Image
API	Application Programming Interface
AWS	Amazon Web Services
BCP	Business Continuity Plans
BIA	Business Impact Analysis
BSI	British Standards Institution
CapEx	Capital Expense
CC	Cloud Computing
CCI	Cloud Computing Interoperability
CCTA	Central Communications and Telecommunications Agency
CDMI	Cloud Data Management Interface
CI	Configuration Item
CIMI	Cloud Infrastructure Management Interface
CMDB	Configuration management database
CMMI	Capability Maturity Model Integration
CMMI ACQ	Capability Maturity Model Integration for acquisition
COBIT	Control Objectives for Information and related Technology
CRM	Customer Relation Management
CSA	Cloud Security Alliance
CSCC	Cloud Standards Customer Council
CSP	Cloud Service Provider
DMM	Decision Matrix Method
DMTF	Distributed Management Task Force
IaaS	Infrastructure as a Service
IEEE CCSC	IEEE Cloud Computing Standards Committee
ISA	Information Systems Area
ISACA	Information Systems Audit and Control Association
ISACF	International Systems Audit and Control Foundation
ISM	Information Security Management
ISO	International Standardization Organization
ISO/IEC	International Standards Organization/International Electrotechnical Commission
IT	Information Technology
ITGI	IT Governance Institute
ITIL	Information Technology Infrastructure Library
ITSCM	IT Service Continuity Management
ITSM	Information Technology Service Management
itSMF	IT Service Management Forum

M_o_R	Management of risk
M2CC	Migration to Cloud Computing Framework
NIST	National Institute of Standards and Technology
OCC	Open Cloud Consortium
OCCI	Open Cloud Computing Interface
OGC	Office of Government Commerce
OGF	Open Grid Forum
OLA	Operating Level Agreements
OpEx	Operational Expenses
OVF	Open Virtualization Format
PaaS	Platform as a Service
PBA	Patterns of the Business Activity
PDCA	Plan Do Check Act
RACI	Responsible, Accountable, Consulted and Informed
RoI	Return on investment
SaaS	Software as a Service
SACM	Service Asset and Configuration Management
SCM	Service Catalogue Management
SEI	Software Engineering Institute
SIUPT	Sistema de Informação da Universidade Portucalense
SLA	Service Level Agreement
SLM	Service Level Management
SLR	Service Level Reports
SME	Small and Medium Enterprises
SOX	Sarbanes Oxley act
SPM	Service Portfolio Management
SPoF	Single Point of Failure
SWOT	Strengths, Weaknesses Opportunities and Threats
UPT	Universidade Portucalense
VLAN	Virtual Local Area Network
VM	Virtual machine
W3C	World Wide Web Consortium

Chapter 1

INTRODUCTION

The pressure of IT managers in doing more with fewer resources is constantly increasing. Cloud computing (CC) emerged as a computing model that promises increasing speed to market, on demand IT resources and a pay-as-you-go model that is transforming the way IT services are provided and consumed. By leveraging economies of scale to lower costs, CC has become an increasingly attractive option for businesses. However, as organizations migrate to CC they may putting their data at significant risks including security issues and fewer control over data.

The migration of in-house IT services to CC brings a complex set of issues implying that the shift should be performed carefully lest cause high losses in the organization. The question is, when a business migrates its IT to CC, it must have a process to balance the issues effectively and rewards of CC and guide the enterprise in its migration.

Moreover, if recently IT managers have been more concerned more with technical issues, nowadays they are engaged in minimizing future investments, capitalizing on investments already made and finding a way to perform their activities to achieve greater productivity with fewer costs. Thus, the improvement of processes and a more efficient management of them, happened to be in the spotlight, becoming the implementation of Information Technology Infrastructure Library (ITIL) regulations, a more generalized IT management, a valuable aid in the management of IT departments.

Taking into account the need to better meet user requirements with fewer resources and the advantages of the CC paradigm, the work now proposed aims to examine the adequacy of ITIL to the migration of IT services, applications data and infrastructures to CC. Therefore, the main research question that this research work aims to solve is:

Is the IT service management, namely ITIL, applicable to the migration of existing IT systems to CC?

Nevertheless, why is it important to answer to this research question? Despite the CC paradigm issues, see section 2.1.6, it is recognized, by the authors of (Birman, Chockler, & Renesse, 2009; Yanpei Chen, Paxson, & Katz, 2010; Chow et al., 2009; Dargha, 2012; R. Hill, Hirsch, Lake, & Moshiri, 2013; Kaur, 2014), that is a paradigm to stay. Furthermore the growing, number of organizations that are planning to migrate IT services to this new paradigm. Unlike other paradigms it is not always easy to migrate services to the cloud and return them to its traditional form if the cloud does not work as expected. Consequently it is advisable to carefully plan the migration to CC and by doing it, or not, after all the issues, impacts and risks have been previously analysed, weighted and studied. When and if it has been decided to migrate to CC it must be done by taking the appropriate steps towards the cloud. Additionally, as it was demonstrated in (ISACA, 2011), ITIL is the framework with the highest acceptance in the organizations and extensively tested by others. As a result, it would be useful if the work undertaken in ITIL implementation and knowledge gathered could be reused to support the organizations in their mission of migrating IT to the cloud by improving the quality of the information gathered and minimizing the work to be done. To answer the research question presented, a framework has been developed to migrate services, applications, data and infrastructures for CC and researched how ITIL could be applied to it.

Amongst the terms found in the literature to indicate that organizations are starting to use CC to deliver their IT services so far available in the data centres of the organization, one of the words found is "adoption" (Ezzat, Zanfaly, & Kota, 2011; A. Khajeh-Hosseini, Greenwood, & Sommerville, 2010; A. Khajeh-Hosseini, Sommerville, Bogaerts, & Teregowda, 2011; Shimba, 2010). However it did not seem quite appropriate, since the issue is not only the use and consequent adoption of CC, because it may also include the change of applications (either simply by changing the operating environment, from one on premise to CC, either by exporting data and importing it on native CC applications). A second word found was "move" (Clemons & Chen, 2011; Dargha, 2012; Gupta, 2010), which didn't also seem to be quite suitable because it is not a simple shift of where the applications are executed and used IT resources.

Another word to identify the process is "outsourcing" (Yao Chen & Sion, 2011; Kajko-Mattsson & Gustafsson, 2010; Pring, 2010). Although the process is similar to the out-sourcing process, there is a fundamental difference between the use of CC and IT outsourc-ing: self-service, scalability, and the "prepaid" model.

According to the motifs identified above and being "migration" defined as: "transfer (data, software or hardware) from one system to another" we believe that it better explains the process in analysis, since it also includes the idea of the possibility of changes (data, soft-ware or hardware) during the transition from one system to another.

Another term that needs to be clarified and why it is used is framework. The term frame-work has dissimilar definitions according to the environment where it is applied. In this work, we follow the definition of (Shehabuddeen, Probert, Phaal, & Platts, 1999) presented on the Terminology section below. Whereas the Migration to Cloud Computing (M2CC) framework, developed in this work, defines the processes that an organization should fol-low to migrate services, applications data and infrastructures to CC; additionally it includes steps that, when carried out by an organization, produce a smooth migration of services and applications to CC; for these reasons, we consider the M2CC a framework.

1.1 Scope and limitations

The scope of a research refers to the domain under which the study will be operational. This study researches the applicability of ITIL to the migration of IT to CC. We start with

the literature review, a continuous work that was as thorough as possible and will be finished when the thesis is completely written. To verify the ITIL applicability a framework has been developed to migrate IT to the CC and is steps were mapped to the ITIL processes.

We hoped to conduct case studies in distinct organizations. However, the restrictions such as the impossibility to find organizations that were, at the time of this study, migrating their IT to CC and predisposed to use the framework developed, limited this study to the Portucalense University (UPT). This study was delimited by the implementation and migration to a private cloud at UPT of 18 virtual servers, housing 35 services using a framework developed in the scope of this work. Each framework process was implemented according to the ITIL v3 good practices.

If we cannot make inferences from case studies, because they involve the behaviour of the persons and organizations who participate in it, additional research was needed, in order to corroborate the findings reached. To overcome this limitation an expert group opinion has been and an action research method was undertaken.

1.2 Contributions

This section presents the contributions of this thesis to the knowledge. Accordingly, the contributions of this thesis include:

- **A literature review (**Chapter 2): The literature review focus is on the topics related to the migration of services to CC and IT service management, namely ITIL. It starts by CC related issues, such as definition and its organization followed by the related technologies and the advantages and challenges of the paradigm. Information regarding CC standards, the scientific and academic projects in CC as well as commercial platforms is also included in the literature review. The review ends with the presentation of the related work and with a section concerning IT governance frameworks. This chapter allowed us to develop a framework to migrate services, applications, data and infrastructures for CC.
- **A framework for migrating services, applications, data and infrastructures to the CC**, (Chapter 3): This framework presents the procedures needed to migrate services to CC.

- **A mapping of the framework processes to ITIL** (Section 3.3): This is a core contribution of this study. The processes defined in the framework are mapped to the ITIL processes supporting the research question concerning the ITIL applicability to the migration of services to CC. It must be emphasized that this mapping to ITIL processes could be used in other frameworks.
- **Publications**
    - Papers in academic conferences
        - (Cardoso, Moreira, & Simões, 2015) - Mahmood, P. Z. (Ed.) Cloud Computing Technologies for Connected Government A Support Framework for Migration of e-Government Services to the Cloud IGI Global Publication, 2015.

          This book chapter is about the aplication of the work developed in an e-government environment. Been a peer review work, it is also usefull as a validation of the work developed.
        - (Cardoso, Moreira, & Simões, 2014) - A Survey of Cloud Computing Migration Issues and Frameworks New Perspectives in Information Systems and Technologies, Volume 1, Springer International Publishing, 2014, 275, 161-170

          In this paper, we present a study of frameworks (section 2.2.1) developed to migrate IT services and applications to the CC. The paper ends with a summary description of the proposed solution to the migration of services, applications, data and infrastructures to cloud computing.

          This paper was useful in section 3.2.
        - (Cardoso & Simões, 2012a) - Cloud computing and Security Proceedings of the 11th European Conference on Security Warfare and Security, Laval, France, 2012, 70

          CC appears to have the right technological and market ingredients to become widely successful. However, there are some key areas where CC is still underperforming – such as security. Availability, security, privacy and integrity of information are some of the biggest concerns in the process of designing, implementing and running IT services based on CC, due to technological and legal matters. In this

paper, we discuss the security implications involved in the migration of IT services to the CC model, proposing a set of rules and guidelines to be followed in the process of migrating IT services to the cloud.

This paper was useful for sections 2.1.6.8, 3.2.1.3.1.5 and 4.5.3.1.8.

- (Cardoso & Simões, 2012b) - Cloud Computing: Concepts, Technologies and Challenges Virtual and Networked Organizations, Emergent Technologies and Tools, Springer Berlin Heidelberg, 2012, 248, 127-136

  This paper presents the state of the art of CC and discusses the key challenges of an ongoing research work, focused on the applicability of IT governance to the migration of existing systems to the cloud.

  This paper was useful for sections 2.1.

- Presentation
  - (Cardoso, 2011) - Aplicabilidade da governança de TI ao paradigma cloud, 2011
- Doctoral consortium
  - (Cardoso & Simões, 2011) - Aplicabilidade da governança de TI ao paradigma da computação em nuvem Doctoral Consorcio, 2011.

1.3 Motivation

A growing number of organizations is expected to migrate their IT systems to CC (Tušanová, 2012). Conversely, CC migration has a great growth potential with the current and predicted total budget to be spent on its services (Nkhoma & Dang, 2013).

However, there has not been much attention given to provide sufficient support to the process of moving IT services to CC. Indeed, there is little literature available on process and methodological guidance on migrating existing software systems to CC (Chauhan & Babar, 2011), namely because it is a new and evolving field (Conway & Curry, 2013). Additionally, as argument the authors of (Beserra, Camara, Ximenes, Albuquerque, & Mendonca, 2012), there is a lack of an overall process to support applications developers in choosing the cloud model to use and the assessment of the risks involved in the migration.

The difficulties organizations are faced with when migrating (partially or completely) their IT to CC has started to gain the attention of the research community with works published on the topic such as (Beserra et al., 2012; Ezzat et al., 2011; A. Khajeh-Hosseini et al., 2011; Kumar & Garg, 2012; Nuseibeh, 2011; Tušanová, 2012). However, none of these works has presented a systematic process, sufficiently detailed, in order to be useful as a guide for IT managers throughout the steps and decisions involved in a typical migration to CC. Moreover, this work was also triggered by the absolute need to improve research in CC as well as in IT Service Management (ITSM) identified by Robert Heininger (2012).

1.4 Methodology

According to Dan Remenyi and Arthur Money in (2004), the research methodology can be defined as a collection of tests and analysis approach that can be used for the comprehension of a phenomenon contributing to the body of knowledge. Giving this definition and the objectives to be achieved with this work, it was first conducted a literature review to know the state of art in CC, the migration of IT to CC and IT services management to frame the research we intends to pursue.

To validate the work, besides the case study and the action research conducted at UPT and taking into account the impossibility of developing other case studies at other organizations, it was also considered necessary to consult a panel of experts in the field as well as a structured interview to demonstrate the results achieved.

1.4.1 Introduction

A research project requires substantial attention to the research methodology that can be defined as a way to systematically solve a research problem. The methodologies of research used in this study includes a literature review, a case study development and analysis, an action research, a survey of a group of experts, the publication of papers peer reviewed and structured interviews. Table 1 presents the usage of each methodology within this work.

Table 1 - Methodology usage

Methodology		Usage
Literature Review		To gather information about CC, related technologies, ITIL, migration to CC and other works developed within the migration to CC. The literature review is useful to gather information concerning the research conducted by other researchers to comprehend how far they have contributed to the knowledge. With this aim, papers, proceedings, reports, books, internet pages and thesis were studied.
To support the development and validation of the framework and the ITIL role on it.	Case study	The case study is used to comprehend, in-depth, how the migration of IT services, applications, data and infrastructures to CC works. If some authors consider that it is difficult to generalize from a case study (Scapens, 1990) others consider (Flyvbjerg, 2006) it a misunderstanding, anyway it can be used to test whether and how, scientific models work in the real world.
	Action research	In some situations, such as when it was necessary to migrate services with special hardware requirements or it was necessary to identify and define training needs or even to answer to issues related with costs, the author has an intervention on the research to test new approaches that resulted in changes of the original framework. These interventions followed the action research methodology.
	Panel of specialists	To overcoming the issues of one case study we may triangulate the study with other methods to confirm the validity of the process (Zainal, 2007) therefore, we appealed to a survey of a group of experts.
	Paper publication with peer review	An additional way to validate our ideas and the work developed. It was also useful to gather the point of view of other researchers and as a brainstorm.
	Structured interviews	It is common to distinguish between structured, semi-structured and unstructured interviews. The structured interviews have very specific objectives while the semi-structured are more flexible since the interviewer has some room to adjust the sequence of the questions and can add new questions. In the unstructured interviews, the interviewer suggests a theme for the interviewed and has few specific questions a priori (Andrea Fontana, 1994; Hove & Anda, 2005; Y. Zhang & Wildemuth, 2009). Three interviews have been performed. 1. To validate the results of the "test the solution in a controlled environment" step, that is, to recognize the results of the migration of the test services migrated to the cloud occurred.

Methodology		Usage
		2. To gather the results of the developed framework implementation from the stakeholder's point of view to demonstrate the usefulness and the results obtained from the work developed. These interviews were carried out with members of the organization where the case study was implemented. The selection of the participants was made according with their involvement and knowledge of the processes migrated to CC. The profile of the respondents corresponds to the support areas of the UPT, and those are, Financial, Human Resources, IT management and Legal. 3. To validate that the solution achieved encompasses the CC technical advantages.

1.4.2 Research process

"The research shall move from objectives and questions, to assumptions and design choices, to specific data uncovered, and finally, to results and conclusions" (Klein & Myers, 1999). To accomplish this we start identifying a suitable problem to study and choose the research question to which we want to answer. The theme chosen was CC. However, this is a broad topic which led necessarily to establish tighter restrictions. Hence, hypotheses such as migrating services to CC, security, applications, and legal considerations were evaluated having been decided that only the migration of IT to CC was going to be treated. Again, despite the scope has been reduced, it was still too general to what was intended. CC's concern is the IT services and a large number of organizations use ITIL to manage their IT services. As such we settled to study the applicability of service management, namely ITIL, to the migration of IT to CC.

To understand what other researchers had done regarding the subject, we conduct literature review, including books, academic papers, research reports, conference proceedings, regarding the topics related to the questions to respond, CC, IT governance and the work done by other researchers regarding migrating services, applications and data to CC. The work follows with the thesis development to answer to the research question identified. Therefore, we develop a framework to migrate IT to CC. This framework has been modified according to the action research principles and validated with a case study in a multi-methodological approach. An additional validation was accomplished with a paper publication and with a survey to an expert group and a structured interview. The following step

presents the discussion of the results gathered in the case study and in the survey of the expert group. The work terminates with the conclusions.

Nevertheless, it must be justified why we chose the action research to validate and change and the case study methodology to validate our work. Accordingly, the characteristics of the research methodologies are identified in Table 2. Besides the case study, we also use the action research methodology since sometimes our position changes from an independent observer to a participant. Therefore, while we are studying the case developed at UPT, we are also participating in the implementation by suggesting some changes in the procedure and evaluating the results, which resulted in changing some aspects of the framework developed and the introduction of some additional steps. An example of these changes was the introduction of the tests that done in the middle of the migration process.

Table 2 - Research methodologies comparison

	Case study	**Action research**	**Structured interview**
Definition	Yin (R.K. Yin, 2003) defined case study as an "empirical inquiry that investigates a contemporary phenomenon within its real - life context, especially when the boundaries between phenomenon and context are not clearly evident "	It is an active process of progressive problem solving designed to improve strategies, practices or a working environment. "It seeks to reconnect action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people."(Reason & Bradbury, 2001)	It is an interview where the interviewer asks each interviewee a series of pre-established questions with a limited set of response categories. (Andrea Fontana, 1994).
Used for	Investigate a contemporary phenomenon and build a theory and answer questions like "how" or "why".(R.K. Yin, 2003)	Intervention, evaluation and testing.	Gather information about a predetermined topic and ensure consistency of response.

	Case study	Action research	Structured interview
Research process	Design the case study, conduct the case study, analyse the evidences and develop the conclusions, recommendations. The research questions are specified prior to the study by researchers (Benbasat, Goldstein, & Mead, 1987).	Interactive, cyclical, participative; Diagnose, action planning, action performing, evaluate, document and learning (Santos, Amaral, & Mamede, 2013);	The researcher asks, to the interviewees, a list of predetermined questions about a previously selected and defined topic.
Advantages	Richness of the collected data; Examination of the data is most often conducted within the context of its use (R.K. Yin, 2003)	Always relevant to the participants. The researcher obtains in-depth and first hand understanding of the research (Benbasat et al., 1987).	It is easy to standardise. It provides a reliable source of quantitative data. Enables the interviewer to ask each respondent the same questions in the same order (Andrea Fontana, 1994; Mathers, Fox, Hunn, & Group, 1998)
Issues	Data collected cannot necessarily be generalized.	Researcher bias	The quality and usefulness of the information depends on the quality of the questions asked.
Investigates	Contemporary phenomenon within its real-life context.	Changes in the practices	Interviewee's knowledge about a particular topic
Researchers position	Independent observer.	Participate in the analysis.	Interview the interviewees.
Focus	Find relevant issues for theory (R.K. Yin, 2003).	Generating solutions to practical problems with engagement of the researchers (Winter & Munn-Giddings, 2001).	Gather detailed information for example for measurement or academic analysis about a topic (Andrea Fontana, 1994).

Introduction

To validate the results of the "Test the solution in a controlled environment", a short interview, presented in Figure 1, was conducted with the employees affected by the services under testing.

1. Was the outcome of the tests performed the expected?
2. Has the access speed to the applications has been improved?
3. Were there breaks in the applications availability?
4. Were the accesses to the applications kept unchanged?

Figure 1 - Interview I questions (tests in a controlled environment)

To understand the perception of the stakeholders and to validate the results obtained with the implementation of the M2CC framework (and its relationship with ITIL) to migrate IT to CC, a structured interview to the employees affected by the migration of services was conducted.

Having in mind the activities required in an interview we started it by selecting the set of participants who must be interviewed. For the interview were considered the employees of administrative services and area managers - a total of 16 interviewed. They were selected according to the use they have of the services that had migrated to private cloud. The concepts that needed to be included in the study were defined. Accordingly, we considered the various aspects of migration that were performed, such as the process evolution, the advantages and the decisions taken. Based on the participants selected and on the concepts we intent to study, the following questions are identified.

1. Were the applications were migrated with the same functionalities?
2. Were there were breaks in the application accesses at migration time?
3. Were the accesses to the applications kept unchanged?
4. Has the access speed to the applications has been improved?
5. Have the applications' availability problems have been solved?
6. Was the information migrated to the new platform was complete?
7. Did your processes, dependent on migrated applications, suffer any changes?
8. Were the applications chosen to be migrated to the cloud were appropriate?
9. Was it important to maintain the existing applications?
10. Was it important to maintain the applications on the premises of UPT?

Figure 2 - Interview II questions

The interviews started by giving to the interviewees an overview of what the purpose of the interview was. Each interview followed the questions presented and a transcript of each interview was produced.

At the same time a technical interview, presented in Figure 3, was conducted with the technical staff of the IT area of the UPT responsible for the migration. This interview was useful to validate the technical details of the new solution and to recognize the CC benefits identified.

The implemented solution allowed?

1. To improve the backup process?
2. To dynamically change the resources allocated to machines?
3. To increase the service's availability?
4. To improve the access speed to the applications?
5. To help you create new machines?
6. Decreasing the amount of time needed to create a new machine and providingnew services?
7. To reduce the number of physical machines?
8. To reduce the consumption of electrical energy?
9. To turn on and off machines according to the needs?
10. To create machines for testing and delete them when they are no longer needed?
11. To generated new machines from a template?

Figure 3 - Interview III questions (technical aspects)

1.5 Problem discussion

The decision of migrating IT to CC, by an organization, is somehow similar to the decision of the traditional outsourcing. However, there are additional concerns and benefits, which cause the CC adoption a more complicated decision (Nuseibeh, 2011). Indeed and as recognized by Khajeh-Hosseini et al. in (2011), there is a key difference between CC and IT outsourcing, self-service, scalability and the pay-as-you-go model.

To achieve the stated objectives and in accordance with the research question presented a reference framework for the migration of existing infrastructure and IT services to the CC shall be elaborated. This framework will take into account the CC, with their service and deployment models, and the actions to be taken when migrating to CC. The developed framework will be used to assist decision makers and IT staff regarding when, how and why IT can be migrated to the cloud. Additionally, the CC is concerned about IT services as well as ITIL and the latter has processes that have been tested by distinct organizations. Therefore, it makes sense to check whether the ITIL processes can be used (if they are applicable) in the migration to CC. If so, the responsible of migrating services to CC are freed to perform tasks that they had already performed when implementing ITIL. If the organization had not implemented ITIL it can still use the ITIL processes separately to

perform the processes identified by the framework, thus taking advantage that the ITIL processes have been tested in distinct organizations.

1.6 Terminology

Many terms used in this thesis are addressed by different authors with slightly different meanings. Therefore and to avoid misunderstandings regarding what is meant by each concept, we present in this section the definition of these terms.

Cloud Computing: "a model for enabling convenient, on demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or CSP interaction." (Mell & Grance, 2011, p. 2).

Catalogue of services: "A database or structured document with information about all Live IT Services, including those available for deployment. The Service Catalogue is the only part of the Service Portfolio published to Customers, and is used to support the sale and delivery of IT Services. The Service Catalogue includes information about deliverables, prices, contact points, ordering and request Processes."(Hanna, 2011, p. 67).

Contract: "A legally binding agreement between two or more parties." (Hanna, 2011, p. 22).

Corporate governance: "Enterprise governance is a set of responsibilities and practices exercised by the board and executive management with the goal of providing strategic direction, ensuring that objectives are achieved, ascertaining that risks are managed appropriately and verifying that the enterprise's resources are used responsibly" (I. G. Institute, 2003, p. 6)

Event: "Any detectable or discernible occurrence that has significance for the management of IT infrastructure or the delivery of IT services" (Hanna, 2011, p. 32).

Framework: "A framework supports understanding and communication of structure and relationship within a system for a defined purpose." (Shehabuddeen et al., 1999, p. 4).

Governance: the way that a city, company, etc., is controlled by the people who run it ("Merriam-Webster," 2013, para. 1).

Hypervisor: is a software generalization of a physical hardware that allows multiple guest operating systems to run concurrently on a single physical machine.

Incident: Is an unplanned interruption to an IT service or a reduction in the quality of an IT service. (Hanna, 2011, p. 37).

IT governance: "IT governance is the responsibility of the board of directors and executive management. It is an integral part of enterprise governance and includes the leadership and organizational structures and processes that ensure that the organisation's IT sustains and extends the organisation's strategies and objectives." (I. G. Institute, 2003, p. 10).

IT infrastructure: "All of the hardware, software, networks, facilities etc. that are required to develop, test, deliver, monitor, control or support applications and IT services." (Hanna, 2011, p. 41).

Information Technology Infrastructure Library (ITIL): ITIL is a public framework that describes Best Practice in IT service management. It provides a framework for the governance of IT, the 'service wrap', and focuses on the continual measurement and improvement of the quality of IT service delivered, from both a business and a customer perspective (Cartlidge et al., 2007, p. 8).

IT service management (ITSM): refers to the implementation of a process-based practice and management of quality information technology services intended to align IT delivery with the needs of the organization.

Migration: Transfer of data, software or hardware, from one system to another.

Organization: "A company, legal entity or other institution. The term is sometimes used to refer to any entity that has people, resources and budgets – for example, a project or business unit." (Hanna, 2011, p. 51).

Requirements: The formal statements of what is needed (Lloyd, Rudd, & Taylor, 2007).

Resource: "is defined as a generic term that includes IT infrastructure, people, financial means or anything that might help to deliver an IT service" (Hanna, 2011, p. 62).

Service: The understanding of service follows the ITIL definition that states "Service is a means of delivering value to customers by facilitating outcomes customers want to achieve without the ownership of specific costs and risks."(Hanna, 2011, p. 66).

Service Level Agreement (SLA): is a legal written agreement, negotiated between a customer and a service provider that documents agreed service levels and "defines the minimal guarantees that a provider offers to its customers" (Baset, 2012, p. 63).

Virtualization: "a technology that introduces a software abstraction layer between the underlying hardware i.e. the physical platform/host and the operating system(s) (OS) i.e. the guest virtual machine(s) (VM) including the applications running on top of it" (Bazargan, Yeun, & Zemerly, 2012, p. 335).

1.7 Thesis structure

The rest of this thesis is organised as follows.

Chapter 2 — we present the related work with this thesis, that is, information concerning CC, IT governance frameworks and works developed regarding the migration of services, applications and data to the CC.

Chapter 3 — describes the framework developed to migrate IT to the CC and the applicability of the ITIL to the framework.

Chapter 4 — presents the case study used to demonstrate the use and the feasibility of the work done.

Chapter 5 — discusses the work done and the results achieved.

Chapter 6 — concludes the thesis by summarizing the conclusions, the contributions of this work, the empirical findings, the limitations of the research and further work.

The Figure 4 presents, in a pictorial form, the thesis structure.

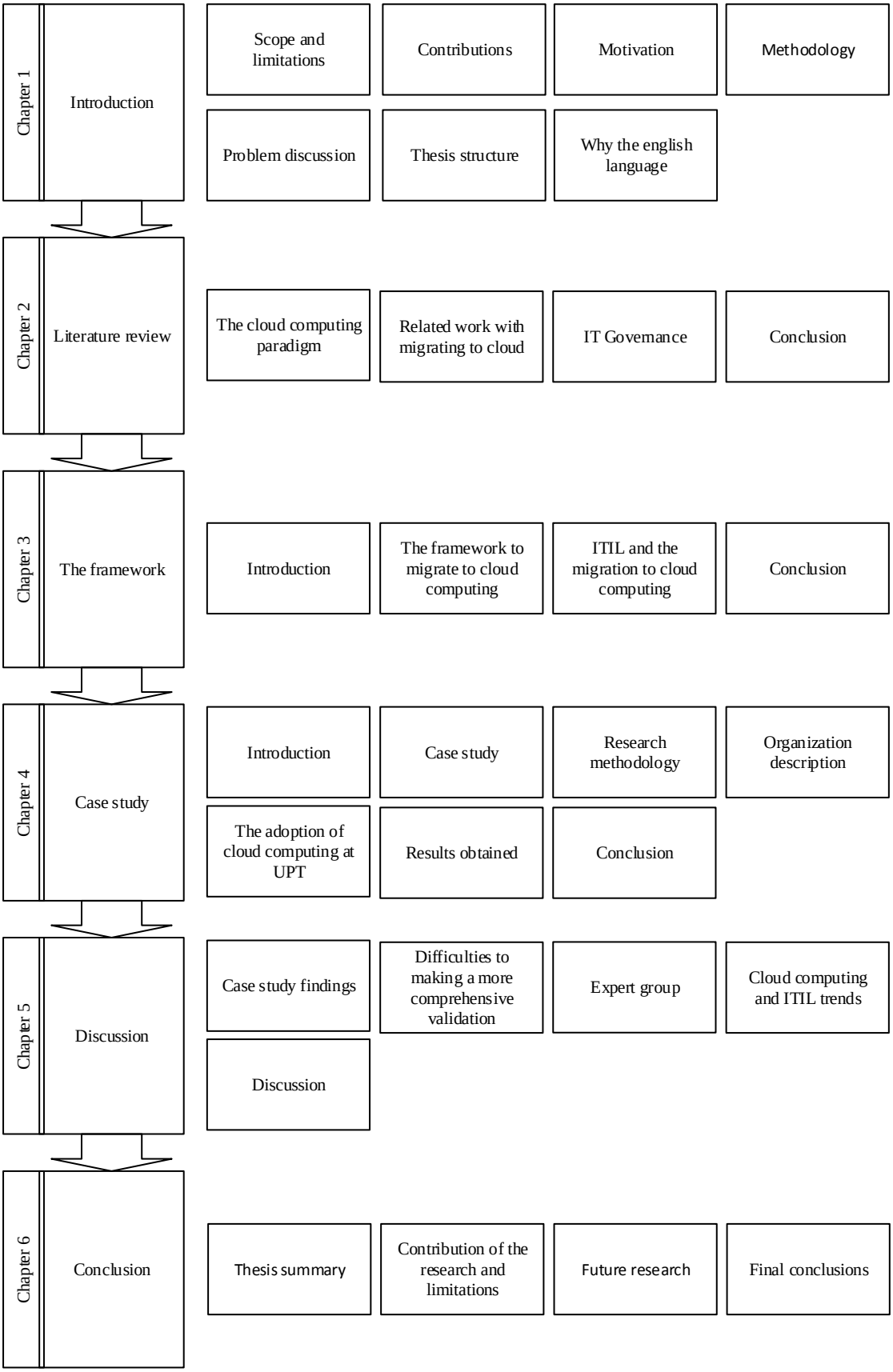

Figure 4 - Thesis structure

1.8 Why the English language

A thesis is a written report regarding the issues in the author's research area and presents what was previously known concerning the theme, what the author has performed in order to solve the problem (the research question) and what progress it adds.

The advantages of having a common language in science are the increase on the number of readers who know our work and accordingly a greater dissemination of knowledge, the facility to be cited and noticed and the easiness of communication between researchers from countries with their own languages. By way of example, only 5% of the references consulted for this work are written in Portuguese (we include the Portuguese and Brazilian Portuguese), the remaining 95% are in English.

Bearing in mind the reasons stated above and since the circumstances of the majority of the consulted papers as well as the attended conferences to this work are in English, we therefore decided writing this thesis in this language.

Chapter 2

LITERATURE REVIEW

The purpose of a literature review is to present a research and knowledge explored by other researchers that is relevant for the work presented. Consequently, the goals of this chapter are, firstly, to introduce the CC paradigm, secondly the IT governance and finally the presentation and analysis of other works regarding the IT migration to CC.

2.1 The cloud computing paradigm

There is always a strong pressure on Information Technology (IT) staff to do more with fewer resources. Over the decades, this pressure to rationalize IT costs spurred a number of paradigms, technologies and buzzwords. Some of them failed to meet their promises; others became successfully embed in IT practices and infrastructures, providing sizeable benefits.

The paradigm of CC is currently riding this wave, promising to be the great revolution in IT. CC appears to have the right technological and market ingredients to become widely successful.

2.1.1 Introduction

CC is a cost-effective (Alsouri, Katzenbeisser, & Biedermann, 2011; Marston, Li, Bandyopadhyay, & Ghalsasi, 2011; R. Wu, Ahn, Hu, & Singhal, 2010) (at least in short periods of time) and flexible (Convery, 2010; Ezzat et al., 2011; Ramgovind, Eloff, & Smith, 2010) platform. This platform provides IT services to customers, typically over the Internet, which are useful for numerous applications performed by the traditional data centres, either by supporting the existing business functions or by expanding and creating to new processes.

The term "cloud computing" was coined in the fourth quarter of 2007, in the context of a joint project between IBM and Google (Vouk, 2008; Shuai Zhang, Zhang, Chen, & Huo, 2010) . However, as it also happens with many other emerging trends – and despite being a subject on which much has been written about – there is no consensual definition of what CC truly means. As an example, in (Vaquero, Rodero-Merino, Caceres, & Lindner, 2009) there is a list of at least 22 distinct definitions of CC proposed during 2008.

The National Institute of Standards and Technology (NIST) ("NIST," 2013) presents one definition of CC recognized by several authors, such as, (Foster, Zhao, Raicu, & Lu, 2008; Grobauer, Walloschek, & Stocker, 2010; Ali Khajeh-Hosseini, Greenwood, Smith, & Sommerville, 2010a; Shimba, 2010; Q. Zhang, Cheng, & Boutaba, 2010), considered as being holistic (Swamy, 2013) and adopting a broad scope.

According to this definition, CC is classified in four deployment models: public, private, hybrid and community. Traditionally, each of the aforementioned deployment models is divided into three layers (also known as service models), according to the services it provides to the users (Mell & Grance, 2011; Vaquero et al., 2009; Weinhardt et al., 2009; R. Wu et al., 2010). These three layers include, on the first level, Infrastructure as a Service (IaaS), where the user can afford, upon request, processor resources, storage and networking, among others. At this level, the user is required to have specialized technical knowledge and the cloud service provider (CSP) delivers computing power/resources. On

a second level, the Platform as a Service (PaaS) layer allows users to implement their applications in the cloud, by using the programming languages and tools provided by the CSP. The third one corresponds to Software as a Service (SaaS), where the applications, provided by the CSP, run in the cloud infrastructure and are typically accessed using a Web browser.

With the large amount of resources that it provides for developing and deploying applications and services, the CC paradigm is an attractive tool to upgrade, extend, replace or backup many of the services hosted by the traditional data centre. Nonetheless, in order to completely fulfil its promises, CC still needs to win the trust of the stakeholders involved. Besides the need of trust, the security is another CC issue as can be seen in a recent survey from International Data Corporation (IDC) (Gens, 2008) which indicates that 74.6% of the respondents point safety as the first challenge of CC.

There are three cloud roles considered in the consummation and delivery of CC services. These roles are customer, CSP and integrator. The cloud can be viewed on a three axes referential where the three axes are the cloud deployment models, the cloud delivery models and the roles previously defined as depicted on Figure 5.

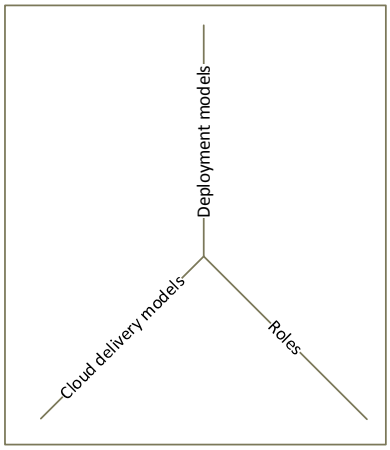

Figure 5 - The three axes of cloud computing

2.1.2 Service models

The architecture of CC is divided into layers described as Everything-as-a-Service, XaaS, being the most common division in three major groups, which define reference architectures for cloud solutions, according to the services provided to their customers.

2.1.2.1 Infrastructure as a Service (IaaS)

With IaaS, the user can afford, upon request, processor resources, storage and networks among others from a CSP. In this model, the customer can also deploy and run software in general, including operating systems and applications. The IaaS model is the one that offers more flexibility and is less liable to vendor lock-in when compared with the other two service models. It is arguably the most accessible to enterprise as they could potentially migrate their systems to the cloud without having to change their applications. The customer does not intervene in the management or control of resources in the cloud; however, he controls the operating systems, storage and applications installed. Examples include Amazon Elastic Compute Cloud (EC2) (Amazon, 2013) Amazon Simple Storage Service (S3) ("Amazon Simple Storage Service (Amazon S3)," 2014), Akamai ("What is Akamai Doing in the Cloud?," 2010) and Google Compute Engine.

Table 3 - IaaS provider's comparison

Characteristic / **Cloud service provider**	**Instance types**	**Locations (regions)**	**Hypervisor**	**Operating systems**
Amazon Elastic Compute Cloud	12	5	Xen	Linux, Solaris, Windows
Rackspace	8	6	Xen	Linux, Windows
Google Compute Engine	15	3	KVM	Linux, Windows
Microsoft	13	6	Microsoft Azure Hypervisor	Linux, Windows

2.1.2.2 Platform as a Service (PaaS)

In the PaaS model, the customers can implement the applications envisioned by them in the cloud, using the programming languages, tools and the corresponding hardware offered by the CSP (a proprietary development platform). In this service model, the customer does not intervene in the management or control of resources in the cloud. Examples of PaaS embrace Google Apps ("Google Apps," 2010), Force.com ("Force.com: The leading cloud platform for business apps," 2013) and Microsoft's Windows Azure Development

("Windows Azure - Develop center," 2012), among others. The downside of this model is due to the lack of interoperability between CSPs, which may cause a CSP lock-in.

In Table 4, a comparison of four PaaS providers is presented and the programing languages they offer to customers to develop applications.

Table 4 - PaaS providers programming languages

Programming language / Cloud service provider	Google Apps Engine	Microsoft Windows Azure	Amazon	Heroku (SalesForce)
Java	✓	✓	✓	✓
Python	✓	✓	✓	✓
PHP	✓	✓	✓	
.NET programming languages		✓		
Ruby		✓	✓	✓
Node.js		✓	✓	✓
Clojure				✓
Scala				✓
Perl			✓	
GO	✓			

2.1.2.3 Software as a Service (SaaS)

SaaS occupies the top layer of the cloud service models. It provides applications that are executed in the cloud infrastructure (owned either by the service provider or by other CSP) being usually accessed by using a Web browser and through the Internet.

The SaaS model provides motivation for organizations to migrate applications to cloud applications (typically exporting data from in-house applications and importing it to cloud applications); however, these applications are more useful for customers who have needs similar to other customers (Clemons & Chen, 2011). Indeed the customization of SaaS applications are not fundamentally different from those done in an organization when it is introduced a new corporate software such as ERP is introduced (Louridas, 2010).

In this layer, the customer does not own the application that is remotely used, has no responsibilities in physical infrastructure structure that hosts the application and does not intervene in the management or the control of resources in the cloud. Salesforce.com

("Salesforce Customer Relationships Management (CRM) system.," 2010), Gmail ("Gmail," 2012) and Facebook ("Facebook," 2012) are examples of this model.

Figure 6 - The cloud computing service models

The Figure 6 shows the hierarchy of the cloud service models as well as examples of CSPs of each level.

2.1.3 Deployment Models

The cloud is traditionally classified, according to the way it delivers its service, in four deployment models, known as public, private, hybrid and community cloud (Mell & Grance, 2011). These deployment models are independent of the service delivery model adopted.

2.1.3.1 Public cloud

In the public cloud, the CC services are available over the Internet to users in general, in a free or on a pay-by-use model. An organization external to the customer owns the cloud resources such as applications, storage and computing. The customers consume these resources over the Internet in general, either in a free or on a pay-by-use model. Furthermore, the customers share components and resources with others that are unknown to them in a multi-tenant environment. In addition, the customer data might be distributed by several regions around the globe. This is the dominant form of current CC deployment model

(Dillon, Wu, & Elizabeth, 2010). An example of this model is the Amazon Web Services ("Amazon Web Services," 2010).

2.1.3.2 Private cloud

The private cloud stands at the other end of the deployment models is the private cloud. In this model, the organization has its own data centre with a large number of servers heavily using virtualization, self-provisioning and an automated resources management. These resources are not shared with unknown users, however it should be emphasized that an external CSP can handle a private cloud (for instance by providing a completely segregated environment that is available only to the customer), (Marston et al., 2011) which can be located either on premise or off . When on premise, the private clouds benefit corporations that have hugely invested in computing power, bandwidth and network storage, by improving the utilization of resources acquired. However, this model does not full enjoy the economic benefits of CC, since the organization still has to maintain the resources when they cease to be used.

2.1.3.3 Community cloud

In the community cloud model, the services are available for a number of organizations that share common interests. The United States Federal Government is one of the biggest users of a community cloud (Marston et al., 2011).

2.1.3.4 Hybrid cloud

These models are not closed and therefore it is necessary to consider another model, the hybrid cloud where the infrastructure is formed by composition of cloud types above. Typically, non-critical information is migrated to the public cloud, while business-critical services and data are kept within the control of the organization (Marston et al., 2011). For example, when an organization offloads part of its private cloud workload to a public cloud the combined infrastructure is a hybrid cloud (Louridas, 2010).

2.1.4 Related technologies

The CC paradigm has a great contribution from grid computing, however it also inherits characteristics from other computing paradigms, such as distributed computing, utility computing, web 2.0 and web services. In the following subsections, an overview of these technologies and their relationship with CC is presented.

2.1.4.1 Grid computing

Grid computing is a form of distributed computing where the resources of networked computers are employed together to obtain large supercomputing resources to solve a problem. This model, recognized by (Foster et al., 2008; Microsystems, 2009; Nurmi et al., 2009; Schwiegelshohn et al., 2009; Shuai Zhang et al., 2010) as a CC predecessor takes advantage of the large amount of time that computers are on low workload and uses this downtime and its computing power for other purposes. These are for instance, scientific research and collaborative projects that require greater resources to achieve their objectives. It is usually necessary to use specific software, such as BOINC ("BOINC - Open-source software for volunteer computing and grid computing," 2013) or Globus Toolkit ("Welcome to the Globus Toolkit Homepage," 2010), among others, to enjoy the free resources on computers and share information so that it can be processed by the computers that are part of the grid.

In Table 5 we show the key differences between Grid and CC identified by Weinhardt et al. in(2009).

Table 5 - Grid vs. Cloud computing (adapted from (Weinhardt et al., 2009)**)**

Criteria	Grid Computing	Cloud Computing
Virtualization	In its beginning	Essential
Type of application	Batch	Interactive
Development of applications	Local	In the cloud
Access	Via grid middleware	Via standard web protocols
Organizations	Virtual	Physical
Business models	Sharing	Pricing
SLA	Not yet enforceable	Essential
Control	Decentralized	Centralized
Openness	High	Low
Ease of use	Hard	Easy
Switching cost	Low because of standardization	High because of incompatibilities

2.1.4.2 Utility computing

Utility computing represents the model of providing resources on demand and charging customers based on the usage rather than a flat rate (Q. Zhang et al., 2010). In other words, utility computing is a business model where resources such as computing, storage and others are provided and charged as electricity.

CC also inherits characteristics from utility computing as recognized by the authors (Armbrust et al., 2009; Foster et al., 2008; Vaquero et al., 2009; Vouk, 2008; L. Wang et al., 2010).

2.1.4.3 Virtualization

The virtualization was first developed in the mid-1960s by the IBM Corporation and it allows the abstraction and isolation of lower level functionality from the underlying hardware to concede portability of the higher level functions such as aggregation and sharing of physical resources (Vouk, 2008).

By using virtualization, the CC is able to have on the same physical machine a variable number of virtual machines that allows not only a practical and fast allocation and release of resources but also a way to standardize the hardware resources. This uniformity makes the development and the implementation of large systems much more accessible (Nurmi et al., 2009).

2.1.4.4 Web 2.0

The word Web 2.0 is used to describe the second generation of the World Wide Web, where the key idea is a dynamic online environment where the exchange of information and collaboration between users, sites and virtual services become increasingly common. The CC services are web services offering computing services dynamically on demand, and thus it is a natural evolution of Web 2.0 (L. Wang et al., 2010).

2.1.4.5 Web services

The World Wide Web Consortium (W3C) defines web service as “a software system designed to support interoperable machine-to-machine interaction over a network” (Booth et al., 2004). Web services (Stantchev, 2009; Vouk, 2008) stand for application components that communicate using open protocols that may be used by other applications. The web services are published and discovered through the Web and are based on the eXtensible Markup Language (XML) operation or JavaScript Object Notation (JSON).

CC uses web services (Stantchev, 2009; Vouk, 2008) as the prevailing way to provide services to its customers and to (Shimba, 2010) improve connectivity and interaction between web applications. Indeed, the majority of the services are likely to consist of web services (Grobauer et al., 2010).

2.1.4.6 Distributed computing

Other authors, (Vouk, 2008; Shuai Zhang et al., 2010), also consider the distributed computing (the possibility of running an application on multiple computers at the same time) a technology related to CC. Indeed, they argue “In fact cloud computing extends grid computing, distributed computing and parallel computing” (Shuai Zhang et al., 2010, p. 1); Foster et al. (2008) also defends this idea when proposing their definition of the cloud paradigm “A large-scale distributed computing paradigm that is...”

Indeed, CC uses distributed computing in two flavours: the first one to provide resources to the customer through the ‘middleware’ and the second to provide distributed computing to the customers’ utilization.

2.1.4.7 Autonomic computing

In mid-October 2001, IBM published the Autonomic Computing Manifesto that defines that the aim of autonomic computing consists in building computer systems capable of doing self-management. The autonomic computing is defined (Kephart & Chess, 2003) as computing systems able to manage themselves given high-level objectives from administrators.

The CSP use autonomic computing to simplify their task of large cloud data centres management to automatically make decisions on its own, use high-level policies and self-manage resources to decrease the need for system maintenance and free some IT staff from running routine maintenance tasks. Without this support, the CSPs could not keep up with the low maintenance costs and demands.

Among others, these are the reasons why many of the authors (Cunsolo, Distefano, Puliafito, & Scarpa, 2009; Marinos & Briscoe, 2009; Q. Zhang et al., 2010) agree with the idea that CC also inherits characteristics from autonomic computing.

2.1.5 Key features and advantages

The CC enables the release of IT resources as services. In this section, we present a summary of the main features and advantages of this paradigm that makes it attractive to customers.

2.1.5.1 Agility/elasticity

The agility, in CC, refers to the easiness with which the resources available in CC are acquired or released. Typically, the CSP allocates resources in minutes unlike what happens in traditional datacentres where the deadline is weeks or months.

The agility and flexibility reflect significantly in the organization business as by allowing the customers to gain speed in the development and deployment of services and applications. Thereby, if the company is planning to migrate its services and applications to the CC, managers must weigh the flexibility provided by the cloud since it can for example allow the capture of new markets for the company, meaning that the flexibility could be considered more important than the cost savings that CC brings to the company.

The elasticity, in CC, refers to the ability a system has to adapt to workload changes by provisioning and de provisioning resources automatically. The customer must check what adaptation processes are in use, what are the elasticity dimensions (what are resource types), the unit resources and the bounds of the scalability (Herbst, Kounev, & Reussner, 2013).

2.1.5.2 Resource pooling

The CSP resources, such as processor, storage, memory and network bandwidth, are pooled, in a public cloud between disparate institutions (perhaps competing ones) and in the private cloud across the same institution, to serve numerous customers in a multi-tenant model, with physical and virtual resources dynamically allocated and reallocated according to customer's demand. In this way, the cloud resources are automatically provisioned as business requirements' change (Mahmood, 2011) without the customer controlling the actual location of the resources. The incentive for such pool-based paradigm lies in two important factors: economies of scale and specialization (Dillon et al., 2010).

2.1.5.3 On demand self-service

It allows the customer to manage, order and release the resources, according to his needs and without human intervention by the CSP, typically using a web-portal (Grobauer et al., 2010; Mahmood, 2011; Sriram & Khajeh-Hosseini, 2010).

2.1.5.4 Measured service

The constant measurement of CC services supports the pay-as-you-go payment model as well as reporting, usage optimization, monitoring, transparency between the customer and the CSP regarding services use (ISACA, 2009) and capacity planning.

2.1.5.5 Cost reduction

In the CC, it is easy to increase the amount of resources when needed and reduce them when they are no longer necessary (on demand self-service). This characteristic, together with the pay-as-you-go model, grants the advantage of allowing great cost savings to the customer, as he does not need to maintain the resources acquired for a peak when they are no longer needed. These economies promised by the CC are reflected differently according to the type of service chosen by the customer. Thus, although the promise in IaaS is to reduce hardware costs and data centre operations personnel, in the SaaS and PaaS models the promise is to reduce software costs (Clemons & Chen, 2011).

2.1.5.6 Reduced upfront investment

In traditional data centres, before starting to provide a service, the organization must acquire all the necessary resources needed and keep them after they are no longer necessary. However, in CC, this upfront investment is not required (Bai et al., 2013; Beserra et al., 2012; Misra & Mondal, 2011) thanks to the easiness provided by CC that enables the customer to acquire resources, as they are needed and in accordance with the evolution of the organization needs.

2.1.5.7 Risk reduction

Closely related to the advantages presented in the earlier subsections, the risks that CC customers have to endure when using cloud services are smaller than their corresponding on premise since (Brand, 2012; Tušanová, 2012), for example, there is no need for a large upfront investment nor the need to maintain resources that no longer are needed. Additionally hardware maintenance and backups are traditionally of CSP's responsibility.

2.1.5.8 Scalability

Recognized by (Dhar, 2011; A. Khajeh-Hosseini et al., 2010; M. Klems, Tai, Shwartz, & Grabarnik, 2010; Marston et al., 2011; Shufen Zhang, Zhang, Chen, & Wu, 2010) as a CC advantage, the scalability is the ability to handle the growing of work in a uniform way. Furthermore, business scalability, can be one of the best reasons for organizations to consider cloud computing migration (Phaphoom, Oza, Wang, & Abrahamsson, 2012).

CC data centres provide huge amounts of IT resources, which facilitate the customer to increase the resources according to their service needs.

2.1.5.9 Broad network access

The access to cloud resources is usually carried out via the Internet, which means that the access services are feasible using a large amount of equipment providing access to the Internet, or other forms to connect to the CSP such as leased lines (ATM or Frame Relay). The NIST, in its definition of CC (Mell & Grance, 2011) considers the broad network access an essential characteristic.

2.1.6 Key challenges - issues

As seen in the preceding section, CC offers many advantages — nevertheless it also has a number of challenges that must be overcome by technology providers.

2.1.6.1 Service Availability

In simple terms, availability means that an organization has its full set of computing resources accessible and usable at all times (W. A. Jansen, 2011). Availability is one of the most critical information security requirements in CC (Ramgovind et al., 2010) to be addressed when deciding to migrate IT to CC. Access interruptions to services (Armbrust et al., 2009) are well known from some CSPs. These interruptions can cause cascading problems in all organizations linked directly or indirectly to the faulty supplier. This challenge can be mitigated if customers and CSPs establish SLAs that guarantee the desired levels of availability. As a precautionary measure, the customer can have his information backed-up in other CSP. Another availability issue that must be taken into account (since resources are typically available through the Internet) is the failure of the Internet link and consequently the discontinuity in accessing the information.

Despite the negative publicity that these service breaks have, few enterprises that have IT infrastructures are as good (Armbrust et al., 2010).

2.1.6.2 Information location

The data location is another issue in the CC paradigm since cloud customers typically do not know the location of their data (King & Raja, 2013). Accordingly, the customer must request information concerning where it is stored, since different locations may have different jurisdictions. Indeed, the dynamic of CC and the movement of data within a CSP cloud may involve data transfer between servers at different locations and possibly diverse jurisdictions. Therefore, dissimilar laws could be applied to the same data depending on the location where the data is stored. Hence, to overcome this issue, the organization may want to restrict the transfer of his data within the CSP to avoid exposure to this variety of laws and regulations.

To illustrate these differences, in Figure 7 we present a world map where these variances are identified. The data privacy requirements in USA are less stringent than in European countries (Swamy, 2013).

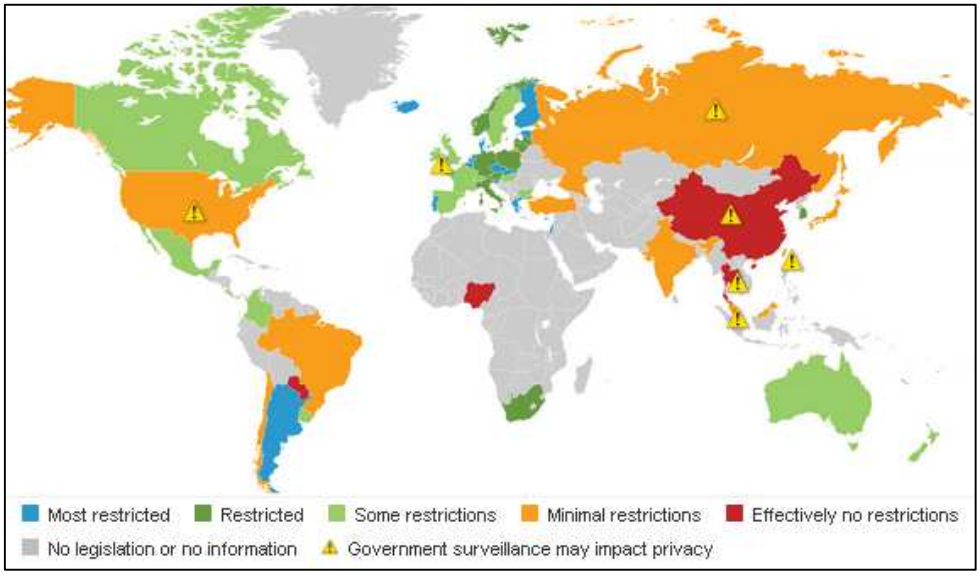

Figure 7 - Privacy and data protection by country (taken from (Research, 2013)**)**

2.1.6.3 Legislation

Right now, there are few legal precedents concerning liability in the cloud. It is essential to obtain appropriate legal advice to ensure that the contract specifies the areas where the CSP is responsible for CC (ISACA, 2009). The customer must determine in detail which law is applied to his data and applications whether they are on premise or on the cloud to verify that, when migrating to cloud they still comply with the legal requirements. Still related to the legal aspect of CC is the need of the customer to know how the CSP acts in case forensic proofs are asked by the court.

2.1.6.4 Information retrieval

The retrieval of data from cloud raises issues because the customer wants to have the assurance that he might retrieve his data at any time, particularly at the end of the contract with the CSP, and without any additional costs or restrictions. By his side, the supplier may want to charge for returning the data in a different format from that used in its cloud (Prodan, 2009). As a result, the customer should evaluate the compatibility between the format he uses with the one in use by another CSP, if he wants to change the CSP, or

externalize his services to the cloud. This is a point of concern, particularly in public clouds (namely in the PaaS and SaaS models), where there may be a high risk of being trapped to a single supplier or “lock-in”. One solution to this problem is the standardization of API's used in the CSP pointed by (Armbrust et al., 2010). The work developed by the Data Liberation Front (“Plan your digital afterlife with Inactive Account Manager,” 2013), an engineering team at Google, whose singular goal is to make it easier for users to move their data in and out of Google products, also illustrates this concern.

2.1.6.5 Lack of interoperability

Closely related to the preceding issue is the lack of interoperability among CSPs. The cloud interoperability term refers to the ease of migration and integration of applications and data between different CSPs (Dowell, Barreto, Michael, & Shing, 2011). According to (Clemons & Chen, 2011; W. A. Jansen, 2011; Louridas, 2010; Phatak & Kamalesh, 2010), the CC offerings were not designed to be interoperable between CSPs. The lack of interoperability increases the risk of customers “lock-in”, limits the ability to scale the clouds from different vendors (Rochwerger et al., 2009), limits the possibility of clouds working together and raises the costs.

Kostoska et al. (2012), presents a survey of the most influential and published Cloud Computing Interoperability (CCI) models - their possibilities and challenges are also discussed. Nevertheless, the solutions are for the IaaS cloud model are without evidence of progress for setting the interoperability in the area of SaaS (Kostoska et al., 2012). Notwithstanding the importance of this issue and the work done by scientists and organizations it seems unlikely, right now and for any of the proposed interoperability model, to be adopted as a standard (Kostoska et al., 2012).

The customer must inquire the CSP to gather the maximum information possible regarding data import and export before committing its IT to a CSP since the impossibility of moving data and applications to another CSP, or back to in-house, may cause serious problems such as vendor lock-in or lose of data. Additionally the lack of interoperability could also compromise the necessity of having backup CSP.

2.1.6.6 Service level agreement

The Service Level Agreement (SLA) defines a written agreement, negotiated between the customer and the CSP, which documents the agreed service levels and costs. A more detailed discussion concerning the SLA and its implication in the CC world can be found in (Kandukuri, V., & Rakshit, 2009).

The authors of (Baset, 2012; Machado & Stiller, 2011; L. Wu, Garg, & Buyya, 2011) recognize the impact of the SLA in CC: on the one hand (Prodan, 2009) it designates the lack of SLA, as the first problem found in CSPs that evaluated. On the other hand (Cochran & Witman, 2011) it emphasizes the importance of records and SLA when stating that the SLA should clearly identify the data that administrators have access to and whether or not there are records of personal data. Another author (Patel, Ranabahu, & Sheth, 2009b, p. 1) also highlights the SLA prominence in CC by stating: "As more customers delegate their tasks to CC service providers, the service level agreements between customers and service providers emerge as a key aspect". In short, the SLA forms an integral part of a customer's first line of defence (Ramgovind et al., 2010).

2.1.6.7 Benchmarks

A benchmark is used to perform the measurement of systems (Stantchev, 2009). The benchmarks are helpful in the process of migrating IT to CC. Firstly, to analyse in-house services in order to create information baseline for comparison of services that is in-line vs. on cloud. Secondly, to accurately define the SLA with the CSP and thirdly, to support the comparison between two or more CSPs. Fourthly, to monitor cloud services to certify the SLA and to ensure that the resources to be acquired are in line with the necessities.

2.1.6.8 Security

A key component in security is the trust, defined by Thampi et al. in (2013, p. 14) as "the degree in which the first party behaves exactly as it was expected from the second party". Indeed, in the traditional data centre, there is already an implicit need to trust on hardware and software suppliers (as well as in outsourced and own staff), since any of the system components (hardware, software and humans) may potentially compromise data security. Nevertheless, it is still possible to improve data protection by overlaying additional security

schemes to obtain a more protected environment – even when there is fewer confidence in each supplier. A good example of this approach would be the installation of multiple firewalls and intrusion detection systems from multiple vendors (serially laid out). However, in CC the data custody is handed over to a third party. Thus, there is a fundamental difference: in traditional paradigms, the information systems can be protected from one specific suppliers, however, in CC all these systems are typically managed by the CSP – resulting in the rather uncomfortable need of completely relying on the CSP.

Under CC, an organization relinquishes direct control over many aspects of security and, by doing so, it confers an unprecedented level of trust onto the CSP (W. A. Jansen, 2011).The customer only knows the CSP, and the whole web of subcontracted service components is usually opaque or, at most, not verifiable by third parties.

From a technical point of view, the majority of security risks associated with CC already exist in traditional data centres (or as argued by (W. A. Jansen, 2011)) known problems cast in a new setting). Possibly, apart from specific risks induced by server virtualization (which also exists, in a certain degree, in traditional data centres using a server consolidation), most of the security risks are shared by both paradigms – for instance SQL injection, cross-site scripting, zero-day exploits of applications and operating systems.

Virtualization increases the impact of some of these risks, since successful attacks on the hosting machine (where the hypervisor is located) may potentially compromise every hosted virtual machine. However, such events can be reasonably avoided and/or controlled using appropriate protection mechanisms for the hosting machines. Faults on the virtualization platforms themselves are also an obvious risk; however, there are few examples of such faults (and even fewer of negative consequences of such faults).

To maintain its systems protected, the customer needs to gather detailed information regarding the security-oriented requirements of its IT services, applications and data. This knowledge will be useful when migrating to CC, since it allows comparing and evaluating traditional services with their cloud-based counterparts.

Before the customer can solve/mitigate the issues on security, he needs to perform a risk assessment to properly identify and evaluate the assets, threats and the countermeasures to implement:

- Identify and evaluate the assets - the customer assets and responsibilities in the traditional data centres, encompass information, applications, hardware, network, installations and IT employees. However, CC moves some of the responsibilities from the customer to the CSP. For instance, the CSP becomes responsible for hardware (in the case of IaaS) or applications and hardware (in the case of SaaS). Therefore, the customer should determine in advance, to the assets he wishes to migrate to the cloud, how valuable they are and what happens if, for instance, the information is stolen or if simply it becomes inaccessible.

- Identify threats - After a proper identification and evaluation of the assets, it is important to recognize the threats that these assets may suffer. On CC scenarios, security threats may arise from sources, such as loss of availability, security flows on the CSP, other customers of the same CSP and attacks from external parties. It is necessary to identify the threats that applications, data and virtual machines may suffer in the cloud.

- Identify and apply countermeasures - After identifying the threats, the customer should evaluate and apply the necessary measures regarding the solution of the encountered problems.

Whenever an organization analyses the possible migration of its IT services to CC, the availability, the security, the privacy and the data integrity are on the top of considerations (or as stated by (Armbrust et al., 2009)) security, privacy and integrity are some of the biggest concerns in the implementation and use of the CC services). The security concerns are connected with technological, legal and business matters once the CSP can be legally responsible for any security breach in the cloud-based services, however the customer and the organization is usually the most severely affected.

Besides the challenges identified in the earlier sections, in (Kumar & Garg, 2012) the authors, Vikas Kumar and Kavindra Kumar Garg, discuss the major challenges towards the migration of services in the cloud environment, considering both public and hybrid clouds. They start by identifying the problems faced by customers who want to migrate services to CC. The first issue found is the trust that customers must have on the CSPs - pursuing with the known technical problems of service's availability, vendor lock-in, abuse of privileges (e.g. by system administrators), the possibility of an uncontrolled automatic increase or

decrease in resources, information governance (encryption, location information), the risks of depending on Internet access and the undefined cloud performance.

On the other side, they place the business problems. Beginning with the reduced possibility that the customer has to manage the platforms provided via the cloud, difficulties of proper monitoring, security and virtualization security, confidence. Additionally, they point some existing solutions for the problems such as the problem of monitoring (Hypernic's CloudStatus) and management (RightScale).

2.1.7 Cloud economics

The traditional IT costs are not negligible. Indeed, before the development of a new project, server's infrastructure, network communications and related software licences must be acquired and installed. With the increasing migration of IT services to CC, the organizations are being able to move from a model where they purchase systems and applications to another where they are charged with a recurring fee based on their usage (Cochran & Witman, 2011) with promised benefits (see 2.1.4 above) for instance, economic ones. Amongst them, we can consider the payment model where the customer pays for what he uses and the time of the investment. In the traditional datacentre, the customer must purchase the IT infrastructure before he can use it, however in the CC, the customer may acquire the services according to his needs without upfront costs leading to a reduction in the time to market. Additionally, the CC promises lower management costs and lower operational and maintenance costs (Rafique, Tareen, Saeed, Wu, & Qureshi, 2011). These CC savings are mainly because of economies of scale and the competition amongst the CSPs. However, the alleged reduction of costs is not always true mainly due to the multitude of prices, which they do not include.

One of the transformations that occurs between traditional and CC, economically speaking, is the move from Capital Expense (CapEx) to an Operational Expense (OpEx) (the costs/expenses can be broken into Capital (initial/setup) or Operational (ongoing/running)) cost model to charge back the customers (Curry, Hasan, White, & Melvin, 2012; Yeboah-Boateng & Cudjoe-Seshie, 2013). However, it is not clear how organizations can benefit from this utility model (Shimba, 2010) though the lease-or-buy decisions have been researched for more than 40 years (Walker, 2009). Moreover, for organizations with established applications, the situation is more complex since CapEx costs are only a slice of the

TCO and the costs over the application lifetime are not related with the initial cost of the application. In financial terms, OpEx is preferred by an organization, once it provides the flexibility to dismiss the costs at will. On the contrary, with CapEx, for example when purchasing a server, the organization no longer has the opportunity to terminate the acquisition costs at will, regardless of whether the server is being used or not.

Other advantages should be considered when migrating to CC such as elasticity. The economics are one of them; therefore, we argue that the migration to CC should not be done only for economic reasons.

Tak et al. in (2011), study the economics of migration to CC. Their research tries to answer the question concerning the decision of migrating or not an application to the CC in economic terms. They recognize an embracing set of issues that influence the costs of a deployment choice and use NPV (Net Present Value)-based cost analysis to generate migration recommendations.

The authors propose a classification of the costs associated with migration into two groups. The first encompasses the direct (e.g. hardware and software) and indirect (e.g. shared storage, networking infrastructure), although the second includes quantifiable and less quantifiable costs (i.e. costs that are easy or difficult to quantify). This idea is illustrated in Figure 8.

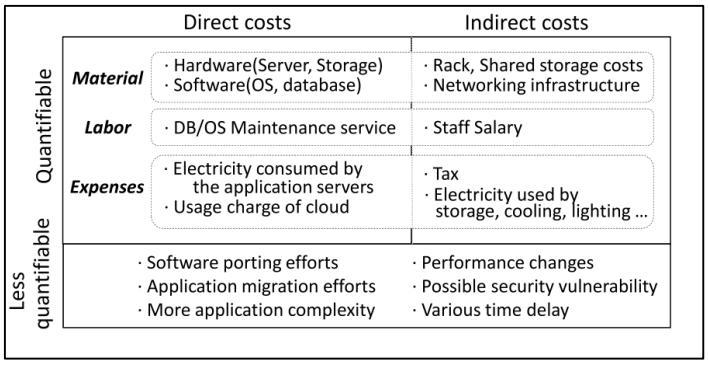

Figure 8 - Classification of costs related to migration (taken from (Tak et al., 2011)**)**

The authors conclude that the complete application migration is beneficiary only for small or stable organizations, however partially migrating some of the application components to the cloud is too expensive due to high costs of data transfer.

Other authors, Chen and Sion (2011), provide a cost model for computing in several environments. By using the model, they evaluate cloud outsourcing end-to-end and define a threshold principle when outsourcing to cloud is economically viable. Accordingly, they define two "outsourcing criteria", the first that postulating that it "is profitable for computation intensive tasks, specifically, when its (mostly computation-related) cost savings are sufficient to offset client-cloud network distances.". In the second criterion, for applications with third-party customers, the feasibility equation changes dramatically postulating that, "for today's pricing points, for mid-size enterprises, it always makes sense to outsource to cloud" (Yao Chen & Sion, 2011, p. 7).

2.1.8 Cloud computing standards

The use of standards and open-source applications in CC is a key aspect to mitigate the vendor lock-in problem (Lewis, 2013; Pahl, Zhang, & Fowley, 2013a; Silva, Rose, & Calinescu, 2013) and ensure the interoperability among CSPs. To the customer it is favourable once it does not stay tied to a single CSP of services - however to the CSPs it can have negative aspects since it can mean the loss of customers. Additionally, the standards' use provides the customer with a greater choice from a variety of CSPs and the ability to more easily and accurately compare CSPs.

Standards organizations are working to create cloud standards; however, the standardization in CC is in its infancy (Labes, Repschlager, Zarnekow, Stanik, & Kao, 2012). Table 6 identifies some of these organizations and what kind of work is being done in favour of CC standards. However, there is also an urge to comprehend the customer's necessities and prioritizations. The Cloud Standards Customer Council CSCC "is an end user advocacy group dedicated to accelerating cloud's successful migration, and drilling down into the standards, security and interoperability issues surrounding the transition to the cloud." ("Cloud Standards Customer Council," n.d.).

There are efforts of standards under way. Indeed, the Distributed Management Task Force (DMTF) is working on the Open Virtualization Format (OVF) (Force, 2014), a standard for representing virtual machines to allow VM interoperability between IaaS providers. The DMTF also works on the Cloud Infrastructure Management Interface (CIMI), (Distributed Management Task Force, 2014) that defines an interface and a logical model for managing resources within an IaaS cloud.

Table 6 - Cloud computing standards organizations

Organization	Concern
Cloud Security Alliance (CSA)	Sponsors a series of best practices related with cloud security. The mission statement of the CSA is "to promote the use of best practices for providing security assurance within CC, and provide education on the uses of CC to help secure all other forms of computing." ("Cloud Security Alliance," 2014)
Distributed Management Task Force (DMTF)	The Cloud Management Initiative of the DTMF is **"**focused on developing interoperable cloud infrastructure management standards and promoting the adoption of those standards in the industry." ("DMTF's Cloud Management Initiative," 2014)
National Institute of Standards and Technology (NIST)	The goal of the NIST-Standards Acceleration to Jumpstart the Adoption of Cloud Computing is "to drive the formation of high quality CC standards by providing worked examples demonstrating how key use cases can be supported on cloud systems that implement a set of documented and public cloud system specifications." (Mell & Grance, 2011; "NIST - Standards Acceleration to Jumpstart the Adoption of Cloud Computing," 2014) The NIST has also compiled a list of cloud related standards that could be found in (Hogan, Liu, Sokol, & Tong, 2011).
Open Cloud Consortium (OCC)	Development of standards and frameworks for cloud interoperability ("Open Cloud Consortium," 2014)
Open Grid Forum (OGF)	The Open Grid Forum "is an open community committed to driving the rapid evolution and adoption of applied distributed computing". The "OGF documents, best practices and standards provide the basis for some of the largest and most powerful grids and CC operational infrastructure systems in the world" ("Open Grid Forum," 2014)
IEEE - Cloud Computing Standards Committee (CCSC)	The CCSC " is chartered by the IEEE Computer Society Standards Activities Board to promote the development of standards in all aspects of the CC ecosystem" ("IEEE Cloud Computing Standards Committee (CCSC)," 2014)

In the area of management, the Open Cloud Computing Interface (OCCI) (Interface, 2014) from the Open Grid Forum defines a protocol and an API specification for remotely managing CC infrastructures. Another management standard, the Cloud Data Management Interface (CDMI) (SNIA, 2014) defines an interface that applications can use to create, retrieve, update and delete data elements from the cloud.

The ISO 27017 standard will provide guidance on the information security elements/aspects of CC. The standard publication is unlikely until 2015 (ISO/IEC, 2014).

Lastly, a de facto standard interface to cloud management (Pahl, Zhang, & Fowley, 2013b), the Amazon EC2 API (Amazon, 2014).

2.1.9 Scientific and academic projects in cloud computing

The academia also offers CC platforms to researchers to offer them an opportunity of testing their ideas.

In the following subsections, we exemplify the work developed in this area. Although the first three projects are grouped in what is called the cloud management software, the fourth project is a live example of IaaS to facilitate the use of CC for scientific purposes.

2.1.9.1 EUCALYPTUS

The EUCALYPTUS ("EUCALYPTUS Systems," 2014), an acronym of Elastic Utility Computing Architecture for Linking Your Program To Useful System, emerged in autumn 2007 as a research project of the Department of Computer Science at the University of California at Santa Barbara. EUCALYPTUS is an open-source platform that implements the IaaS layer of the CC. It is compatible with the Amazon Web Services' platform allowing the migration of jobs between EUCLYTUS and AWS. EUCALYPTUS' project runs with most Linux distributions, hypervisors and virtualization software such as VMware, Xen and KVM. It is comprised by six components: Cloud Controller, Walrus, Cluster Controller, Storage Controller, Node Controller and an optional VMware Broker described in Table 7.

Table 7 - EUCALYPTUS components (adapted from ("EUCALYPTUS Systems," 2014)**)**

Component	Function
Cloud Controller	Queries the other components for information about resources and makes high-level scheduling decisions. It is responsible for exposing and managing the virtualized resources.
Walrus	Allows users to store and manage persistent data in an interface compatible with Amazon Simple Storage Service.
Cluster Controller	Manages the node controllers and the virtual machines' networks.

Component	Function
Storage Controller	Similar to Amazon Elastic Block Store, interfaces with storage systems by exporting storage volumes that can be attached to a virtual machine.
Node Controller	Controls the virtual machines' activities.
VMware Broker	It is an optional module that enables EUCALYPTUS to deploy VMware virtual machines.

2.1.9.2 Nimbus

The Nimbus ("Nimbus," 2014) is an open-source platform, developed by scientists at the Department of Energy of the United States (DOE) Argonne National Laboratory and the University of Chicago that also implements the IaaS layer of CC whose primary mission is to develop an infrastructure with emphasis on the needs of science.

The Nimbus has support for Xen and KVM hypervisors and implements interfaces to Amazon EC2 allowing the use of clients developed to EC2 clouds based on Nimbus. The components of the Nimbus project are depicted on the Table 8.

Table 8 - Nimbus components (adapted from ("Nimbus," 2014)**)**

Component	Function
Workspace service	It is a virtual machine manager that can be invoked by the frontends.
WSRF and EC2 protocol	Web services for cloud clients interacting with Nimbus.
RM API	It is a bridge between the remote protocols and the site manager.
Cloud client	Allows users to run their services.
Reference client	Exposes the entire feature set to be used in scripts and websites or portals.
Workspace pilot	Allows the integration of virtual machines and resources
Workspace control	Agents that implements virtual machine management and network specific tasks on each hypervisor
Context broker	Allows clients to automatically coordinate large virtual cluster launches
Context agent	An agent that is installed on each virtual machine to achieve information concerning the cluster. It interacts with the context broker when the virtual machine is booted.
EC2 backend	This is a workspace service backend that serves as a portal to the Amazon Elastic Compute Cloud (EC2).

2.1.9.3 OpenNebula

The OpenNebula (Project, 2014) is the result of a research project initiated in 2005 by Ignacio M. Llorente and S. Ruben Montero at the Complutense University in Madrid. The first release was made available as an open-source platform in March 2008. Operating on IaaS CC layer it is compatible with virtualization software such as Xen, KVM, VirtualBox and VMware. Similarly to what happens with earlier projects it is also compatible with Amazon EC2. The Table 9 presents the OpenNebula main components.

Table 9 - OpenNebula components (adapted from (Project, 2014)**)**

Component	Function
Frontend	This machine runs the OpenNebula services. It is responsible for containing the management daemon, the scheduler of virtual machines, a tool to monitoring and accounting, the web interface and the cloud API servers.
Hosts	Matches to the physical machines that run the virtual ones that are managed by the OpenNebula daemons.
Cluster	Pool of hosts sharing data stores and virtual networks.
Image repository	Storage for registered Images.
Sunstone	The OpenNebula web interface.
OCCI Service	Server that enables the management of the web service that allows to launch and manage virtual machines.
Self-Service	Interface towards the end user.
EC2 Service	Enables the management of OpenNebula with Amazon EC2 interface.
OCA	The OpenNebula API, a set of libraries that ease the communication with the XML-RPC management interface.

2.1.9.4 OpenStack

OpenStack is a cloud operating system that controls large pools of compute, storage, and networking resources throughout a datacentre, all managed through a dashboard that gives administrators control while empowering their users to provision resources through a web interface (Foundation, 2014).

Originally developed by NASA and Rackspace in 2010, in September 2011 the project is managed by the OpenStack Foundation, a non-profit corporate entity. The OpenStack is based on core services summarized in Table 10.

Table 10 - OpenStack components (adapted from ("OpenStack Projects, History, and Releases Overview," n.d.)**)**

Component	Function
Compute Infrastructure (Nova)	CC fabric controller (the main part of an IaaS system).
Storage Infrastructure (Swift)	Scalable redundant storage system
Block Storage (Cinder)	Provides persistent block level storage devices
Networking (Neutron)	A pluggable, scalable and API-driven system for managing networks and IP addresses
Dashboard (Horizon)	Provides a graphical interface to access, provision and automate cloud based resources
Identity (Keystone)	Affords a central directory of users mapped to the OpenStack services they can access to
Image Service (Glance)	Provides discovery, registration and delivery services for disk and server images

Tech companies such as AMD, Brocade Communications Systems, Canonical, Cisco, Dell, EMC, Ericsson, Groupe Bull, HP, IBM, Inktank, Intel, NEC, Rackspace Hosting, Red Hat, SUSE Linux, VMware, and Yahoo have joined the OpenStack project ("OpenStack Projects, History, and Releases Overview," n.d.). Similarly to what happens with other projects in CC such as EUCALYPTUS and OpenNebula, the OpenStack is also compatible with Amazon EC2, although with different levels (Cassio et al., 2013) (OpenStack - 23,01%, EUCALYPTUS - 30,09% and OpenNebula - 8,85%).

The OpenStack's project is mostly written in python and uses different drivers to interface with a maximum number of hypervisors such as Xen, KVM, Hyper-V, Qemu.

2.1.9.5 Projects comparison

EUCALYPTUS, Nimbus, OpenNebula and OpenStack are open-source CC software platforms (Sempolinski & Thain, 2010). Though in earlier sections are presented the generic characteristics of CC projects here, we compare them as a whole as exposed in Table 11.

Table 11 - Cloud computing projects comparison

Characteristics / Projects	EUCALYPTUS	Nimbus	OpenNebula	OpenStack
Service models	IaaS	IaaS	IaaS	IaaS
Amazon Compatible	Yes	Yes	Yes	Yes
Cloud deployment models	Public Hybrid Private	Public Community Private	Public Hybrid Private	Public Private
Hypervisors	Xen KVM VmWare	Xen KVM	Xen KVM VmWare	Xen KVM Hyper–V LXC
Developed at	UC Santa Barbara	University of Chicago	NASA Ames Research Center	Rackspace and NASA
Licence	GPLv3 (free version)	Apache 2.0	Apache 2.0	Apache 2.0
Initial Release	2008	2009	2008	2010
Operating System	Linux, Windows	Linux	Linux	Linux, Windows

All the frameworks have an Apache 2.0 licence with the exception EUCALYPTUS that has a GPL licence type. Besides these two licencing schemas are compatible, the Apache 2 licence products can be included in the GPLv3 licence schema, the Apache licenced projects could not be licenced under the GPL licence.

All the platforms support the Xen and KVM hypervisors. However, the commercial hypervisor VmWare, is only used by EUCALYPTUS and OpenNebula while the Microsoft Hyper-V is used by the OpenStack framework.

2.1.9.6 Science Clouds

The academic institutions share interest on CC besides the development of cloud platforms, such as the ones presented in the earlier sections it is also the creation of a cloud infrastruc-

ture platform. In fact, in 2008, two American Universities, namely the University of Chicago and the University of Florida launched the Science Clouds (Keahey, Figueiredo, Fortes, Freeman, & Tsugawa, 2008; "Science Clouds," n.d.) project. The project has two main objectives: to facilitate the use of a CC environment such as IaaS for scientific projects and to a provide better understanding by the scientific communities of this paradigm (Keahey et al., 2008). The Science Clouds is made of an informal group of small clouds that make the resources available on a voluntary basis. Presently part of this group are the Universities of Chicago, Florida, Purdue and Masaryk. This project builds on the platform Nimbus IaaS including a gateway to allow the user to migrate the work of the Science Clouds to a commercial infrastructure.

2.1.10 Commercial Platforms

The commercial organizations have also adhered to CC. To demonstrate this interest, in the following sections, will present the commercial platforms offering cloud services most often cited by the authors (Armbrust et al., 2009; G. Wang & Ng, 2010; Xu & Liu, 2010; Q. Zhang et al., 2010; Shufen Zhang et al., 2010), that is, Amazon, Google, IBM's Blue Cloud and Microsoft.

2.1.10.1 Amazon

The authors (Beserra et al., 2012; Dowell et al., 2011; Lewis, 2013; R. Wu et al., 2010) recognize Amazon as one of the world references in the CC. The company has a huge computer infrastructure that was created to respond to the great peaks of sales, Christmas and special occasions (DaSilva, Trkman, Desouza, & Lindič, 2013) and was underutilized at other times of the year. For this reason, the Amazon attempted to monetize their investment offering cloud services via Amazon Web Services, AWS. With these services, it is possible to request and obtain within minutes, computing power, storage and other services in the infrastructure of the Amazon's cloud.

The AWS provides a huge array of cloud services ("Amazon Web Services," 2010) among which stand out:

- **Amazon Elastic Compute Cloud (EC2)** (Amazon, 2013) **–** This service offers dynamic computing capacity, in the Amazon cloud, according to a payment model,

pay-as-you-go where the user pays only for the resources he uses. The user can choose from a set of images, Amazon Machine Image (AMI) preconfigured and ready to use or create a new image, choosing the processor, configuring security, network and access network and choose the system operating to use. These images are executed on top of Xen hypervisor ("Getting Started," 2013).

- **Amazon Simple Storage Service (S3)** ("Amazon Simple Storage Service (Amazon S3)," 2014) **–** It is a collection of Web services that can be used to store and retrieve data from the Amazon cloud infrastructure. These services are equivalent to those that company uses to store information from their websites.
- **Amazon Relational Database Service (RDS)** ("Amazon RDS," n.d.) **–** It is a web service that allows the customer to configure, operate and scale a relational database, similar to MySQL, on the Amazon's cloud. The routine tasks of the database, such as backups and engine updates, are automatically made. Parallel to the RDS, Amazon also provides access to data storage without using a relational database via the SimpleDB service. These Web services provide a simple interface for creating, storing and querying multiple data sets. The information is automatically indexed; there is no need to pre-define a database schema.

Other services provided by AWS include e-commerce, message management, monitoring, network, billing and payments, Web traffic and human labour power.

2.1.10.2 Google

The Google App Engine ("O que é o Google App Engine?," n.d.) is the cloud platform of Google that allows the execution of applications in the infrastructure of Google's servers. These applications can be written in Java, JavaScript, Ruby and Python and if the developer is using the SDK's provided by Google, the local computer is able to emulate the services provided by App Engine, and thus test locally the applications that will be run in the cloud of Google. The application execution is carried out in a controlled environment, a sandbox that isolates the application in a protected environment independent of hardware and operating system. Google offers two execution environments, one for Java and another for Python.

The App Engine provides services that perform common tasks freeing the customer of coding them. These services include obtaining URLs, messages, cache, image manipulation

and programming tasks. In addition to these services, the programmer can also use Web frameworks (a set of modules that allow developers to create web applications and services without having to deal with low-level details), such as Django, CherryPy, Pylons and web2py (Q. Zhang et al., 2010) to further facilitate their work. The platform also provides a storage service for distributed information, different from traditional relational databases. The storage is completed by assigning to each entity a type and a set of properties, allowing queries by type or by the value of the properties.

2.1.10.3 IBM

In November 2007, IBM entered on the CC by presenting the first plans for "Blue Cloud" ("IBM Introduces Ready-to-Use Cloud Computing," n.d.), a set of CC offerings that would allow moving the corporate data centres to IBM cloud. This is made of IBM BladeCenter servers with the Linux operating system and software virtualization based on Xen, and managed by the IBM's Tivoli software. This solution is based on IBM technologies developed for it over several years, such as Parallel Sysplex, IBM's Deep Blue SP Cluster and Blue Gene.

Currently, IBM offers SmartCloud ("IBM cloud," 2014) as a family of enterprise-class CC technologies and services for securely building and using private, public and hybrid clouds.

2.1.10.4 Microsoft

The Windows Azure platform includes a group of technologies providing a cloud specific set of services for the execution of applications and storing data in a Microsoft cloud ("Windows Azure platform," n.d.). The platform includes three components:

- **Windows Azure ™ –** It is a cloud operating system based on Microsoft Windows, which enables to run applications and store data on servers provided by Microsoft's cloud – it is worth underlining here the great compatibility between Windows Azure and the Windows world existent on local computers. According to Microsoft, what an application "sees" on Windows Azure is similar to what it "sees" in Windows Server 2008, and for programmers developing an application for Windows Azure it is similar to a traditional application development's environment for Windows.

- **SQL Azure –** It offers services of a relational database to the cloud and is based on the technology Microsoft SQL Server.
- **Windows Azure platform AppFabric –** The Azure AppFabric provides services to facilitate the interconnection amongst applications running in the cloud and locally. The AppFabric includes two components: the service bus and the access control. Though the first one simplifies the publication and access through the Internet to services provided by applications, the second allows the RESTful client's authentication to servers by providing information so that they can decide what applications customers can execute.

Because Windows Azure supplies an environment similar to the one found on the Microsoft Windows, the applications therein implemented can be written in traditional programming languages used in the Windows environment, such as, C #, C + +, Visual Basic and Java. Thus, the migration logic of an application from the Windows environment to the Windows Azure platform is usually easy and absent of troubles.

The information in a Microsoft's cloud can be stored in blobs (unstructured data), tables (structured data), messages and queues for access to NTFS drives. The data storage service of the Azure's platform can be accessed both by Microsoft Windows Azure's applications and by applications running locally using a RESTful approach. The Representational State Transfer, REST, is used to describe any interface transmitting data from a specific domain over HTTP without an additional layer such as SOAP message (Fielding, 2000). RESTfull is the name given to the systems that follow the REST principles.

2.2 Related work with migrating to cloud

With the large amount of resources provided for developing and deploying applications, the CC is a tool of major importance to the replacement and migration of many of the services hitherto available in data centres. Nonetheless, some researches are dedicated to determine the drivers of migrating to cloud computing thus the literature is limited on this topic (Nkhoma & Dang, 2013).

In earlier sections, we presented the challenges and issues of CC and the concerns of the migration to this paradigm. In this section we expose some solutions, envisaged by several authors, aimed at the CC migration (Banerjee, 2012; Beserra et al., 2012; Chauhan & Babar,

2011; Ezzat et al., 2011; Frey, Hasselbring, & Schnoor, 2012; "Innovation Value Institute (IVI)," n.d.; Ali Khajeh-Hosseini, Greenwood, Smith, & Sommerville, 2010b; Kundra, 2011; Mithani, Salsburg, & Rao, 2010; Tušanová, 2012).

2.2.1 Migrating to cloud, frameworks

Several authors investigated the migration to CC. Accordingly, in this section, we expose the frameworks envisaged by them for a CC migration.

2.2.1.1 The Vivek Kundra decision framework

In February 2011, Vivek Kundra, Chief information officer of the United States, in (Kundra, 2011) proposes a decision framework for cloud migration. This framework exhibits a strategic perspective, to federal US agencies, concerning the thinking and planning for a CC migration. The framework contains three major migration steps, Select, Provision and Manage that are presented in more detail in Table 12.

The framework outlines a methodology that may be used to determine which services are ready for CC today, what can be considered for later migration and demonstrates how to choose provision and then manage services in the cloud. Although this is a framework specifically designed for the migration of US federal agencies to CC its recommendations are applicable to other organizations.

The work shows a set of high-level rules that the agencies should follow when migrating to CC. Yet, they do not point specifically the steps needed to know the current organization IT state such as IT infrastructure and services, nor the relationship between the software applications and the data, the hardware capacity needed, neither concretely points the steps to migrate to CC.

Table 12 - Decision Framework for Cloud Migration (adapted from (Kundra, 2011)**)**

Select	Provision	Manage
• Identify which IT services to migrate and when	• Aggregate demand where possible	• Shift IT mind-set from assets to services • Build new skill sets as required

Select	Provision	Manage
· Identify sources of value for cloud migrations: efficiency, agility, innovation · Determine cloud readiness: security, market availability, government readiness, and technology life cycle	• Ensure interoperability and integration with IT portfolio • Contract effectively • Realize value by repurposing or decommissioning legacy assets	• Actively monitor SLAs to ensure compliance and continuous improvement • Re-evaluate vendor and service models periodically to maximize benefits and minimize risks

2.2.1.2 The decision-making framework for adoption of cloud computing by Adela Tušanová

In another work (2012), the author, Adela Tušanová, argues that the CC migration is a complex process of decision-making, reason which motivated her to present a framework in order to facilitate the process of decision-making for cloud migration.

The framework comprehends six steps:

1. Workload definition;
2. Workload suitability Analysis;
3. Definition of Alternatives;
4. TCO Calculation;
5. Definition of criteria;
6. Multi-criteria method application.

In the first step, the collections of IT components are defined as well as the relationship among them. After that, they are classified in the three main types of cloud workload (SaaS, PaaS and IaaS).

The purpose of the step “Workload suitability Analysis” is to ask the IT manager a set of questions, which will be helpful to evaluate the suitability or unsuitability of particular workload for the CC.

The “definition of alternatives” step is where the solutions of the CC where characterized by a set of criteria defined in the fifth step of the framework.

In the fifth step, are defined the criteria that delineate which alternatives are to be considered.

The last step, “Multi-criteria method application” is where the author suggests the application of the application of the Decision Matrix Method (DMM) (Pugh, 1981) for multi-criteria decision-making.

Although the traditional IT components are grouped into cloud categories, this does not mean that, when migrating CC, the categories are equivalent as previously defined. For instance, when the organization replaces an existing application with a SaaS solution, the initial category is IaaS, which is migrated to a SaaS solution in the cloud. Moreover, no structured way to gather this information is pointed. The workload suitability analysis may be influenced by the definition of alternatives, a subsequent step; however, there is no life cycle notion between any of the steps of the framework.

As presented, the solution costs, affects the CC migration’s decision. Again, a cycle is needed since the cost can lead to a suitability analysis.

2.2.1.3 The Cloud Adoption Toolkit

Ali Khajeh-Hosseini et al., in (2010b), describe the challenges that a decision maker faces when assessing the feasibility of the CC migration in their organizations, and presents the Cloud Adoption Toolkit, which has been developed to support this process. The steps of the purposed toolkit are depicted on the Figure 9:

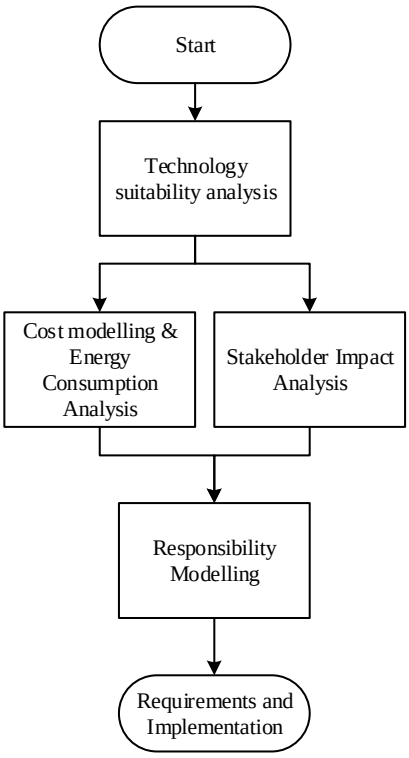

Figure 9 - Ali Khajeh-Hosseini framework (adapted from (Ali Khajeh-Hosseini et al., 2010b)**)**

The framework starts by supporting the decision makers on determining if CC is the most appropriate technology to solve the proposed issues and continues with the accountable step accountable by supporting the decision makers in obtaining accurate estimate costs and energy consumption. At the same time, it assesses the organizational fit to the cloud paradigm regarding “practicalities, social factors and political factors”. After these two steps in parallel, the operational feasibility step follows by verifying the workable set of responsibilities and by determining the socio-political acceptability of strategic dependencies between organizations and departments. The framework ends with the requirements and implementation’s phase.

This toolkit is an attempt to establish a framework to organize the thinking regarding the problems placed to the decision makers during the migration to CC in the enterprise. It provides a set of tools to address the concerns of decision makers, allowing them to focus on shaping the attributes of the organization or IT systems.

Besides the work developed and the new ideas presented this framework lacks considering other issues besides the cost-related and supports a decision process that stays on an abstract decision level.

2.2.1.4 Fly over clouds or drive through the crowd: A cloud adoption framework from Ezzat

Ezzat et al. in (2011) proposes a framework focused to support decision makers, in their migration to CC, depending on their own business cases and predefined issues. They view the migration to CC under three perspectives, the business, the technical and the economic ones. The first is studied regarding business requirements' description to depict the organization as a whole. The goal of the technical perspective is based on the technical application itself. Lastly, the economical perspective deals with a precise cost analysis, for the necessary application/service to define whether it is better to migrate to the cloud or remain with on premise.

The framework includes three main layers. The first one is the integration between businesses, technical and economical perspectives all sharing the same level of importance. The second layer comprises the basic factors that are considered under each perspective. The third and final layer is a supplementary decomposition of sub-factors within each basic factor for assessment and evaluation.

Besides the work developed and the new ideas presented, this framework does not seem to expose a formal process supporting customers on the task of migrating to the cloud.

2.2.1.5 Migrating service-oriented system to cloud computing: An experience report from Muhammad Aufeef

In (Chauhan & Babar, 2011) the authors summarize their practical experience by reporting the information gathered when they migrated the Hackystat open-source software's framework, to the CC. They assert that the following steps should be included as a process' support for migrating software systems to CC.

1. Evaluation of components for scalability;
2. Evaluation for orchestration;
3. Identification of the components for refactoring;
4. Evaluation of the solution against the target cloud's environment.

This work contains a summary of a practical experience of migrating an open-source software application to the CC. Besides presenting the steps that have been taken to migrate,

the Hackystat's application to CC does not expose a formal framework for migrating services to CC.

2.2.1.6 Cloudstep

Patricia V. Beserra et al., in (Beserra et al., 2012) present Cloudstep, a step-by-step decision process aimed at supporting legacy application migration to the cloud. The process was exemplified with the migration of a medical commercial application to the CC.

The Cloudstep process is centred on the guided identification and analysis of relevant issues that might influence the cloud's selection and migration's task.

In short, the Cloudstep method depicted in Figure 10 starts by determining the key characteristics of the application that are to be migrated to CC and few potential CSPs to make a profile. Afterwards, this profile is analysed with the purpose of discovering constraints that prevent a company from migrating to cloud. After analysing the profile, the constraints identified can be solved if possible and the organization can adopt a cloud solution that best suits to the company needs. The nine activities that compose the whole Cloudstep decision's process.

The Cloudstep process, developed new ideas for supporting the migration of legacy applications to CC. However, we do not find processes related with the migration of data, the infrastructures and services, impact of this change on the organization, SLAs management, amongst others.

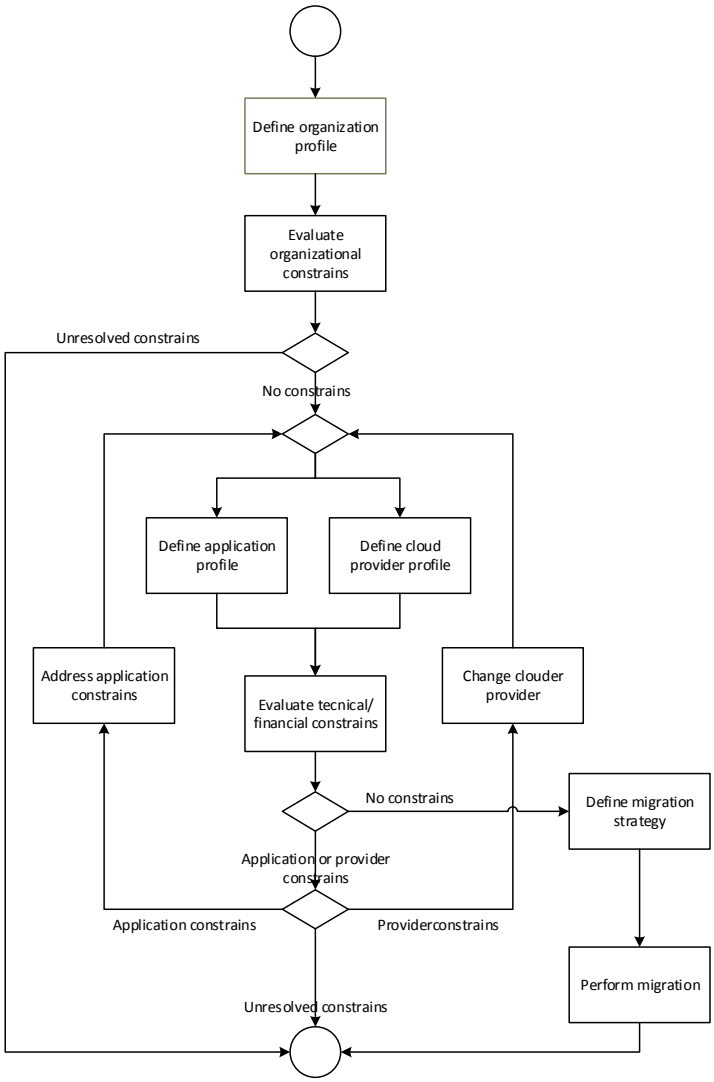

Figure 10 - The Cloudstep workflow (adapted from (Beserra et al., 2012)**)**

2.2.1.7 CloudMIG

The approach followed by Frey et al. (2012), CloudMIG for migration to CC, aims at supporting SaaS providers in the comparison and planning phases to migrate enterprise software systems to IaaS or PaaS based clouds. This model, depicted on Figure 11, encompasses six steps:

A1 – Extraction – This step comprehends the extraction of architectural and utilization models of the legacy software systems.

A2 – Selection – In this step (can be performed in parallel with step 1), an appropriate cloud profile candidate is chosen. The criteria for the decision can be the preference of renowned CSP, defined cost structure or a feature that has to be supported.

A3 – Generation – The generation activity produces the target architecture and a mapping model. In addition, the constraint violations are detected (a violation describes the breaking of a limitation of a specific CSP, for instance).

A4 – Adaptation – In this step, a reengineer could manually adjust some aspects of the generated target architecture.

A5 – Evaluation – The evaluation activity involves a static analysis and a runtime simulation of the target architecture.

A6 – Transformation – The actual manual migration towards the target architecture.

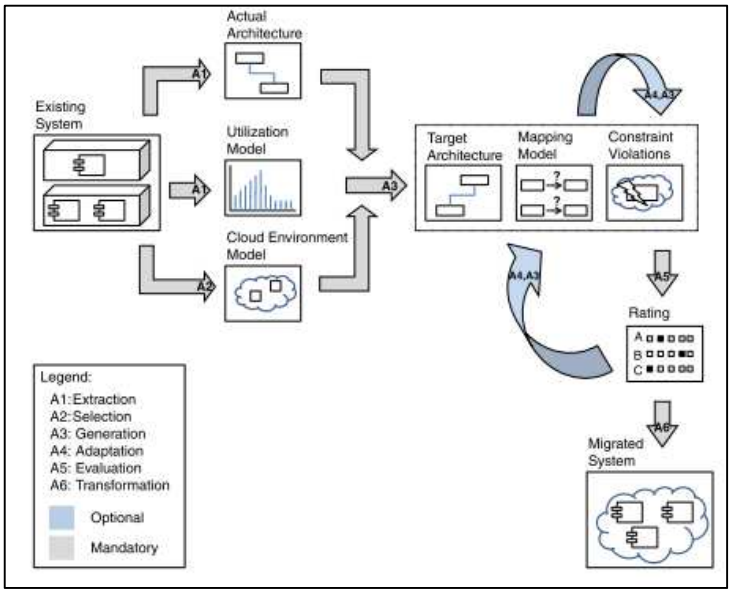

Figure 11 - CloudMIG approach (taken from Frey et al. (Frey et al., 2012)**)**

Besides the work developed and the concepts and the new ideas presented, this framework does not seem to expose profiling and a categorization of the applications.

2.2.1.8 Moving to the cloud: Workload migration techniques and approaches from Banerjee

Banerjee in (2012) addresses the migration to CC of enterprise level workloads without redesigning or re-engineering the existing applications. To achieve this goal, the author presents the five steps of migrating workload to CC. The Figure 12 illustrates these steps.

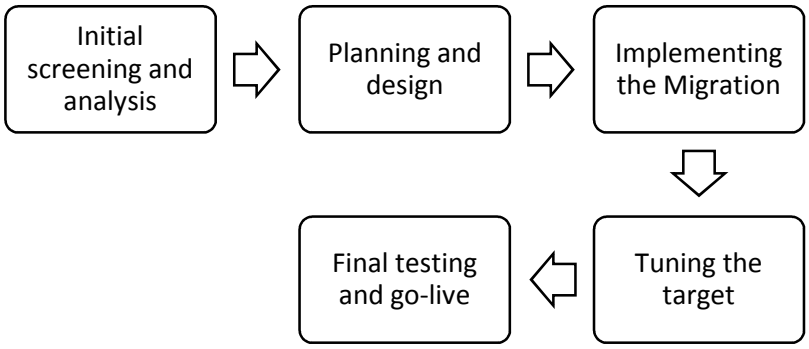

Figure 12 - Workload migration techniques and approaches (taken from (Banerjee, 2012)**)**

In the 'Initial screening and analysis' step, the aim is to gather key data on existing workloads, applications and their dependencies to analyse these data and determine plausible migration candidates. The next step, 'Planning and design', takes care of the logical design of the applications in the cloud. The 'Implementing the Migration' step follows, and here the workloads are migrated to the cloud platform using the most appropriate technique. Once in the cloud, the instances have to go through an adjustment stage, which is performed in the 'Tuning the target' step. In the final step, 'Final testing and go-live', it is confirmed, that the migrated workloads are performing as expected and the cloud becomes the production environment.

Besides the work developed and the new ideas presented, this framework does not seem to emphasize the importance and the role of business in migrating to the CC. It started the process of collecting information without the previous preparation of a strategic plan. The framework is a high-level one; however, it has little details regarding the tasks to be performed.

2.2.1.9 IVI Cloud Computing Life Cycle

The Innovation Value Institute (IVI) from the National University of Ireland Maynooth ("Innovation Value Institute (IVI)," n.d.) consortium (a consortium of leading organizations from industry, the not-for-profit sector, and academia), to address the issues involved in the CC migration developed and tested a life cycle for systematically managing cloud migration projects, the IVI Cloud Computing Life Cycle (Conway & Curry, 2013).

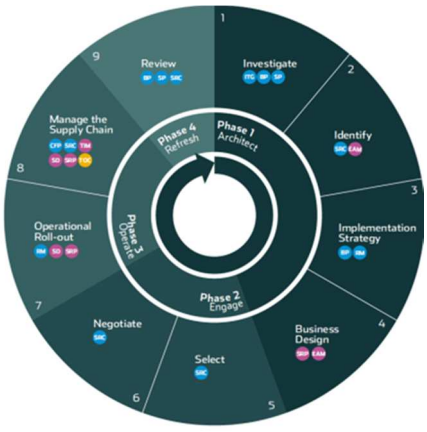

Figure 13 - The IVI Cloud Life Cycle (taken from (Conway & Curry, 2013)**)**

The cloud life cycle includes four phases, further divided into nine steps, as illustrated in Figure 13 and presented in more detail in Table 13.

Table 13 The IVI Cloud Life Cycle - stages and steps. (Adapted from (Conway & Curry, 2013)**)**

Phases	Steps
Architect **Starts with the investigation and planning of the cloud project**	**Investigate –** Provides an insight into and comprehension regarding what an organization wants to achieve when migrating to CC as well as what goals and expectations are to be met.
	Identify – Assesses business areas to identify those that are appropriate to migrate to the cloud and what impact this will have on the current delivery model.
	Implementation Strategy – Defines, at a strategic level, how the cloud services will be migrated and how they will be rolled out.
	Business Design – Designs what is to be migrated to the cloud and what the future state will be.
Engage **Selects a CSP that can deliver the required cloud service**	**Select –** Based in the requirements and the other criteria defined on the Architect phase, this step will be selected the best supplier based on value, sustainability, and quality.
	Negotiate – In this step is completed the final negotiation is completed, the preferred supplier is chosen, internal approval is acquired and the contract(s) is/are signed.
Operate **Implementation and the day-to-day management of the cloud service**	**Operational Rollout –** This is the step where the transition plans will be finalized and published and where the transition team is selected and managed. The acceptance criterion is agreed, the transition is carried out, progress is communicated and the knowledge transfer is conducted.
	Manage the Supply Chain – It is important to manage the new cloud service as efficiently and effectively as possible.

Phases	Steps
Refresh **Ongoing review of cloud services**	**Review –** Reviews the cloud service requirements based in: the cloud service itself, other changes within the business, changes within the supplier organization, or the need to change the supplier.

Besides the good work developed and the new ideas exposed this framework does not seem to present the CSP view.

2.2.1.10 Cloud Decision Support System

Mithani et al. (2010) identify the need to validate business applications and workloads in relation to technical portability and business requirements/compliance so that they can be deployed in a public cloud without considerable customization.

In this work, the authors present the approach, Cloud Decision Support System (CDSS), that helps the stakeholders in the process of migrating to the CC, namely to automate the process of identifying business workloads that that should be migrated to a public cloud without re-architecting the applications or changing their business logic as comprehending its cost-benefits.

2.2.1.11 Comparison of the presented proposals

In Table 14 the frameworks presented are compared. As can be seen, according to the analysed documents, the majority of the studied frameworks does not include an initial step to define a strategy for the migration of services to CC. It does not address risk management nor legal issues either, nor analyses the impact of migrating services to CC. Additionally, the contracts management, the vendor lock-in, the testing of the achieved solution, the use of good practices and the continual improvement of the solution are other issues that are not covered by the analysed solutions. Notwithstanding each of the studied frameworks offer a solution to migrate IT to CC, none of them points a way to enforce that the actions developed to complete each process (that make up the framework) are managed, done appropriately and in an organized way. To solve this issue an IT governance framework, such

as ITIL or COBIT, could be used as a reference to define each of the framework processes to achieve the best solution for the organization.

Table 14 - Related proposals comparison

Characteristic / Project	Strategic perspective for federal US agencies	Six step framework	Cloud Adoption Toolkit	Ezzat et al. work	Hackystat	Cloudstep	CloudMIG	Banerjee work	IVI Cloud Computing Life Cycle
Understand CC	Yes	No	Yes	No	Super-ficial	No	No	No	Yes
Definition of a strategic plan	No	No	Yes	No	No	Yes	No	Yes	Yes
Includes business management participation	No	No	Super-ficial	Yes	Yes	Yes	Yes	No	Yes
Analyses the current organization t's IT	Yes	Super-ficial	No	Yes	Yes	Yes applications	Yes applications	Yes	Yes
Migration of services, applications, data and infrastructure	Yes	No	Yes	Yes	No	Legacy application	Applications	Applications	Yes
CSP selection	Yes	Yes	Yes	No	No	Yes	No	Superficial	Yes
Risks management	Yes	No	Yes	No	Super-ficial	No	No	Superficial	Yes
Security	Yes	Super-ficial	Yes	Superficial	Yes	Yes	Yes	Yes	Yes
Legal	Yes	Super-ficial	No	Superficial	No	Superficial	No	No	No
Impact	Yes	No	Yes	No	No	No	No	Superficial	Yes
Costs	Yes	Yes	Yes	Yes	No	Superficial	Yes	Yes	Yes
Issues considered	Yes	Yes	Cost-related	No	Super-ficial	Yes	No	Superficial	Yes
Staff	Super-ficial	No	Yes	Superficial	No	Superficial	No	No	Yes
Contracts	Yes	No	No	No	No	Superficial	No	No	Superficial
SLA	Yes	No	Yes	No	No	Superficial	No	Yes	Yes

Characteristic / Project	Strategic perspective for federal US agencies	Six step framework	Cloud Adoption Toolkit	Ezzat et al. work	Hackystat	Cloudstep	CloudMIG	Banerjee work	IVI Cloud Computing Life Cycle
Vendor lock-in	Yes	No	No	No	No	No	No	No	Yes
Presents a formal process to support CC migration	Yes	No	Ab-stract	Yes	Ab-stract	Yes	Yes	Little de-tails	Yes
Solution testing	No	No	No	No	No	Superfi-cial	Yes	Yes	Superficial
Continual improvement	Yes	No	No	No	No	No	No	No	Yes
Support of case studies	No	No	Yes	Yes	No	No	No	No	Yes
IT Governance (good practices)	No	No	No	No	No	No	No	No	No

2.2.2 Migration to the cloud, miscellaneous tools

There are tools that per se are not a complete solution for the migration to CC per se, however they could be used as a support for particular issues. Accordingly, they are presented in the following paragraphs (Costa & Cruz, 2012; A. Khajeh-Hosseini et al., 2011; Li, Yang, Kandula, & Zhang, 2010; Misra & Mondal, 2011).

Ali Khajeh-Hosseini et al. expose two tools that aim to support decision-making during the migration of IT systems to the public IaaS clouds in (A. Khajeh-Hosseini et al., 2011). The first is a modelling tool that produces cost estimates of using public IaaS clouds and can be used to compare the cost of dissimilar CSPs, deployment options and usage scenarios. The second tool is a spreadsheet outlining the benefits and risks of using IaaS.

Misra et al. (2011) present a comprehensive analysis where to explore the viability of transition from traditional computing to CC for business enterprises. They concluded that a large proportion of business has financial benefits if they migrate to CC.

The CloudCmp, a tool presented in (Li et al., 2010) by Li et al. is aimed to support CC customers in selecting a CSP being used to systematically compare cloud services. CloudCmp includes a set of benchmarking tools used to compare components whose results are

then used to predict the performance and cost of a customer application when deployed on a cloud.

Paulo Jorge and António Miguel in their paper (Costa & Cruz, 2012), show the steps to migrate a traditional windows' application to the Windows Azure world. With their study and through a small case study they have concluded that the application's performance does not deteriorate when migrating to the cloud. However, they finish by stating that the migration to CC will be primarily accomplished for non-critical business applications, protecting therefore the core applications of the organization from errors and security faults while the organization gains experience with cloud usage.

2.3 IT governance

IT governance enables the management to make better decisions pertaining to IT initiatives and investments (Raodeo, 2012). The proper management of Information Technology has a significant influence on organizations and should therefore be a growing concern in organizations that intend to use technology to better compete better in a world of continuous and rapid change. The term IT governance born of the accounting and audit abuses that prompted the Sarbanes-Oxley (SOX) Legislation of 2002 (Winniford, Conger, & Erickson-Harris, 2009).

Over the years, a variety of IT governance frameworks arose, each one having their own strengths and weaknesses, each one with its own focus and purpose. The following sections present some of these frameworks.

2.3.1 Governance frameworks and standards

IT has stopped being a support area becoming increasingly a necessity in the business strategy of organizations. With this increasing dependence on IT by the organizations, the management of IT services has become a key area within organizations whose main objective is aligning IT to business and promote costs reduction.

Comparing the management of IT services with the traditional model, oriented to IT operations, the management of IT services is a discipline oriented to customer-defined processes and IT to manage IT "as a business" (Winniford et al., 2009). The IT service management

(ITSM) , refers to the implementation and management of quality IT services that meet the needs of the business (Mourad & Johari, 2014).

There is already an extensive set of recommendations for IT management and IT governance in general. The ITIL, (Axelos, 2013; Lee, 2012; Lesihla, Coetzee, & Lall, 2012; Sharifi, Ayat, Rahman, & Sahibudin, 2008), the Control Objectives for Information and related Technology (COBIT), the Capability Maturity Model Integration (CMMI) that support IT governance and a standard ISO 20000. The most applied and widely used (Cots & Casadesús, 2014; Sahibudin, Sharifi, & Ayat, 2008; SILVA, ROSA, & others, 2012) is the ITIL. The main objective of these models and standards is to give transparency to the actions and processes of IT (Duque & Lyra, 2010).

2.3.1.1 ITIL

The ITIL (Axelos, 2013) is a de facto standard and the reference model for IT management processes. It consists of a set of good practices that should be observed in the operation and maintenance of IT. This model was developed by the English government for use in IT companies, and was quickly adopted across Europe as the standard for best practice in service delivery IT.

2.3.1.1.1 Overview

Considering the general field of IT, the ITIL (Axelos, 2013), stands out as a widely recognized reference guideline for IT service management.

Published by the Central Communications and Telecommunications Agency (CCTA) and, more recently, the Office of Government Commerce (OGC), ITIL provides a practical, no-nonsense framework for identifying, planning, delivering and supporting IT services to the business. Consisting of a set of good practices, described over five volumes known as Service Strategy, Service Design, Service Transition, Service Operation and Continual Service Improvement, ITIL is currently in version 3 (known as ITILv3 and ITIL 2011 edition). Its last update was in 2011, ITILv3 it has been rapidly adopted throughout Europe as the de facto standard for best practices in IT service delivery.

2.3.1.1.2 History

The first version of ITIL, developed between 1989 and 1995, was published in England by the CCTA now known as OGC and its initial use was to be a guide to the Government of England. This initial version, consisting of more than 40 books, covers all aspects of IT service delivery. In 1991 the ITIL user's forum was created, the IT Information Management Forum (ITIMF), which subsequently changed its name to IT Service Management Forum (itSMF) ("itSMF International," 2013). Later, between 1996 and 2004, the initial version was revised giving rise to ITIL V2 and consisting of seven books that were widely used around the world. In 2007, a new revision takes the ITIL version 3, and another reduction in the number of books, now to five core books covering all phases of the service life cycle represent the main content of ITIL V3. In 2011, ITIL had an update in order not only to resolve errors and inconsistencies, but also to improve the publications, to answer to suggestions for changes to make easier to teach ITIL and to review the Service Strategy publication for clarity (Ltd, 2011) which resulted in the ITIL v3 2011 edition. This review also adds, in accordance with the editor, "some coverage on how IT service management is impacted by cloud computing" (Office, 2011, p. 5). However, despite the launched updates in the course of the present research, it was not necessary to reorganize the work firstly because, according to our knowledge, there are no implementations of ITILv3 2011in any organization and secondly because the added coverage concerning CC is reduced.

2.3.1.1.3 Goals

ITIL provides a set of organized procedures with which an organization can manage its IT. Among the main objectives of ITIL are the integration of IT services with business; the reduction of IT services costs; improvement of the quality of IT services; increase efficiency and effectiveness.

2.3.1.1.4 ITIL books

The current version of ITIL, version 3, comprises five books known as Service Strategy, Service Design, Service Transition, Service Operation and Continual Service Improvement. These five publications are arranged around the concept of service in an iterative life cycle's structure as depicted in Figure 14.

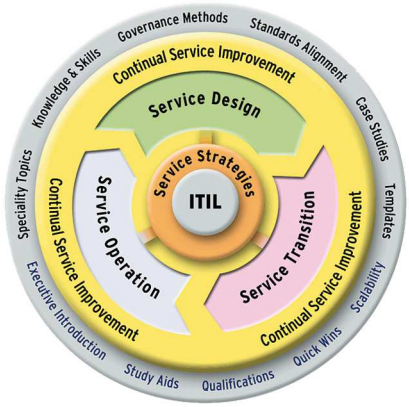

Figure 14 - ITIL service life cycle (taken from ("IT Governance, IT Security & IT Service Management," n.d.)**)**

In the following paragraphs, an overview of each book is made and the processes recognized in each one are identified.

2.3.1.1.4.1 Service Strategy

The Service Strategy book provides a guidance on how to design the service management and ensures that organizations are in a position to achieve operational efficiency. Its main goal is to make the organization think and act in a strategic way. It is at this stage that the customers idealize the services that will be in accordance with the organization's business and generate business value, define to whom offer the services that is, the markets for which the service should be developed, among others.

This stage is divided into the following four processes:

- **Strategy generation** - To support the service provider think and act strategically;
- **Service Portfolio Management (SPM)** - The main objective of this process is to ensure that the service's provider has the services needed by the business with an appropriate investment and outcome;

- **Demand Management** - With a critical role in the strategy of the service, demand management tries to reach a balance between the supply and demand for the services by anticipating the demand;
- **Financial Management** - To provide services in economic conditions it is necessary to have a transparent view of all costs for all processes in the service organization. The financial management assesses the value of IT services and the implied value of assets. It includes budgeting, accounting and charging of services.

2.3.1.1.4.2 Service Design

ITIL believes that a good design depends on the services of an efficient and effective use of the four P's of design:

- People: people, skills and competencies involved in the delivery of IT services;
- Processes: the processes, duties and activities involved in the provision of IT services;
- Partners: vendors, manufacturers and suppliers who help and support the provision of IT services;
- Products: technology and management systems for the supply of IT services;

This stage includes the following processes:

- **Service Catalogue Management (SCM)** - It aims to provide consistent information to authorized persons, on all services currently available. It also ensures the creation and maintenance of the service catalogue so that it has updated information on each service;
- **Service Level Management (SLM)** - To guarantee an agreed level of services, SLAs, provides a comprehension between the supplier and the customer. The service level management is a core function in the management of IT services;
- **Capacity Management** - The capacity management intends to ensure a compliance with the requirements of the customers using the optimal utilization of the existing resources and ensuring that future needs will be made available in due time.
- **Availability Management** - Aims to ensure that all existing services meet the objectives, agreed availability and that all the new or changed services reach their goals without affecting the already existing ones.

- **IT Service Continuity Management (ITSCM)** - By putting the emphasis on prevention of service breaks, the service continuity management prepares organizations for emergencies considered significant by the company and which may become a disaster or a catastrophe.
- **Information Security Management (ISM)** - This process that must be closely coordinated with the company security. It includes the security policy and an information system security's management.
- **Supplier Management** - It includes the identification, registration and control of the suppliers and associated contracts The primary aim to ensure that suppliers comply with the conditions of contract.

2.3.1.1.4.3 Service Transition

The purpose of this stage is "putting into production" the IT services that were produced or modified, ensuring that changes made to the services are performed in a coordinated manner. It is also responsible, for an initial term, of the provision of support for the services newly migrated to production. The faults committed here have impact on the Service Operation stage.

The processes constituted at this stage are:

- **Transition Planning and Support** - It aims to ensure the orderly transition of a new or changed service to production, along with the necessary adjustments to the processes of service's management.
- **Change Management** - This process intends to answer to changes in IT, often in response to market changes, by implementing these changes in an economical and in a timely manner minimizing the impact on the services.
- **Service Asset and Configuration Management** - (SACM) - With a focus on asset management, this process aims to identify, monitor and account service assets and configuration items, protecting and ensuring its integrity throughout the service life cycle.
- **Release and Deployment Management** - This process seeks to establish an optimal use of new or changed services.

- **Service Validation and Testing** - To ensure a proper transition of the services so that these comply with the needs of the business, this process points how to test and validate the service.
- **Evaluation** - This process is intended to verify the usefulness of a service to the business.
- **Knowledge Management** - The knowledge management is aimed to provide the "right information to the right person at the right time" so that high quality services can be provided.

2.3.1.1.4.4 Service Operation

The service operation ensures that services are delivered effectively and includes requests from users, fault resolutions, problems' correction and the carrying out of routine tasks. It is at this stage the value for the service is generated, i.e., the services actually generate value for the business (Taylor, 2007). This happens because it is at this stage that is the service desk function (that serves as a meeting point between the service customer, the client and the service provider) can evaluate the customer service's quality. This stage includes the following process:

- **Event Management Process** - In (Cartlidge et al., 2007), event is defined as "a status change that has meaning for the management of an item or a setting of an IT service". The event management depends on monitoring, however it is something else since it also generates and detects notifications.
- **Incident Management Process** - An incident is defined in (Cartlidge et al., 2007) as "an unplanned interruption or reduction in the quality of an IT service. A failure in a configuration item that has not had an impact on service is also considered as one incident". The incident management aims to resume the normal service operation as quickly as possible as to ensure the highest levels of quality and service availability.
- **Problem Management Process** - ITIL (Taylor, 2007) defines a problem as "an unknown cause of one or more incidents". The main purpose of problem management is the prevention of problems avoiding incidents to occur, eliminating the recurring incidents and minimizing the impact of those that cannot be avoided.

- **Access Management Process** - This process is intended to allow access to users who may have access to a service or a group of services and deny it to those who are not authorized.
- **Request Fulfilment Process** - The process of fulfilling the request aims to provide users with a means to be able to request and receive services, inform users and customers regarding services and ways of how they can obtain help provided widespread.

2.3.1.1.4.5 Continual Service Improvement

The main purpose of the continual service improvement is to continually align and re-align IT services to the changing business' needs by identifying and implementing improvements to IT services that support business processes (Spalding, 2007). The activities of the continual service improvement includes, reviewing management information and trends, conducting audits and service reviews. The presentation of recommendations to senior management, the support on prioritizing improvement opportunities, leading managing and delivering improvement projects and influencing all levels of management to ensure that the service improvement activities are receiving the correct support and resources are activities of this ITIL process. The key steps of the continual service improvement are depicted in Figure 15.

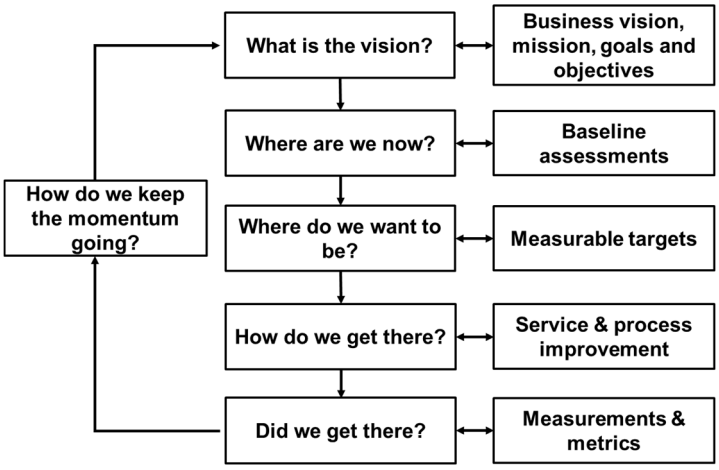

Figure 15 - The Continual Service Improvement model (adapted from(Spalding, 2007)**)**

The goal of the "**What is the vision"** step is to comprehend the business vision, the strategy, the goals and objectives, without neglecting that the IT's strategy and goals should be

in support of the business. Following is the "**Where are you now**" step that takes care of an initial evaluation to create a baseline from which the upcoming improvement's can be measured. The next step "**Where do we want to be**", defines the targets for the improvement initiative based on the requirements identified by the business. The fourth step, **"How do we get there**", is where the improvement processes are acknowledged, agreed and financed. The last of these steps is the "**Did we get there**", whose main objective is to ensure that the improvements have been achieved.

2.3.1.1.5 ITIL v3 2011

Since 2009, an ITIL project update was in progress to provide answers for the received feedback, the advice from the change advisory board and the issues raised through the change control's log (Office, 2011). In July 2011 the ITIL v3 2011 edition was published, mainly to correct errors, implement improvements, remove inconsistencies and improve the clarity and content's structure of five books. The majority of CC's related content is collected in the service strategy book (Office, 2011). The "Appendix C: Service Strategy and the Cloud" introduces the characteristics and attributes of the cloud services with a definition that is aligned with NIST definition though without adding a significant value. The remainder of the book refers CC to demonstrate how the service strategy applies to this new sourcing model. The other books scarcely refer CC.

Table 15 shows the major changes introduced in ITIL v3 2011 and how they relate with the migration to CC.

Table 15 - New processes in ITILv3 2011 related with migration to cloud computing

Book	Process	Objective
Service Strategy	**Demand Management** and Demand Manager role	A dedicated demand management process was introduced. The Demand Manager role objective is to perform the activities in the Demand Management (Cannon, 2011)
	Strategy Management for IT Services	The process that defines and maintains an organization's perspective, position, plans and patterns regarding its services. After the strategy is defined, the Strategy Management for IT Services is responsible for the implementation of the defined strategy (Cannon, 2011).

Book	Process	Objective
	Business Relationship Management	This process' aim is to maintain a healthy relationship with customers by identifying their needs and guarantee that services are developed to solve these needs. (Cannon, 2011)
Service Design	**Design Coordination** and the service design manager role	The aim of this process is to coordinate all service design activities to ensure that the goals and objectives of the service design are met (Hunnebeck, 2011).
Service Transition	**Change Evaluation**	The goal of the change evaluation process is to evaluate changes in a consistent and standardized way to determine the performance of the service. (Rance, 2011).

Despite this update has been launched in the course of the exposed research, it is not necessary to recast the work carried out. Firstly, because according to our knowledge there is no implementation of ITIL 2007v3 update. Secondly, because the coverage added concerning the CC, is reduced in accordance with editor terms "some coverage has been added on how IT service management is impacted by cloud computing" (Office, 2011, p. 5). The changes introduced improve the steps of the framework namely those related with direct CSPs interaction and relationship. More details can be found in the next chapter specifically in Table 31 on page 160.

2.3.1.1.6 ITIL and the migration to cloud computing

We recognize that it is not, either economically or temporarily, viable for a company that does not follows yet ITIL implement to only to migrate their services to the CC. Thus, and as part of this work, we developed a migration framework to the CC paradigm which, although based on ITIL, does not force the organization to previously implement ITIL to properly be able to perform the migration cloud. However, if the organization already follows the ITIL framework, the implementation of the developed framework, by the team responsible for the migration of computing, is simplified since there are steps already accomplished and information already gathered.

2.3.1.2 COBIT

The Control Objectives for Information and related Technology (COBIT), is defined by ISACA ("COBIT Framework for IT Governance and Control," n.d.) as "an IT governance framework and supporting toolset that allows managers to bridge the gap between control requirements, technical issues and business risks."

2.3.1.2.1 Overview

The COBIT framework addresses both business and IT functional areas through an enterprise and considers the IT-related interests of internal and external stakeholders. Enterprises of all sizes, whether commercial, not-for- profit or in the public sector, can benefit from COBIT 5 (ISACA, 2014). The COBIT, guides its action, in five key principles presented on Figure 16:

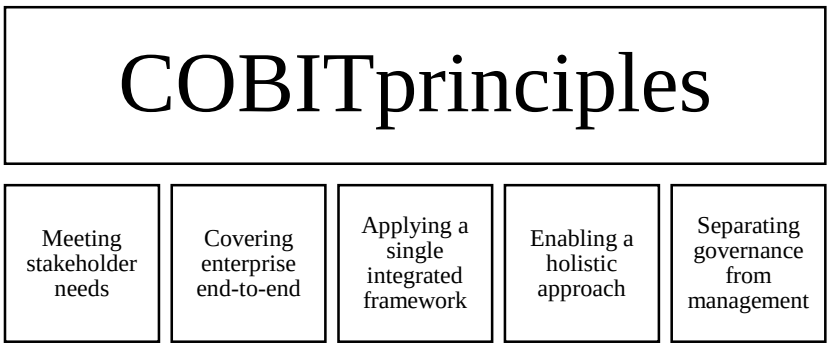

Figure 16 - COBIT principles (adapted from (Wal, Lainhart, & Tessin, 2012)**)**

- **Meeting stakeholder's needs** – provides all required processes and other facilitators to support the creation of business' value and taking into account the stakeholders and their concerns.
- **Covering enterprise end-to-end –** addresses the governance and management of information and related technology from an enterprise wide, end-to-end perspective.
- **Applying a single integrated framework** – yet intends to align their practices with other relevant frameworks and best practices to serve as a single comprehensive framework for governance and management of enterprise IT.
- **Enabling a holistic approach** – defines a set of enablers to support the implementation of a comprehensive governance and management system for enterprise IT.

- **Separating governance from management** – the COBIT framework makes a clear distinction between governance and management. These two disciplines encompass several types of activities, require different organizational structures and serve different purposes in the organization.

2.3.1.2.2 History

The first version of COBIT was developed in 1969 by International Systems Audit and Control Foundation (ISACF) the research arm of the Information Systems Audit and Control Association (ISACA) (Cater-Steel, Tan, & Toleman, 2006) as an audit framework for IT. In 2003, the ISACF was renamed as IT Governance Institute (ITGI) and COBIT was released and used primarily by the IT community. However, Management Guides were later added and COBIT became the internally accepted framework for IT governance and control (Sahibudin et al., 2008).

The Sarbanes-Oxley Act ("Sarbanes-Oxley Act," 2002) is a federal law enacted in the United States on July 30, 2002 that establishes new or enhanced standards, for all U.S. public companies to ensure the creation of auditing mechanisms, security and confidence. In accordance with the Sarbanes-Oxley, each organization is obliged to do everything possible to avoid loss of service and data, preventing manipulation of and improve security.

Table 16 shows the COBIT evolution. To be noted the influence that the Sarbanes-Oxley Act had on the development of COBIT.

Table 16- COBIT evolution

Year	Version	Action
1967	NA	ISACA was founded.
1969	1	Developed by ISACF
1996	1	The first edition of COBIT was released. Scope audit.
1998	2	Includes a tool to support the implementation and the specification of objectives and high-level of detail. Added the control scope.
2000	3	Published the third version that includes standards and guidelines related to the management. ITGI becomes the main editor. Added the management scope.

Year	Version	Action
2002	Sarbanes-Oxley Act	Approved the Sarbanes-Oxley Act which had a significant impact on the adoption of COBIT in the U.S.
2005	4	Improved controls to ensure the security and availability of IT assets in the organization. Added the governance scope.
2007	4.1	Published version 4.1
2012	5	Published the current version. Added governance of enterprise IT's scope.

2.3.1.2.3 Goals

COBIT, group's 300 IT governance objectives covering planning and organization, acquisition and implementation, delivery and support, monitoring and evolution (Winniford et al., 2009) divided in four areas:

- **Plan and Organize (PO)** – Covers the use of information and technology and how to put them in practise the best way possible to achieve the company's objectives.
- **Acquire and Implement (AI)** – This domain covers the identification of IT's requirements, the acquisition technology and its implementation in accordance with the existing procedures in the company and the maintenance plan to be used.
- **Delivery and Support (DS)** – Encompasses aspects of IT's delivery, including areas such as application execution and achievement of results as well as the support processes that enable an efficient execution.
- **Monitor and Evaluate (ME)** – This area estimates the strategic needs of the company included the evaluation of the current system to verify that this achieves the objectives for which it was specified.

Figure 17 shows the structure of COBIT.

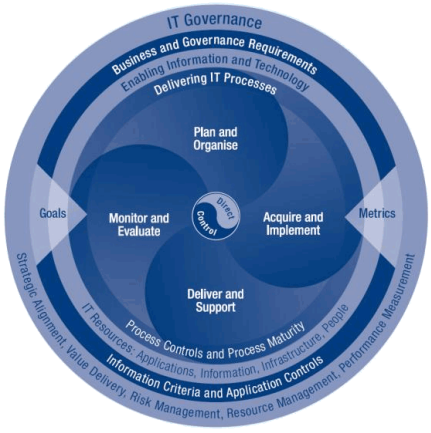

Figure 17 – COBIT (taken from ("COBIT 4.1: Framework for IT Governance and Control," n.d.)**)**

2.3.1.2.4 COBIT and the migration to cloud computing

"By using this framework an organisation tries to answer questions related to governance and best practices and determine whether the organisation is capable of IT's governance in the cloud" (Shimba, 2010). As stated by Sahibudin et al. in (2008) "implementers should use ITIL to define strategies, plans and processes and use COBIT for metrics, benchmarks and audits". Evelina et al. in (2010) reinforce this idea when affirming that "COBIT is commonly used for IT auditing purposes and not for improvement purposes".

2.3.1.3 ISO/IEC 20000

The need for an IT service management's standard became obvious with the evolution of IT and its preeminent role in the business as a positive differentiation. The urge for certification should be, according to (Disterer, 2009), to increase the importance of IT in supporting the business. Furthermore, the need to have lower costs and improve performance also leads to the need for certification mainly when IT departments no longer have a monopoly on the provision of IT and are therefore subject to a market competition. Moreover, being ITIL a framework and not a real standard, demonstrate compliance with ITIL, is impossible for service providers.

2.3.1.3.1 Overview

The International Standards Organization/International Electrotechnical Commission 20000 (ISO/IEC 20000) (ISO, n.d.-a) is the first IT service management process standard

developed by the ISO/IEC under the direct responsibility of ISO/IEC JTC 1/SC 40 Secretariat (ISO, n.d.-b). The standard is heavily based on BS 15000 (British Standard) and ITIL (Disterer, 2009). Indeed, the "ISO/IEC 20000-1 was prepared by the British Standards Institution. (BSI) (as BS 15000-1) and was adopted, under a special "fast-track procedure", by Joint Technical Committee ISO/IEC JTC 1, Information technology, in parallel with its approval by the national bodies of ISO and IEC." (ISO, 2011a).

The ISO/IEC 20000 standard set up requirements for service management processes – however, it does not provide orientation to implement them. Since ITIL and ISO/IEC 2000 are aligned, many requirements of the standard could be accomplished through the implementation of one or more ITIL processes. To better explain the relationship between ITIL and the standard, we now present Figure 18 as a depiction of the liaison.

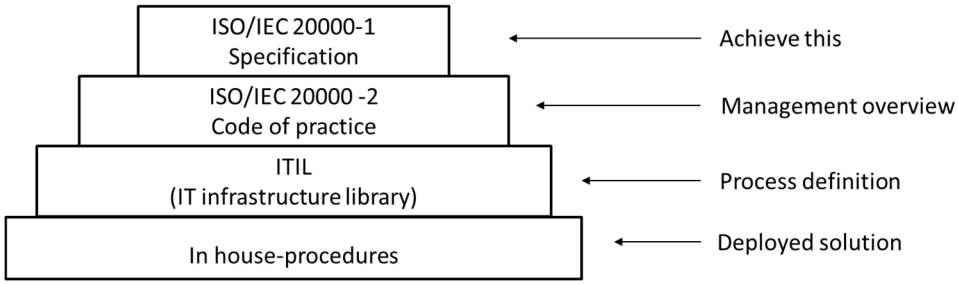

Figure 18 - ITSM pyramid (adapted from ("ISO 20000 and ITIL," 2005)**)**

Despite the strong relationship between ITIL and ISO/IEC 20000, the standard is not exclusively based on ITIL, which results in the possibility of the organization to choose the preferred IT Service Management Framework. The standard is encoded in the documents presented on Table 17.

Table 17 - ISO/IEC core documents (ISO, n.d.-a)**)**

Document	Part	Description
ISO/IEC 20000-1:2011	1	Service management system requirements
ISO/IEC 20000-2:2012	2	Guidance on the application of service management systems
ISO/IEC 20000-3:2012	3	Guidance on scope definition and applicability of ISO/IEC 20000-1
ISO/IEC TR 20000-4:2010 (technical report)	4	Process reference model

Document	Part	Description
ISO/IEC TR 20000-5:2013 (technical report)	5	Exemplar implementation plan for ISO/IEC 20000-1
ISO/IEC WD 20000-6 (under development)	6	Requirements for bodies providing audit and certification of service management systems
ISO/IEC CD 20000-7 (under development)	7	Guidance on the application of ISO/IEC 20000-1 to the cloud
ISO/IEC NP 20000-8 (under development)	8	Guidance on the application of service management systems for smaller organizations
ISO/IEC TR 20000-9 (technical report)	9	Guidance on the application of ISO/IEC 20000-1 to cloud services
ISO/IEC TR 20000-10:2013	10	Concepts and terminology
ISO/IEC PDTR 20000-11 (under development)	11	Guidance on the relationship between ISO/IEC 20000-1:2011 and service management frameworks

In short, according to the information in the ISO site (ISO, 2011b), the document ISO/IEC 20000-1, encompasses the formal specification of the standard and describes the necessary requirements to comply with to achieve the certification. The second document (ISO/IEC 20000-2) (ISO, 2012a) provides recommendations for implementation, and the third (ISO/IEC 20000-3) (ISO, 2012b) includes a practical guidance on scope definition, applicability and demonstration of conformity to the requirements in ISO/IEC 20000-1. The purpose of ISO/IEC TR 20000-4:2010 (ISO, 2010) is to facilitate the development of a process assessment model according to ISO/IEC 15504 process assessment principles. The document ISO/IEC TR 20000-4:2010 (ISO, 2010) is an exemplar implementation's plan providing guidance on how to implement a service management system (SMS) to fulfil the requirements of ISO/IEC 20000-1:2011. The documents 6 to 8 are under development. Lastly, the ISO/IEC TR 20000-10:2013 (ISO, 2013) provides an overview of the concepts and the terminology of ISO/IEC 20000 and the ISO/IEC PDTR 20000-11 is under development.

The ISO/IEC 20000 standard is organized, as depicted in Figure 19, in five groups of processes: Service Delivery, Relationship, Resolution, Release and Control.

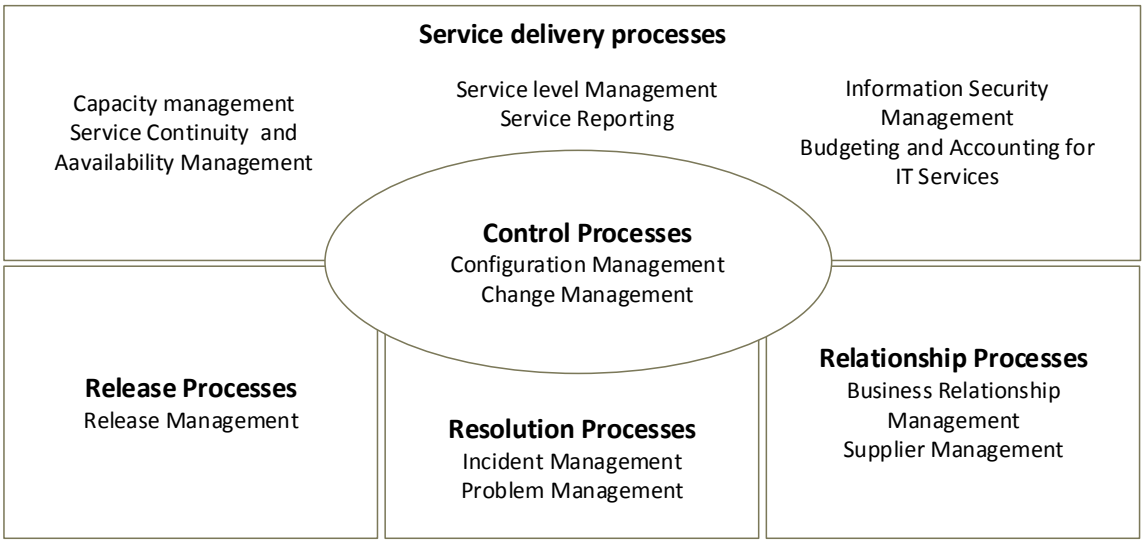

Figure 19 - Process model in ISO / IEC 20000 standard (adapted from (ISO, 2011a)**)**

The ISO/IEC 20000-1 document (specification of the standard) sections 3 to 10 contain the requirements for compliance. So, in section 3 the "Requirements for a Management System" are presented the and these include what the management "shall", the requirements of the documentation provided by the service providers to "ensure effective planning, operation and control of service management" (ISO, 2011a). This section ends with the requirements of competence, awareness and training.

Section 4 "Planning and implementing service management" prescribes IT service delivery processes and explains how they are related with the Plan-Do-Check-Act's (PDCA) methodology. This kind of methodology applies to all the ISO/IEC processes and outlines how the standard is to be implemented. The standard continues with section 5, "Planning and implementing new or changed services" whose goal is to "ensure that new services and changes to services will be deliverable and manageable at the agreed cost and service quality" (ISO, 2011a). In section 6 "Service delivery process", the emphasis is on "Service Level Management", "Service Reporting", "Service Continuity and Availability Management", Budgeting and accounting for IT service, Capacity management and Information security management. Section 7 takes care of the "Relationship Processes", which means the compliance requirements for Supplier Management and Business Relationship Management processes.

The last three sections comprise Resolution Processes (incident and problem management), in section 8, Control Processes (configuration and change management) in section 9 and Release Process (release management processes) in section 10.

2.3.1.3.2 History

The ISO/IEC 20000 standard has arisen in response to an urge of an organization for having to implement an IT standard in its business' environment. This environment will replace the ISO/IEC 9000 standard (only focused on quality) (Kunas, 2011).

In November 2000, the BSI published the first edition of the BS 15000. Five years later, in December 2005, the International Standardization Organization (ISO) publishes the first edition of the ISO/IEC 20000 standard, the first international standard for IT service management (Tanovic & Orucevic, 2013), as an internationalization of the BS 15000. The Figure 20 presents, in short, the history key points of ITIL, BS 15000 and ISO/IEC 20000.

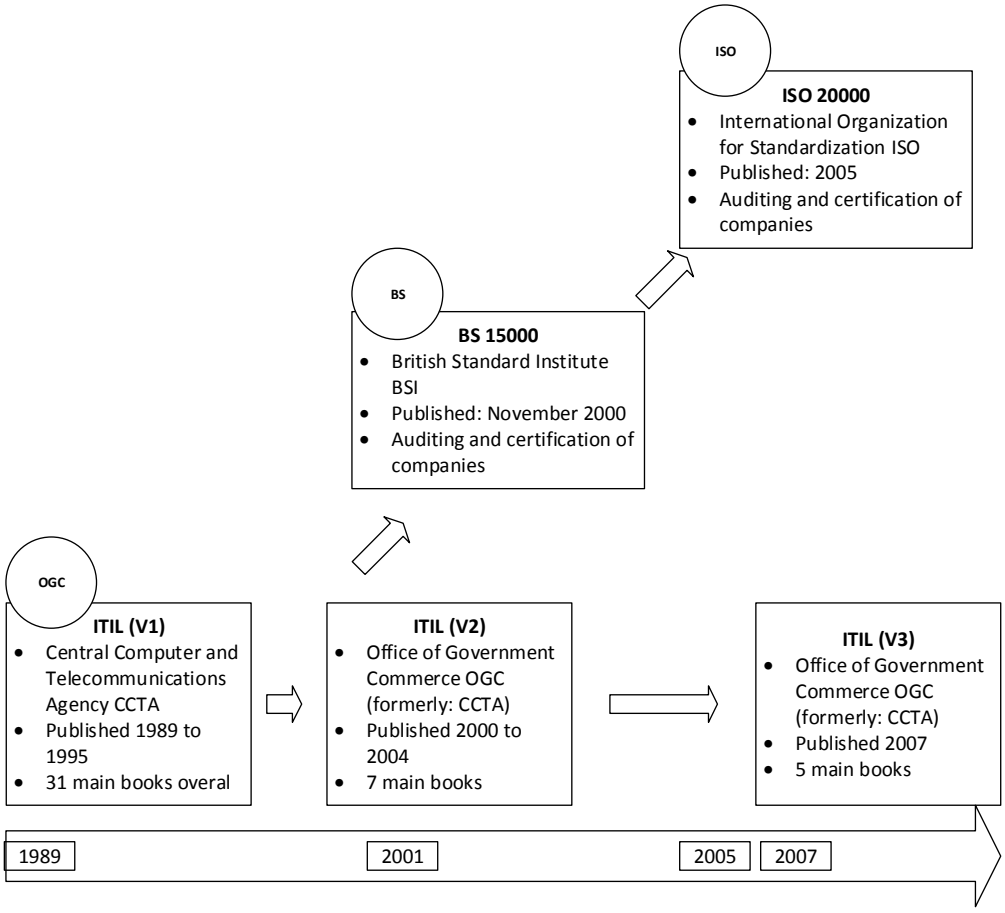

Figure 20 - ISO 20000 history (adapted from (Disterer, 2009)**)**

2.3.1.3.3 ISO/IEC 20000 and the migration to cloud computing

The ISO/IEC 2000 may also support the migration to CC as illustrated by the migration of Orange Business Services (Orange, 2014) to CC in (Haentjens, 2012). However, when the

organisation does not have an ISO/IEC 2000 certification, it is superfluous to certify an enterprise merely to migrate some or all of their services to CC.

2.3.1.4 CMMI

The Software Engineering Institute (SEI) at the Carnegie Mellon University developed the Capability Maturity Model Integration (CMMI) - a suit of models including the software CMM, the System Engineering CMM, the CMMI for services (CMMI-SVC) and the Integrated Product Development CMM that have been merged and extended into the CMM Integration (CMMI).

2.3.1.4.1 Overview

The CMMI is a process improvement model of products and services, composed of five maturity levels (ML) achieved via implementation of the specific and generic goals of that ML and all the preceding ones (Lopes Margarido, Pascoal Faria, Moreira Vidal, & Vieira, 2012). It is often used as a reference model for organizations implementing IT governance (Raodeo, 2012), identifying three critical dimensions; People Tools and Procedures (Evelina et al., 2010).

One advantage of the CMMI is that it points areas where improvement is needed and suggests the appropriate actions (Evelina et al., 2010).

According with the CMMI institute ("CMMI and ITIL," 2014) the CMMI and ITIL technologies work well together, indeed they complement each other.

2.3.1.4.2 History

In 2000, the CMMI Product Team (a team of process improvement experts from the government, industry, and the SEI) published the original CMMI model, a training and an appraisal method, which incorporated software and systems' engineering (C. Institute, 2007). Table 18 shows the evolution of CMMI.

Table 18 - CMMI evolution

Date	Version
Late 1980	The U.S. Department of Defense (DoD) sponsored the Software Engineering Institute at the Carnegie Mellon University (SEI) and the development of the Capability Maturity Model (CMM).
1988	The work starts on a Process Maturity Framework for judging a company's capability to produce software
1991	Release of the CMM version 1
1992	Release of the CMM version 1.1
1999	Begins the development of CMMI
2002 (March)	CMMI SE/SW/IPPD/SS version 1.1

Considering that the migration to CC can be viewed as services acquisition, the CMMI institute also provides a collection of best practices CMMI for Acquisition (CMMI-ACQ) providing a comprehensive set of guidelines for acquiring products and services. The model backups up to improve the relationship with the suppliers by supporting the business to enrich their own processes ("CMMI for Acquisition," 2014).

2.3.1.4.3 CMMI and the migration to cloud computing

The CMMI is a process improvement model that points out areas where improvement is needed and suggests appropriate actions (Evelina et al., 2010; Lopes Margarido et al., 2012) - as such it is not the most adequate for the task in question with this work, that is, the development and definition of the tasks needed to migrate to CC.

2.3.2 Why was ITIL selected

Enterprise activities increasingly rely on the fundamental support of IT to sustain the growth of the business. Amongst the frameworks presented, ITIL gains prominence on the migration to CC because, as stated by (Sahibudin et al., 2008), implementers should use ITIL to define strategies, plans and processes, which are the key actions to migrate to CC.

Furthermore, ITIL is chosen by its acceptance. Indeed ITIL is the most widely adopted approach for IT (Mourad & Johari, 2014), with an acceptance of 28% followed by COBIT with 12,9 % (ISACA, 2011). Additionally, in a survey of the IT Service Management forum (itSMF), where the years of 2010 and 2013 are compared (International Publishing Group, 2013), the framework adoption index also indicates that the ITIL is in advantage when compared to others frameworks, as Figure 21 demonstrates. Indeed, ITIL has the lead in organizations with either more or less than 500 employees.

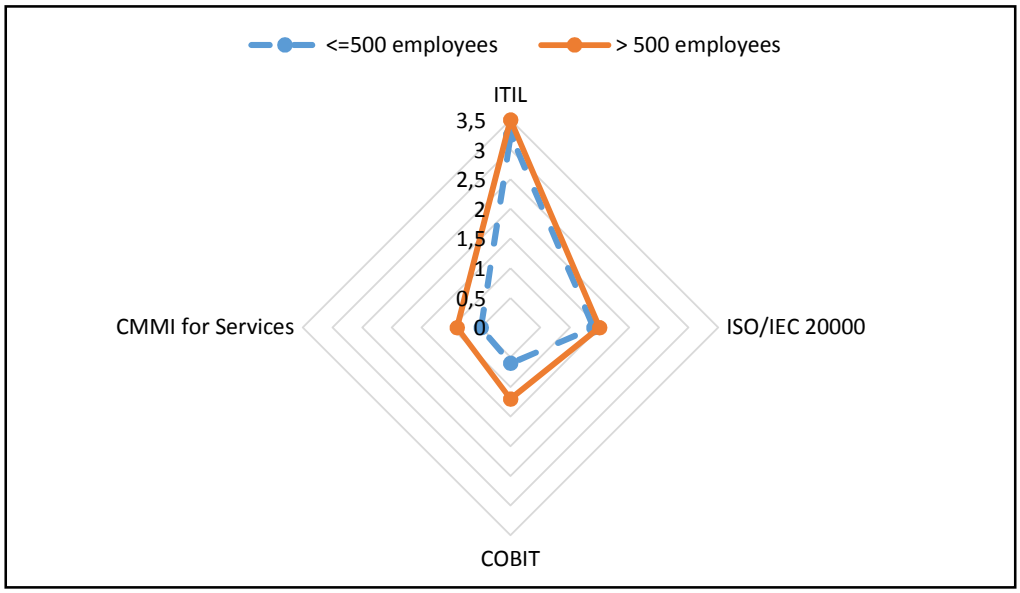

Figure 21 - IT governance frameworks adoption index (adapted from(International Publishing Group, 2013)**)**

The major frameworks influence the way IT is managed. Although they are considered by themselves as complementary, they have differences. To better comprehend why we choose ITIL, Table 19demonstrates a comparison of the three frameworks and a standard of IT governance.

Unlike the frameworks that certify individuals, the ISO/IEC 20000 standard certifies enterprises. It is superfluous to certify an enterprise merely to migrate some or all of their services to CC. If the enterprise is already certified, tasks such as information gathering and financial management among others, are already accomplished which facilitates the migration.

Having in mind the concerns of each of the frameworks presented in Table 19 and the aim of the Migration to Cloud Computing Framework (M2CC) (part of this work), that defines

what should be done to migrate IT services to CC, it is more advisable to choose a framework that complements the M2CC framework. That is possible by showing **how** the steps envisaged by the M2CC framework should be performed (ITIL) rather than a framework that describes **what** is to be made (COBIT). In other words, we use ITIL for process design while the COBIT framework is used in a subsequent phase for benchmarking. Peña et al. in (Peña, Vicente, & Ocaña, 2012) reinforce this idea when stating that "COBIT can help guide an organization in what should be covered in processes and procedures (whereas ITIL provides guidance on how the processes or procedures should be designed)". Additionally, ITIL is better in concepts/processes, activities and in planning to implementation than the COBIT (Sahibudin et al., 2008), the key actions to migrate to CC, that lead us to choose ITIL over COBIT to support the migration to CC.

Table 19 - ITIL, COBIT, CMMI-SVC and ISO/IEC 20000 comparison

Characteristic	ITIL	COBIT	CMMI for Services	ISO/IEC 20000
Name	IT Infrastructure Library	Control Objectives for Information and related Technology	Capability Maturity Model Integration	ISO/IEC 20000
Origin	UK	USA	USA	USA
Born in	1989/1990	1995/1996	2000	2005
Developed by	CCTA OGC	ISACF ITGI ISACA	Carnegie Mellon University (Software Engineering Institute (SEI))	ISO (International Organization for Standardization)
Most recent version	3, 2011 edition	5	1.3	ISO/IEC 20000-1:2011 and ISO/IEC 20000-2:2012
Model	Collection of good practices (Radovanovi, Šarac, Adamovi, & Luci, 2011)	Collection of good practices (Radovanovi et al., 2011)	Collection of good practices	Standard
Processes	26	37	24	13
Based on	Real world experience	Real world experience	Real world experience	BS 1500

Characteristic	ITIL	COBIT	CMMI for Services	ISO/IEC 20000
Focus	Service management and operations (Soomro & Hesson, 2012)	IT Control and governance and control (Soomro & Hesson, 2012)	processes customers and quality of deliverables	IT service management
Prescriptive/ Descriptive	Descriptive	Descriptive	Descriptive	Prescriptive
Certification	Individuals	Individuals	Individuals	Enterprise
Level of abstraction	Lesser	Greater than CMMI	Greater than ITIL	High level of abstraction
Goal	Delivery and support of IT services	Governance, process control and audit	Development and maintenance of applications	To promote the adoption of an integrated process approach to deliver managed services to meet the business and customer requirements
Aim	Provide a reference or framework according to which IT services are to be provided in a process-oriented and systematic way(Disterer, 2009).	Support organizations to manage IT from a business perspective	Software development, integration, deployment and maintenance	Information technology service management
Guidance	How to develop and implement effective solutions	Delivering an end-to-end business view of the governance of enterprise IT	For developing or improving processes that meet the business goals of an organization	What should be done to offer the clients of an IT organization adequate IT Services
Concern	How (to do it/manage it) (Sánchez Peña, Fernández Vicente, & Ocaña, 2013)	What (should be done/managed) (Sánchez Peña et al., 2013)	What to perform	
Used by	Any type of enterprise	Any type of enterprise	Any type of enterprise	Any type of enterprise
IT relevance	More	Less	IT and non-IT services	IT Services

Characteristic	ITIL	COBIT	CMMI for Services	ISO/IEC 20000
Official site	http://www.itil-official-site.com/home/home.asp	http://www.isaca.org/COBIT/Pages/default.aspx	http://cmmiinstitute.com/	http://www.iso.org/iso/home/store/catalogue_ics/catalogue_detail_ics.htm?ics1=35&ics2=020&ics3=&csnumber=51986
Relationship between ITIL and …	NA	Complementary (Sánchez Peña et al., 2013)	Complementary and compatible	Strongly aligned
Relationship between COBIT and …	Complementary	NA	Complementary	Complementary
Relationship between CMMI-Service and …	Complementary	Complementary	NA	Complementary
Relationship between ISO-20000 and …	Fully compatible	Complementary	Complementary	NA
Migration to cloud computing	Applicable. If the organization already follows the ITIL framework, the migration to CC, is simplified since there are steps already accomplished and information already gathered.	Used for metrics benchmarks and audits	The CMMI is a process improvement model as such it is not the most adequate for the task in question with this work	It is superfluous to certify an enterprise an organisation merely to migrate its IT to CC, however if the organisation is already certified the information gathered and the procedures in use support the migration to CC.

2.4 Conclusion

To develop a framework for migrating IT services, applications, data and infrastructures to CC it is first of all necessary to comprehend the paradigm, its relationship with other technologies and how it is made available (service and deployment models).

The purpose of this literature review is to carefully examine the literature pointing to the answer of the question's research and justify it, i.e. to understand the state of the art of CC, IT governance, specifically ITIL, and to know the works developed regarding IT migration to CC.

Following the definition of CC, we start section 2.1 by introducing the CC. In subsection 2.1.4, to better comprehend the CC's concept, the technologies related to CC are exposed. The grid computing is somehow similar to CC since both employ distributed resources to achieve their objectives. However, CC takes the lead by resorting to virtualization. Additional differences between the two technologies can be found on Table 5. Next, there is the utility computing, that represents the business model of selling IT resources as metered services. The CC can be seen as a realization of utility computing. The next technology regarded is the virtualization, which is the core of the CC. By using the virtualization, the cloud service providers can create and allocate machines for customers based on their demands.

The key idea of the Web 2.0 is a dynamic online environment where the exchange of information and collaboration between users, sites and virtual services become increasingly common. Since CC services are web applications, the Web 2.0 is a natural adoption for the CC paradigm. In simple terms, the distributed computing is computing over distributed computers that communicate over a network. CC can be seen as a particular form of distributed computing. The last technology presented, related with CC, is the autonomic computing, defined as making computer systems capable of doing self-management. The CSPs use autonomic computing to simplify their task of managing the large cloud data centres.

The following two sections introduce the cloud service and the deployment models. Besides supporting, the reader on the ongoing comprehension of cloud concepts identifies models that the staff responsible for the migration to CC must have into account, since each model has its own particularities. Additionally useful, for those who are planning to migrate services to the cloud is to be aware of the pros and cons (sections 2.1.4 and 2.1.6) that the new technology may have. The next two sections (2.1.9 and 2.1.10) add information to this purpose. The first one, besides presenting scientific and academic projects in CC that could be used by organizations to implement, for instance, private clouds, also demonstrates the interest of the academic community on the topic. The section 2.1.10 presents the commercial aspect of CC.

Sections 2.2 and following are based on the frameworks for migration to CC. We could not start the development of a framework for services, applications and data migration to CC without first analysing other frameworks already developed by other researchers under penalty of being reinventing the wheel. Therefore, in the section 2.2.1, the chosen frameworks developed to migrate to CC are presented and compared and a summary of the comparison is exposed in Table 14.

CC's concern is IT services; therefore, it is understandable that the great effort done, the information gathered and the good practices acquired with the ITIL implementation, or other service management frameworks, can be somehow used in conjunction with the migration to CC, since core practices and principles remain the same. For example, ITIL recommends defining a service catalogue, which makes easier to know the organization services and thereby determine which services are good candidates to go to the cloud. Additionally, the capacity management, another ITIL process, is important in in-house IT acquiring a new significance in CC to control the quick acquisition and release of capacity.

None of the works studied in section 2.2.1 builds on the work done in implementing an IT service management framework by the organization wasting the information produced, the knowledge gained and the modus operandi by using the use of the framework. However, it is impracticable to develop a framework that adopts all the IT service management frameworks. As such, it was necessary to evaluate frameworks and choose one. For that purpose in section 2.3 the frameworks are presented, compared and one is elected to work with the framework to be developed. The section ends by explaining why we chose ITIL.

Despite the advantages of developing a solution that that does not reinvent the wheel and exploits the work and the information already available in the organization, the work would decrease a lot its usefulness if the academic and commercial communities lost interest in the topic. On the contrary, the two communities maintain interest in the topic. Indeed, the CC migration is "highly relevant to industry and academia as there are growing numbers of organizations adopting or using cloud" (Chang, Walters, & Wills, 2014). Adel et al. in (2013) also corroborate the importance of the migration to CC when they state, "that there is a need to provide adequate knowledge and expertise for managing the migration to the cloud". Other authors - Oliveira at al. (2014) are also concerned with the migration to CC, namely the determinants that influence the migration of CC, while Gonzenbach et al. (2014) are interested in deciding what content should be managed in the cloud and what should

not. Albakri et al. present their research on CC migration challenges in (Albakri, Shanmugam, Samy, Idris, & Ahmed, 2014).

In short, the information gathered in this chapter will be used in the development of the framework shown in Chapter 3 and in the case study of the Chapter 4.

Chapter 3

THE FRAMEWORK

This chapter presents the framework developed to support in the migration to the CC of services, applications, data and infrastructure. It starts with the presentation of the framework processes, sub-processes and activities followed by the mapping of the framework to ITIL processes as well as its justification. Finally, the conclusions gathered from the framework and its relationship with ITIL are exposed.

3.1 Introduction

CC holds the great promise for start-ups (Forrest & Barthold, 2009; Repschlaeger, Erek, & Zarnekow, 2013) however, the challenge comes when making a decision for the organization with an existing and working datacentre (Misra & Mondal, 2011).

The CC, providing a large amount of resources for developing and deploying applications and services, is a tool for the replacement of many services available in the traditional datacentres. Notwithstanding, CC has many advantages for the organizations and their IT services, that does not make it a universal solution for all organizations and all services. Conversely, CC also has a set of associated risks that lead to the need of a framework to support the organization in their migrations to the CC and thus minimize the risk of the cloud's adoption (Chang et al., 2014). Therefore, the customer must carefully plan and conduct the migration's process because cloud migration decisions are inherently complex since multiple, possibly conflicting, issues such as cost, performance, security and legal concerns influence them (Saripalli & Pingali, 2011).

When developing the framework, we began by defining a high-level structure including the steps that must be performed to properly migrate services to the CC. During this process we have noticed that these steps had a correspondence with ITIL processes. For example, in order to define which processes of an organization can be migrated to the cloud, it is first necessary to know what they are and how they are interrelated. ITIL, in turn, has processes indicating what should be done to achieve this information "Service Portfolio Management" and "Service Catalogue Management". Therefore, and considering that ITIL describes in detail what to do and not how to do it (how to implement it), we can state that it can virtually be incorporated in any organization. There is also a mapping between the processes of the ITIL's framework that was not considered necessary to be described here as what should be done in each of the processes of our framework, since this description is contained in ITIL books. What is considered to be insufficient relevant information has been added.

3.2 The framework to migrate to cloud computing

CC is the latest trend to outsource IT operations to run a business from the public cloud providing a flexible and highly scalable technology's platform for an organization's business' operations (Dhar, 2011). However, "In order to deliver the advantages and overcome the challenges faced by organizations that want to migrate to CC, there is now a need to define a management framework for how a cloud's migration's project can be successfully managed." (Conway & Curry, 2013, p. 4). Mathew in (2012, p. 183) also reinforces this

idea by saying “Organizations should have a well-defined methodology before migrating to CC. “. To satisfy this need we develop the Migrating to CC’s (M2CC) framework presented in this section.

In the outsourcing processes there is always an interaction between IT’s service provider and the customer. Accordingly, we have grouped the activities of the M2CC, into two major groups, the **on premise** and the **off -premise**, both aggregating the activities that an organization has to perform when migrating services towards the CC. These groups match the key’s stakeholders of this process, that is, the customers and the CSPs.

Although this framework was primarily designed for the migration to public clouds, it can also be used in other cloud models.

To achieve the best results, the framework’s activities must be properly managed and performed. Therefore, and according with the motifs presented in the section 2.3.1, we advise the use of ITIL as the support for the way the framework’s tasks should be performed.

In Figure 22 shows a pictographic view of the proposed M2CC framework.

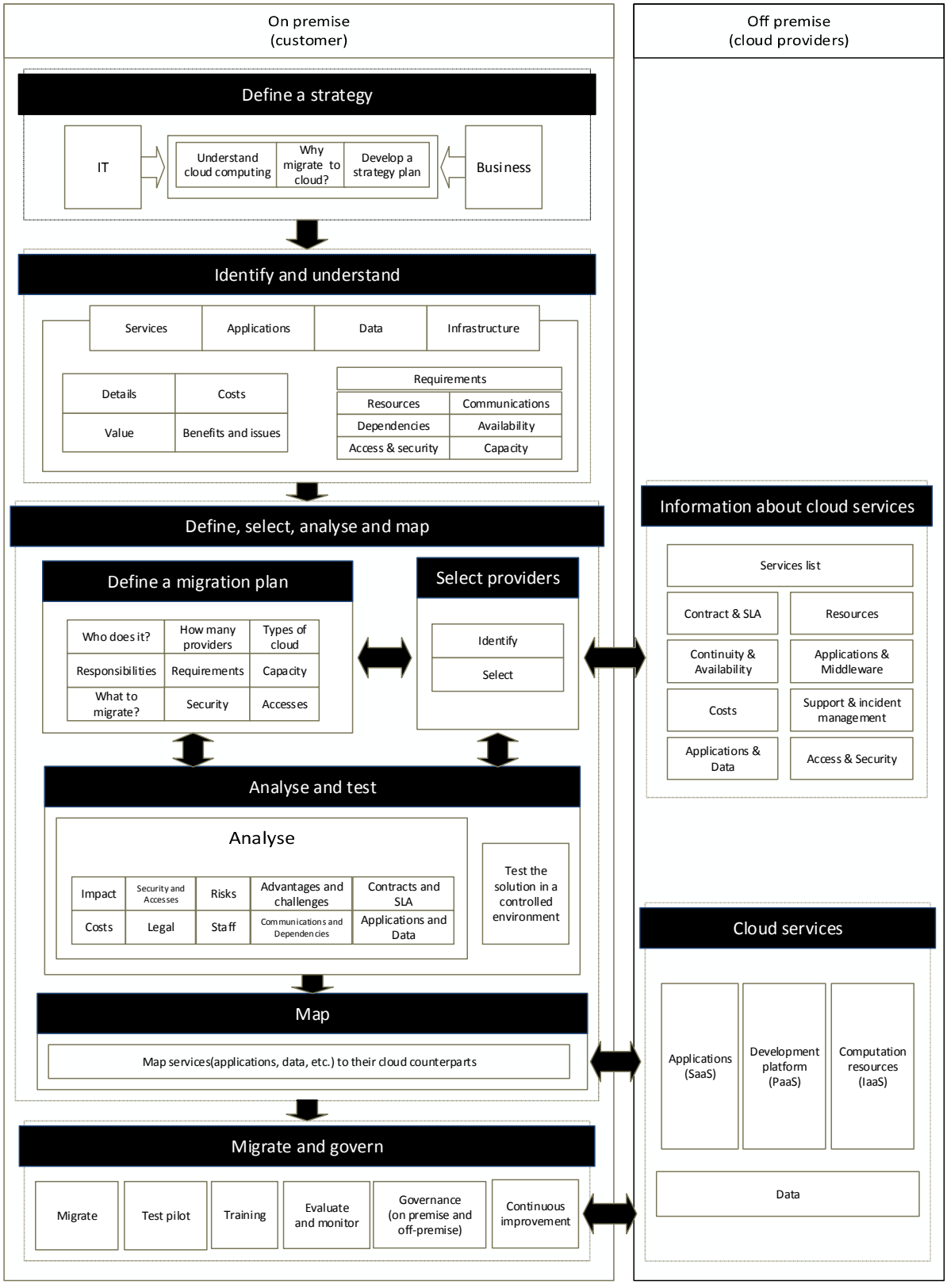

Figure 22 - The Migration to Cloud Computing Framework (M2CC)

3.2.1 On premise

The “on premise” group embraces the activities that the organization must solve on their own to migrate services to the cloud.

3.2.1.1 Define a strategy

The process starts with the recognition, by the IT manager, in cooperation with the business’ management of the organization, of the real reasons why to migrate to the cloud. Subsequently, it is necessary to study the details of each IT process and service on the organization and to evaluate, together with the business’ management of the organization, what should be migrated to the CC and what should remain in the organization.

This is a preliminary process, accomplished before beginning the migration process to the CC by the IT’s department and in collaboration with the business management. Migrating to the cloud requires the active involvement of the governing body of any enterprise to be successful (Bisong & Rahman, 2011). The strategy’s plan to be developed should take into account the issues shown in the section 2.1.6 as well as the information regarding CC exposed in Chapter 2.

Whether to migrate to the CC or not is one of the first questions that IT managers need to ask (Tušanová, 2012). Thus, in this process, the customer gathers information concerning CC in order to clearly comprehend the paradigm and to recognize the real reasons why the organization should to migrate IT services to the CC. Indeed, companies need to look beyond the CC hype and seriously consider the real value of incorporating the cloud in their own businesses (Misra & Mondal, 2011).

It has to be emphasized that the migration to the cloud must be done to better meet the business’ needs of the organization and not to follow new trends. Therefore, and considering the importance of the alignment between the organization’s functional and operating model with the cloud-based model (Géczy, Izumi, & Hasida, 2012), it is necessary to gather information from the business once the business’ requirements are not of lesser importance than the technical needs for any professional or precise decision makers (Ezzat et al., 2011). Indeed, it is important that the decision makers consider organizational implications of changes brought along with the CC (A. Khajeh-Hosseini et al., 2010). Furthermore, in this

process, the organization develops a migration's strategy, including the identification of investments, which are likely to be made, an initial definition of what is to be migrated and a clear definition of the objectives that are to be achieved.

Table 20 compares the characteristics of the conventional IT with the cloud environments in order to support the decision of migrating to the CC.

Table 20 – Conventional IT vs Cloud Computing

Characteristic	**Conventional IT**	**Cloud**		
		IaaS	**PaaS**	**SaaS**
Security	Reduced risks if accesses are internal	Internet access increases security risks		
Privacy	Assured by IT's staff	Assured by third party		
Initial investment	High upfront's investment in hardware and software	Pay-as-you-go		
CapEx vs. OpEx	CapEx	OpEx		
Scalability	Slow	Fast		
Time to market	High	Low		
Elasticity of capacity	Low	High		
Need of IT staff	More	Less (or reorganized, requalified)		
Legal	Typically the same jurisdiction of the organization	Jurisdiction may change		
IT infrastructure	Owned by the customer typically located on premise	Leased or rented, located on the CSPs data centres		
Trust	IT staff	CSP		

Characteristic	Conventional IT	Cloud		
		IaaS	**PaaS**	**SaaS**
Data transfer	Free, on the inside of the organization, however the customer must invest on a LAN	Pay for use		
Management / maintenance	The organization manages the whole hierarchy	The CSP manage to the below to the OS level while the organization IT manage upwards	The CSP manages beneath the data level while the organization's IT manages above it	CSP manages the whole hierarchy
Update/Upgrades	Customer's responsibility	Customer's responsibility	CSP's responsibility	CSP's responsibility
Vendor lock-in	Low	Low	High	High
Customization	CSP dependent	High	Low	Limited
Software Licences	Customers own the software, typically with annual renewals	Similar to conventional IT	Similar to SaaS	Licence fee enables software to use possibly for short periods of time, and includes hardware's infrastructure

3.2.1.1.1 ITIL relationship

Table 21 summarizes the relationship between "Define a Strategy" framework process and the ITIL's framework. The **Strategy generation** process of the service strategy's book mainly supports this first process of the framework.

Table 21 - Define a Strategy / ITIL

Framework processes	ITIL processes																								
	Service strategy				Service design							Service Transition							Service Operation					CSI		
	Strategy generation	Service portfolio management	Demand management	Financial management	Service catalogue management	Service level management	Capacity management	Availability management	IT Service continuity management	Information Security management	Supplier management	Transition planning and support	Change management	Service asset and configuration management	Release and deployment management	Service validation and testing	Evaluation	Knowledge management	Event Management	Request fulfilment	Incident management	Problem management	Access management	Service measurement	Service reporting	7 step improvement
Define a strategy	•																								

3.2.1.2 Identify and understand

After recognizing the reasons that led the organization to migrate services to the CC, it is necessary to identify the details of the IT services of the organization, applications, data and infrastructure to undoubtedly recognize the interrelationships between them and thereby elect what can be migrated to the cloud and what should stay in the organization. Large enterprises inevitably have highly interconnected IT infrastructures containing a large number of computing systems that have been developed over a long period of time (Ali Khajeh-Hosseini et al., 2010b). The work of Bai et al. (2013) provides support to the discovery of the dependencies among servers. Indeed, it is necessary to decide on the correct workload to be transferred to the cloud and select the best alternative with respect to the conditions of the organization (Tušanová, 2012), which are not possible without first deeply understand the IT infrastructure of the organizations .

In this process, the IT staffs, along with a business cooperation collect detailed information regarding their IT services, applications, data and infrastructure related to them. This information includes details such as security, the resources used, communications, access, costs, dependencies, value, availability, benefits and requirements. Here we introduce the costs so that the manager has a basis to compare later, in-house (services applications and data) with their CC counterparts although the cloud can use a different payment’s scheme.

The requirements for applications include, for instance, the special needs that a legacy's application might have, such as the operating system and hardware. Special attention should be given to the business' criticality of each of these items, identifying core and non-core (Dargha, 2012) services and applications, since they need special attention if they are to be migrated to the cloud. Additional information on core and non-core applications and their relationship with the CC can be found in (Dargha, 2012).

The record of occurrences and answers of the organization's help desk service (internal or external) is an important source of information that must be analysed so that the reported problems can be minimized (if not resolved) with the migration to the CC (A. Khajeh-Hosseini et al., 2010).

3.2.1.2.1 Services

The IT's staff, in charge of the migration to the cloud, must identify all the details of the services provided by the organization in order to take the most suitable decision concerning what is to be migrated to the CC and what is to be left in the organization.

Table 22 presents the minimum information, based on ITIL Service Design - service Portfolio (Lloyd et al., 2007), that must be gathered regarding services, applications and data, in order to carry on with the process of migrating to the CC.

Table 22 - Information regarding services (adopted from (Lloyd et al., 2007)**)**

Information regarding services	
Name	Warranty level, SLA and SLR references
Description	Supporting services
Status	Supporting resources
Classification and criticality	Dependent services
Applications used	Supporting OLAs, contracts and agreements
Data and/or data schema used	Costs
Business processes supported	Charges
Business owners	Revenue
Business users	Metrics
IT owners	Hardware requirements
Security requirements	Legal issues

Moreover, a definition of the interaction points among the services is also needed, namely the relationship between the services, with the view to ponder those that can be migrated to the cloud.

The detailed information regarding the costs of having these services/processes in-house is essential to compare them later with their counterpart on the cloud. In other words, the customer must create a cost-benefit-risk analysis to compare the traditional solution with the equivalent cloud-based solution.

3.2.1.2.2 Applications

One of the main components of IT services is the applications. While it may not be difficult to develop a completely new application on the cloud, there is a question of whether legacy applications could be migrated to the cloud (Vu & Asal, 2012). The IT's manager, in order to acquire the necessary information concerning the applications, must organize a list with the detailed depiction of the existing applications including a definition of the interactions among them. Additionally, he needs to collect information concerning the data they are handling, as well as the relationship among them and the resources they use such as hardware, staff and equipment. The complexity of the applications with interdependent relations leads to new challenges for selecting appropriate cloud services (C. Chen, Yan, Zhao, Lee, & Singhal, 2012).

To support solving the problem of finding relationships between servers, the Bai et al. work (2013) proposes a technique for systematically discovering complex server and application dependencies validating their findings by using real enterprise data. Based on the Galapagos system (Magoutis, Devarakonda, Joukov, & Vogl, 2008), as a data collection's agent they present a Kullback-Leibler (KL) divergence-based method for discovering complex server-to-server and application-to-server relationships.

Some applications have specific constrains or requirements that can only be met in traditional computing platforms and therefore cannot be satisfied in the cloud's environment. Thus, to determine the feasibility of application's migration to the CC, it is important to deduce which of the requirements cannot be satisfied in the cloud (Vu & Asal, 2012). Moreover, and similarly to what happens with the services, it is necessary to know what are the

costs of having these applications in-house are, in order to ascertain the cost-benefit of moving each of the applications to the cloud.

The migration of applications to the CC can typically be done in three ways. The first, by exchanging from a local application to another that is already available in the cloud (typically exporting data from the local application and importing it in the cloud's application) such as a SaaS' solution. The second way, by using an application developed for the purpose (such as a PaaS' solution) and the third one "simply" by moving the application to a server in the cloud (in an environment such as IaaS). The latter is usually easier since this layer is arguably the most accessible one to enterprise, as they could potentially migrate their systems to the cloud without having to change their applications (A. Khajeh-Hosseini et al., 2010).

Integration issues are on top of the CC adoption barriers' list (Yao Chen & Sion, 2011; Gupta, 2010; Phatak & Kamalesh, 2010; Shimba, 2010). Therefore, special attention must be given on how to integrate heterogeneous environments of the solution with the other applications (internal or external). An example of this issue occurs when it is decided to use a SaaS' solution, such as a Customer Relation Management (CRM) ("Force.com: The leading cloud platform for business apps," 2013, "Salesforce Customer Relationships Management (CRM) system.," 2010), to replace an existing in-house application rather than migrating the existing application. Moreover, it is required to identify how to retrieve the organization's information (after having been migrated to the new application) and how to prevent the hypothesis of vendor lock-in (the vendor lock-in happens when the customer is dependent on a single supplier for a product).

3.2.1.2.3 Data

The Merriam-Webster dictionary defines data as information in numerical form, i.e., that can be digitally transmitted or processed. Among the activities of the IT manager, when planning the migration of data to the CC, it includes arranging to gather a detailed data definition, along with the size, format, support and the relationship between the clusters of information.

Migrating data to the CC expands the insider security's risk (W. A. Jansen, 2011) and causes a break in the control and management (Géczy et al., 2012). As such, the characterization of security policies in use is necessary, being also required to evaluate the confidentiality, the accesses and the criticality of the information in order to better evaluate if it is convenient to migrate or not this information to the cloud.

Some CSPs charge extra values for network data's traffic therefore we suggest to recognize the necessity of data's exchange with the cloud and other hidden costs such as inbound or outbound data transfer or data transfer within CSPs' infrastructure (Martens, Walterbusch, & Teuteberg, 2012).

3.2.1.2.4 ITIL's relationship

The aim of this process is to understand the IT structure and operation mode of the organization. ITIL's process, from all the books, support to the "Identify and understand" framework's process. Table 23 summarizes this association.

Table 23 - Identify and understand / ITIL

Framework processes	ITIL processes																								
	Service strategy				Service design							Service Transition							Service Operation					CSI		
	Strategy generation	Service portfolio management	Demand management	Financial management	Service catalogue management	Service level management	Capacity management	Availability management	IT Service continuity management	Information Security management	Supplier management	Transition planning and support	Change management	Service asset and configuration management	Release and deployment management	Service validation and testing	Evaluation	Knowledge management	Event Management	Request fulfilment	Incident management	Problem management	Access management	Service measurement	Service reporting	7 step improvement
Identify and understand		•	•	•	•	•	•	•		•	•			•				•					•	•	•	

From the **Service Strategy** book, the **Service Portfolio Management:** A service portfolio describes the services of a supplier regarding their business value. By identifying, the value of services for the organization can obtain important information about the value of each service so that it can assess more precisely what services should be migrated to the cloud. **Demand Management:** The demand for services serves as a weighting to select the service

supposed to be migrated to the cloud. Services with a high demand may be strong candidates for the cloud migration. **Financial management**: By providing financial management for the whole process of migrating services to the CC, by delivering services' value it is possible for the manager to use this information to be compared with the cost of the same cloud's service and by the changing prices in the CC.

From the **Service Design** book, the **Service Catalogue Management** supports the framework by providing the organization with ways to gather detailed information on each service offered. This process, complemented by the service portfolio management, offers information regarding all the IT services provided by t the organization. The **Service Level Management**, by documenting the level that the "on premise" services must accomplish, allows the manager to ensure that all running services and their performance are measured in a consistent and professional manner throughout the IT organization. The reports and the documentation achieved are useful as a basis for the cloud services' necessities. Although using cloud's resources can be easier to manage the capacity (increase and decrease), the **Capacity Management**, is used to establish a baseline of capacity required for each service as well as maintaining an adequate capacity in order to minimize costs. In a similar way, the **Availability Management** process supports the migration to the CC. The **Information Security Management** ITIL's process by defining IT's security in the organization also serves as a point of comparison with the security that the CSP must afford. Either before or after the migration to the CC it is necessary to manage the organization suppliers. The **Supplier Management** will be helpful in this process.

The **Service Asset and Configuration Management** process from the **Service Transition** book will support to comprehend the relationships between the services since it covers policies, project's documentation, IT's infrastructure and employees regarding the services. The **Knowledge Management** process, being the process used to improve the quality of the decision-making and ensuring that reliable and accurate information is available is used as a ubiquitous' process to manage the whole knowledge of the organization, in particular the one that will be used in the migration to the CC.

The **Service Operation** book contains good practices to provide a guidance on efficient and effective delivery of services (Cannon & Wheeldon, 2007). The **Access Management's** process supports the framework in the initial definition of the accesses necessary to each service.

The **Service Measurement** and the **Service Reporting**, processes of the **Continual Service Improvement** book, are useful to gather information that serves as a baseline for a later comparison of the services with their cloud counterparts in order to evaluate the improvement suffered by the processes that were migrated to the CC.

3.2.1.3 Define, select, analyse and map

While the earlier process gathers detailed information concerning the current operation of IT at the organization, this process defines the aspects related with the migration to the CC. Moreover, are identified and selected the CSPs, analysed the impact of migrating to the CC and finally, with the information gathered, the in-house services are mapped to their cloud's counterparts.

This process includes a collaborative sub-process among customers and CSPs (provider's selection) however, since the first ones have the major effort and responsibility is here included.

The sub-processes "define a migration plan", "select providers" and "analyse and test" make up a cycle once the mapping with the cloud counterparts means that the solution reached was deeply analysed and validated. If the solution it is not valid or has some issues, it is necessary to go back and analyse the solution until it passes the analysis' phase.

3.2.1.3.1 Define a migration plan

This sub-process includes activities related to the decision and the definition of details that are to be used in the migration to the CC such as what is to be migrated and when. This sub-process receives information from preceding sub-processes and interacts with other sub-processes of the "Define, select, analyse and map" processes, namely exchanging information with the CSPs' selection sub-process and supplying information to analyse and map sub-processes.

The definition of the migration's plan is a collaborative activity between the IT services and the organization's business management, to ensure the participation of the organization

in the whole process of migration to the cloud and to assure a complete alignment between IT and the organization.

3.2.1.3.1.1 Who does it?

The aim of this task, it is to define who intervenes in the process of migrating to the cloud. At least the team must include the IT's staff, the business management, the financial management, the organization's legal support and any other staff with relevant knowledge. Even if some of this staff does not have a direct participation on the migration to the CC, their collaboration is important to reduce the reluctance to change.

3.2.1.3.1.2 Responsibilities

As stated in (Cochran & Witman, 2011; Kandukuri et al., 2009; Onwudebelu & Chukuka, 2012) it is imperative that the customers of the CC services identify their responsibilities, before the cloud migration (A. Khajeh-Hosseini et al., 2010; Mathew, 2012), and comply with them. Thereby, the organization should clearly define who will manage the whole process, identify what are the responsibilities of each participant, that is, the organization, the CSP and the services integrator (if any). Finally, but also importantly is the designation of who will manage the relationship with the CSP(s) in order to obtain a central point of interaction between the customer and the CSP.

Additionally and considering that, an important participation in this process comes from the CSP, there are a large number of participants and that there are actions to be implemented, it must be clearly defined what their roles are what support they provide, as well as what the CSPs responsibilities are. Besides that, it is also necessary to define (on the customer and the CSP's side) who is responsible for each of the steps of the cloud's migration.

Besides the identification of responsibilities, the organization must, in its turn, discover who, within the organization, has relevant information to the process and include them, at least, as a useful source of information.

For the depiction of the responsibilities of each of the actors in the migration's process, we followed the RACI (Responsible, Accountable, Consulted, and Informed) model (Jacka &

Keller, 2009) advocated by ITIL (Lloyd et al., 2007). This model relates the entities (columns) with the activities pertaining to the project (lines) putting the interception values (R, A, C, I) according to Table 24.

Table 24 - Responsibilities in the RACI model

Type	Value to insert	Description
Responsible	R	Entity that performs the necessary work to accomplish the activity
Accountable	A	The entity that has the power of decision on the activity. Only an entity representing authority for a given activity can exist. This authority is responsible for delegating work.
Consulted	C	Entities whose opinions are sought. Typically experts.
Informed	I	Those which are kept up-to-date on the development of an activity, often only after the completion of the activity.

Figure 23 shows the form that should be filled with, R, A,C, I, to record the responsibilities assigned to each area or employee.

Entities / Activities	Institution						Outside	
	IT area			Other institution entities/staff			Installer company	Other entity
	IT management	…	…	Legal	Financial	…		
Process 1								
Activity 1								
…								
Process 2								
Activity 1								
Activity 2								
…								

Figure 23 - Responsibilities assignment

3.2.1.3.1.3 What to migrate?

Based on the knowledge acquired in earlier processes, sub-processes and activities, as well as the information gathered from the CSPs and in the decisions of the management, the staffs responsible for the migration to the CC defines, in this task, what, when and in what sequence to migrate to the CC.

3.2.1.3.1.4 Requirements

Similarly to earlier tasks and based on the requirements identified there and in the capabilities offered by CSPs, this task identifies the minimum requirements such as hardware, software and legal, that must be considered so that it is possible to migrate services to the CC.

3.2.1.3.1.5 Security

Migrating from a traditional IT's environment, owned and controlled by the business, to one relying on a plethora of third party suppliers will bring along a significant change to the way enterprises manage the risk and security (Yam, Baldwin, Shiu, & Ioannidis, 2011).

Security, privacy and integrity are some of the biggest concerns in the implementation and use of CC (Armbrust et al., 2009; Nkhoma & Dang, 2013). In a survey (Reporter, 2009) where more than 500 executives and managers from 17 countries have been asked, it was found out that, despite the benefits of CC, the executives have more confidence in internal systems rather than in cloud-based ones because of threats' safety and loss of control over information. Another study (Gens, 2008) where 244 IT directors were questioned indicates that 74.6% of the respondents point out safety as the first challenge of CC.

In this task, the IT's staff defines the security requirements for the services, applications and data that are going to be migrated to the CC.

3.2.1.3.1.6 Access

Taking into account that the access to CC services are usually made via Internet (Armbrust et al., 2009; Yanpei Chen et al., 2010; Grobauer et al., 2010), the access control should reflect that fact. For instance, while in the in-house IT solution the systems' administrators have a wide access to data and applications and are under the control of the organization, in the CC this is no longer true since the customer no longer controls the systems' administrators.

In this activity, the staffs responsible for migration to the CC define the details of the access for each service application and data that is going to be migrated to the CC. This definition is based on the information collected in earlier processes, sub-processes and activities.

3.2.1.3.1.7 Types of cloud

The migration to the CC depends on the type of clouds (Chang et al., 2014). To choose the appropriate models, the customer supports his decision in the evaluation of the traffic volume that the applications will use in the CC, the security and the integration requirements with other applications that somehow are related to the ones migrated to the CC, the security and privacy of the information and the type of work among others. This choice is accomplished with the support of the information gathered in the sub-process of identification and selection of the CSPs as well as the "identify and understand" process.

Based on the research of Chang et al. (Chang et al., 2014), Table 25 depicts the most appropriate use for each type of cloud.

Table 25 - Choosing the most appropriate type of cloud

Cloud type	Public	Private	Hybrid	Community
Small or start-ups organizations	✓			✓
Organizations with sensitive data		✓	✓	✓
Large-scale simulations and experiments	✓	✓	✓	✓

3.2.1.3.1.8 How many cloud service providers?

In this activity, the organization, defines how many CSPs will be used in the migration, not forgetting to check the interoperability between, as well as between them and the services that remain in the organization. If the customer decides to have a backup CSP, he should include it in this number.

3.2.1.3.2 Select cloud service providers

One of the major obstacles in CCs service selection is the offer's diversity that hinders the comparison's process of one CSP or service against others (Rehman, Hussain, & Hussain, 2011). In this process the customer, queries the CSPs market to find the CSPs holding the solution that best fit his needs.

The CSP's selection takes into account certain issues such as price and performance of their computer resources, the availability, security, quality of the communication lines between clients and the CSP's, reputation, legal and organizational (Beserra et al., 2012). Besides, the confidence shared by the customer on the CSP is an issue in choosing a CSP. Additional information in choosing CSPs can be found on (Bose, 2012; Li et al., 2010; Repschläger, Wind, Zarnekow, & Turowski, 2011).

3.2.1.3.2.1 Identify

The CSPs selection's process starts with the identification of potential CSPs in accordance with the customer requirements identified in preceding processes, sub-processes and activities, in the CSP's transparency and in the suitability for the migration's project. Consequently, the organization must obtain from the CSPs, details and features of each service provided by the CSPs, such as the time required supply a service, the time between updates, the time required to increase and decrease the capacity of the service and the service uptime. The organization, consecutively, must validate the gathered information with the needs previously identified to make a judicious choice of the CSPs.

Each CC deployment model has its own pros and cons. The IaaS requires more expertise from the customer who needs to know a priori the necessities of computing resources for the applications. Alternatively, in the PaaS model the customer must consider the vendor

lock-in, the knowledge and the development's time required. The SaaS facilitates the management and responsibility, however, it requires the use of standard applications, which could be more difficult to obtain the customer's data by the end of the contract and may also cause the vendor lock-in.

To minimize vendor lock-in issues, besides the use of standards as presented in 2.1.8, we suggest following (or verifying if the CSP follows) the measures proposed by Hill and Humphrey in (2010). The first one relates to the use of APIs, which have multiple independent implementations. For example, the EC2 APIs are used by other implementers and are a de facto standard for interface to cloud management (Pahl et al., 2013b). The second is to choose APIs that can run on multiple clouds environments, for example, Map Reduce and Hadoop and the third to split the application's logic and the cloud layer.

The customer IT infrastructure may have a combination of virtualized and traditional servers. Consequently, the customer must know how to migrate these virtual machines to the CC's environment, for example, simply by moving the virtualized servers to the cloud's infrastructure, by converting the virtual image to the one adopted by the CSP or by installing each application on the CSP's server. The data migration to the CC should also be analysed by the customer and the CSP, studying hypotheses such as validating the possibility of maintaining the same database server, moving data to another database server or other CSP.

3.2.1.3.2.1.1 Software as a Service - SaaS

The SaaS model offers applications provided, by the CSP, in the CC's environment. If there are CC applications available with the requirements identified by the customer, it is desirable to choose this model.

To adopt the SaaS model, it is typically required to migrate the organization data to an application in the CC. In most cases, this is not a migration of an organization's application to the CC, it is a switch to a new application already running in the CC. Additionally, the accountability of backups and server's maintenance moves from the customer to the CSPs, a detail that should be reflected in the SLA. The SLA, for this model, also requires attention to guarantee that the CSPs have the required capacity to allow the customer to be able to

access his data and to migrate it to other applications, as well as to access the necessary information to validate the SLA. The security of information that these applications have, as well as the verification that the customer is able to do of this security are also related to the SLA.

3.2.1.3.2.1.2 Platform as a Service - PaaS

Other circumstances exist where there are not applications in the CC's environment that fulfil the customer needs. In these cases, the customer may opt to implement solutions in the CC's environment by selecting the IaaS or PaaS models. In the PaaS model, the customers can implement the applications projected by them in the cloud's environment by using the programming languages and tools offered by the CSPs. The adaptability and compliance of the development platform made available by the CSPs with customer needs influences the choice of one CSP over another. Additionally, in this cloud model the customer must carefully evaluate the SLAs, the security issues, the information's privacy and the possibility of moving, or not, the information to other vendor's platforms, that is, to prevent the vendor lock-in.

3.2.1.3.2.1.3 Infrastructure as a Service - IaaS

In some specific circumstances (for instance to migrate legacy applications to the cloud; too long development time; inability to develop an application, among others), neither the applications offered by SaaS, neither the available development platforms PaaS, provided by the CSPs, meet the customer needs. The IaaS deployment's model, where the CSP offers virtual machines to install customer's applications, is the most suited for these situations. This service model is the most affordable way for organizations to migrate their applications to the CC, since they may not need to change the applications they already have (A. Khajeh-Hosseini et al., 2010). However, to deploy properly the customer's applications, the IT team committed to the migration to the CC needs to confirm that the virtual machines provided by the CSPs comply with the requirements of the applications already developed in-house.

3.2.1.3.2.2 Select

After identifying the best-suited CSPs, according to the IT requirements identified, the customer selects a smaller group, amongst them, to work. To support the organization of electing this group of CSPs, the organization obtains additional information regarding each CSP. And they manage to do that by querying other customers who have already acquired the services of the selected CSPs. Additionally, the customer must evaluate the CSP's experience in the market, its technical expertise, reputation, credit, company's stability and trust (from other customers of the CSP or from the customer who is migrating the services to the CC). Another source of information is a live test to the service in form of a free trial of the services used in real migration.

However, the services provided by CSPs are a heterogeneous world and this leads to the necessity the customer may have of a more objective method for this selection. To support this purpose, the CloudCmp's tool (Li et al., 2010, p. 14) helps by "systematically compare the performance and cost of CSPs along dimensions that matter to customers". It is a framework for the systematic comparisons of cloud services aimed to support cloud customers in selecting a CSP. CloudCmp includes a set of benchmarking tools used to compare components. The results are then used to predict the performance and cost of a cloud user's application when deployed on a CSP.

Additionally, with a similar purpose, Repschläger et al. in (2011, p. 163) present a model to supply "a provider independent classification model for Infrastructure as a Service (IaaS)".

3.2.1.3.3 Analyse and test

After the big decisions have been taken, it is time to confirm that everything is in accordance with the identified requirements in order to proceed to the implementation's process of mapping the local services to their CC's counterpart. Correspondingly, the pros and cons of the migration to the CC must be checked, as well as what kind of impact the organization and the services suffer and the costs that are to be expected. The analysis of the security issues should not be forgotten and the ought to be covered and safeguarded; the risks must

be appropriately managed, the staff is restructured and it is decided what to do with unnecessary ones, the legal issues are all satisfied, the communications lines should have the required capacity.

3.2.1.3.3.1 Advantages and challenges

CC offers many advantages; however, it also holds a number of challenges. In this activity, the customer ponders the pros and cons of the solutions to compare them and choose the most adequate to the organization. A starting point for this evaluation is based on the issues presented in sections 2.1.4 and 2.1.6. To this purpose the SWOT analysis, a planning tool used to identify Strengths, Weaknesses, Opportunities and Threats involved in a business is applied.

Strengths are typically internal characteristics of the business that give advantages over the competitors. To support the framework we mainly consider the CC advantages that are related with the study. The **weaknesses** are classically internal features of the business placing the organization on disadvantage with other competitors. Accordingly we consider the weakness of the current IT solution, namely its age, its lack of capacity to support the current requests, its hardware problems, and the CC's issues. **Opportunities** are the external conditions that present a chance to improve the organization. Finally, the **threats** are external conditions presenting the risks to the organization.

The strengths and weaknesses are issues that the organization can control. On the other side are the opportunities and threats that the organization could not control although it could influence.

Based on the SWOT analysis the organization derives ideas and goals for the migration of services to the CC.

3.2.1.3.3.2 Impact

The CC changes the way an organization delivers IT's and business' services leading to not being always clear what the repercussions in the organization will be. In this activity, the organization tries to find the answer to the question: What kind of impact will the organization have if these processes and applications migrate to the CC?

The organization should analyse the influence experienced by the shift from IT products to services and in the responsibilities from technology's implementation and support towards activities of sourcing and monitoring (Rohmeyer & Ben-Zvi, 2012), driven by the CC. For instance, what changes occur in an organization when adopting a SaaS solution opposed to when it needs to purchase and maintain the software for every computer in the organization? Furthermore, which organization areas suffer an impact with this change is something that should also be explored. For example, migrating to the CC makes it possible to create a new product or service, up to now forbidden because of the prohibitive amounts of computing power required. What new services should be created? To whom?

Another issue that must be observed, also identified in (Conway & Curry, 2013), is the need to fully comprehend the impact on the user's community and on the IT's staff, (more information regarding the issues related with staff can be found in the section 3.2.1.3.3.7). Moreover, in this activity, the impact suffered by the organization should also be analysed, for instance, if the CSP is no longer able to deliver the contracted services, for example because of a prolonged service outage, or bankruptcy.

3.2.1.3.3.3 Costs

In the CC world, things often change and without much notice and there are also different pricing schemes (Onwudebelu & Chukuka, 2012). Indeed, migrating services to the CC may arise unknown costs in the IT, some of which might be un-expected to the organizations, leading to a necessity of clarification, along with the CSPs, the available payment models and what they include. Additionally, the customer must gather information regarding extra costs, if any, such as monthly fees, extra taxes for traffic above the limit or extra storage and data transfer.

A concern, shared by IT managers, is whether the cost of transition to the CC will be sufficiently low to benefit from any medium-term savings (Armbrust et al., 2009, 2010; Bibi, Katsaros, & Bozanis, 2010). Indeed, if on the one hand the customer must gather information concerning the CC costs, on the other hand, he needs to benchmark the costs of maintaining the solution at home in order to assess if it pays economically off migrating services to the CC, once the CC services are not always cheaper than traditional IT services.

However, we argue that the migration to the CC should not be only done for economic reasons, since there are issues that must be analysed before migrating to the CC such as trust, security, availability and vendor lock-in, among others. Klems at al. (2009) present a framework that can be used to compare the costs of using the CC with traditional IT infrastructures. Additionally, as previously mentioned, the CC causes a change of the cost model from CapEx to OpEx that must also be considered when migrating to the CC.

3.2.1.3.3.4 Security and Accesses

From a technical point of view, the majority of security problems endorsed to the CC already exist in the traditional data centres. Accordingly, when migrating services to the CC the customer, in collaboration with the CSP, needs to clearly define the responsibilities of each stakeholder in the process. Similarly, the customer needs to confirm that the CSP meets the security requirements identified. It is also necessary to check which security standards are being used.

The security must also be analysed from the infrastructure's standpoint, i.e., equipment and data network levels and from the staff's point of view, i.e., the one responsible for the management of systems, including systems administrators and network managers, by knowing his certifications, training and background. We acknowledge that gathering this kind of information for public clouds could be difficult; however, as it represents a benefit for the migration to the CC, it is mentioned here. Beyond the infrastructure's standpoint, the registration of actions and results (logs) represent another security issue (Kandukuri et al., 2009) that the customer must analyse and gather information from the CSPs. Indeed, it is required to know, among other information, if the CSPs allow accesses to logs (Beserra et al., 2012), what is registered in these logs (Cochran & Witman, 2011), how long these records are kept, who has access to the data recorded and how the customer can access this information. M. Cochran and P.D. Witman in (2011) emphasize the importance of records (logs) and personal data when stating that the SLA should clearly identify the data that administrators have access to and whether or not there are records of personal data. Still on security and legal requirements, the customer must check how long the information is stored in order to allow, if necessary, a forensic analysis (Marston et al., 2011). Besides the technical problems, the implicit need to trust on external parties to maintain critical information and provide critical IT services, is recognized by the authors of (Ahmed, Xiang, &

Ali, 2010; W. A. Jansen, 2011; Kandukuri et al., 2009; Ramgovind et al., 2010; Roberts & Al-Hamdani, 2011; Shimba, 2010) a security issue. The customer must recognize if there is a security breach and in case his data has somehow compromised, the CSPs can be legally responsible; however, the customer is typically the most affected one (Guo, Song, & Song, 2010; Kandukuri et al., 2009; Sabahi, 2011; Spring, 2011).

3.2.1.3.3.5 Contracts and Service level agreements

As more customers delegate their tasks to the CSPs, the SLAs between customers and CSPs emerge as a key aspect (Patel et al., 2009b).

The SLA should include, among others, service uptime, problem solution time, performance, response time, security measures and terms definition. When articulating the SLA with the supplier, the customer should highlight the most critical components for his business so that he is able to apply measures that are more stringent.

The quality of services affects the service's value to the customer and therefore it must be possible, for the customer, to be able to validate the quality of the contracted services. Accordingly, the customer must find out how to validate the SLA clauses and recognize how to control the contracted services. Support on how to manage, validate and monitor SLAs in the CC can be found in (Baset, 2012; Chazalet, 2010; Nor Shahida Mohd Jamail, 2013; Patel, Ranabahu, & Sheth, 2009a; Ul Haq, Brandic, & Schikuta, 2010).

For some customers the SLA provided by default by the CSP is not sufficient, for example if it needs to guarantee certain parameters for a cloud application (Machado & Stiller, 2011). In those circumstances, the customer must discover the possibility of SLA's customization to meet their needs.

The contract, unlike the SLA, whose focus consists on the performance and service quality, is as a legal document describing the services provided along with predicates such as of cost, duration, resources available and used.

The customer, in collaboration with the CSPs, should evaluate the feasibility of negotiating the contract, regarding a detailed definition of the responsibilities of each stakeholder. Regarding to the legal issues - the applicable jurisdiction, the information provided in an audit, who has access to the customer's information and what happens in the event of a data loss attributable to the CSP – all of this must be analysed. Furthermore, some circumstances must be studied, such as whether there are plans of disaster recovery (Clemons & Chen, 2011), clarifications regarding situations of abrupt contract termination (Convery, 2010) and security problems.

The contract must also reflect what occurs at the end of the contract (Onwudebelu & Chukuka, 2012), that is to say, what are the possible formats to retrieve the customer's data and applications, what the costs are, for how long, and what kind of support is provided by the CSP.

3.2.1.3.3.6 Risks

The migration to the CC encompasses some risks (see section 2.1.6), that must be analysed and identified to mitigate them. Therefore, the customer must study the risks inherent to the CC's migration and service models chosen. Table 26 presents the four core areas of risk (enterprise risk, technical risk, legal risk and common risk) for the organizations when migrating services to the CC recognized by Onwudebelu and Chukuka in (2012).

Table 26 - Cloud risks (based on (Onwudebelu & Chukuka, 2012)**)**

Risk	Include
Enterprise	CSP switches off, lock-in, lacks in service provision (cloud outage)
Technical	Fails in infrastructure, malicious activities, data damage, software vulnerabilities
Legal	Lacks providing legal evidences, changes of jurisdiction, software licencing
Common	Natural disasters, backup failures, data disclosure

The CSP lock-in is a risk that the customer should analyse to prevent it, given that it may result in significant costs - for example, if he wants to migrate his applications and data to other CSP or back home. Another threat that deserves the customer's attention is the cloud's

interoperability, to prevent CSP lock-in, or if the provided solution encompasses the interaction between two or more CSPs.

3.2.1.3.3.7 Staff

Evaluating the staffing requirements for data centres is an extremely complex endeavour as it involves components such as software development and management, hardware repair, maintenance of cooling, building and the network and power services (Yao Chen & Sion, 2011), amongst others. Notwithstanding, the organization should consider the human side of the migration to the CC, given that it results in a significant transformation of responsibilities and roles of IT managers (Adel et al., 2013), in the elimination of some in-house services and in the redesign of others. These issues lead to a planning by the organization on what to do with employees that are no longer needed (Convery, 2010), also reformulating the roles of others, for example learning new skills (Adel et al., 2013; Cochran & Witman, 2011; Heier, Borgman, & Bahli, 2012) and expect resistance to change from other employees.

When migrating IT services to the CC it is compulsory to rethink the tasks assigned to internal IT's staff because the services, formerly performed by them, will be the of CSPs responsibility. Considering the plethora of services made available by the CSPs, the IT's staff must start performing the integration among the contracted services from the CSPs and those that stayed at home and the management of the CSPs and their relationships beyond the internal helpdesk.

3.2.1.3.3.8 Legal

The organization must determine, in detail, what are the legal requirements applied to its applications and data whether they are "on premise" or on the CC, to verify that, when migrating to the CC they still comply with the legal requirements. Accordingly, the organization should know the location (Helmbrecht, 2010) where his information its stored. Although this information may not be available for all the CSPs, it is mentioned here because different locations may have different jurisdictions and therefore different laws may be

applied to the same data depending on where it is stored and comprehend how the CSP reacts if forensic proofs are requested by a court.

In synthesis, in this activity the organization verifies the fulfilment of the legal IT requirements after migrating to the CC. For more information regarding legal issues, it is advise to read (Helmbrecht, 2010).

3.2.1.3.3.9 Communications and dependencies

In the CC, the organizations acquire IT services from remote CSPs and consume them (predominantly) via Internet (Bibi et al., 2010; Kandukuri et al., 2009). Providing and consuming services over the Internet offers an increase in efficiency and virtually an access to services from anywhere, it conversely turns communications, mainly Internet access, into a point that deserves special attention by the organization because it can easily become a bottleneck and a single point of failure. Accordingly, the organization must evaluate which is the required capacity; the need for a backup line, the security, the costs, what is the information carried by this line, the data encryption needs (Cochran & Witman, 2011) among others, to prevent forthcoming problems such as information leakage, inability to access their applications and data. Additionally, the customer must understand the communications services costs and conditions available in the CSP, to satisfy his needs. Support on the management of communications costs can be found in (Mazhelis & Tyrvainen, 2011).

The identification of the dependencies identified in the 3.2.1.1.1 section may change with the migration of services to the CC or with the development of new services, consequently it is here necessary to analyse the bandwidth requirements to prevent any issue.

3.2.1.3.3.10 Applications and data

There are three groups of applications within the CC. The first group encompasses the applications developed or migrated to the CC by customers commonly available via IaaS or PaaS. The customer must validate, among others, the safety, confirm who has access to the customer's information, the integrity of the information, how are the updates made, how are backup and replacement copies accomplished, what methods are available for importing and exporting applications, what is the portability's level of applications between dissimilar CSPs and how can the client test the applications.

The second group (SaaS model), is the approach used by CSPs to make the applications deployed by them available. The customer should investigate what are the possibilities for customization to better adjust the applications with his needs. Additionally, it is necessary to know who developed the applications, where and by whom they were tested to increase the confidence in the applications. The customer must also gather information regarding the details of the software update's process, how the customer is notified and the issues concerning the compatibility among the various versions. With these applications, it is mandatory to analyse how to monitor them, particularly to validate contracts and SLA.

The third group covers the applications used by the CSP to manage their clouds. It is required to know by whom they were developed and tested, how they can be monitored and what accesses and security they have regarding to the customer's information.

When migrating applications to the CC, a number of issues must be handled such as the changes that the applications must undergo to take full advantage of cloud scalability. Applications can be migrated to the IaaS model, although the flexibility of this model has a serious drawback, the fact that a considerable amount of work is needed by the developers to ensure that the advantages of the cloud are fully exploited. At the other extreme, SaaS can reduce, the work of the development team, since it has less flexibility and greater scalability. A midway solution is PaaS, where the customer has less development's work than with IaaS since the platform made available by the CSP already implements various details related to cloud development, although it is more susceptible to vendor lock-in.

The traditional development of applications includes three layers, namely, the presentation, the business logic and the data. The existence of these three layers allows the migration of the applications to the CC to be performed separately for each of them. Hence, migrating applications to the CC can be carried out by following various architectures. For example, the business logic can be implemented by using the Google App Engine whereas the data can be handled by the Amazon Relational Database Service. In view of this, several issues must be solved, such as the following: defining what part(s) of the applications should be migrated, understanding how to recode the application to comply with this new environment (Andrikopoulos, Binz, Leymann, & Strauch, 2013) and determining what cloud models should be used, should any part of the application remain "on premise" (for security

reasons for example), should we use one or several CSPs (compatibility issues may arise), and assessing what impact the applications will undergo as a result of these changes. In (Andrikopoulos et al., 2013) more information can be found on migrating applications to CC. Additionally, some CSPs also provide information on how to migrate applications to CC. For instance in (Varia, 2010) a phase-driven method is employed to migrate applications to the AWS cloud.

From the data side it is necessary to find the answers, from the CSP, to the questions raised by the data import and export (to and from the CSP), concerning what type of support is provided, what are the standards in usage in the information's transfer and what are the costs to transfer data to and from the cloud. With regard to data's storage, the customer must identify what data formats and standards are used to store data, who manages the storage, that is, a third party or the CSP himself, what are the backup procedures and whether there is redundancy of data, among others. The legislation governing the protection of data can vary according to the location where they are stored, leading to that is also needed to know which one is the location (or locations) where the data is stored, what jurisdiction is governing the access (who has access to his data).

Applications in traditional data centres are subject to dissimilar licencing schemes, for instance the payment, for a certain period (for example annual) of a fee or by perpetual when purchasing the application. With the migration to the CC, the organization should listen to the CSP as to know how to transport his licencing scheme to the CC, not to forgetting new licencing schemas that may be more favourable or that they include a dynamic number of servers (because of the dynamic nature of the CC).

3.2.1.3.3.11 Test the solution

Zhang and Liu in (2011) identify the following reasons that leads the migration to CC is error-prone. The first reason is based on the environment changes that invalidate many environment dependent configurations, for example, IP configurations and its dependencies. The second reason, are the dependencies among the components that are to be migrated to the CC, the third reason is related to the great number of controlling settings and lastly the human factor.

Although the earlier processes and activities already address these issues, in this task, the solution is tested in a controlled environment to confirm that all the details are working properly before they go to production.

3.2.1.3.4 Map

In this sub-process, with all the information gathered and validated the customer defines, for those services who has been decided to be migrate to the CC, the matching between the in-house services and applications and the CC's equivalents. This mapping, concerning the applications, data and infrastructure, could be performed either by migrating the in-house application to the CC environment, by developing a new CC application to replace a legacy in-house application or "simply" by migrating the data to an already available cloud's application.

Each of the items to be migrated to CC should be described, at least, with the information portrayed in Table 27. The reference should be equivalent as the item is described in the service portfolio to link this table with a complete service description. In a similar way the CSP should refer the CSP in the same way the CSP management does.

Table 27 - Map of services to their cloud counterparts

Item	Description
ID	Reference
Department	Department or section that owns the service
Name	Name of the item to be migrated
Type	Service, application, data ….
Part	Part of the service or 'all' if no subdivision
Responsible	Person responsible for the service
Scheduling	Timetable for moving the service to the cloud
Order	Order by which the services will be migrated to the cloud
Cloud service provider	CSP for which the service will be migrated
Cloud service provider responsible	Person (of the CSP) responsible for the service
Cloud type	IaaS, PaaS or SaaS
Service	Service name, on the CSP side
SLA	Service SLA "on premise"

Item	Description
Cloud SLA	SLA to be observed on the CSP's side
Action to do before	Action to be done before the service is migrated to the cloud
Action to do after	Action to be done after the service is migrated to the cloud
Special conditions	Special conditions to be considered when migrating this service
Observations	Any additional comments

3.2.1.3.5 ITIL relationship

As expected, since the aim of the M2CC framework is to migrate services to the CC, the major ITIL support comes from the ITIL books Service Design and Service Transition. As already stated, the ITIL **Financial Management** process provides support throughout the entire process of migration to the CC. Table 28 summarizes the relationship between the Define, select, analyse and map M2CC framework's process and the ITIL framework.

While in the earlier process of the M2CC framework, the **Service Level Management** from the **Service Strategy** book mainly aims to document the existing SLAs, in this process it is useful to support the negotiation, with the CSPs, of the SLAs based on the information gathered. The **IT Service continuity management** process supports the framework to manage the risks caused by the migration to the CC and the impact on IT services, by assuring that the services, when migrated to the CC, have alternative service options to guarantee that they are still able to operate in the event of a significant business outage or disruption. Likewise in the "Identify and understand" M2CC framework process, the **Information security management**, another global process, supports the framework in security related issues. To support the management and selection of CSPs the **Supplier management** ITIL's process is advised.

Table 28 – Define, select, analyse and map / ITIL

Framework processes	ITIL processes																								
	Service strategy				Service design							Service Transition							Service Operation					CSI		
	Strategy generation	Service portfolio management	Demand management	Financial management	Service catalogue management	Service level management	Capacity management	Availability management	IT Service continuity management	Information Security management	Supplier management	Transition planning and support	Change management	Service asset and configuration management	Release and deployment management	Service validation and testing	Evaluation	Knowledge management	Event Management	Request fulfilment	Incident management	Problem management	Access management	Service measurement	Service reporting	7 step improvement
Define, select, analyse and map				•		•			•	•	•	•	•			•		•					•			

From the third ITIL book, **Service Transition**, M2CC gets support in planning and coordinating the resources in order to put a service into production with a predictability of cost, quality and time, from the **Transition planning and support** process. From the **Change management** process the support is to ensure the use of standardized procedures for the efficient and prompt handling of all changes to minimize the impact on service quality. Still from the same book, the M2CC framework gets backup from the **Service validation and testing** process, to validate and test the services migrated to the CC. The **Knowledge management,** as mentioned earlier, is a ubiquitous process that supports the whole M2CC's framework in the gathering, analysing, storing and sharing knowledge.

The framework manages issues related with accesses by reinforcing the policies defined in the Information security management, according to the information prescribed in the **Access management** process from the **Service operation** book.

3.2.1.4 Migrate and govern

This is the final process of the M2CC framework. This process, embraces a strategic definition of how the identified services are migrated to the CC. It includes a test pilot to try, once more, the new architecture before it goes into production and, in this way, find out whether the new functionalities are working as expected or not. After a successful test pilot, it is time to put the whole architecture (in-house and the CC services) into production.

Once the migration has been tested and everything runs accordingly, it is advisable to start a continuous improvement and monitoring process. This process is useful to maintain, validate and improve the services' quality and consequently to evaluate and validate the SLA and the fulfilling of the contract.

3.2.1.4.1 ITIL relationship

As expected, this last process of the M2CC's framework ("on premise" issues) gets most support from the **Service transition**, **Service operation** and **Continual service improvement** of ITIL processes, because it aims to migrate the IT services from traditional environments to the CC and govern them. The relationship between this M2CC process and ITIL is summarized in Table 29.

Table 29 – Migrate and govern / ITIL

Framework processes	ITIL processes																								
	Service strategy				Service design							Service Transition							Service Operation					CSI		
	Strategy generation	Service portfolio management	Demand management	Financial management	Service catalogue management	Service level management	Capacity management	Availability management	IT Service continuity management	Information Security management	Supplier management	Transition planning and support	Change management	Service asset and configuration management	Release and deployment management	Service validation and testing	Evaluation	Knowledge management	Event Management	Request fulfilment	Incident management	Problem management	Access management	Service measurement	Service reporting	7 step improvement
Migrate and govern			•	•		•			•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•

Beginning from the Service strategy book processes, the **Demand management** is useful to support the organization in managing the continuous demand of the services. As said earlier, the **Financial management** is a holistic ITIL process regarding the support given to the M2CC framework.

The second book, **Service design**, supports the "Migrate and govern" process of the M2CC framework with the **Service Level Management**, the **IT Service Continuity Management**, the **Information Security Management** and the **Supplier Management**. The **Service Level Management** is a useful process targeted to monitor the SLAs conditions. Conversely, the support provided by the **IT Service Continuity Management**, is similar to the

one given in the preceding M2CC process framework, excluding the fact that this process is applied to the selected CSPs. As mentioned above, the **Information Security Management** ITIL process is an omnipresent process in the M2CC framework because of the large weight that security holds on the migration to the CC. The last process of this book, the **Supplier Management**, ensures that the contracts made with the previously selected CSPs, are consistent with the needs of the business and that the CSPs meet their contractual commitments.

The Service transition book, as the name implies, has its focus on the conversion of services into a live/operational use. As such, it is expected that the majority of the processes of this book support the Migrate and govern M2CC framework process, because it is the one taking care of the real migration to the CC. The **Transition Planning and Support** process ensures the methodical transition of new or modified services into production. Therefore, this ITIL process supports the "Migrate and govern" framework's process by preparing, coordinating and supporting the services' transition to the CC. The **Change Management**, support this framework process by handling all the changes (resulting from migration to the CC) necessary to achieve the minimum disruption to the IT services. Despite the urge to handle configurations in CC environments is far lesser than in-house, it continues to be necessary to keep the configurations for in-house services, for services migrated to the CC and for their relationship between them. The **Service Asset and Configuration Management** ITIL process supports this framework process by providing an accurate configuration's information to minimize the number of quality and compliance issues caused by an incorrect or inaccurate configuration.

The **Release and Deployment Management** ITIL process aims to build, test and deliver services specified in the service design. It is for this reason why this process supports for the M2CC's framework. Accordingly, the IT's staff in charge of migrating IT to the CC, must decide what to do and verify if the release management of the CSPs is compatible with the organization business' calendar and regulations.

In its turn, the **Service Validation and Testing**, supports the framework by helping the IT management ensuring that the IT services still meet the organization's expectations after the migration to CC. The **Evaluation** process, as the name implies, aims to evaluate the

processes on a regular basis, an important part of the “Migrate and govern” M2CC framework mainly for the “Evaluate and monitor” and “continuous improvement” sub-processes. Lastly, the **Knowledge Management,** a ubiquitous process of the whole M2CC framework, supports it in the management of the knowledge collected and produced in the migration to the CC process.

Because this M2CC framework process takes care of the real migration to the CC and the initial operation of services into the CC, all the **Service Operation** processes support the M2CC framework process of “Migration and govern”. Although the **Event Management**, **Incident Management** and **Problem Management,** per se, are not directly related with the migration to the CC, they are considered in this final process of the framework and the initial period of production to cope with the events, incidents and problems found in this process. However, it is advisable that the responsible by the migration of IT to the CC knows how the events, incidents and problems are tracked and reported by the CSP.

The **Continual Service Improvement** book supports the M2CC’s framework process not only to evaluate the services that were migrated to the CC but also do the needed adjustments.

3.2.2 Off premise

This second group of processes includes the work performed with the support of the CSPs. It includes the provision, by the CSPs, of information on the services they deliver, namely the ones concerning IaaS, PaaS and SaaS.

3.2.2.1 Information regarding cloud services

The identification of services provided by each CSP is vital when the suppliers are to be selected. In this process, the CSPs make available the information concerning the services they provide, which could automatically be gathered by using the sematic web technology (Joshi, Yesha, Finin, & Joshi, 2012; Joshi, Finin, et al., 2012). The information includes details regarding the possible contracts and SLA, what are the available resources, the information concerning continuity and availability, the software in use such as the applications made available via SaaS and the software in usage by the CSP to manage the cloud

services. Additionally, the CSP must also offer complete information regarding the costs of each service and security.

The communication of problems and issues among customers and the CSPs must be fluid so that the migration to the CC and the CC's work takes place in a smoothly way. The support issues can be divided in two groups, the first one encompassing the incident's management and the problem's resolution, while the second group covers the relationship between customer and CSP.

In the first group, the customer must take into account how the CSP does the detection, registration, handling and what are the responsibilities for each player, and incident occurs.

The second group ensembles customer/service provider communications, and gives information to the customer regarding how the incidents and problem solving, are reported, what support is given to the customer, what training, if any, is given to the customer.

3.2.2.1.1 ITIL's relationship

Table 30 – Information regarding cloud services and cloud services / ITIL

Framework processes	ITIL processes																								
	Service strategy				Service design							Service Transition							Service Operation					CSI		
	Strategy generation	Service portfolio management	Demand management	Financial management	Service catalogue management	Service level management	Capacity management	Availability management	IT Service continuity management	Information Security management	Supplier management	Transition planning and support	Change management	Service asset and configuration management	Release and deployment management	Service validation and testing	Evaluation	Knowledge management	Event Management	Request fulfilment	Incident management	Problem management	Access management	Service measurement	Service reporting	7 step improvement
Information about cloud services		•	•	•	•	•	•	•	•	•	•			•	•			•							•	•
Cloud services												•	•	•	•	•		•	•		•	•	•	•		

A major impact of ITIL on outsourcing is via mechanisms that are designed to improve communication (Alojail, Rouse, & Corbitt, 2012). As such, this communication between the parties involved in the migration to the CC, is also improved by the use of use ITIL.

This M2CC's framework's process, as it represents the whole tasks of the CSP, gets support from the whole ITIL books as illustrated in Table 30.

3.2.3 In synthesis

The M2CC framework includes the processes, "Define the strategy", "Identify and understand", "Define, select, analyse and map" and "Migrate and govern".

Before starting the process of migrating to the CC, the organization must at first identify and understand the business and technical issues, which lead to a migration of services and applications to the CC. Among these issues, there are cost savings, agility and scalability offered by the CC. At the "Define a strategy" process, the organization comprehends the concept of CC, identifies the reasons why to migrate services to the CC and develop a strategy plan. In the "Identify and understand" process, the customer performs a full assessment of the infrastructure, services, applications and data, to perceive in full detail its IT, to identify what to move and to later compare in-house versus CC solutions. After comprehending his IT, the customer is ready to define a migration's plan in the "Select analyse and map" process. Based on the information of the earlier processes, on the migration plan and in the information gathered from the CSPs, he chooses the most appropriate suppliers for the migration.

A sub-process analyses and ponders the whole information to produce the input to the "map" sub-process mapping out services to their cloud counterparts or creating new ones. Lastly, in the "Migrate and govern" process, the organization migrates the selected services and applications to the CSPs according to the defined migration's plan. The migration is performed with the joint participation of the IT department, business, CSPs and with the service integrator (where appropriated). This migration may be phased, and there must be a validation by the end of each phase, according to the customer needs. Finally, the customer collects information regarding the performance of the CSPs and checks if they are in accordance as specified in the contracts and the SLA.

3.3 ITIL and the migration to cloud computing

To migrate IT services to the CC in a straightforward way, with more control and in a more accurate way, the organization must use the right tools. The migration to the CC involves

a standardization (Banerjee, 2012) as such, we advocate that the use of ITIL, a de facto standard (Iden & Eikebrokk, 2011; M. Jansen, 2012; Sahibudin et al., 2008), and the reference model for IT management processes, is appropriate to support the migration of IT services, applications and data to the CC.

While the preceding section presents our framework with the processes that must be undertaken by the organization, with and without the CSP's collaboration, to migrate services to the CC, this section demonstrates how ITIL could be used to support the application of the framework.

The activities and issues presented in the framework are similar with the tasks and issues found in the implementation and management of the traditional IT services life cycle. Additionally, so that CC delivers real value, it must be aligned to the enterprise rather than simply be a platform for simple tasks, such as application testing or running product demos (Ali Khajeh-Hosseini et al., 2010b). Consequently, being the ITIL's framework a set of good practices for the identification, planning, delivering, supporting of IT services and alignment of IT services with the business, it could also solve the issues presented for the migration to the CC and support the organization in the development of those activities. Furthermore, ITIL facilitates the communication between the CSPs and the customers (Nehme, Persson, & Lahiji, 2009), the two main actors of the migration to the CC process.

To summarize the whole mapping between ITIL and M2CC, Figure 24 exposes the relationship between the processes defined in the ITIL books, the **Service Strategy**, **Service Design**, **Service Transition**, **Service Operation** and **Continual Service Improvement** and the activities of our framework, the M2CC.

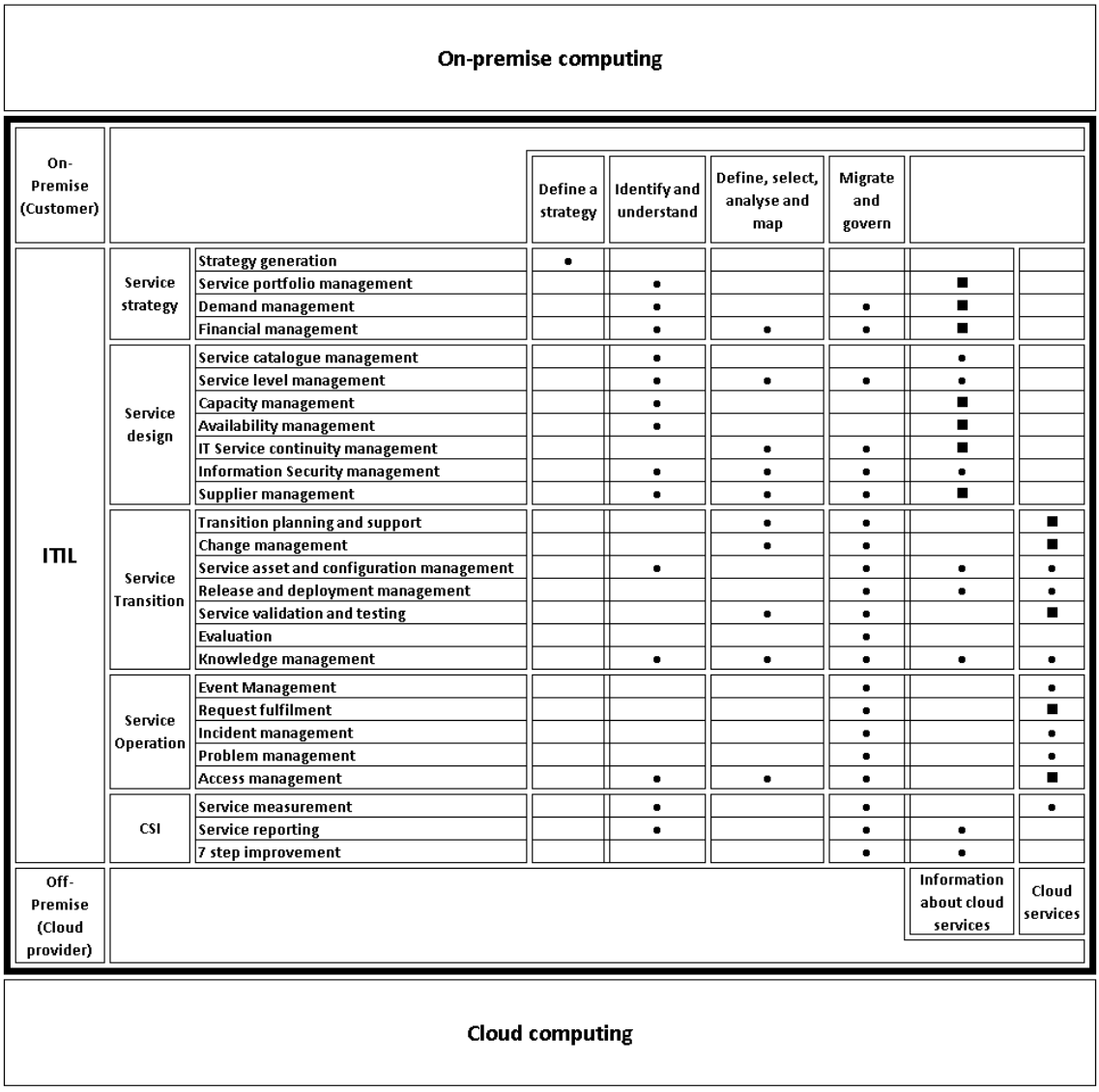

Figure 24: ITIL and the migration to cloud computing

3.3.1 Service Strategy

As previously mentioned, the CC is similar to a solution outsourcing IT operations. In this area, the ITIL also supports the migration to the CC by having in its **Service Strategy** book (Iqbal, Nieves, & Taylor, 2007) a specific section for outsourcing "Sourcing Strategy".

3.3.1.1 Strategy generation

Because of the issues involved and bearing in mind what surrounds the migration to the CC, we must not start without it first outlining a migration strategy's process. A strategically designed migration's process will ensure that the migration to the CC is suited to its purpose and not to follow the trends or because others carried it out. This ITIL process will support the first step of the framework, that is, "define a strategy".

3.3.1.2 Service Portfolio Management

The "Service Portfolio Management" is a key process within the migration of IT services to the CC because it provides a service's catalogue including information concerning all services, that is, existing services (services catalogue), services under development (services pipeline) and retired services, allowing the evaluation of each one their value and costs, so that organizations can make informed decisions.

This ITIL process is useful not only for the organization that wants to migrate services to the CC but also for the CSP. The organization uses it to identify the features of their services in order to support it in recognizing what can be migrated to the CC as well as to assist in the comparison of the services' characteristics between different CSPs. When the CSPs also use ITIL, it allows them (Iqbal et al., 2007) to be able to comprehend the quality requirements and related delivery costs and that means they can strive to reduce costs through alternative means while maintaining the quality of the service. Additionally, it supports the CSPs to produce a catalogue of services delivered and supporting it when answering questions such as: (Iqbal et al., 2007) Why should a customer purchase these services? Why should they purchase these services from us? What are the pricing or charge back models? What are our strengths and weaknesses, priority risk? How should our resources and capabilities be allocated?

As aforementioned, it is important to recognize the responsibilities of each actor in the migration to the CC. The "service portfolio management" also provides support in this activity since it requires that the services and applications to be clearly specified to all parties so that they comprehend their roles and responsibilities.

3.3.1.3 Demand Management

The demand of services needs to be managed to overcome problems in the business' processes. Over and under subscription of services is a source of risks and costs. The ITIL "Demand Management" process presents the good practices on how to solve the challenge of maintaining the IT resources on an ideal level. If the organization has more resources than the ones necessary, it will not create value and instead it will incur in unnecessary expenses; conversely, if there are fewer resources than those needed, the quality of services will be negatively affected. Although the acquisition and release of resources in the CC is based on an easy process, the "demand management" still has an important role to maintain the resources at an optimum level, lowering costs and maximizing the CC benefits.

In the CC if the organization has a contract where services are automatically provided according to the needs and the agreed level is lagged from the real needs, the costs of the cloud services can become expensive.

Conversely, if the customer has a pay-as-you-go model, to reduce the costs, the demand should follow the necessities over the time; this is also done with "demand management". For example, the "demand management" also mitigates the costs of a flooding security attack. When a server is in CC and the owner pays by usage, there is a seemingly an infinite amount of resources for the server (Roberts & Al-Hamdani, 2011), causing an increase of the costs to the costumer due to this misuse of resources by the flooding attack.

To take advantage of the CC's ability to manage the changes on demand, the activities presented in the "demand management" should be followed to follow the trends and Patterns of the Business Activity (PBA) (Hanna, 2011).

The "demand management" is required to perform the initial study, before starting the migration's process, to clarify what the resources needed are, when and from whom. Moreover, in the detailed definition of the processes, services and applications it is also necessary to identify the initial requirements of resources needed when deciding what to migrate to the CC. The information gathered in the "demand management" process also supports the customer on the CSP's selection since he can only choose a CSP if it guarantees that he can provide the services according to the identified demands. This warranty should be encompassed on the SLA or on contract made between the organization (costumer) and the CSP.

Additionally, the customer needs to evaluate the available CC services against internal services regarding competitiveness for dissimilar workloads so it should be aware of the demands for different workloads.

As already mentioned, this ITIL process will support the “Identify and understand” process of the framework by identifying the demand of the processes. However, the information it provides is also helpful in other processes such as the “Define, select, analyse and map”.

3.3.1.4 Financial Management

The “Financial Management” is an ITIL process defined in the “Service Strategy” book used in all the ITIL books. The purpose is to provide, both the organization and the IT, financial information concerning IT services value, the value of the assets behind the provisioning of the IT services and the budgeting of the costs of providing IT services. In the CC, the financial management is also used because the organization must clearly comprehend the services’ costs (both in-house and in the cloud).

The budgeting of services on site and within the cloud is useful in order to know where and how much it is spending, to compare the costs of the services in different CSPs and to compare them with the costs of services within the organization, that is, to conduct a cost-benefit analysis. In other words, the “Financial management” process provides details on the “Return on Investment”, (RoI), and on the TCO, on “on premise” and on the CC services.

By definition, in the CC, the customer is charged based on the service consumption, which means that Financial Management can no longer be neglected.

Because of its importance, this ITIL process is useful in the whole framework’s processes.

3.3.2 Service Design

The ITIL “Service Design” book (Lloyd et al., 2007, p. 23),”covers the design principles and methods for converting strategic objectives into portfolios of services and service assets. The scope of “Service Design” is not limited to new services. It includes the changes

and improvements necessary to increase or maintain value to customers over the life cycle of services...".

3.3.2.1 Service Catalogue Management

According to (Taylor, 2007) the objective of the "Service Catalogue Management" process is to manage the information contained within the service's catalogue and to ensure that its information is accurate and reflects the current details, status, interfaces and dependencies of all services that are being run or being prepared to run in the live environment.

The service catalogue holds information regarding the currently available services. Both the customer and the CSP must use an accurate and consistent picture of the services. The customer, to decide which could be migrated to the CC and to recognize the necessary resources (based for example on the requirements and services' interrelations identified when they are "in-house"). In its turn, the CSPs to clarify the customers on understanding of what services are made available by the CSP, the options and costs for each one so that customers can easily find the services they need.

3.3.2.2 Service Level Management

The objectives of "Service Level Management" process includes the monitoring and the improving of customer's satisfaction with the quality of the services delivered. However, it should be highlighted that (Taylor, 2007) nothing should be included in the SLA unless it can be effectively monitored and measured at a commonly agreed point. The achievement of "Service Level Management" purposes support the CC migration and maintenance because while monitoring the SLA, the customer is also validating the quality of services provided by the CSPs and therefore ensures that the CC services are being supplied in accordance with the contract. Additionally and taking into account that the SLA must also reflect (M. Jansen, 2011) the amount of the responsibility transferred towards the CSP, there is a prior clarification of the responsibilities of each actor in the process.

The CSP must have a mature and well-designed service level's agreement to attract customers and give them assurances of a service quality. Conversely, the customers weigh their decisions of which service's supplier to choose, on a detailed analysis of levels of

service guaranteed by each CSP, that is, the “Service level management” also assists customers to compare the candidates CSPs. Furthermore, the service level agreement allows customers to be able to verify that the services available in the CC have the same or a higher level of service than those available on premise.

The “Service Level Management” process supports the M2CC framework in the “Define, select, analyse and map” process because it is in this process that the SLAs of the different CSPs are analysed and compared and the “Migrate and govern”, to allow the customer to monitor service performance against the SLA. Additionally it also gives support to the “Information regarding cloud services” process to assist the CSPs in developing the SLA for their services.

3.3.2.3 Capacity Management

The goal of the “Capacity Management” ITIL’s process is to ensure that cost-justifiable IT capacity in all areas of IT always exists and is matched to the current and future (Lloyd et al., 2007).

With the information gathered with the support from this ITIL’s process and from the “in-house” services/processes, the organization can consciously, manage, choose, purchase and monitor the resources from the CSPs in an efficient way with costs’ minimization. To understand of how much of the cloud’s infrastructure to use, and therefore, how much it will cost, the customer first needs to comprehend the resource requirements. The capacity management also supports the validation of the SLAs since having a correct idea of what the requirements are the customer could confirm if the CC SLAs are reasonable for the needs. Moreover, the customer uses the capacity management, when migrating to the CC, to know, in detail, the capacity needed for each service.

The “Capacity Management”, when used to manage traditional data centres, focuses on peak needs and guarantees that they are meet. However, this management is done taking into consideration that these resources are limited since the organization must own these same resources as well as the staff used to manage it. Yet, when used in the CC, the organization no longer holds the obligation to own the resources or the staff in charge of its management and maintenance. Therefore, the “Capacity Management” process is used to

take advantage of the CC's elasticity and to manage (more efficiently) the services contracted to minimize costs and acquire the necessary resources.

The "Capacity Management" process has three sub-processes: component, service and business capacity management that can be mapped into the three service models of the CC (IaaS, PaaS and SaaS). The Component Capacity Management's emphasis is on the IT infrastructure, which holds the service provision, and is related with IaaS. The Service Capacity Management focuses on the delivery of the existing services that support the business and is associated with the PaaS. The Business Capacity Management enhances the current and future business' requirements and could have repercussions in the SaaS.

Thus, in short, this ITIL process is suitable to support the "Identify and understand" framework's process to gather information concerning the "in-house" services in order to have a baseline for the capacity needed when the services are migrated to the CC.

3.3.2.4 Availability Management

According to (Lloyd et al., 2007), the goal of the "Availability Management" process is to ensure that the level of service's availability delivered in all services matches or exceeds the current and future agreed needs of the business, in a cost-effective manner. The outcomes of this process support the customer on the establishment and validation of the SLAs and on the risk analysis of migrating the services to the CC.

The ITIL "Availability Management" process supports the framework in the "Identify and understand" process by gathering information concerning the "in-house" services and provides information to the "Define, select, analyse and map" process. Additionally, it should be highlighted that much of the responsibility for availability management is transferred to the CSP.

3.3.2.5 IT Service Continuity Management

The goal of the "IT Service Continuity Management (ITSCM)", is "to support the overall Business Continuity Management process by ensuring that the required IT technical and service facilities (including computer systems, networks, applications, data repositories,

telecommunications, environment, technical support and Service Desk) can be resumed within required, and agreed, business time-scales." (Lloyd et al., 2007, p. 216).

As organizations, depend more on the use of technology, the requirement for ITSCM increases in order to be able to maintain its services. The use of ITSCM, by the CSP, can become a competitive advantage by demonstrating its skills to reposition services in operation, which can affect the choice of CSP by the customer.

As stated in (Lloyd et al., 2007) the only way to effectively implement ITSCM is identifying critical processes and analysing of the required technology and supporting services. This identification, although it may be challenging (if the CSP and customer Business Continuity Plans (BCP) must be combined), it is important and useful to know the organization processes, namely those to be migrated to the CC. The Business Impact Analysis (BIA), a process under the ITSCM and whose aim is to quantify the impact to the business that lose a service, is useful to explore and quantify some of the impact problems stated in section 3.2 and should be reflected in the SLA with the CSPs.

In turn, the CC also supports the organization in the implementation of some ITSCM envisaged recovery options, such as gradual, intermediate, fast and immediate recovery by temporary providing the affected services and releasing them when the recovery's process ends. Considering that it is widely perceived that implementing ITSCM is an expensive challenge (M. Klems et al., 2010) and that the CC offers a model for dynamic, scalable infrastructure resource allocation on a pay-per-use basis, the CC provides cost-efficiency to ITSCM.

Although most of the responsibility of this process is moved to the CSPs, it is still necessary, because of the resources remaining the organization. The ITSCM's process is suitable to support the "migrate and govern" framework's process in order to provide advice on continuity and to negotiate the necessary contracts for service continuity in the process of the supplier's management.

3.3.2.6 Information Security Management

The purpose of the "Information Security Management (ISM)" process is (Lloyd et al., 2007) to ensure that the security aspects regarding services and all Service Management activities are appropriately managed and controlled in line with business' needs and risks.

As aforementioned, one of the major concerns when migrating to the CC is security. Therefore, ISM is a key area of concern and it is mandatory to ensure that the IT security is integrated with the business security. However, it must be highlighted that the migration of services to the CC, transfer some of the security concerns to the CSP, albeit the customer still has responsibilities (the ultimate responsibility is always from the customer) in the security of his services.

The ISM supports the migration to the CC in the same way the SLM does, that is, it assists in defining the security requirements and responsibilities, their inclusion within Service Level Reports (SLRs) and SLAs and the validation of security measures made available by the CSPs. After migrating the services to the CC, this ITIL process, supports the validation of the security made available by the CSPs. It is a ubiquitous process in the M2CC's framework.

3.3.2.7 Supplier Management

The ITIL "Supplier Management" process is responsible for ensuring that all contracts with the suppliers support the needs of the business and that all suppliers honour their contractual commitments (Lloyd et al., 2007).

This ITIL process becomes important in the "Define, select, analyse and map" process of the framework by supporting the organization in choosing the CSPs. Given the easiness that the CC services are made available to the customer, the "Supplier Management" process also assumes the role of eliminating an unwanted proliferation of service contracts with the CSPs. Additionally, after the contracts have been signed, it is employed, in the "Migrate and govern" process, to maintain and renegotiate them and to manage the relationships with the CSPs.

3.3.3 Service Transition

The aim of the ITIL processes, from the "Service Transition" book, is to move the planned services into production, to remove old and worthless services, and to improve services in order to keep the business in competitive levels.

3.3.3.1 Transition planning and support

This first process of the ITIL "Service transition" book aims to plan and coordinate the resources that are to be used to successfully put, a new or changed service into production with cost predictability, quality and deadlines. Additionally it provides support to service transition teams and ensures that the service transition problems, risks and deviations are reported to the stakeholders and decision makers (Lacy & Macfarlane, 2007).

The M2CC framework use this process to support the "Define a migration plan" stage of the "Define, select, analyse and map" process to assist in the production of the migration plan and define the necessary resources. Additionally it contributes to the "Migrate and govern" process by putting the CC services into production (with the CSP's support).

3.3.3.2 Change management

The aim of the "Change management" process is to ensure the use of standardized procedures for an efficient and immediate handling of all changes to minimize the impact on service quality and consequently to improve the day-to-day. Moreover it ensures that only the authorized and carefully considered changes are applied (Lacy & Macfarlane, 2007).

Similarly to the "Transition Planning and Support", the "Change Management" process supports the M2CC's framework in the "Define, Select, Analyse and Map" and in the "Migrate and Govern" processes. The process helps solving the problems arising with the changes, that IT processes experience along with the migration to the CC. Bearing in mind that the migration to the CC could itself be a change to the existing "in-house" processes the "Change Management" process also supports the organization in defining the migration itself.

3.3.3.3 Service asset and configuration management

The main goal of the SACM is to support the services management processes in an efficient way. This is possible by providing accurate information concerning the configuration to enable the decision-making at the right time, with accurate information when planning and authorizing changes and releases and solving incidents and problems more rapidly. Moreover, it ensures the integrity of the assets and configurations required to control the IT's infrastructure and services. Therefore, this ITIL process, provisions the "Identify and understand" framework's process with information necessary to better know the IT's infrastructure, IT's components and their relationship.

3.3.3.4 Release and deployment management

While the change management process determines, what will be changed and why, the "Release and Deployment Management" regulates how these changes are implemented. This ITIL process supports the CSPs in deploying new releases into production and establishes an effective use of the service to add value for the customer and to be able to make the transfer to Service Operation.

When migrating services to the CC the need to maintain the releases of software remains (although in a smaller level), such as the Internet browser and other cloud related software that should be maintained according to the requirements stated by the CSPs. For example, if there is a software update on the CSP's side an update of the browser plugin may be necessary so that the CC applications continue to function properly. Consequently, this ITIL process, in addition to supporting the framework's process of "Migrate and govern" also assists the CSP to provide information to the customer regarding how he processes the availability of new releases (framework processes "Information regarding cloud services" and "Cloud services").

3.3.3.5 Service validation and testing

This process is responsible for the validation and testing of an IT Service (new or changed). It ensures that the service meets the specifications and the needs of business. Thus, it assists the framework in the processes "Define analyse and map", by verifying that the CC services

delivered by the selected CSPs meet the requirements previously identified and the “Migrate and Govern” to assure a service quality of the services that were migrated to the CC.

3.3.3.6 Evaluation

This ITIL process aims to evaluate the processes on a regular basis. According to (Cartlidge et al., 2007, p. 28) the “Evaluation” process “ensures that the service will be useful to the business is central to successful Service Transition and this extends into ensuring that the service will continue to be relevant by establishing appropriate metrics and measurement techniques.”. This process provides a way to the “Migrate and Govern” framework’s process to validate that the CC services continue to meet the required obligations.

3.3.3.7 Knowledge management

The “Knowledge Management” process is responsible for the gathering, the analysis, storage and sharing of information and knowledge in the organization. The main goal of this process is to improve efficiency by reducing the need of rediscovering the organization’s knowledge.

Being the information, the knowledge and their management are mandatory for all processes; they are also required for the whole process of migration to the CC where it supports all framework processes. This support is based on managing the information collected concerning the “in-house” datacentre (“Identify and understand” process) or by taking care of the information gathered from the CSPs and the migration plan (“Define, select, analyse and map” process). Additionally it supports the process of “Migrate and Govern” to manage the information gathered in this process. On the CSP’s side, it is useful to document all the aspects of the services they provide.

Similarly, to the process “Financial Management”, the “Knowledge management” is a ubiquitous process supporting the M2CC framework in all processes.

3.3.4 Service Operation

The objective of the ITIL book, “Service Operation”, is to make sure that the IT services are delivered effectively and efficiently, i.e., (Cartlidge et al., 2007) in accordance with the agreed levels of service to users and customers.

3.3.4.1 Event management

Similarly to what happens when the services are “in-house”, in the CC the events are still generated, hence must be managed. When the services are migrated to the CC, the number of events that must be managed by the organization decreases because some of the responsibility is moved to the CSPs. Consequently it is mandatory to have a clear definition of the responsibilities and roles of the organization and the CSP.

The “Event Management” supports the “Migrate and Govern” (organization’s side) and the “Cloud Services” (CSP’s side) processes of the framework, to cope with the events generated by the services migrated to the CC according to the responsibilities and roles identified for each one. Besides that, the “Event Management” process continues to deal with the events of the services that remain in the organization.

3.3.4.2 Request fulfilment

The purpose of the “Request Fulfilment” process is to allow users to request and receive standard services; to acquire and provide these services; to provide information to users and customers regarding services and procedures to obtaining them; to assist them with general information, complaints and comments.

Since, by definition, the request of the CC services is made by the selected members of an organization, it is advantageous to have a process that manages the whole procedure. Therefore, this process is useful for the framework’s process of “Migrate and Govern” and the “Cloud Services”, although, for the last one, it is for management of the CC services.

3.3.4.3 Incident management

The ITIL process taking care of the incidents is the “Incident Management” that aims to restore normal service operation as quickly as possible, and to minimize the adverse impact on business operations. As such, this ITIL process supports the processes of the framework more closely related to put services into production on the CC “Migrate and Govern” and “Cloud Services”.

3.3.4.4 Problem management

The main goals of the “Problem Management” are multiple, such as preventing problems and their resulting incidents from happening, eliminating recurring incidents and minimizing the impact of incidents that cannot be avoided. Similarly to what happens with “Event Management” and “Incident Management”, this process supports the “Migrate and Govern” and the “Cloud Services” processes of the framework.

Although the “Event Management”, “Incident Management” and “Problem Management” are not directly related with the migration to the CC, they are considered here since the final phase of the framework and the initial period of production are normally more susceptible to have problems.

3.3.4.5 Access management

The objective of the “Access Management” process is to guarantee authorized users the right to use a service and preventing the access to unauthorized ones. It backups the framework processes, “Identify and understand” to identify the access to services and to provide a baseline for the access within the CC, the “Define, Select analyse and Map” to define the access in the CC and the “Migrate and Govern” process to provide the initial set of accesses to the systems migrated to CC.

3.3.5 Continual service improvement

This last ITIL book, “Continual Service Improvement” (CSI), consists on maintaining the value for customers through a continuous assessment and improvement of quality of services and the overall maturity of the IT and service life cycle as well as the underlying processes (Spalding, 2007). It is useful for the framework, to gather information regarding the organization’s services in order to later compare with the CC’s counterpart services, to evaluate the services that were migrated to the CC and to do the necessary adjustments (framework processes “Identify and Understand” and “Migrate and Govern”).

3.3.6 In synthesis

Five books compose the version 3 of ITIL. The “Service Strategy”, where the requirements are identified and the business outcomes are verified; the second book, “Service Design”, handles the design of the service in all its facets and documents every detail.

In the third book, “Service Transition”, the emphasis is on the service implementation where this is monitored, tested and validated. The fourth book, “Service Operation”, is about the issues concerning the maintenance of the service in operation in accordance with the established SLA.

The fifth and last book, “Continual Service improvement”, deals with the identification of opportunities to improve the service. These books can be grouped in three major areas: the requirements analysis and initial definition (including the “Service Strategy” and “Service Design” books), the migration to the production environment (including the “Service Transition” book) and the operation and improvement in production (consisting of “Service Operation” and “Continual Service Improvement”).

This chapter demonstrates how each process of the five ITIL books are related to the M2CC’s framework proposed in the section 3.2. Indeed, the M2CC framework processes could be mapped to the identified ITIL groups. Accordingly, the framework’s processes “Define a Strategy” and the “Identify and Understand” can be acknowledged into the ITIL group of “Requirements analysis and initial definition”. Similarly, the “Define analyse and map” process could be recognized in the “Migration to production” group. Finally, the

framework's process, "Migrate and Govern", could be mapped in the ITIL group "operation and improvement in production".

Beyond these macro relationships, the same occurs but a lower level. On the other side, and having ITIL to support the whole process, it adds benefits such as providing a common language between the customer and the CSP, improving support in the decision-making process and discipline IT. From the foregoing we can conclude that ITIL can be applied to support the migration of IT services to the CC. However, this does not mean that every organization that wishes to migrate services to the CC must at first implement the whole ITIL's good practices.

As mentioned earlier, in 2011, ITIL has suffered an update to incorporate improvements and suggested changes. This update (Ltd, 2011), not a new version, was designed to solve errors and inconsistencies as well as to improve the publications, address suggestions made by the training's community and to review the "Service Strategy" book to guarantee that the concepts are explained more clearly. This creates new processes and updates others; however, the considerations with the CC are limited (Mourad & Hussain, 2014). The new processes and their relationship with the M2CC's framework are exposed on Table 31.

Table 31 - The relationship between new ITIL 2011 processes and the M2CC framework

Book	Processes introduced /reformulated	M2CC support
Service Strategy	Demand Management and Demand Manager role	Identify and understand – to recognize the current demand for services and resources needed to compare later with CC counterparts and to increase the potential of migrating a service to the CC. The services with high or variable demand are strong candidates for migration to the CC. Migrate and govern – When in the CC and because of the dynamic of the CC this process is useful to reduce the costs by maintaining the demand so that it follows the necessities over the time.
	Strategy Management for IT Services	Define a strategy (and globally the whole framework) – By assuring that, the strategy is defined, maintained and achieves the purposes.

Book	Processes introduced /reformulated	M2CC support
	Business Relationship Management	Select CSPs – Since this ITIL process manages the relationship between the provider and the customer it supports the CSP's selection. Migrate and govern – Namely the continuous improvement sub-process in all the issues related with the relationship between the CSP and the customer.
Service Design	Design Coordination and the service design manager role	Define, select, analyse and map process – Since this framework process is where the solution is designed this ITIL process is useful to coordinate the process.
Service Transition	Change Evaluation	Define, select, analyse and map and migrate and govern – To evaluate the changes (migrating to CC) in a consistent and standardized way.

3.4 Conclusion

The migration of services to the CC includes activities and issues that must be managed and resolved. This chapter proposes a framework to support organizations in the task of migrating IT services to the CC. The activities of the framework are assembled into two major groups: the "on premise" and "off premise". While the first one gathers the issues that must be addressed by the organization, the second combines the activities that are undertaken with the collaboration of CSPs.

Despite the services' migration for the CC is not typically a one-way task, that is, once migrating to the CC they cannot move back home, it is a complicated and time-consuming job, not always possible to accomplish and not always the better solution. Therefore, to properly migrate services to the CC and to take advantage of the real benefits of the CC the organization must hold all the required information and run the process in a controlled and structured way.

The study has revealed that the best practices of ITIL support the framework presented in section 3.2, either by obtaining necessary information or by pointing the appropriate methodology for the resolution of issues.

In (Chang et al., 2014) the authors, identify four desired features for a framework for cloud adoption. These features and how the M2CC meet the criteria are exposed in the Table 32.

Table 32 - Chang et al. criteria vs. M2CC

Criteria	How M2CC meets the criteria
Align technical activities with business models and strategies	In the first stage of the framework, "Define a Strategy" the information coming from the business with the information gathered from the IT are the base for the generation of the strategy of migrating to the CC. The same alignment is presented in the whole framework, when gathering information, from actual services, applications and data, in the "Identify and Understand" process and in the "Define, select analyse and map" stage, where, for example, all the analysis and tests are accomplished by having as a background the needs of the business. On the other side, and bearing in mind that ITIL is a framework whose focus is on the alignment between IT and business and that the M2CC framework follows ITIL's principles, the framework aligns its activities with the business.
Be easily adopted by the industry or any organization	Although the framework has not yet been used in many organizations we believe that the adoption is easy since it was not difficult to follow the recommendations established in the case study.
To fully integrate fully with activities of the organization that adopt the Cloud Computing	The close relationship of the framework with ITIL will support this integration.
Compile all key lessons learned and recommendations that might be influential to the academia and industry	Since the proposed framework is the result of a research based both in the current academic state of the art and in industry technical reports, the result framework was based on the compilation, organization and development of the ideas presented on the consulted studies.

Chapter 4

CASE STUDY

This chapter introduces and discusses the research methodology and the case study that underpinned the validation of the developed framework.

The chapter begins with a perspective of the case study's methodology followed by the characterization of Portucalense University, the organization where the case study occurs.

In the subsequent section, the case study of migrating services and applications to the CC is carefully presented, following the demonstration of results and the validation of the framework itself. Finally, the conclusions drawn from this case study are exposed.

4.1 Introduction

The framework for migrating applications and services to the CC, developed and described in preceding chapters, presents the procedures that should be adopted when migrating services and applications to the CC.

According to Yin (2003) the case study is used to test (ratification, contradiction or alteration) of a formulated theory (framework developed). Taking into account, on the one side, the benefits that the methodology of the case study expose in investigating real life phenomena (R.K. Yin, 2003) and for the other hand the prescription the same author does of it, we consider the case study to be the adequate choice of a methodological approach to comprehend the problem under the research.

The migration of services to the CC includes a deep knowledge of the organization's IT infrastructure, such as information, applications and the processes and as well as their interrelationships. Nevertheless, privacy issues generally limit this knowledge's availability to the outside of the enterprise, causing the credibility of released information to hold a reduced backup as far as a research work is concerned.

On the other side, the organization must be able to offer time, human resources and support to the project's development.

These constraints led us to consider the option of conducting a single case study to obtain the necessary information to develop the research. To perform an additional validation of the developed work the opinion of an expert group has been collected, three interviews were conducted, a book chapter and other peer-reviewed papers were published.

4.2 Case study

After the migration's framework to the CC is presented and how ITIL can support each process is identified, this chapter follows with the validation of the work done. We therefore begin this section by identifying the aims of this case study and the reasons the why the University Portucalense Infante D. Henrique (herein referred to as UPT) was adopted as the organization of this case study. In subsection 4.3, we discuss the details of the research methodology used (the case study) and in the following subsection the instruments used in gathering information and the working methods used in the pursuit of this study. Finally, the motives that led us to consider the followed methodology as valid are explained.

4.2.1 Goals

The migration of infrastructures, applications, data and services to the CC includes processes that must be followed, managed and organized so that the drive to the new environment runs smoothly. Accordingly, with this case study, we intend to deeply comprehend the migration's process.

The aim of this case study is to understand, explore and describe the migration's process to the CC under the framework developed as part of this work (presented in 3.2). With this approach, we validate and demonstrate the use of the framework as well as its relationship with ITIL.

The purposes of this case study include an in-depth study of the process of migrating infrastructures, data, applications and services of a traditional data centre to a CC's environment. Additionally we recognize the applicability of the developed framework to the migration to the CC. Lastly we validate the ITIL's applicability to the framework developed for the migration to the CC and accordingly, to the migration to the CC.

4.2.2 Why this case study

According to the knowledge previously gathered, the migration to the CC implies that a thorough knowledge of the organization, IT, business, services and operating mode is necessary. This fact, concomitantly with the obligation of finding an organization that is developing its migration to the CC by the time of this study makes the choice more difficult. Additionally and considering the urge of having an opening large enough to expose its internal structure to this study and to support the researcher in the development of this research, made it impossible to timely find an organization under these circumstances.

The UPT is in process of migrating part of their IT services to the CC (private cloud). Bearing also in mind that the issues we had to solve (with this migration) were coincident with the ones addressed by the framework developed, it has been decided to use the UPT and this case study to validate the developed framework of migration to the CC.

4.3 Research methodology

This case study focuses on the thorough investigation of the implementation and migration of IT services from a data centre to a private cloud.

According to (R.K. Yin, 2003), three questions must be analysed to assist in the selection of the most appropriate research methodology for the topic being studied. The first of these questions relates to the type of research questions, the second with the extent of control the investigator has over the events and the third question is regarding the focus on contemporary versus historical events. To answer the first question, we can state that the present work aims to answer questions such as "how" (how to perform the migration of services and applications for the CC, how can ITIL support this purpose). Regarding the second question, the phenomenon is observed in its natural environment. Concerning the third question, this research focusses on contemporary phenomena of real life.

We also take into account the fact that the case study is one of the most meaningful researches in information systems (Palvia, Mao, Salam, & Soliman, 2003), the specific features of this type of study (see section 4.2.2), the research questions leading to this work's development, the relevance of the study itself, the case study is widely used in the characteristics survey and the operation rules or operation of systems and processes (Jung, 2003).

According to the above and with the case study projects recognized by (R.K. Yin, 2003) (Figure 25), the research methodology chosen was on the case study of typology of "uniqueness" as a method of validation's work, that is a holistic single-case .

Izak Benbasat et al. in (1987, p. 370) define case study as "a methodology that examines a phenomenon in its natural setting, employing multiple methods of data collection. The boundaries of the phenomenon under study are not clearly evident at the beginning of the investigation and is not used control or experimental manipulation.". In summary, this methodology allows to create theories from practice (Pozzebon & Freitas, 1998) and to answer questions such as "how" and "why" in order to comprehend the nature and complexity of the processes.

The present study focusses on contemporary events (by the time of this study's development the UPT is migrating some of its IT to the CC). This migration has been developed in

a real context, which allowed the events of the actual migration to be properly observed, described and studied.

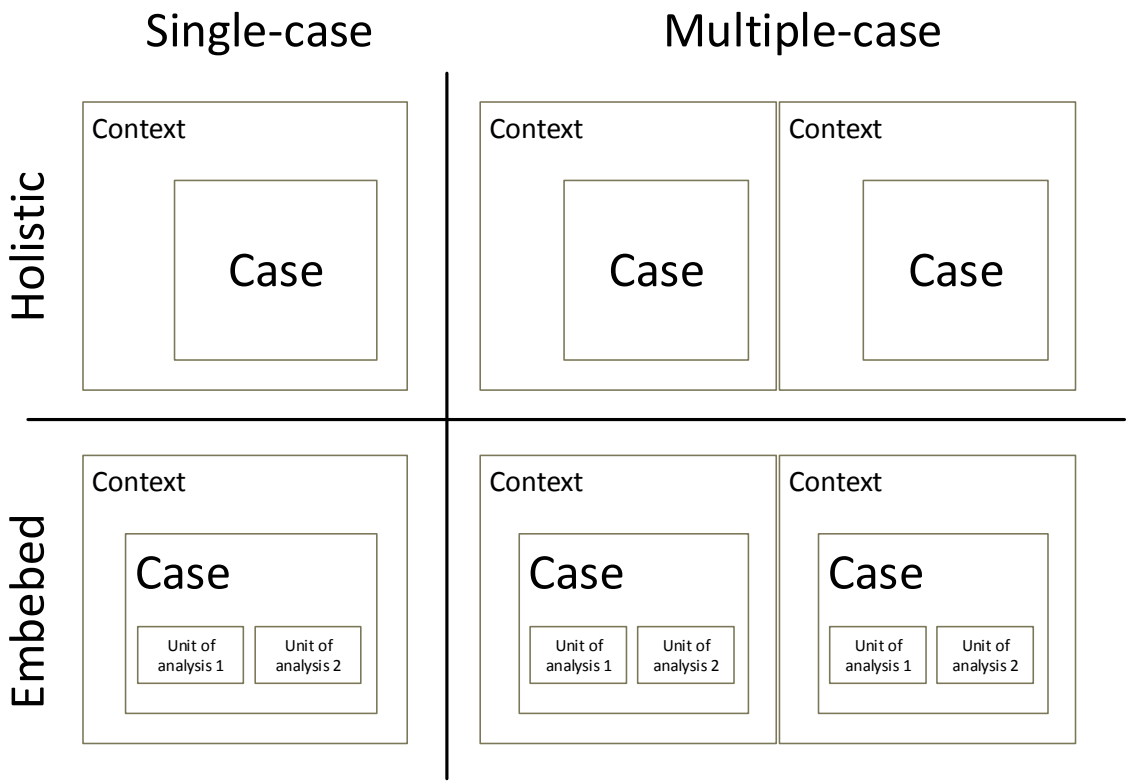

Figure 25 - Basic types of case study projects (adapted from (R.K. Yin, 2003)**)**

The research for this work includes four major steps, including the literature review, the case study and action research, the writing of papers and a book chapter, the validation of the work done by a group of experts and interviews with the staff affected by the services migrated to the private cloud and with the IT's staff that performed the migration. The aim of the literature review is to conduce a critical and comparative analysis of the works published in the area of the current work. Additionally, it was useful to gather deep knowledge concerning the CC, the ITIL and research methodologies. The knowledge gathered together with the case study, has been advantageous to validate the applicability of the framework developed to the migration of processes, applications, data and infrastructure to the CC and to work out some rough edges in the developed framework. The writing of papers and the opinion of experts have also been important to gather opinions, concerning our work, from other researchers in the area. The interviews with the staff affected by the services migrated is useful to authenticate the fact that the migration was successful and smoothly performed.

The interviews with IT's staff provide information about the technical advantages of the migration of services to the CC.

4.3.1 Tools used to collect information

The sources of information are one of the components of the case study's protocol including, according to (Robert K. Yin, 2005), documents, records, interviews, a direct observation and a participative observation. The goal is to use qualitative data (data whose purpose is to provide information that can be described in terms or theories) collection techniques.

Consequently, to provide this study with the necessary depth, the following instruments were used to gather information:

- **A survey of existing systems and processes -** This survey was entirely conducted by the UPT IT's area and includes the gathering and analysis of detailed information regarding IT services, data and servers under the responsibility of the IT's area. Armed with this information, the decisions concerning not only what could, what should be migrated to the CC but also what should remain unchanged, are taken much more consciously and accurately.
- **Meetings' participation and definition of what processes, systems and data to migrate -** The majority of these meetings only involve IT elements of the UPT. The contribution of the team providing the solution (solution provider) was merely used to clarify technical details that could influence the installation.
- **Review of documents and electronic messages exchanged with the suppliers -** The review includes documents made available by the University and by the contacted companies. This documentation consists on the initial proposals from different companies, the final proposal, the contracts and SLAs of the selected firm, the technical report of the installation, the contractual and financial documentation and in email messages. This information was helpful in understanding the whole project as well as its interactions.
- **Meetings' participation with the suppliers -** These meetings have proved to be useful when acquiring knowledge concerning the proposed solutions, the service offerings of each provider, the contracts and SLAs. After selecting the vendor that would implement the solution, these meetings were helpful to clarify details related

to either installation or operation mode, so that it could follow the developed framework.

- **Direct and attendee's observation -** These observations allowed the author to contact with a real migration of services to a CC's environment, which enabled the knowledge capture in real time and, consequently, a better understanding of the work to be performed. Furthermore, this observation was also advantageous because it was possible to monitor the activities developed by the users (either from those with responsibilities in the migration and for those that were somehow affected by it) in their day-to-day work. Those observations were performed on a daily basis throughout the period of the project's development.
- **Participation in the testing activities before the migration –** The participation in test activities was fruitful to smooth out a few rough edges from a technical forum that persisted, such as checking the possibility to migrate machines with old Microsoft operating systems and the possibility of dynamically changing memory settings. Moreover, it was profitable to make some slight adjustments to the M2CC's framework, such as increasing the importance of the testing phase so that it is aligned with the reality.
- **Active participation during the effective migration -** By participating in the most practical stages of the migration to the CC, we made contact with the reality of migration and thus we saw how all the previous work had been useful since this phase ran smoothly and in a completely transparent way for end users of service's migrated.

4.3.2 Working methodology

The followed working methodology towards this case study entailed a close monitoring of all stages leading to the migration of services to the CC, the participation in the decision-making process and the intervention in the whole process of installing a private cloud and on the migration of services to the implemented environment.

All of the work in this case study took place in accordance with the directions of the framework developed and presented earlier. Thus, the UPT IT's area starts the whole process by defining the initial strategy with broad outlines and guidelines for the whole process. This

phase is followed by the stage of identification and understanding of all services, applications and data in use by the UPT area of information technology. This stage is vital to establish a strong foundation of information for pursuing the subsequent phases of the framework.

The next process, “Define, select, analyse and map” begins by defining a migration’s plan, which delineates all the details of the migration process itself. Concomitantly, it runs the “Select providers” sub-process where the proposals are analysed and the suppliers that best fit the needs identified are selected. Following these processes and according to the information added so far, the team responsible for the migration’s process analyses the aspects of the solution and conducts, in collaboration with the supplier, a test to the solution. The “Map” sub-process follows near the end of this process. It is a sub-process where the services’ applications and data, defined to be migrated to the CC, and the corresponding CC services are matched. The migration’s process ends with the physical migration of the selected services to the CC’s environment. This process also includes a pilot test of the entire solution as well as the training of actors and the beginning of a continuous process of monitoring and improvement of the solution as a whole.

The case study, similarly to all scientific investigations, requires the definition of the criteria for evaluate their credibility. The quality of the research undertaken depends on the fulfilment of requirements such as reliability, validity and credibility that, once satisfied, ensure that the goal to be achieved with the research was reached with credibility. Consequently, the reliability is related to other investigators, who by that using the same methods would achieve the same results as they perform the research. The validity relates to the interpretation of the adequacy of the collected information, which implies that the findings have to be based on data. Finally, the credibility is the degree of probability between observed and described.

Considering that the research methodology used, the case study (selected among the methodologies presented according to the identified motifs) and that the results achieved have been subject of published papers and subjected to a set of experts, we consider valid the research methodology used in this work valid.

4.4 Organization's description

This section is now presenting the UPT, the organization where this case study has been developed. This description will be accomplished in two levels, the first one where the environment surrounding the case study will be disclosed and the second, a more technical one, where the details of the IT's infrastructure of the UPT will be known.

4.4.1 Problem statement

With the ever-changing necessities of day-to-day and the subsequent demands of IT to accommodate these developments, the circumstances where the requirements of an occasional IT resources' needs - such as higher processing capacity, memory and extra servers to attend the necessary requirements - appear recurrently.

Some of the existing servers, of the UPT IT's infrastructure, are no longer able to fulfil the tasks requested. Yet, others had to be temporarily replaced to solve some technical failures, causing a downtime in services, a circumstance not always compatible with the services' needs and not well suited with the normal functioning of the organization. Therefore, the UPT, decided to search a solution for their problems in the availability of services and servers. The solution should solve the technical issues and conform to the needs of the organization, including the financial services and academic ones. To this extent, the information received from the different areas of the University proved to be an important contribution.

4.4.2 The organization

The UPT is an organization of higher education cooperative and scientific research whose creation was legally supported by Order no. 122/86 of June 28 being its usefulness recognized. This organization teaches academic degrees and post graduations, recognized by the authority, for which features its own university skilled and qualified, spread over four departments: "Law", "Economy, Management and Information Technologies", "Psychology and Education" and "Tourism, Heritage and Culture". The UPT offers a large campus, in-

serted into the University's polo of Asprela, recognized for their high degree of technological innovation, a commitment that aims to provide students who attend high quality education ("Universidade Portucalense Infante D. Henrique - Apresentação," 2013).

UPT was chosen for this case study, to allow confront theory (migration's framework developed) with practice and thus demonstrating the validity and feasibility of the developed work. The motives that led us to choose this organization are based on the knowledge that we have of the organization and the openness demonstrated by its heads that enabled this study. Furthermore, the University is on the development time of this study, performing a migration of a group of its servers to a private cloud and the problems they had to solve were at all similar to the framework developed intended to address.

4.4.3 The information technology's infrastructure

At UPT, the IT's infrastructure supports the activities of the University, such as teaching, support services (Administrative Services, Academic Services, Technical Services, Legal Consultancy and Advisory Planning Services and Social Action) and students' associations.

The team in charge of the UPT IT's infrastructure is the Information Systems Area (ISA). It includes seven full time technicians and one working in part time. The ISA's responsibilities include the servers' maintenance, network's management, Helpdesk, application's development and maintenance (hardware and software).

4.4.3.1 Servers

The UPT computing infrastructure includes three major server groups, one supports the teaching activities, while the second holds all tasks related to administrative services also supporting the University and a third backs up the IT's infrastructure. These server groups support 17 computer labs, school activities, classrooms, administrative offices and the management of the University.

The services offered by these groups of servers are accessed by workstations both within the University's network and via Internet (VPN and traditional). The multitude of services

provided includes databases servers from different vendors (Microsoft SQL, MySQL, PostgreSQL) that give information for applications either Web (running on Web servers such as Apache and Internet Information Server) or client server applications (such as print management and ERP).

Additionally, and because the set of services have been constantly evolving over time, these server applications (both database and web servers) exist in distinct versions and are installed on multiple server operating systems (typically Microsoft Windows and Linux in various versions). The backups for all of these applications and servers are configured and running according to the UPT policies. Similarly, the security is properly configured according to the security policies in use in the organization, both at the server and at network levels.

In its most basic form, a cluster is a set of two or more computers (the so-called nodes) that work together in order to run applications or to perform other tasks so that the cluster's users have the impression that it is only a single computer. The cluster's nodes are constantly communicating with each other to detect a failure or an unavailability of a node. If one of the nodes is not available, another one immediately starts providing the service without human intervention in a process known as failover. The administrative area database servers - because of the importance of their role in the normal functioning of IT (and consequently the organization) and the need to maintain a high availability of access to information - are installed in a cluster environment with the operating system Microsoft Windows 2000 Server.

4.4.3.2 Applications

The servers, applications and data's architecture of an organization are closely related to the applications and services intended to be provided by the organization.

The Information System of University Portucalense (SIUPT) is an application continuously being developed by the ISA of UPT. It is used in the management of academic activities, such as, student's enrolment, registration and teaching. It is a web application (running on an Apache web server) for general use by the entire population of the University (faculty, students and staff) whose information is stored in a database Microsoft SQL Server 2008. This application already works on a virtual server (with an operating system Microsoft

Windows Server 2008) which caused a decrease in costs as a direct result of reducing the number of physical servers required, a better usage of the hardware, and a higher easiness in migrating to other environments (avoiding reinstallation and reconfiguration). The virtualization also facilitates the migration to the CC. The UPT website, which shares the servers' infrastructure with SIUPT, is closely related to this application (sharing and management of information). Another web platform that interacts with the SIUPT (a learning platform) is the platform providing information to the curricular units. It is used by teachers for the content's availability of different degrees taught at the University. This platform, available to teachers and students, operates on other servers, not yet virtualized, with the Linux operating system, the Apache web server and the MySQL database.

The SIUPT also interacts (at database and web services levels) with the application of the financial support, based on an application installed on each user's workstations and a database server Microsoft SQL Server 2000. The database's cluster houses the database of an old academic management's application still available for information's reference and other database from an old application of financial support (only in use for historical reference).

In addition, also interfacing with the SIUPT and making use of a server with the operating system Microsoft Windows 2000 Server and an engine database Microsoft SQL Server 2000 (non-virtualized) is the application that controls the printing system. The interaction between this application and SIUPT is also performed at the database level, allowing students to query the history of prints and the maintenance of the balance (loading and query values).

This set of applications, with their intricate relationships and dependencies as well as their issues, contributed to the decision of migrating to a private cloud.

4.4.3.3 Data communications network

Consisting of a structured network-based on the Internet Protocol (IP) over Ethernet and Asynchronous Transfer Mode (ATM) the network data communication interconnects all workstations, servers, printers and other resources on a local computer's network. To allow an easy access management and security, the data network is split into multiple virtual networks (VLANs) grouping students, teachers, researchers and support services, which

are interconnected on a router that defines the security policies inter-vlan. The network fixed access points are distributed by the offices of teachers, classrooms, computer labs, the different rooms of users and services all over the University.

The Internet connection is provided through a link supported by fibre optics. This connection allows the access to services provided by external suppliers, and the sharing of the resources of the organization for users located outside the University.

4.5 The adoption of cloud computing at UPT

To obtain all the information for this case study, the author followed the implementation's project of a private cloud at UPT. This follow-up took place with us being present both in working meetings held (with the selected suppliers, the approved vendor, the technical team responsible for the implementation of the IT project and other staff members with responsibilities in the UPT) and in decision-making throughout the whole project as the IT area's manager of UPT. Thus, the information provided in this work reflects the author's participation during the course of the entire migration's project, which allowed an in-depth knowledge of the whole procedure and a privileged access to the information necessary for this case study.

Under framework's validation, we understand the confirmation that the developed framework behaves properly in relation to the goals of the study. The implementation of this case study (described in this chapter) followed the directives defined on the M2CC's framework. This way, together with the papers published and the information gathered with the group of experts, we intent to validate the developed framework, reason why the following sections match the processes of the framework.

4.5.1 Define a strategy

A first approach to solving the problems with the servers was based on purchasing some servers for the most urgent situations in order to replace those who had the greatest impact to the business. However, this option has been placed aside, since there were some servers whose use increased exponentially during some periods (e.g. admissions' time for different degrees of the UPT, the beginning of school semesters, times of school evaluation) and on

the remaining this extra capacity was not used. Moreover, the problem of maintaining the service in operation (for instance, due to technical problems) remains.

Another issue that caused the rejection of this type of solution was the fact that some servers were used for testing server's applications, and thus once the tests were made, the servers were no longer necessary.

However, attributable to the specified constraints, it was envisaged to use a CC solution that could solve the three major issues, namely elasticity, the use of temporary servers (and hence the profitability of the investment) into operation and the maintenance services (quality of the services provided). Accordingly and to understand and ascertain the suitability of a CC's solution to fill the needs, the ISA of the University, started researching on the CC, more details on this paradigm can be found in in section 2.1. After the paradigm was understood, the IT and the business' management found that the CC was the most appropriate technology to solve of the problems presented and was thus initiated the development of a plan that would indicate the next steps to be taken, the participants in the process and would outline their responsibilities and major requirements.

Table 33 presents the inputs, outputs and the participants of the "Define a strategy" process to better comprehend the behaviour of the M2CC's framework. A similar table is presented at the end of each section describing the use of each of the M2CC processes. The column "Input" contains the external information needed by the process to work. The column "Output" includes the results produced and the participants' column includes the stakeholders and the staff responsible for the process.

Table 33 - Define a strategy synthesis

Input	Output	Participants
Issues to solve and constrains.	Strategy to follow, implement a private cloud, maintain the actual services, although on the cloud	**ISA** General overview with technical information regarding the current IT's infrastructure, main issues of the current IT solution, pros and cons of CC **Business management** Information concerning the business, business' constrains, support the project of migrating to the CC;

4.5.2 Identify and understand

To obtain all the necessary details and fully comprehend the entire IT's infrastructure, that is software, hardware, data, applications and services, the ISA gathered information concerning its server's infrastructure, information handled and the available services. This information will be helpful throughout the whole process to select what to migrate to the CC, to request proposals from the CSPs in for solving the problems, to enable a correct evaluation of the proposals received, in short, to make a proper and effective migration to the CC. To structure the gathering of this information, groups were formed according to the subsections indicated below (according to the developed framework). Due to the information already available in the UPT, no extra tools were necessary to gather this information. However, this same information could be added using the ITIL's processes as well as tools such as the purposed in (Bai et al., 2013).

4.5.2.1 Details

The details of the IT services delivered are presented, according to the ITIL (service transition), in the catalogue of services. Since the present migration to the CC does not intend, in this phase, to change the services already available to users, it was not considered necessary to use more details than those previously exposed. Thus, we can group the information regarding the services in Table 34 where we introduce an excerpt of the UPT's catalogue of services (business + technical), matching the services that would equate to migrate to the CC.

Table 34 - Service catalogue

Service name	Description	Type	Supporting Services	Business impact	Owner	Business Priority	Service hours	Security Rating
SIUP	Service available via web whose role is academic management	Customer-facing	DB,ERP	High	Development team	Critical	24x7x365 with an availability of 99.99%.	High
ELEARN	Open Source Learning Management System (LMS)	Customer-facing	DB1,SIUP	High	ASI	Critical	24x7x365 with an availability of 99.99%.	Medium
WWW	Portucalense Web site	Customer-facing	DB,SIUP	Medium	ASI	Medium	24x7x365 with an availability of 99.99%.	Medium
Library1	Is an open source Integrated Library System (ILS),	Customer-facing	DB2	Medium	Library	Medium	24x7x365 with an availability of 99.99%.	Medium
Library2	Is an open source repository software package typically used for creating open access repositories for scholarly and/or published digital content	Customer-facing	DB2	Medium	Library	Medium	24x7x365 with an availability of 99.99%.	Medium
ERP	Institutional ERP	Customer-facing	DB2	High	Financial area	Critical	24x7x365 with an availability of 99.99%.	High
DB	Database SQLsrv3	Support		High	IT	Critical	24x7x365 with an availability of 99.99%.	High
DB1	Database MySQL	Support		High	IT	Critical	24x7x365 with an availability of 99.99%.	High
DB2	Database	Support		High	IT	Critical	24x7x365 with an availability of 99.99%.	High

4.5.2.2 Costs

The information regarding the costs of the current solution is useful to compare them with the costs of the solution migrated to the CC. Since a private cloud is to be installed on the customer's premises, the UPT must initially support all charges as opposed to a public cloud, where the customer simply pays the services he uses. Conversely, we solved several issues simultaneously. One of those issues is the trust, since the infrastructure is on premise

and maintained by the in-house staff. The legal problems associated to the legislation applicable to the information stored on the cloud are related to this, and these are solved in this implementation. The Single Point of Failure (SPoF) caused by the Internet access or the need to upgrade/create a backup solution is solved and consequently the loose of access to the service due to Internet access problems. Additionally the compatibility and interoperability questions are also solved.

4.5.2.3 Value

The value indicates the importance that is assigned, by the organization, to each of the services, applications or information that is considering migrating to the CC. Thus, applications with too much value should not be migrated to the cloud unless the cloud's environment is fully trusted by the organization, for example a private cloud owned by the organization who migrates services to the cloud.

In the current study, the UPT's cloud (private) is fully trusted by the organization. Therefore, the value was not considered as a weakness to migrate the applications to the private cloud. Contrariwise, a decisive aspect for migration was considered, mainly because of the great value that the applications and data in question represent for the normal functioning of the University. These will guarantee the improvement of service quality that the cloud brings to these services.

4.5.2.4 Benefits and issues

In this subsection, we introduce the benefits and issues included in the actual solution. Accordingly, Table 35 presents the benefits and issues recognized to this current solution.

Table 35 - Benefits and problems of the current solution

Benefits	Issues
• Provides the currently required services by the business. • The services and applications are properly integrated • The security is properly configured according to the identified needs • Accesses properly configured	• Hardware problems • Difficulty in creating new services • Availability • Poor performance of the services • Maintenance costs

4.5.2.5 Requirements

The identification procedure includes requirements analysis of the features to be considered for services, applications and data to meet the needs and expectations of the organization. Therefore, and taking into consideration that was it was planned to migrate services to a private cloud, in a short time and to maintain the already existing applications running, the requirements presented match the current characteristics. It is considered, however, the possibility of upgrades concerning operating systems and databases management systems that enhance the quality of services provided not entailing changes in applications already existing.

Taking into consideration the constraints exposed, the following requirements for the services candidates for migration to the CC were identified:

- Database management system: the applications either developed by the ISA or acquired externally such as the financial area and the printing control, are based on database servers Microsoft SQL Server 2000. Not being economically feasible, nor part of the planning in the short or medium-term amendments to such applications, the requirement is to keep the vendor's management of the system database (although being possible to perform version updates). This is a mandatory requirement for these applications. Likewise, a former application of the financial area (retained for consultation issues of historical information) works using a different database management system and must be maintained.
- Operating Systems: Similarly, the Microsoft Windows operating system must also be maintained, although version updates can be considered possible. This same solution must be adopted for the web applications providing a content for school activities and the management of library work using another operating system. This situation should also remain unchanged.
- Cluster's environment: The existing database servers work in a cluster's environment. Therefore, it is mandatory that this server will be migrated to a virtual machine or kept in a cluster functioning in the cloud's environment.
- The backup process: All the services have configured the backups of information according to the policies defined by the UPT. Therefore the backup's responsibility of the services migrated to CC should be transferred to the management of the cloud.

- Computer Network: All IT services of the UPT are available over the TCP/IP communication protocol. Consequently, the solution to be installed should also work on this protocol. An important aspect on the security and access control to IT is based on the data's network, namely, the operation of virtual networks. Therefore, the solution to be installed must support the separation of services / servers through virtual networks now existing or to be created.
- Dependencies of services: The services planned to be migrated to the CC hold dependencies from other services that will be migrated to the CC and from services that will remain unchanged. Therefore, the dependencies presented on subsection 4.5.2.5.4 below, are also seen as a requirement that must be satisfied when migrating to the CC.

4.5.2.5.1 Resources

According to the strategy initially drawn, the applications that were equated to being migrated to the CC require no additional resources for its normal functioning. Therefore, taking into account that one of the goals of this migration is to achieve a significant improvement in the availability of the existing services as well as a consolidation of the same, they shall be considered as requirements for the normal functioning of each of the applications and identified as recommended manufacturers of each of the applications.

4.5.2.5.2 Communications

All servers access the computer's network with a speed equal to or greater than 100 Mbps using the TCP/IP protocol over Ethernet and Gigabit Ethernet.

To overcome the limitations imposed by the physical architecture of a data's network, the servers are connected using the VLANS[1]. The number of virtual servers in each network diverges according to the needs; however, each server belongs to a VLAN only. The access control, performed by way of the network, is achieved not only through the firewall installed on each server but also through the access lists configured on a router.

[1] A Virtual Local Area Network (VLAN) is a local network that groups a set of machines in the same logical network instead of a physical one.

4.5.2.5.3 Access and Security

According to ITIL (Lloyd et al., 2007) the security objectives of most organizations consist on availability, confidentiality, integrity and trust transactions. The identification of what must be protected as well as the degree of protection is defined by the business. Accordingly, the security policies for the services that the UPT is planning to migrate to the CC are properly configured. The security items, the authentication of multiple services using Microsoft Windows platforms, the configuration of each server's firewall, the settings of the services and the existing network configurations must not be changed.

4.5.2.5.4 Dependencies

To understand the dependencies of services and servers, Figure 26 presents (only to those who UPT intends to migrate to DC or are in any way related to the services to be migrated) the dependencies between the different servers and between applications.

The information introduced in the following paragraphs is an excerpt of the information contained in the configuration management database (CMDB).

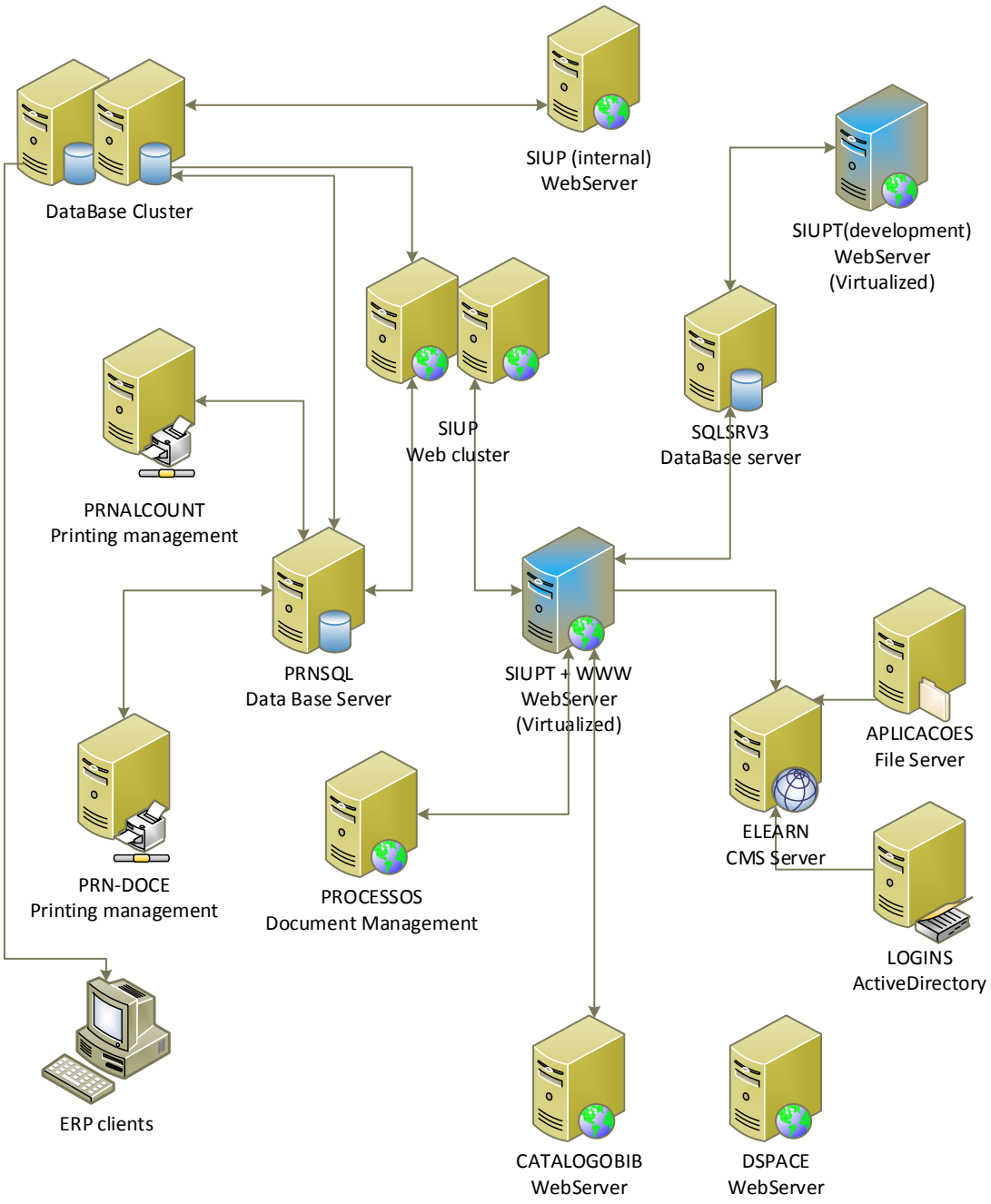

Figure 26 - Dependencies among the services

As defined by ITIL (Lloyd et al., 2007) the CMDB is part of the Configuration Management System and is a repository containing an authorized view of the components within the IT's infrastructure, with each component – such as a server or application – represented by an ITIL-defined Configuration Item (CI). The CMDB also captures relationships between these CIs – for instance, if an application runs on a specific server.

Case study

The set of servers and applications UPT has intent to migrate to CC includes some servers already virtualized (marked as virtualized) and some physical machines with different processors, operating systems and memory.

The machine SIUPT (one of the machines already virtualized) runs an Apache web server on a platform Microsoft Windows Server 2008 R2 and provides a web application with the same name, used throughout the University's community to manage the academic activities. The information in use by this application's server is managed by a database server Microsoft SQL Server 2008 running on an operating system Microsoft Windows Server 2008 R2. This group also provides other web servers such as the University web server and web servers from research centres.

The second machine also already virtualized, is used by the development's team, as a server for development and testing of Web applications before being put into production. An access to this machine is restricted to the development's team and Helpdesk services. The SIUPT in a programmatic level provides web services, for example for authentication to other services such as document's management and Portucalense University Library management applications.

The SIUPT's former version, the SIUP, is currently used mainly to query historical data and is distributed over five physical servers. Two belonging to the databases cluster, providing database services for applications (including SIUP) , the other two servers, belonging to the web's cluster providing web services for applications, such as a website that hosts the web pages of the teachers of the UPT and the SIUP's interface to the outside of the University. The internal interface of this application, providing another type of operation for internal clients such as academic services, is available through the machine SIUP (internal). The SIUP also supplies web services, used in other applications, for instance by SIUPT, to access information from the application's printing and financial management.

4.5.2.5.5 Availability

ITIL (Iqbal et al., 2007) defines availability as the ability of a Configuration Item or IT Service to perform its function as agreed when necessary.

According to Hui Liu et al. (2010), the availability can be viewed from the perspectives of business and users. From the point of view of the business, availability is related to the impact on vital functions of the business itself. For the users, the significance is the response time; however, to the CSP the importance is the IT service and the component's availability. Therefore and considering the importance of the information stored on these servers for the University and for students and teachers, the servers must have an availability of 99.9%. Additionally, and bearing in mind that the availability is also affected by servers problems, including hardware, the solution to be installed should reduce these problems.

As stated by Vernon Lloyd in (2007), the availability of a service is as good as the weakest link of the solution. The availability of the solution can be much incremented through the elimination of SPoFs, for example at the components' level. Thus, and unlike the current solution, the key components of the solution must have solutions to eliminate the SPoFs, including, for example, components' duplication.

4.5.2.5.6 Capacity

The purpose of the ITIL process "Capacity management" (Lloyd et al., 2007) is to ensure the existence, at a cost-justifiable capacity and in all areas of IT, according to current and future needs of the business. The process should cover all areas of technology, both hardware and software for all components and information technology environments.

Currently, the systems are being installed according to the available hardware if it fulfils the required minimum capacity of the systems that should support.

4.5.2.6 Synthesis

Table 36 presents the inputs, outputs and the participants of the "Identify and understand" M2CC's process.

Table 36 - Identify and understand synthesis

Input	Output	Participants
The output of the "Define a strategy" process	Detailed information regarding current IT's infrastructure (services, applications, data, infrastructure)	**ISA** Technical details concerning IT services, benefits and issues, requirements, dependencies among services; **Financial services** Budgeting (existing solution costs); **Business management** Value of services, priorities;

4.5.3 Define, select, analyse and map

Although in the earlier process, the goal was to gather information concerning the current IT's infrastructure and the operation at the UPT, in this process the aspects related with the migration to the CC are defined. Moreover, the CSPs are identified and selected, the impact of the migration to the CC is analysed and with the information gathered, the in-house services to their CC counterparts are mapped.

4.5.3.1 Define a migration plan

The migration plan includes the delineation of details such as the definition of the stakeholders in the process and allocation of responsibilities, the definition of the applications and information to migrate requirements and security, among others. This section presents the constituents considered in the migration's plan.

4.5.3.1.1 Migration stakeholders

This task identifies the actors of the migration's process. The actors involved in the process of migrating to the CC include all those who directly or indirectly participate in the process. The participants were grouped, (see Table 37), according to the type of interaction they had in the process.

Table 37 - Actors of the migration process

Group	Interaction
Information systems area	Technical issues related to the implementation and technical decisions
Financial services	Includes financial issues for analysis of payments forms and related issues
Juridical services	Legal issues and contracts
Administration	Business decisions
Users	Interact with the services provided
CSP	The CSP and technicians who installed the solution

In the financial and legal areas, the actors were the area managers; in the computing technical area, beyond the manager, also cooperated the responsible for the network and server management and the team responsible for the applications' development.

The goal of this migration is to improve the working conditions of the users; we consider them as stakeholders in the process with the role of validators of the whole process.

4.5.3.1.2 Responsibilities

The allocation of responsibilities to each of the stakeholders of a process is a crucial step towards a fluid way of migration, allowing each player to know the role it he has to play, in addition to allow a professional to complete a task and another professional to start the execution of the next task without any service breaks.

Accordingly, Table 38 introduces the RACI model that outlines the responsibilities of each actor in each activity of this project's migration to the CC.

Table 38 - Responsibilities assignment

	UPT						Ouside
Entities / Activities	IT area			Other UPT entities			Installer company
	IT management	Network and server management	Application development management	Legal	Financial	Administration	
Define a strategy							
Define a strategy	AR	C	C	C		C	
Identify and understand							
Details	AR	C	C				
Costs	AR	C			C		
Value	AR	C	C	C	C	C	
Benefits	AR	C	C	C	C	C	
Requirements	AR	R	R		C		
Resources	A	R	C				
Communications	A	R					
Access and security	A	R					
Dependencies	A	R	C				
Availability	AR	C	C				
Capacity	A	R					
Define, select analyse and map							
Define a migration plan							
Migration stakeholders	AR	I	I				
Responsabilities	AR					C	
What to move	AR	C	C				
Cloud computation typpes	AR	C					
Requirements	AR	C	C				
Capacity	A	R	R				
Number of providers	AR					C	
Security	A	R	R				
Access	A	R	R				
Select service providers							
Identify	AR	C	C				
Select	AR	C	C	C	C	C	
Analyze and test							
Analyse							
Impact	AR	C	C				
Risks	AR	C	C				
Advantages and issues	AR	C	C				
Costs	R				C	A	
Staff	AR			C			
Communications	IA	R					
Security	IA	R					
Legal	I			R		A	
Applications and data	AR						
Contracts and SLAs	C			R	C	A	C
Solution testing	A	R	R				R
Mapping	AR	R	C				
Migrate and govern							
Migrate	A	R	C				R
Perform a pilot test	AR	R	R				
Training	I	I					AR
Evaluation and monitoring	AR	R	C				
Governance	AR	R	C				
Continuous improvement	AR	R	C				

Legend

R: Responsible **A:** Accountable **C:** Consulted **I:** Informed

4.5.3.1.3 What to migrate

Based on the knowledge acquired, in the information gathered from the CSPs and in the decisions of the management in this stage, the staffs responsible for the migration to the CC (technicians from ISA) define what to migrate. Thus, it was decided to migrate primarily the applications related to the academic and financial management, the applications used by the library services and the applications related to the availability of content for the degrees taught at the University.

4.5.3.1.4 Cloud computing types

According to the availability, the CC services are typically divided into public cloud, private cloud and hybrid cloud. The selection of the CC considered three major issues: the technical, safety and availability and the economic.

Under the technical point of view it was taken into consideration the impossibility of updating some applications still in production and the need to keep operating systems and other resources used for these applications, unchanged and the intricate relationship between the delivered IT services. Additionally, the difficulty to return (if necessary) to the traditional environment after unsuccessful migration to a public cloud and the limited time with the process for migrating to the CC it was taken into account.

Regarding the safety and availability, the confidentiality of the information handled by the processes migrated to the cloud and the high degree of availability of necessary applications and data were weighed.

As far as the economic issues are concerned, we did not ignore the higher initial investment carried out when installing the private cloud regarding the use of the public cloud.

Opposed to this high initial investment, we took into account that the migration to the CC significantly improved the operating costs since the processes of virtualization, automation, standardization dramatically reduce, support costs and operation the migrated server as well as reducing time-to-production of new servers.

Therefore, taking into account the above issues, the decision was made to use a private cloud architecture. The public cloud was put aside mainly because of issues related with

data privacy, impact on the current IT infrastructure and vendor lock-in. The hybrid's cloud solution also holds great impact on the IT infrastructure since the services and applications have to be reconfigured, in some cases recoded, to allow some services to remain at UPT while others are migrated to the CC. Currently, it is not feasible to make such changes to applications. Another issue is the latency that is the time required to transfer data over the Internet between the CSP and the UPT.

4.5.3.1.5 Requirements

In this sub-process, we identify the requirements that the organization wishes to see fulfilled with the migration of applications and data services to the CC. The requirements identified herein are an addition to those identified in section 4.5.2 and as such should be compatible with them. Accordingly, the requirements to migrate to the CC are identified in Table 39.

Table 39 - Solution requirements

ID	Requirement	Description
R1	Servers' consolidation according to their function or operating system	Physical machines should be grouped according to the security requirements and the services they provide based on the operating system they run. For example, the servers' database Microsoft (control prints, and SIUP, SIUPT, financial management's application, they should be together in the same machine), similar to MySQL server (e-learn, Catalogobib among others).
R2	Modification of IP networks of servers	Some of the current servers are on the same network of their users, but in order to improve safety, so that it does not only depend on the server's software, the intention is to place the servers in other networks, something that will be created for this purpose, allowing the traffic control to be mastered by the network's equipment.
R3	Dynamically changing servers' characteristics	Ability to dynamically change servers' characteristics like CPU, memory and disk space so that the services achieve the organization's objectives and thereby fulfilling the ITIL specifications of capacity's management.
R4	Usage statistics and performance analysis	Allow to access, gather and create records (logs) of usage statistics and performance regarding the constituents of the system.
R5	Protection of host machines	Bearing in mind that an attack on a host machine (physical) can have great impact on all virtual machines that depend on it, the host machines must belong to an IP network dissimilar from all virtual machines' networks. This way should be used a network with access only from the team dealing directly with the machines. Additionally, all sensitive components must be duplicated.

4.5.3.1.6 Capacity

Being aware that a key factor in the success of capacity's the management is to ensure that it is taken into account during the design phase (Lloyd et al., 2007), we considered it here in plan design's migration to the cloud. Thus, the capacity identified in the section 4.5.2 is also regarded here so that the capacity to migrate services to the cloud remains in accordance to the business needs and cost-justified.

The ability to dynamically change the features of the servers will facilitate the maintenance of the capacity's plan that adequately reflects the current and future needs. This happens because it is no longer necessary to plan in advance the increases in memory or disk space or a processor's update to answer to work peaks or new requests in a more adequate way. Moreover, the certification that the results meet all the performance targets established, it is easier to achieve because the solution it is installed to allow adjustment of characteristics of the applications servers to migrate.

An additional goal of the capacity management is to assist in the diagnosis and resolution of incidents and problems related to the performance and capacity. Since this solution must enable a dynamic modification of the features that may influence the performance of the solution, the incident's diagnosis is made easier because it allows to perform a "what if" analysis in a simple way once it is not necessary to physically change the hardware components to be able to evaluate the best solution. Similarly, we can assess the impact of any changes in the "Capacity Plan" as well as in the performance and capacity of all services and resources.

One last objective of "Capacity Management" (ITIL) includes an implementation of proactive measures to improve the performance of services wherever it is economically justifiable to do so. To meet this goal the solution must comply with the requirement R4 to make it possible to monitor the performance and, if necessary, take the corrective measures.

4.5.3.1.7 Number of CSPs

As far as the installation of a private cloud with a relatively small number of services is concerned, no other cloud service models will be used (PaaS and SaaS) nor was it considered necessary to have more than one CSP.

4.5.3.1.8 Security

According to Michael Armbrust et al. (2009), the main concerns in the deployment and utilization of the CC services are security, privacy and integrity. Accordingly, this task defines the security requirements for services, applications and data to be migrated to the CC.

From a technical point of view, the majority of security risks associated with CC are already present in traditional data centres (Cardoso & Simões, 2012a). Accordingly, and considering that what is to migrate and to a private cloud, the arising security problems are similar to those already found on the servers of UPT.

The virtualization can increase the impact of some safety hazards since the successful attacks host machines (where the hypervisor is located) can potentially compromise each virtual machine hosted on the host machine. However, such events can be reasonably avoided and / or controlled by using appropriate protective mechanisms to host machines. Failures in virtualization platforms themselves are also an obvious risk but, so far, there are few examples of such failures (and fewer negative consequences of such failures) (Cardoso & Simões, 2012a).

The ITIL process responsible for the security is the "Information Security Management" (ISM) whose main objective is to align IT security with business security to ensure that the information security is effectively managed in all service (Lloyd et al., 2007). However, most problems of the CC are not inherently technical, but they relate to the implicit need to trust third parties to maintain critical information and provide critical IT services (Cardoso & Simões, 2012a).

It is taken into account that the services to migrate to private cloud already follow the safety standards defined in UPT and that there will be no differences in the way services work. Additionally, since it is a private cloud installed the premises of UPT and that the responsibility and maintenance continue to be carried out by members of UPT, we does not consider necessary to change the security policy of these services.

4.5.3.1.9 Access

In a similar way to what happens with the security, the access policy to services is regarded as appropriate and should remain unchanged after the migration to private cloud's environment. With this procedure, we also intend to cause the least possible impact on the normal operation of services.

4.5.3.2 Select CSPs

An incorrect supplier's selection causes problems affecting the organization in either the cost or the quality of the final solution. In this process, the potential suppliers are identified according to the needs uncovered above, and selected those that best fulfil the constraints presented by the UPT.

4.5.3.2.1 Identify

According to what has been the established earlier, the solution to be implemented undergoes a private cloud mainly providing infrastructure services (IaaS). A solution that does not place the UPT in a vendor lock-in condition is envisioned, i.e., an independent solution in terms of supplier. The initial investment was offset by the information's privacy, the access speed, the nonexistence of vendor lock-in, by decreasing legal problems (related to the location of information). Thus, the prospection was accomplished either by direct contact, or by mail or even by an appointment of corporate websites from companies to ascertain which of them would be able to install an intended solution.

4.5.3.2.2 Select

In possession of the collected information in" Identify and understand" (section 4.5.2) and in "Define a migration plan" (section 4.5.3.1) and to obtain the initial proposals, individual meetings with each of the selected suppliers were held. The University IT's infrastructure was disclosed to allow service providers to draw a first attempt of the solution. After this first interaction, some of the competitors were eliminated because they did not have suitable proposals. Two more interactions followed, this time with a smaller set of suppliers, to clarify some issues and present the final proposals. Upon the receipt of proposals from this set of suppliers it was necessary to validate the information received and select the CSP

that best met the needs previously identified. After analysing the advantages and problems, the security issues and risks that each selected solution involves, the supplier that would implement the solution was elected by the management of the information's technology area in collaboration with the team responsible for managing servers and the team responsible for the application's development,

4.5.3.3 Analyse and test

In this sub-process, the aim is to verify that everything is according to the requirements identified to proceed to the implementation's process of mapping the local services to their cloud's counterpart.

4.5.3.3.1 Analyse

In this step, the issues that may influence the process of migrating the IT services to the CC are evaluated.

4.5.3.3.1.1 Impact

ITIL defines impact as a measure of the effect of an incident, problem or change in business processes (Iqbal et al., 2007). The impact is usually based on how service levels will be affected.

During the tests, one of the results achieved was an expected and significant improvement in terms of response time in the tested application (SIUP) either in application execution or in the database access. The other applications migrated to the CC also suffered improvements, namely in runtime. Therefore, we expect a positive impact on services migrated by an increased speed of processing, reliability and availability of services. Regarding to the availability of services, we go from a solution with a reduced level of redundancy to another completely redundant in network access, power supplies, storage and processor.

4.5.3.3.1.2 Risks

A risk, according to ITIL (Iqbal et al., 2007), is a possible event that may cause damage or loss, or affect the ability to achieve goals. A risk is calculated by the likelihood of a particular threat to occur, the vulnerability of the asset to the threat and the impact generated if it had occurred.

To properly assess the risks with the purpose of important countermeasures, the methodology prescribed by ITIL's management of risk (M_o_R) (process responsible for identifying, assessing and controlling risks) (Iqbal et al., 2007) was followed.

Therefore, we started identifying the potential risks and threats. The results are illustrated in Table 40.

Table 40 - Risks and threats

Risks	Threats
Losing access to IT systems	Natural causes
	Electrical power's failure
	Sabotage
	Software problems
	Attacks
	Equipment's failure
	Data network problems
Information loss	Technical failure
	Human error
	Malicious software
	Software problems
	Virus
Security	Virus
	Malicious software
	Technical failure
	Application attacks
	Software problems
	Unauthorized access
Infrastructure	Data network
	HVAC
	Electrical power failure

After identifying the risks that the implementation may suffer, these were analysed to evaluate and comprehend the effects and exposure that the organization may have and thus

enable the UPT to take the appropriate decisions. Given that the implementation occurs on the premises of a UPT data centre, most risks are already adequately safeguarded. However, as we will add more equipment to the already existing, will be necessary to validate that the current infrastructure, namely the cooling, energy supply and data network can accommodate the addition of the new equipment. Issues like viruses, software problems or hardware problems were reported to solution providers so that they were solved either with antivirus solutions or failover systems, or even with redundant hardware components.

Based on the risks identified in Table 40 the risk profile was set up in Figure 27, which relates the probability of the risk happening at different levels of severity. With the help of this profile, some preventive measures have been taken such as strengthening the HVAC equipment, the increasing of network equipment and validated, with the supplier, redundancy and warranty for the solution to be installed. Thus, it was possible to reduce the probability and severity of risks to diminish the impact that they would have for the solution and consequently for the business.

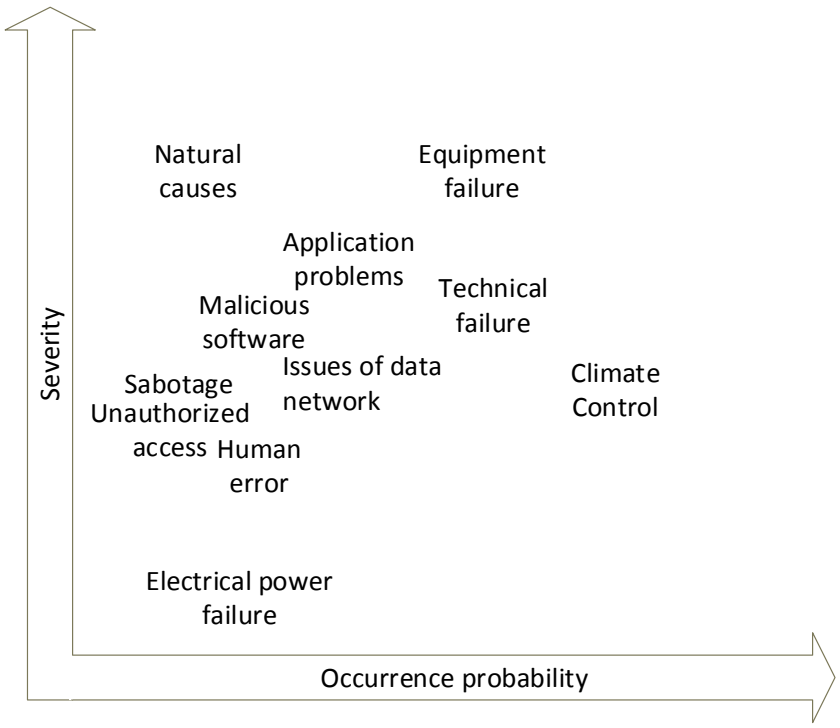

Figure 27 - Risk profile

4.5.3.3.1.3 Advantages and challenges

The SWOT analysis is a strategic planning method used to evaluate the strengths, weaknesses, opportunities and threats involved in a project. By using this tool, Figure 28 identifies and compares the advantages and challenges found both in the actual infrastructure and in the migration of services to the CC.

As may be seen, the weaknesses of the actual infrastructure are solved by the strengths afforded by the CC. For example the, "Unstable applications" are attributable to issues on the hardware platforms supporting these applications. These weakness are solved with the migration to the CC and the equivalent improvement in hardware both made available in this application.

Strengths	**Weaknesses**
Resource pooling On demand self-service Measured service Cost reduction Risk reduction Scalability Service's Availability Improve hardware Agility/elasticity Broad network access	Our technologies facilities are obsolete Internal operating problems Higher overall costs Unstable applications The ERP works slowly The web site technology need to be updated Initial investment
We can expand our services to meet the customer needs Provide better services	The competition offers new services
Opportunities	**Threats**

Figure 28 - Advantages and challenges SWOT analysis

4.5.3.3.1.4 Costs

Although it was not possible to determine the cost of the original installation, there will be achievements from implementing the solution. At the end of the migration, 14 physical machines (with corresponding savings of energy consumption, space requirements and operational management) will be released. Accordingly, considering not only the sum of the average consumption of the old servers but also the sum of the average of the new servers,

the number of physical machines reduced (14) and the fact that these new machines' power consumption is lower than the old ones, the power consumption decreases more than 70%. Regarding the software licences, four licences of operating systems and four of engine databases are released. This licences' release happens because, from now on, it is possible to consolidate some servers.

4.5.3.3.1.5 Staff

In this section, the issues related to the migration of services to the CC affecting the IT's staff are considered. Taking into account that, there will be many services, which would remain unchanged and available with use of the traditional servers, the team responsible for the data's network and the servers will remain the same. However, the need for training in use and maintenance of this new paradigm for this group should be pointed out. The remaining IT team, such as helpdesk, applications' development and maintenance of hardware and software have the same procedures for the services migrated.

4.5.3.3.1.6 Communications and dependencies

Since this migration does not consider the need to introduce new services requiring network access and since among the issues previously equated, network access does not appear, it is not considered necessary to change the features of the existing communication lines. However, the physical network is designed to enable either an increase in the number of applications or an increase in bandwidth requirements for the applications.

The dependencies of the services migrated are still satisfied.

4.5.3.3.1.7 Security

According to the migration plan, the information received from the supplier, the tests performed and classified as being a private cloud, it is not considered necessary to make changes to the initial plan.

4.5.3.3.1.8 Legal

One of the areas that concern the most when migrating services to the CC relates to the legal issues concurrently with the problems of security and data's protection. However, with a private cloud (hosted on the premises of the owner and managed by the same and in one locality) the issues of information's location and the applicable legislation do not arise. Nevertheless, it is also important to consider the subjects of an improper disclosure of information as well as other questions placed before the use of the CC. Therefore, it was not necessary to take these extra measures with concerning legal matters into account.

4.5.3.3.1.9 Applications and data

Here, the applications and data that are to be migrated to the CC as well as the necessary software to migrate to the CC are identified. Since the solution is based on IaaS and the private cloud supports our operating systems and our applications, no additional requirements have been identified.

4.5.3.3.1.10 Contracts and SLAs

As said by Vernon Lloyd et al. the "services providers should be aware that SLAs are widely used to formalize services based relations, both internally and externally."(Lloyd et al., 2007, p. 269). Internally among the departments of an organization, there may be other types of agreements, Operating Level Agreements (OLA) that define the support services to be provided and the responsibilities of each stakeholder. The objectives of these service level agreements include monitoring and increasing the customer's satisfaction with the quality of services provided. Achieving these objectives will support the migration to the CC as well as the maintenance of the services in the cloud. Thus, according to this idea, we considered in this implementation two types of agreement in this implementation, an SLA between the supplier of the private cloud and the University Portucalense and an OLA (existing) between the IT area of the University and the University itself. The first one is related to the installation, an initial configuration of the equipment and ensuring that the equipment remains operable for a specified period. The second assures that the IT area has to give to the University so that, with a certain degree of confidence, that the services offered work as expected.

Security issues found in the processes must also be reflected in the SLA, to take a written agreement with the supplier to ensure that the security needs of the customer are met. To that extend, the University has agreed, along with the supplier, the minimum-security requirements (such as security copies, network traffic separated by VLANs, duplication of key components and access levels) that should be ensured by the installation.

4.5.3.3.2 Solution testing

To solve minor issues prior to the presentation of the final proposal, a working meeting with the provider was held to schedule tests for some migration solution details. Thus, the selected provider, gave technical support and some specialized equipment with versions of operating systems and characteristics similar to those of the final solution to evaluate the solution and clarify the doubts that persisted.

These tests included, in an initial phase, the migration of an Oracle database engine (running so far in the cluster's environment on the operating system Microsoft Windows 2000 Server), and other databases engines Microsoft SQL Server 2000. After the installation of this prototype, services were available for 14 weeks for key users of the management, finance, IT computer area, who could assess the suitability of this migration.

In a second step, migrations from other physical servers to virtual by IT area were tested. These two sets of tests were successfully performed according to the answers of the first questionnaire. The Oracle machine (which was expected to be the trickiest stage of testing either by the age of the operating system or because it operates on a cluster and became a virtual machine environment without cluster) was successfully migrated. The same happened with the other set of virtualized machines during the testing.

4.5.3.4 Map

In this sub-process are mapped the in-house IT applications and data to their cloud counterparts. Accordingly, Table 41 shows examples of the mapping of services to their cloud counterparts.

Table 41 - Map services to their cloud counterparts

ID	Department	Name	Type	Part	Responsible	Scheduling	Order	Provider	Provider responsible	Cloud type	Service	Action to do before	Action to do after	Special conditions	Observations
1001	ALL	ERP	Data	All	FA,ISA	Outside working hours	1	UPT	UPT	IaaS	ERP	Migrate database	NA	NA	Physical to virtual
1002	ALL	ELEARN	Service	All	AC,ISA	Outside working hours	2	UPT	UPT	IaaS	ELEARN	NA	NA	NA	Physical to virtual
1003	ALL	WWW	Service	All	MA,ISA	Any time	4	UPT	UPT	IaaS	WWW	Migrate SIUPT database	NA	Uses the SIUPT database	Physical to virtual
1004	ALL	SIUPT	Service	All	AC,ISA	Outside working hours	3	UPT	UPT	IaaS	SIUPT	Migrate SIUPT database and SIUPT	Test connectivity with SIUP database	NA	Physical to virtual
1005	Library	DSPACE	Service	All	LIB,ISA	Any time	5	UPT	UPT	IaaS	DSPACE	NA	NA	NA	New virtual machine
1005	Library	Koha	Service	All	LIB,ISA	Outside working hours	6	UPT	UPT	IaaS	Koha	Migrate DSPACE	NA	NA	New virtual machine

Responsibles: FA - Financial area ISA - Information Systems area MA - Marketing LIB - Library AC - Academia

4.5.3.5 Synthesis

Similarly, to previous processes, Table 42 introduces the inputs, outputs and the participants of the "analyse and map" process.

Table 42 – Define, Select analyse and map synthesis

Input	Output	Participants
Define a migration plan		
The output of the previous processes	Stakeholders' identification Assignment of responsibilities Migration plan	**ISA** Identify stakeholders Assignment of responsibilities Define what to migrate Define cloud details Identification of requirements Decide the number of CSPs **Business management** Assignment of responsibilities Approval of ISA decisions Identification of requirements
Select CSPs		
The output of the identify and understand, the migration plan information gathered from the CSPs	CSPs list including prices and conditions	**ISA** Identify suitable CSPs Select the CSPs that most fit the identified needs **Business management** Approve the solution **CSPs** Detailed information regarding the services provided
Analyse and test		
The migration's plan and the list of the selected CSPs	Information regarding the solution that best fits the needs	**ISA** Evaluate the impact and risks Identify the advantages and challenges Staff's reorganization Requirements' validation Validate contracts and SLA **Financial area** Costs **Legal area** Validate contracts and SLA

Input	Output	Participants
		Business management Identify the advantages and challenges
Map		
All the information gathered	The map of applications and services to the cloud	**ISA** Map services to their cloud counterparts **CSP** Support the mapping process

4.5.4 Migrate and govern

This last process of the framework includes the sub-processes to achieve the physical migration of services and data to the CC and a pilot test to verify that everything is working as expected. It also includes a training step to provide the stakeholders with the necessary information to operate the new services, a step to address the governance of the new services and a step to continually improve of the achieved solution.

4.5.4.1 Migrate

Here the services defined in the earlier processes were physically migrated to the CC. The servers that were already operating as virtual machines further facilitated this step. To this group of servers the migration is resumed to the copy of the virtual machines' files to the new environment and the backup system's configuration. For the other group of servers the migration to the CC was trickier since prior to putting the servers on the new environment the IT's staff needed to virtualize the servers, which is not always an easy task to accomplish because of the servers' age, hence with old operating systems, with little or non-existent support, installed on old hardware platforms.

4.5.4.2 Perform a pilot test

ITIL defines pilot, under the "Transition of the Service" book, as the limited deployment of an IT service, launch or a process for the live environment (Iqbal et al., 2007). A pilot is used to reduce the risk and to acquire the user's feedback and acceptance. Thus, we tested, in this task, the functionality of the services migrated to the CC to verify that the new architecture works as expected before going into production.

The tests were performed by the supplier's team in collaboration with the IT area and the other areas of the University that had migrated services to the CC.

4.5.4.3 Training

The task of training the IT area (responsible for maintaining the private cloud after installation by the CSP) was taken into account from the outset of the project. For this purpose, all suppliers were ordered to include in their proposals the training and documentation of the solution they intend to install.

The training included components: the first one, the details of the installation were explained whereas the second was based on a one-day on-job training. In both types of training were present the management of the IT area and the network and server's management teams were introduced. If, in the first training, the themes followed the timing of the installation's process, in the second one an overview of the installed solution was given and followed by a detailed training (aimed at the continuing operation of the system) on each of its constituents.

4.5.4.4 Evaluation and monitoring

The evaluation of the solution included checking the acceptance conditions identifying that the migration is complete as well as the accordance with what has been hired by University Portucalense. Thus, the physical installation of the equipment (servers, system backups), tests of redundancy, the installation of software (operating systems, backup software, monitoring), the migration of servers agreed for the production's environment, the receipt and delivery of training documentation of the entire system have all been validated. The solution was deemed acceptable after the successful validation of all items (see Table 43).

Table 43 – Solution acceptance conditions

Group	Item	Done
Equipment physical installation	Servers	✓
	Management computer	✓
	Storage	✓
	Backup equipment	✓
Redundancy tests	Electrical power	✓

Group	Item	Done
	Servers	✓
	Storage	✓
	Connections	✓
Software installation	Operating systems	✓
	Virtualization platform	✓
	DHCP and DNS services	✓
	Active directory	✓
	Backup	✓
Migrating servers to the production environment	Oracle	✓
	Microsoft SQL Server	✓
	Apache	✓
	Windows 2000	✓
	Documental management	✓
Training and documentation	On-job	✓
	Training	✓
	Documentation delivery	✓

The solution was conditionally accepted though, since some problems might arise from a normal operation. Simultaneously its monitoring as a whole for detecting any anomaly that has not been possible to detect in the earlier tests was started. During the first week, some problems with backup software were detected and the supplier of the solution promptly solved these. Moreover, and according to the requirements by ITIL, as in SLA, it is important that OLAs be monitored to detect potential problems. Thus was the IT's area responsible for monitoring the compliance with the SLA and OLA and take corrective action it deems necessary when problems arise.

4.5.4.5 Governance

As previously said, the governance in CC is defined in (Guo et al., 2010) as the set of processes used to monitor and control the approval and implementation of a service based on the CC, in accordance with recognized policies, audit procedures and management policies. The governance, until now applied to traditional IT, has been expanded to the private cloud without major problems.

4.5.4.6 Continuous improvement

In this step, the solution is continually improved, that is the services, applications data and infrastructure migrated to the cloud. Since this is a continuous process, the IT area is continually searching for improvements that can be implemented to improve the solution.

4.5.4.7 Synthesis

Table 44 presents the inputs, outputs and the participants of the "Migrate" process.

Table 44 – Migrate synthesis

Input	Output	Participants
Migrate		
List of services defined in the earlier process	Services migrated to the CC	**ISA** Migrating services to the CC **CSP** Migrating services to the CC
Perform a pilot test		
List of services defined in the earlier process	The results of the pilot test	**ISA** Perform the pilot test **CSP** Perform the pilot test
Training		
Issues regarding the installation	Training sessions	**ISA** Receives the training sessions **CSP** Give the training
Evaluation and monitoring		
Acceptance conditions	Acceptance conditions validated	**ISA** Validation of the acceptance conditions **CSP** Validation of the acceptance conditions
Governance		
Governance in traditional systems	Governance in the CC	**ISA** Do the governance
Continuous improvement		
Information regarding the cloud system installed	Continuous improvement	**ISA** Discover and implement the improvements **CSP** Support the improvement

4.6 Results obtained

The UPT, organization that hosted this case study, is a typical organization teaching higher education. In technical terms the solution implemented improved, the operating conditions of services migrated to the private cloud. This improvement reflected at the level of management, which became centralized and was carried out in a much more automated way and the services provided require now considerably less time in order to produce results.

Since UPT decided to improve its IT's infrastructure, we foresaw an opportunity to apply the new CC's paradigm and accordingly to validate the developed framework. Thereby, we requested the University's management permission to start the migration to the CC by following the rules identified in the developed framework. Practice suggested a different path from the followed framework after it was fully considered and the pros and cons weighed. The framework was improved where it was convenient.

The work started by an in-depth research regarding the CC, its related technologies, the service and deployment models and the pros and cons. Based on the research developed and on the Portucalense IT needs identified it was confirmed that the private cloud is the best suitable solution.

To perform the migration of IT services, data and infrastructures to the new paradigm a framework has been developed to know in detail what must be done and in what order to achieve the task in a smoothly way. However an issue arises: How should each of the framework tasks be done? For that purpose we began studying the frameworks presented in section 2.3.1, which could help us resolve the issue and find that ITIL is the most appropriate to this end. Armed with these two tools, the M2CC's framework and the ITIL, the migration to the private cloud could now begin.

The tasks of the framework were performed according to ITIL. The developed framework does not fit well a few times and, after a careful analysis and evaluation, the framework has finally been adapted.

For every process of the M2CC's framework, we found out that ITIL has support, except in what relates to the management of the IT's staff. The complete results are presented in major detail in Chapter 5.

4.7 Conclusion

The case study developed at UPT allows us to observe, comprehend, analyse and describe a particular real situation of migrating services to the CC. Specifically speaking, this study allowed us to gain knowledge of the whole process of migrating some UPT IT processes, data and infrastructure to a private cloud and recognize therefore the issues involved in such undertaking. By using ITIL to support the framework, we can perceive that the ITIL's framework has support for the majority of our needs with the exception of the issues related to the management of the IT staff. It could not be found in ITIL's support for reconverting and adapting IT personnel to the new demands of the CC's framework neither for the staff that is no longer necessary since their tasks are being performed by the CSP.

Chapter 5

DISCUSSION

This chapter synthesizes the research findings gathered both in the academic literature and in the overall work.

The main objective of the study was to verify the applicability of IT governance, namely ITIL, to the migration to CC. Accordingly, the research explored the information regarding CC and governance frameworks. To provide an in-depth understanding concerning the migration to CC a case study has been developed. To validate the work developed besides the case study and the published papers we appealed to the opinion of a group of experts and made structured interviews to the stakeholders to gather their perception of the results achieved with the migration and to validate the work developed.

5.1 Case study findings

This section shows the results of the case study developed at UPT. The deployment of a private cloud at the UPT and the corresponding migration of IT to that cloud served as the basis for the case study that we use to validate the M2CC's framework developed.

The research question defined in the beginning of this work mentions the applicability of the IT governance, namely ITIL, to the migration of IT services to the CC. The findings of the case study indicated a close relationship between the process identified in the M2CC's framework to migrate IT to the CC and ITIL, although some aspects, like the management of IT's human resources and the project management, are not covered by ITIL. All other are sufficient to cover the demands of the M2CC's framework.

The first ITIL book, "Service Strategy", provides a guidance on clarification and prioritization of service provider investments in services. As such, and as observed in section 3.3.1 as well as in Figure 24 on page 145, the major usage occurs is in the first two processes of the M2CC's framework – the first defining a strategy and the second gathering information concerning the current state of the in-house IT's infrastructure. The second book, "Service Design", aims to design appropriate and innovative services to meet the business requirements.

Hence, as seen in Figure 24, its major usage is based on the gathering of information from current IT's infrastructure and definition of the services in the cloud. Hereinafter is the "Service Transition" book, and as the name suggests, it takes care of the transition of services, that is, builds and deploys IT services. Its major usage, as seen in Figure 24, is in the "Migrate and Govern" M2CC framework's process, which is the process that is responsible for the real migration of services, applications and data to the CC. This last process of the M2CC's framework is also responsible for the services in the cloud environment functioning and its improvement. As such, and as it was demonstrated, the last ITIL books, "Service Operation" and "Continual Service improvement" provides major support to this process.

The first ITIL book, "Service strategy", supports the migration to the CC. The activities of the strategy generation's process give their contribution. The "definition of the market" activity is helpful to identify new markets, for example, those that are until now impossible to reach so far - important to reach/expand, and as such considered to migrate the corresponding services to CC as to provide the services accordingly.

In the same way, the “development of the offering” activity helps to identifying the possible candidates on the migration to the CC or the new products that can now be developed, because of the cloud’s functionalities. The “development of the strategic assets” activity gives information regarding the importance of the assets to the organization so that we can more properly decide if a service is a strong candidate for the migration to the CC, or not.

The last activity “prepare for execution”, whose aim is to select the appropriate strategy to deliver the services, once again gives information to help decide what to migrate to the cloud. The “service portfolio management” process provides information concerning IT services required to meet organization business outcomes to support the decision of what to migrate to the cloud.

By its turn, the “demand management” adds more information concerning the IT services to comprehend and anticipate the customer’s demand for services. This is a useful to support the decision’s process of what to migrate to the cloud since services with high demand may be strong candidates for the cloud migration.

The financial management**,** as the name implies, takes care of the budgeting and financial aspects of services, an omnipresent process is in the migration’s procedure. The information provided is used to recognize, or not, the economic advantage of migrating to CC.

The second ITIL book, “Service design”, also supports the migration of services to the CC. Actually, the “Service catalogue management” process aims to ensure the service catalogue to be produced and accurately maintained. Since the service catalogue provides service details, status and services interdependencies, it is a vital process to be aware of the organization services’ details that necessary for its migration to the CC. The “Service level management” process is responsible for negotiating the SLAs and OLAs as it ensures they are met, either on premise or in cloud. SLA documents the level that the on premise services must accomplish - a starting point to define the minimum service level that the services on cloud have to observe.

Additionally, by migrating of services to the CC there are responsibilities that change, therefore this ITIL process is also used to support the migration of services to the cloud when defining the responsibilities as well as in their inclusion on the SLAs. Although in CC the resources can be easier to manage, acquire and release, the “Capacity management”

process is important to maintain the adequate capacity and to establish a baseline of capacity required for each service. Besides the majority of the availability, the issues are moved to the CSP, the “Availability management” process supports the migration to the CC by defining a baseline for the necessary availability for each service in the organization and therefore it supports the SLA’s definition. The **“**IT Service continuity management” process supports the M2CC by managing the risks that the migration to the CC cause on IT services, by ensuring that these services, when migrated to the CC, have alternative service options, such as another service provider, to guarantee that they still operate in the event of a significant business outage or disruption. The role of the “Information Security management” process in the migration to CC is twofold: a baseline of information’s security for the definition of the cloud security requirements and a proof, after the services are migrated to the cloud, the security constrains are applied.

This book continues with the “Supplier management” process, that supports the management and selection of the cloud service providers. The organization needs to manage its providers both before and after the migration of the IT to the CC. Additionally, and given the easiness the cloud services are hired, the “Supplier Management” process plays an important role to eliminate an unwanted proliferation of cloud contracts. Moreover, after the contracts are signed, it is used to maintain and renegotiate them and to manage the relationships with the CSPs.

The third ITIL book, “Service transition”, also provides support to the M2CC framework. The “Transition planning and support” process supports the “Migrate and govern” framework’s process by preparing, organising and backing up services’ transition to the CC.

Following, in the same book, is the “Change management” that supports the M2CC framework in the “Define, Select, Analyse and Map” and in the “Migrate and Govern” processes. This process contributes in the sense that solves the problems arising with the changes, that IT processes experience, when migrating to the CC.

The next process, “Service asset and configuration management” helps to understand the relationships between the services as it covers policies, project documentation and IT’s infrastructure regarding services.

The “Service Transition” book continues with the “Release and deployment management” process that supports the CSPs when they deploy new releases into production. “Service

validation and testing" assist the M2CC processes: "Define, analyse and map", by confirming that the CC services delivered by the CSPs meet the requirements previously identified and the "Migrate and Govern" process by assuring the service's quality of the services that were migrated to the CC.

The "Evaluation" process follows. It supports the "Migrate and Govern" M2CC framework by evaluating the services migrated to the CC. The last process of the "Service Transition" book, "Knowledge management", is a ubiquitous process in the M2CC framework.Being the information, the knowledge and their management mandatory for all processes, this ITIL process is also the case.

The processes of the fourth ITIL book, the "Service Operation", also support the M2CC framework. Indeed, the "Event Management" supports the "Migrate and Govern" (on the organization side) and the "Cloud Services" (on the CSPs side) processes of the framework. They are used to cope with the events created by the services migrated to the CC according to the responsibilities and roles identified for each one. Moreover, it continues to process the events of the services that remain in the organization.

The next process, "Request Fulfilment", aims to provide users with such means so they can be able to request and receive services. Accordingly, it supports the M2CC on the "Migrate and Govern" process.

Thereafter we have the "Incident Management" and the "Problem Management": supporting the final phase of the framework and initial period of production - normally more susceptible to have problems, that is the "Migrate and Govern" process. Subsequently, there is the "Access Management" process that supports the framework processes, "Identify and understand", "Define, Select analyse and Map" and the "Migrate and Govern". The first one identifies the access to services and provides a baseline for the access on the CC. The second defines the access that the services and applications must have in the CC and finally the third process provides the initial set of accesses to the systems migrated to the CC.

The last of the five ITIL books, "Continual Service Improvement", also supports the M2CC framework. Indeed, the "Service Measurement", the "Service Reporting" and the "7-step improvement" are useful to gather information serving as a baseline for a later comparison of the services with their cloud counterparts to evaluate the improvement that the migrated

processes to the CC have suffered. Accordingly, they support the “Identify and understand” and the “Migrate and Govern”.

Despite the M2CC framework widely benefits from ITIL, it is not required that the organization previously implements ITIL so that it is able to perform the migration to the CC. The team responsible for the migration to the cloud may only implement the necessary ITIL processes to gather the required information or to manage some processes.

However, it should be pointed out that if the organization already follows the ITIL framework, the application of the M2CC framework by the team responsible for the migration to computing, is simplified.

The case study allowed us to validate the developed framework and solve minor issues. For example, the task “Test the solution in a controlled environment”, was added because of a practical necessity by the time of the cloud’s implementation. This testing is helpful to validate and test each of the proposed solutions to verify, in practice, the real the issues of each solution. Another improvement was about to the reformulation of the cycle between the sub-processes of the “Define, select, analyse and map” process.

The use of CC involves the automation of processes (for example the allocation of a new server) rather than the “simple” migration of a process to an external CSP (outsourcing).

However, as another result obtained from the work, we could say that the CC may be seen as an evolution of outsourcing.

5.2 Difficulties in making a more comprehensive validation

As mentioned, it was not feasible, by the time of this work, to find the appropriate number of organizations where this work could be validated. According to the knowledge gathered, in the initial phase of this work, the migration to CC implied that the owner of the process had to have an in-depth knowledge of the organization, concerning IT, business, services and the operating mode. This fact, along with the requirement to find an organization that was in the development time of this study, making its migration to CC and having implemented ITIL (or being available to implement the necessary processes by the migration to CC) makes the choice more difficult. In addition, considering the need for the organization to be sufficiently open in order to either expose its internal structure to this study, or to

support the researcher in the development of his work and also to deploy the developed framework, we were able to observe that it was not timely possible to find organizations under these circumstances. Therefore, it has been decided to use the migration of services to a private cloud that UPT is deploying and apply the developed framework and the ITIL mapping to carry out a more thorough validation of this same developed work. Furthermore, to complete the validation we appealed to the opinion of an expert team regarding the work developed, the comments received from the submission of published papers and questionnaires to the UPT staff related with this work.

The following paragraph describes the necessary environment to perform a complete framework's validation. The verification and validation of a framework are crucial steps of the of its development process. The verification is accomplished to ensure that the framework does not contain errors and that the requirements are complete. The validation ensures that the framework meets the requirements and ensures that the framework addresses the true problem.

We recognize that, in order to fully validate this work, it is necessary to find organizations, where the framework could be applied for the four cloud deployment models that are public, private, hybrid and community (first axis of the cube); for each deployment models each service model, IaaS, PaaS and SaaS must be considered (second axis of the cube).

The above combinations should be tested in organizations that have already implemented ITIL and others that do not have implemented ITIL (third axis of the cube).

Finally, the identified sequences must be verified in dissimilar types of organizations for example small and medium sized enterprises.

Figure 29 illustrates the three axes of the complete validation of the M2CC framework. This cube has to be considered for the disparate types of organizations like as SMES.

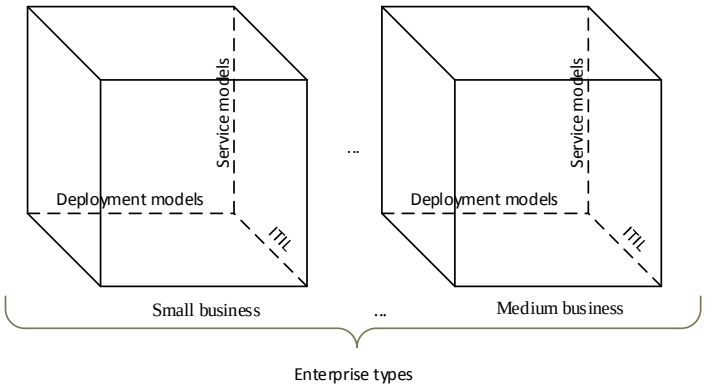

Figure 29 – Framework's validation

Furthermore, in order to truly validate the impact of the framework, it would be advisable to have baseline migrations to compare what happens with and without the application of the developed framework.

5.3 Expert group

The difficulty in finding organizations that could accommodate the validation of this work lead us to finding out other ways to proceed with the necessary validation. Therefore, we conducted a survey to collect the opinion of an expert group regarding the work developed.

This expert group has agreed that ITIL is applicable to the migration of IT services to CC. The legal issues of the migration to CC, namely on the migration to a private cloud such as the one used in the case study, are reduced when comparing with the migration to a public cloud.

One of the experts indicated that the work would improve if a deeper comparison amongst the various governance frameworks were explained. Accordingly, in the chapter of the literature review that same comparison has been improved. The same expert also pointed out that neither the meaning of the service nor the reason why ITILv3 was selected was clear. To answer to these issues a terminology section has been added and reformulated the section that explains the reasons why this ITIL version has been chosen.

Another expert, when answering the question about the appropriateness of the framework, wrote "In general I believe the framework can be useful for medium sized companies…". The same expert also indicates that the differences between the CC and the conventional IT were not clearly stated. Therefore, a table comparing both technologies was introduced.

The three experts share the opinion that the ITIL is applicable to the migration of services to the CC. The third expert also mentions the fact that the issues occurred at the level of the interfaces between the various applications are not properly discussed. The applications step of the framework has been rewritten to explain this issue in major detail.

5.4 Cloud computing and ITIL trends

To demonstrate that both the public and the academic community maintain their interest on the focus of this work and thus ensure it is current, this section introduces statistics concerning the CC, ITIL and the migration to the CC gathered from a number of recognized authorities.

Figure 30 presents the Google search trends ("Google Trends," n.d.) of ITIL and CC. Although CC follows the Gartner Hype Cycle ("Hype Cycles," n.d.), the ITIL maintains its interest. Because of the increased research and the use of CC, some of its issues started to appear causing the hype to be fading away.

However, as the Gartner Hype Cycle for Cloud Computing 2013, depicted in Figure 31, demonstrates, not all CC's aspects are decreasing in terms of interest.

Additionally, many companies are suddenly including pictures of clouds in their adverts and adding phrases similar to "cloud-based" or "web-based cloud applications", indicating that "cloud finds its way to all aspects of life since it seems to attract customers!" (R. Hill et al., 2013).

Nevertheless, it is commonly agreed by experts that CC is here to stay (Birman et al., 2009; Yanpei Chen et al., 2010; Chow et al., 2009; Dargha, 2012; R. Hill et al., 2013; Kaur, 2014).

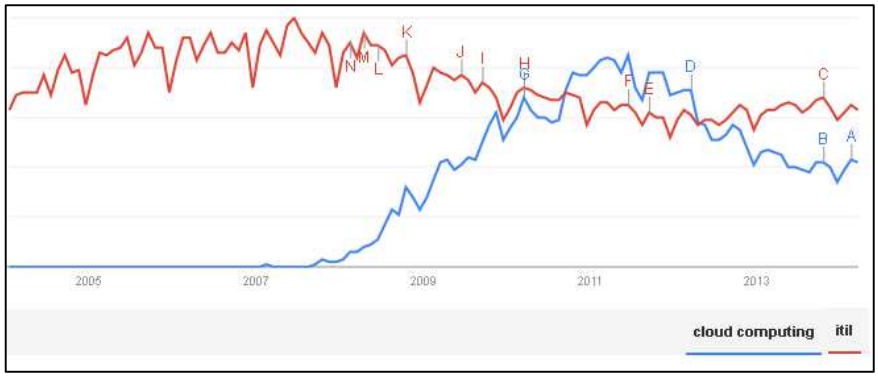

Figure 30 - Cloud computing, ITIL trends (“Google Trends,” n.d.)**)**

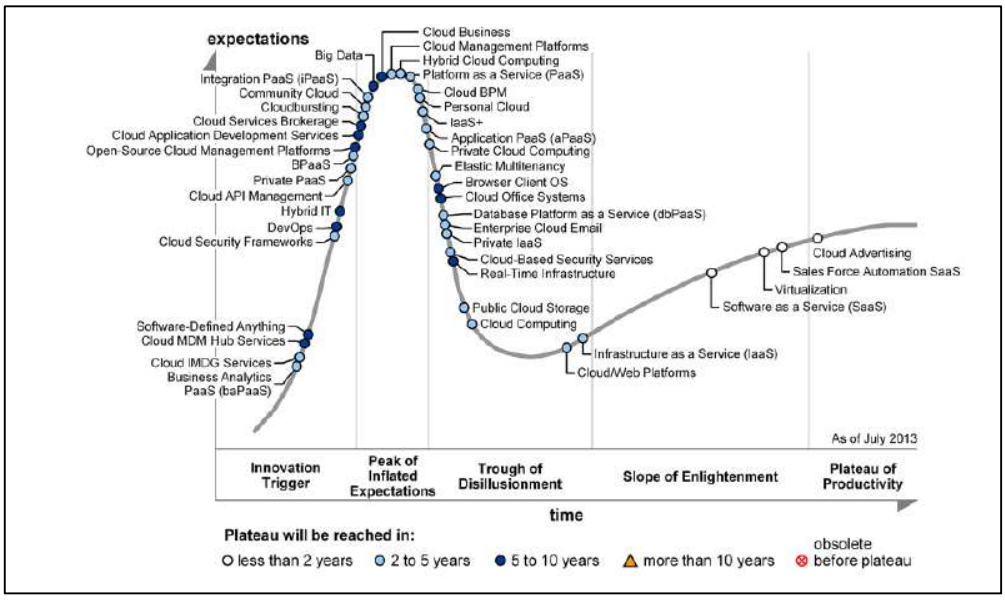

Figure 31 - Hype Cycle for Cloud Computing, 2013 (“Hype Cycles,” n.d.)

Additionally, to further demonstrate the interest of the academic community in the CC area, each editor, i.e., IEEE, Springer, Google Scholar and ACM was individually searched with the string “cloud computing” individually for the years 2011, 2012 and 2013. Examining the numbers of the scientific production published during the years in study by the editors, we build the Table 45 where the maintenance of the interest of the academics in CC for the period 2011-2013 is noticeable.

Table 45 - Scientific production related with cloud computing

Editor	2011	2012	2013
IEEE	3062	4717	4527
Springer	1716	2253	3038
Google Scholar	31300	40800	39100
ACM	29036	30880	25303
Total	65114	78650	71968

Table 46 - Scientific production related with migration to cloud computing

Editor	2011	2012	2013
IEEE	9,05%	8,63%	9,65%
Springer	47,49%	40,79%	43,32%
Google Scholar	47,03%	48,65%	48,49%
ACM	1,36%	1,65%	2,42%
Total	26,23%	24,93%	25,97%

Similarly, to edit the Table 46, illustrating the percentage of papers concerning CC which analyse the migration to this new paradigm, we added the string “and (move or adoption or outsourcing or migrate)” to the search string and, for each cell of Table 46, we computed the percentage.

Analysing the numbers of the scientific production related to migrating to the CC, summarized in the Table 46, it is possible to observe that an average of 25,71% of the scientific production regarding the CC is concerned with the migration to CC itself. Notwithstanding the slightly decrease in 2012 the researchers’ interest remains.

By analysing the Google Trends of the management frameworks, ITIL, COBIT, CMMI and ISO20000, depicted on the Figure 32, it is possible that although ITIL, similarly to other frameworks, slightly lowers the interest, ITIL still has a notorious advantage compared to of all others.

In accordance with the presented values, the interest of not only the researchers but also the public’s by CC and the migration to this paradigm has remained constant for the period of this work’s development. Thus, we consider that the theme of this work keeps updated, drawing the attention of the scientific community as well as the public.

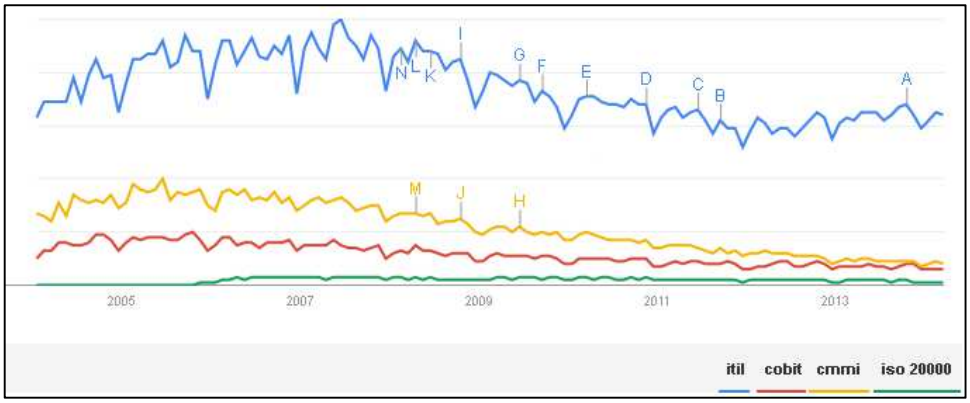

Figure 32 - ITIL, COBIT, CMMI and ISO 20000 trends ("Google Trends," n.d.)**)**

5.5 Discussion

According to the results obtained from the case study, the published papers as well as the expert's opinion we can positively answer to the research question raised at the beginning of this research work: The IT service management, namely ITIL, can be applied to the migration of existing systems to the CC?

According to our study, the use of good practices to implement the migration of services to the CC benefits the organizations, mainly because these can reuse the majority of the work performed by them when deploying the good practices' framework and their results in the migration to the CC. These good practices have already been tested by organizations around the world and proved their value.

Additionally, when both the customer and the CSP have implemented the same good practices, they have a common language facilitating therefore their communication.

To demonstrate the ITIL's applicability to the migration of services, applications and data to the CC it is necessary to find out how the process works and to verify that for each step the ITIL could be used. Accordingly, to find the answer to the research question, we defined a generic framework for migrating IT to the CC, which was sought to be used by the majority of organizations.

The framework must take into account the issues identified in the Chapter 2. Therefore, and following the structure of Chapter 2, it must consider the services and deployment models of the CC. Indeed, the M2CC framework processes of "Select the CSPs", "Information regarding cloud services", "Cloud services" and the tasks types of the cloud take

care of this organization of cloud. The chapter continues by introducing the Key features and advantages and the Key challenges - issues considered in the whole M2CC framework processes namely to define a strategy's plan, ponder the risks and the legal constrains, evaluate the impact of migrating services to the CC that are so far in-house, comprehend the service level agreements and the security issues.

Besides the information gathered, the related work also gives an important contribution to the development of the M2CC framework, namely the subsection 2.2.1. The M2CC framework starts with a process devoted to comprehend the paradigm and, with business collaboration, develop a strategy's plan. The business participation is useful in the whole process as recognized by the majority of the authors of the related work presented.

Another finding was the urge to obtain a thorough knowledge of the IT of the organization prior to the migration. This conclusion is also corroborated by the analysis done in section 2.2.1 since all the frameworks studied consider this necessity, with the exception of the Khajeh-Hosseini's work (at least according to the paper consulted).

Based on the Table 14 on page 76 which compares the works about the migration to CC analysed against the M2CC framework developed, we edited Table 47 that summarizes the findings gathered. The values indicate the percentages of frameworks analysed had the indicated feature. For example, the first row indicates that 56% of the works analysed do not consider a step to "Understand CC" while 33% do consider a step to understand the paradigm. The remaining (11%) consider it superficially. The column "Other" includes classifications such as, "Superficial", "Yes (applications)", "Legacy applications" and "Abstract".

As expected, the security and costs are the topics covered by the majority of the frameworks analysed. In its turn, the majority of the frameworks analysed does not cover vendor lock-in neither a continual improvement nor the use of good practices.

Despite 44% of the works analysed do not mention the risk's management, all changes in IT involve some risks. Yet, migrating IT to the CC includes changes in the organization IT and it also includes moving our information to third parties which can induce increased risks to the organization's IT, reason why we consider a task in our framework to manage risk.

Table 47 - Related proposals comparison's summary

Features	No	Yes	Other
Understanding the CC	**56%**	33%	11%
Definition of a strategic plan	**56%**	44%	0%
Includes business management participation	33%	56%	11%
Analyses the current institution's IT	11%	56%	33%
Migration of services, applications, data and infrastructure	22%	44%	33%
Cloud provider selection	33%	56%	11%
Risks management	44%	33%	22%
Security	0%	**78%**	22%
Legal	**56%**	11%	33%
Impact	**56%**	33%	11%
Costs	11%	**78%**	11%
Issues considered	22%	44%	33%
Staff	44%	22%	33%
Contracts	**67%**	11%	22%
SLA	44%	44%	11%
Vendor lock-in	**78%**	22%	0%
Presents a formal process to support CC migration	11%	56%	33%
Solution testing	56%	22%	22%
Continual improvement	**78%**	22%	0%
Support of case studies	67%	33%	0%
IT Governance (good practices)	**100**%	0%	0%

The legal issue, with no reference to more than 50% of the considered works, is another task taken into account in our framework. It is mainly included because of the need of placing information outside the organization, the dynamic of CC and consequently the possibility of changing the jurisdiction governing the information and to support in SLA and contract's management.

The human side of the migration to the CC must be considered since it holds a significant transformation, dependent of the migrated services, responsibilities and roles of IT managers in the elimination of some in-house services and in the redesign of others.

Although more than 44% of the works analysed do not consider this issue that varies according to the organization human resources policy and the capabilities of each member of staff affected by migration to the CC, we see it in M2CC as a reminder of these issues.

The solution testing, in the migration of IT to the CC, supports finding defects/errors and to ensure the created solution meets design specifications prior to going into production. Although 56% of the frameworks for migrating IT to CC studied does not address the solution testing issue the M2CC does it, either before the final solution is defined, to verify that the solution meets the specifications of the design phase and after going to production to filing edges and resolve small issues that arise.

Bearing in mind the effort undertaken by the organizations to implement good practices' frameworks such as ITIL, the framework adoption's index introduced in Figure 21 on page 98, ITIL and CC both concern are services and the output of the ITIL processes' respond to the necessities of the framework we studied. We also implemented our framework with the support of the ITIL's good practices.

None of the analysed frameworks addresses this support from ITIL or other good practices' framework. Thus, since we already have a framework to migrate IT to the CC it was necessary to validate the fact that the processes described therein could be executed in accordance with ITIL prescriptions.

As expected, however, there is no direct mapping between the framework processes and the ITIL ones. Accordingly, we analysed each step of the framework and researched which ITIL processes could be used to produce the necessary results for the full implementation

of the framework. As can be seen in the case study, section 4.2, and in Figure 24, all the processes of the framework are addressed in one or more of the ITIL processes.

In short, the ITIL “Service design” book with its processes takes the lead of the “Identify and understand” process’ support of the M2CC framework. The “Service transition” processes give more guidance to the “Migrate and govern” framework process that also gets backup from the “Service operation” book since it also takes care of the initial “steps” of the services on the cloud’s environment.

The issues related with the migration to the CC have been taken into account both in the literature’s review and the design of the framework developed. However, the case study serving as the basis for one form of the validation’s work addressed in a less deeply way some of these issues.

Thus, the following paragraphs, present the issues that due to constraints of the case study were less deeply considered.

The first issue is about the legal aspects. Although the case study used to validate the work developed does not fully consider the problems related to the legal aspects of migration to the CC, these are analysed throughout the document, introducing the actions to be performed so as to minimize the impact on migration and illustrated its use in the case study, namely in what concerns to contracts and SLAs.

The security concerns is the second issue to ponder. Several aspects related to the security of CC have been taken into account on the case study when migrating to a private cloud like a network security, user accesses and data’s security.

Moreover, as mentioned, most of the security problems in CC are already present in traditional environments. With the migration to a public cloud, beyond the traditional security issues (that the leading providers of CC services beware better than most organizations (“Examining Cloud Maturity and Adoption in the Age of Digital Business – Gartner Symposium / ITxpo 2014 Q&A with Daryl Plummer,” 2014), there are some confidence issues since the information of an organization is placed on servers controlled by third parties.

However, this type of problems are treated throughout the document and a paper exclusively dedicated to the topic of security in the CC is published.

When migrating to a public cloud, the access to the services is done by way of the Internet. Accordingly, the breaking of Internet access is another issue to contemplate. Using a private cloud installed on the premises of the organization solves the issue of Internet connection becoming a SPoF. The migration to a public cloud, outside the premises of the customer, in its turn, emphasizes the issue of Internet access, however, this can be solved, for example, by using redundant links. Once again this issue is explained throughout the document.

The financial issues is another concern to envisage. When migrating IT services to a private cloud, the organization does not enjoy all of the financial advantages of the CC's adoption. These advantages are compensated by an increased confidence in the place where information is saved and the staff in charge of its management and the non-appearance of the problems of jurisdiction of the CC.

However, the case study's implementation, proved to continue to having economic advantages such as the easiness with which resources are released and ordered, the reduction of the physical servers and the ease of maintenance.

To further, demonstrate the results achieved, the following paragraphs present the results of the interviews I, II and III, presented on pages 26, 26 and 27 .

The first interview, done to a restricted audience is intended to validate the tests performed in a controlled environment to validate the details of the achieved solution. According to the results, the tests provide the expected outcomes - the migration to the CC of the selected applications was successful and the technical difficulties were overcome.

Interview II was accomplished to evaluate the perception of the staff directly affected by the migration to the CC. Taking into account the answers to questions one, two and three of the conducted survey, we can conclude that 100% of the users consider that the functionalities of the applications remains unchanged and not suffer any access breaks during the migration's period.

In terms of access, the users also recognize that there had been no change in accessing the applications they already had. The previous and detailed analysis of the applications used and the users' habits led to selecting a period for the migration of applications that would have less impact to the users. This analysis was performed in the process of "Identify and Understand" and reinforced in the "Define, select, analyze and Map" particularly in "Define a Migration Plan" for example in the access definition.

Questions four and five refer to the troubleshooting, equated in the initial phase of implementation of the framework, in the process "Define a strategy" when defining "Why move to cloud". It is widely spread view that the speed of access to services has been improved and the availability problems were solved. Some of these, still felt by some users, are due to intermediate servers that have not yet migrated to the new solution, such as proxy servers.

Question six aims to assess the initial study of the information that each application uses. According to the feedback from the users, all the information used by applications has been preserved in the new environment. This information was collected in connection with the "Identify and Understand".

According to the answers obtained to questions seven, eight and nine, we found out that the migration did not cause any disruptions during normal day-to-day of the users. These issues resulted from the validation of processes "Identify and Understand", "Analyse and test" and "Migrate and govern", for example in gathering information about services in the process "Identify and Understand", in analysing the impact on the sub-process "Analyse and test" and in selecting applications to migrate from sub-process "Define a migration plan", namely "What to move".

Question 10 relates to the cloud type chosen in the sub-process "Defines the migration plan". However, it is also comprehends the security required by the institution validated in the sub-process "Define a migration plan", with the risks discussed in the sub-process "Analyse and test" and the sub-process "Select the providers".

Interview III, aims to validate the fact that the solution achieved encompasses the CC's technical advantages.

This interview has proved that the solution achieved includes various CC advantages such as, the capacity to dynamically change the resources of the machines, facilitate the task of

creating new machines, activate and deactivate machines according to the needs and the possibility of having templates to create new machines based on a common configuration.

Moreover, the solution also solves some problems found, such as improving the backup processes, increase the service's availability and the speed to access these services.

Chapter 6

CONCLUSION

IT managers are increasingly concerned in minimizing investments; capitalize on investments already made and the way the services are performed to achieve greater productivity with lesser costs. The CC is a paradigm that allows customers to start new services or expand already existent ones without requiring large upfront investments, enabling customers to acquire and release resources dynamically according to their needs in a pay-as-you-go form.

One of the main challenges facing the migration to this new paradigm is the need to review and to adapt the services and IT processes to operate in the new paradigm. Another issue arises from the difficulty of bringing services back to the environment they had before, after they have migrated to the cloud. One other issue occurs from the costs involved in the migration. Therefore, the migration to CC must be carefully planned and performed. So, it

is important to investigate how the organizations can efficiently and effectively migrate IT from the conventional model to CC.

Taking into account, the need to better meet the user requirements with lower costs, the advantages of the CC presented, the advantages of ITIL in managing IT services (with its major acceptance and adoption's index compared with other service management frameworks) and the possibility to use the information gathered by ITIL, the work developed examined the adequacy of ITIL in the migration of traditional IT environments to CC.

Therefore, the present study sought to answer the following research question:

Can the IT service management, namely ITIL, be applied to the migration of existing systems to CC?

The IT service management frameworks, such as ITIL, COBIT and CMMI, provide a deep understanding regarding IT services and providing the organization with processes to deal with IT services. However, as it has been observed in Table 14, none of the analysed related works for the CC migration makes use of an IT service management framework, in order to to take advantage of the work done at deployment or to use the procedures prescribed in the frameworks that have been tested by a large number of organizations.

By creating a framework to migrate services to CC and mapping the processes of the framework to the ITIL processes, we validate the applicability of ITIL to the migration to CC.

In the following section, we present the contributions of this research and the ideas to forthcoming research related with the aim of this work.

6.1 Thesis summary

Thus, after the introductory information (Chapter 1), the literature review is presented on Chapter 2, providing the base concepts to understand the CC and IT governance paradigms' base of the entire work.

The same chapter also introduces the works found on the academic literature, developed regarding the migrating issues to the CC.

Chapter 3 describes in detail the framework developed to migrate IT to CC. It begins with the presentation of the framework and proceeds with the mapping of the framework processes, sub-processes and activities to ITIL processes. The validation of the work done is underpinned in the case study clarified in Chapter 4. An additional validation, of the results obtained by the implementation of the work developed, was accomplished with a structured interview to the UPT's staff, more closely related with the performed migration.

Lastly, in Chapter 5 the results achieved are discussed.

6.2 Contribution of the research and limitations

To support the work to be developed, a consistent literature review regarding the topics "CC", "migration to CC" and "IT service management" was carried out.

By means of this work, it was possible to achieve the purpose of developing a framework to guide the organizations in the task of migrating IT to CC. Moreover, a mapping between the framework processes and the ITIL ones was also produced. This is a main contribution as it supports the answer to the research question concerning the ITIL applicability to the migration of services to the CC.

In addition, papers have been published concerning the CC "Cloud Computing: Concepts, Technologies and Challenges" (Cardoso & Simões, 2012b), CC and security "Cloud computing and Security" (Cardoso & Simões, 2012a), applicability of IT governance to CC "Aplicabilidade da governança de {TI} ao paradigma da computação em nuvem" (Cardoso & Simões, 2011) and a survey of CC Migration issues and frameworks "A Survey of Cloud Computing Migration Issues and Frameworks" (Cardoso et al., 2014). Additionally, a book chapter about how the work developed could be used in an e-Government environment "A Support Framework for Migration of e-Government Services to the Cloud" (Cardoso et al., 2015) was also published.

With these contributions, we intend to prove that ITIL is applicable to the migration of IT to CC.

The migration of IT to CC implies an in-depth knowledge regarding the organization, its IT, its business, its services and overall operating mode. This fact, concomitantly with the

requirement to find an organization that, in the development time of this study, was performing its migration to the CC makes the choice of finding more organizations to validate the developed work more difficult. This leads to one of the limitations of this work, that is, the small number of case organizations since the case study was accomplished in one single organization.

Another limitation stems from the challenge to generalize from case studies, especially single case designs (Scapens, 1990). This leads to the fact that these generalizations may be limited to other organizations. However, and to overcome the restriction, the work was also validated not only by an expert group but there were also papers published concerning the work developed.

A third limitation was the participation of the researcher in the development of the case study. If on one hand, it is possible to assist the gathering of information and rely on the data, on the other hand, there is the chance of having researcher bias. To minimize this issue the participants in the case study - the financial, human resources and academic support – authenticated the data gathered by means of interviews.

6.3 Future Research

Bearing in mind that there are some interdependencies among the ITIL processes and that implementing the whole ITIL is not an easy task, we purpose to develop a “mini-ITIL” to support the Small and Medium Enterprises (SMEs) that have not implemented ITIL, in the migration to the CC.

A second purpose to future work is an attempt to map the developed framework to other IT governance frameworks, combining ideas and processes from distinct frameworks.

Sometimes it is difficult to track the entire process of migration to the CC. Therefore, the development of an application supporting the migration to the CC, according to the framework presented, it is a facilitating tool for monitoring and accompanying the entire process.

Another tool that can be developed is a framework to automatically gather information about the services provided by various CSP in order to make it easier to perform the task of comparing various providers, besides including legislation from various countries (which could be a key point to choose a CSP).

6.4 Final conclusions

The work developed, presented in this thesis, studies the ITIL support to the migration of IT to the CC. It starts by introducing the service and the deployment models, followed by the various technologies related with CC. The advantages and disadvantages follow.

A summary of cloud economics is presented in the next subsection followed by the cloud standards' projects within the CC, the related work and the IT governance.

Amongst various IT governance frameworks, we selected ITIL due to its goals and wide acceptance. To demonstrate the applicability of ITIL to the migration of IT to the CC it was necessary to implement the migration as stated by ITIL guidelines and to confirm it runs smoothly.

To do so, a framework has been developed and its steps have been mapped to the ITIL processes. The resulted work was implemented in a real-life scenario of an IT migration to the CC and the outcomes validated by means of a structured interview with the main players of the migration. The results proved that the ITIL is applicable to the migration of IT to CC. With minor issues not covered by ITIL, such as those related with the reorganization of IT technicians who changed functions, all the framework processes get backup from the ITIL framework.

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