A Characterization of Cloud Computing Adoption based on Literature Evidence

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Abstract: **Context**:The cloud computing paradigm has received increasing attention because of its claimed financial and functional benefits. This paradigm is based on a customizable and resourceful platform to deploy software. A number of competing providers can support organizations to access computing services without owning the corresponding infrastructure. However, the migration of information systems and the adoption of this paradigm is not a trivial task. For this reason, evidence from the literature reporting and analyzing experiences in this migration should be widely disseminated and organized to be used by companies and by the research community. **Goal**:Characterize main strategies and methodologies reported in the literature to describe and analyze the adoption and migration to cloud computing **Method**: The characterization followed a four-phase approach having as a start point the selection of studies published in conferences and journals. **Results**: Data gathered from these studies reveal a tendency for companies to choose the public deployment model, the IaaS service model, the amazon platform, and how the most important characteristics in the cloud adoption decision are cost, performance, and security and privacy. **Conclusion**: Due to the variety of strategies, approaches and tools reported in the primary studies, it is expected that the results in this characterization study would help in establishing knowledge on how the companies should adopt and migrate to the cloud. These findings can be a useful reference to develop guidelines for an effective use of cloud computing.

1 INTRODUCTION

Cloud computing (CC) has increased its adoption by enterprises in an attempt to include agile, flexible and provident practices in their TI infrastructure. This platform has also changed the way information system users deal and perceive computing (Weiss, 2007). The possibility to remotely use hardware and software resources, as well as the expectation of economies of scale are main reasons that drive the shift for migrating existing core business applications to the cloud (Hashmi et al., 2011). Considering the availability of a plethora of cloud services and providers (Stieninger et al., 2014), many companies have engaged to transfer their business processes mechanisms to the cloud platform (Sadighi, 2014).

This scenario has created opportunities for enterprises that have manifested perceived inclination toward cloud computing and the benefits reaped by them such as low start-up cost, pay only for utilized services, up-to-date resources, features, and rapid deployment (Buyya et al., 2009)(Li et al., 2013). On the other hand, moving to the cloud means giving up incumbent information systems practices and facing the initial perception of losing control of data that in a previous scenario were stored in local servers (Lee et al., 2013). The paper published in (Hurtaud and de la Vaissire, 2011) considers that consolidating huge amounts of data within large public clouds is also perceived as creating a massive point of failure in the event of a communication breakdown (impairing data availability) or espionage activities such as the recent PRISM programme revelations (a clandestine mass electronic surveillance data mining programme created by the NSA - US National Security Agency).

Therefore, it is important to gain an understanding of not only opportunities but also the challenges regarding the migration and adoption as well as the reasoning of an attractive cost-benefit relationship and the selection of service providers that best fit the stalkeholders needs (Li et al., 2012a) (Li et al., 2012b). Previous studies have investigated the adoption and acceptance of public cloud services at both the individual and organizational levels (Chang and

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Hsu, 2016). From the organizational perspective, several studies have identified the factors that affect cloud computing adoption,i.e., relative advantage, complexity, compatibility for enterprise (reference omitted due to the blinded review).

This paper presents a characterization study of strategies and methodologies reported in the literature to describe and evaluate the adoption and migration to cloud computing study to identify evidence from the literature related to strategies used to conduct studies focusing on adoption and migration to the cloud computing. The rest of this paper is organized as follows: Section 2 outlines the research methodology; Section 4 analyzes the selected studies; Section 5 presents and discusses the results of this characterization. Section 6 presents the threats to validity of the characterization. The concluding remarks as well as limitations and scope for future research have been discussed in Section 7.

2 METHODOLOGY

This work considered studies selected following the phases described in Figure 1 to select the studies for the characterization. The research questions are presented in Table 1.

2.1 Systematic Literature Review (SLR)

In contrast to a non-structured review process, a Systematic Literature Review (SLR) (Brereton et al., 2007) and (Kitchenham and Charters, 2007) reduces bias and follows a precise and rigorous sequence of methodological steps to research literature. SLR rely on well-defined and evaluated review protocols to extract, analyze, and document results as the stages conveyed in Figure 2. This section describes the methodology applied for the phases of planning, conducting and reporting the review.

We aimed to answers the following questions by conducting a methodological review of existing research:

RQ1. *Which strategies are used by companies to adopt and migrate to the cloud computing?* Identifying goals, proposals and motivations for the adoption of CC, help organizations to better characterize their needs and therefore provide conditions to a successful migration. **RQ2**. *Which factors companies consider to assess the cost-benefit relationship of adoption and migration to the cloud computing?* The knowledge of the costs and benefits of migration to the CC can be used as a support for its planning and reference for other companies. **RQ3**. *How companies select cloud computing service providers according to their needs and profile?* The knowledge of successful strategies and problems raised by inappropriate selection of CC providers allow organizations to be more confident to identify providers that best fit their needs.

Publications Time Frame. We conducted a SLR in journals and conferences papers from January 2005 to June 2016. In a first version of this study, we performed the search from January 2005 to June 2015 and in this new version we extended it to June 2016.

The relevant studies selected in the previous step was the start point for this characterization study whose planning is described in the next section.

3 PLANNING THE CHARACTERIZATION

Identify the Needs for a Characterization Study. To the best of our knowledge, there is no previous study characterizing strategies, methodologies, approaches applied in the literature to describe and evaluate how companies adopt and migrate to cloud computing. These results have the goal to understand how companies have adopted and migrated to the cloud, and how this experiences have been reported in the literature. This is a requirement to develop guidelines for an effective use of cloud computing, specially for newcomers.

Specifying the Research Question. Considering this context, we have focused on the following research question: What are the main strategies and preferences adopted by studies reported in the literature addressing issues related to the migration to cloud computing? We derived this research question in three Specific Research Questions (SRQ) as follows and presented in Table 1.

Table 1: Specific Research Questions (SRQ).

SRQ1	How can the studies from the selected papers be organized to support the identification of main strategies?
SRQ2	How can we classify elements and strategies adopted in the studies from the selected papers?
SRQ3	What are the main evidence of tendencies and preferences in the planning and execution of the studies from the selected papers?

Phase 1: Applying the Search String. The applied search string is presented as follows:

"case study" or "simulation" or

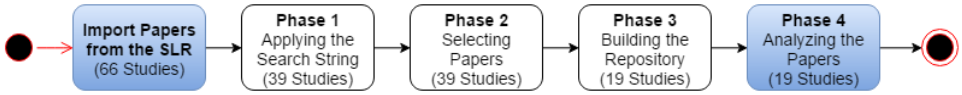

Figure 1: Study Characterization Phases.

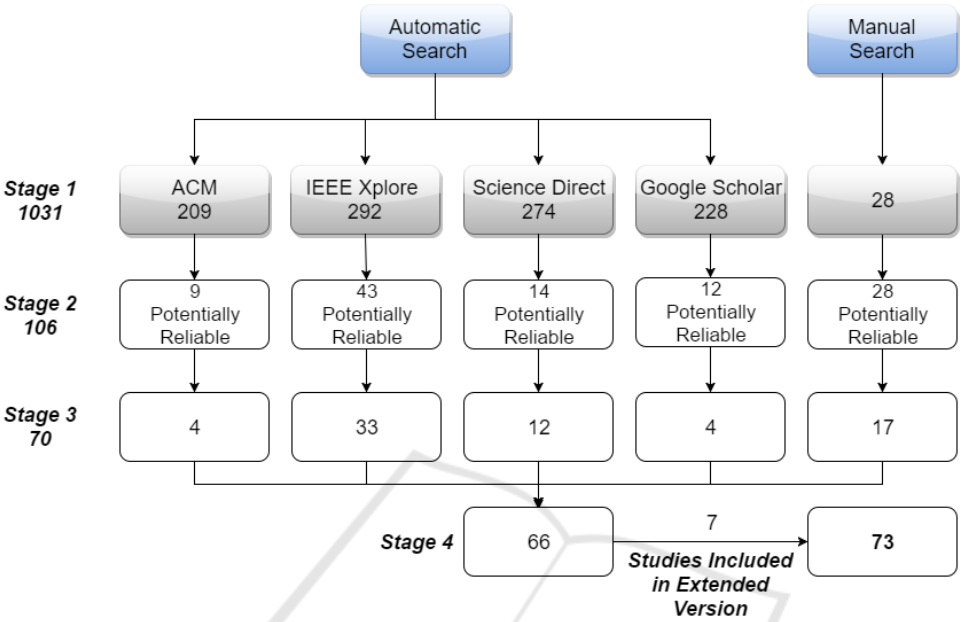

Figure 2: Stages of the Study Selection Process containing the Studies included in the extended Version of this SLR.

"benchmarking" or "experimental results" or "experience report" or "empirical study"

The result of this phase was a list of 39 papers as a subset of papers from the SLR (reference omitted due to the blinded review) containing the aforementioned string.

Phase 2: Selecting the Papers. The 39 selected papers from the previous phase were analyzed to identify evidence of strategies adopted in the studies related to the migration of legacy systems to the cloud. Papers that do not described their own studies were discarded. The result of this phase was a list of 19 papers.

Phase 3: Building the Repository. In this phase we created a repository of 19 selected studies with corresponding data. The decision of which type of elements should be included in the repository was based on their relevance in the context of migration to the cloud. We considered as relevant the elements that were mentioned at least once in the selected studies. In this case, elements more cited are more relevant in the set of the selected studies. To provide an intuitive view of how these elements were organized and to facilitate the identification of the strategies used in the studies, we decided to organize them in a mental model as conveyed in Figure 3. The nodes are numbered to identify the elements in the structure. The node 1 represents cloud deployment models: (1.1) Public, (1.2) Private and (1.3) Hybrid. The node 2 represents the three service models: (2.1) SaaS, (2.2) PaaS and (2.3) IaaS. The node 3 represents possibilities of cloud platforms identified in the studies: (3.1) Amazon, (3.2) Azure, (3.3) Coresuite, (3.4) Force.com, (3.5) Google, (3.6) Openstack, (3.7) Rackspace and (3.8) Salesforce.com. The node 4 represents evaluation issues considered in the studies: (4.1) Agility, (4.2) Auditability, (4.3) Accountability, (4.4) Cost, (4.5) Performance, (4.6) Scalability, (4.7) Elasticity, (4.8) Effort, (4.9) Flexibility, (4.10) Quality Assurance, (4.11) Governability, (4.12) Infrastructure, (4.13) Interoperability, (4.14) Timeframe, (4.15) Business Popularity, (4.16) Information Technology Skilled Staff, (4.17) Security and Privacy, (4.18) Business Size and (4.19) Usability. The elements of node 4.12 represent infrastructure resources and correspond to the following elements: (4.12.1) Storage, (4.12.2) CPU, (4.12.3) Memory and (4.12.4) Network. The node 5 represents the types of studies identified in the selected papers as follows (5.1) Feasibility Study and (5.2) Experience Report. And the node 6 is related to analysis method: (6.1) Difficulties Analysis, (6.2) Proposed Solution and (6.3) Comparison of Results.

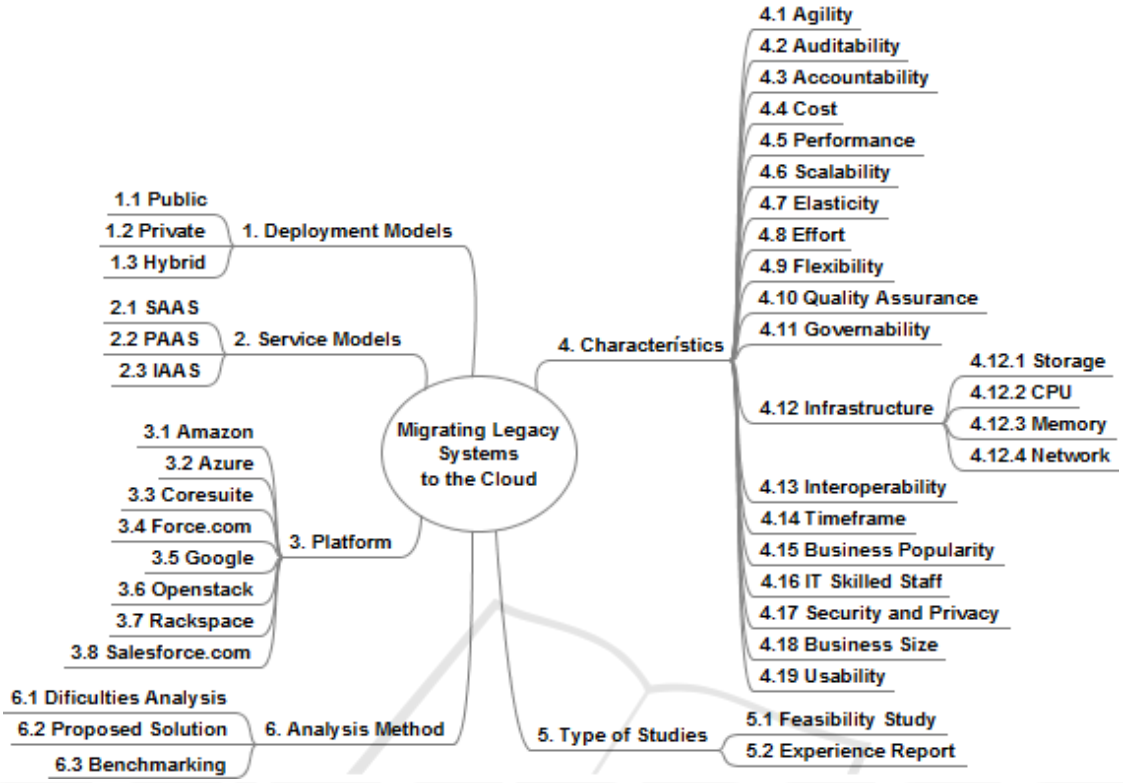

Figure 3: Findings from the Selected Studies.

From the metamodel conveyed in Figure 3, it was possible to build the repository represented in Table 2 comprised by 19 studies. This repository is the deliverable of Phase 3.

Table 2 represents data related to two specific research questions: SRQ1 can be mapped to the column ”Studies” that contains the identification of the selected studies for the characterization. The strategy and phases to select the papers were described in the paragraphs following Figure 1. The SRQ2 can be addressed in the identification of elements and strategies in the studies. These elements and strategies were classified and presented in the columns as Deployment Models, Service Models, Platforms, Characteristics, Types of Study and Analysis Method. Regarding the specific research question (SRQ3), the evidence identified in the studies will be discussed in the next section.

Phase 4: Repository Analysis. The strategy to analyze the repository consisted in identifying the influence of the selected issues presented in Figure 3 and according to the levels of abstraction prestend in Figure 4: Deployment Model, Service Models, Platform and Characteristics. In the level of Service Model, a new sub-level was created to contain the following elements Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). In the characteristics level, a new sub-level of infrastructure characteristics was created to contain the following elements: Memory, Processor and Storage. In addition, two other levels comprise the repository: Type of Study and Analysis Method. These two latter levels are considered as transverse elements when compared to the other ones previously listed.

Adjusting the Study Characterization Phases. After performing the phases presented in Figure 1, we identified the opportunity to adjust it by the inclusion of two new phases ”Create the Mental Model”, represented in Figure 3 and ”Design the Abstraction Level”, represented in Figure 4. The phase ”Create the Mental Model” was included to enable the creation of a visual representation of a hierarchy of the elements identified in the analysis. And the ”Design the Abstraction Level” is a visual representation to organize the identified elements according to their groups in the cloud domain. As can be viewed in Figure 5.

4 DESCRIBING THE STUDIES

In this section, we describe the main characteristics of the 19 selected studies according to the level of ab-

Table 2: Study Repository to Answer SRQ1.

Studies	Deployment Models (1)	Service Models (2)	Platform (3)	Characteristics (4)	Type of Studies (5)	Analysis Method (6)
S2	Public	2.3	3.1	4.4	5.1	6.2
S8	Private	2.3	3.6	NM	5.1	6.3
S9	Public	2.1	3.5	4.4 and 4.8	5.1	6.2
S11	Public	2.3	3.2	4.5	5.1	6.3
S13	Public	2.3	3.1	4.4, 4.12.2 and 4.12.3	5.2	6.2
S16	Public	2.2 and 2.3	3.5	4.4	5.1	6.1
S25	Private	2.3	NM	4.17	5.2	6.1
S31	Public	2.1 and 2.2	3.3, 3.4 and 3.8	4.6 e 4.9	5.2	6.3
S32	Public	2.2	NM	4.4, 4.9, 4.14, 4.15, 4.16, 4.17 and 4.18	5.1	6.1
S40	Public	2.3	3.1	4.4, 4.12.1, 4.12.2, 4.12.3 and 4.12.4	5.2	6.3
S44	Public	2.2	3.2	4.5	5.2	6.3
S45	Hybrid	2.3	3.1	4.4	5.2	6.3
S46	Private	2.1	NM	4.17	5.2	6.2
S49	NM	2.1	NM	4.2, 4.11, 4.13 and 4.17	5.2	6.2
S50	Private	2.2	NM	4.4 and 4.5	5.1	6.3
S54	Public	2.3	3.1	4.4 and 4.5	5.2	6.3
S55	Public	2.2 and 2.3	3.1, 3.2, 3.5 and 3.7	4.4 and 4.5	5.2	6.2
S56	Public	2.3	3.1 and 3.5	4.4, 4.12.1, 4.12.2, 4.12.3 and 4.12.4	5.2	6.3
S57	Public	2.3	3.1, 3.2 and 3.7	4.1, 4.3, 4.4, 4.5, 4.10, 4.17, 4.19, 4.7, 4.12.1, 4.12.2 and 4.12.3	5.2	6.2

NM = Not Mentioned.

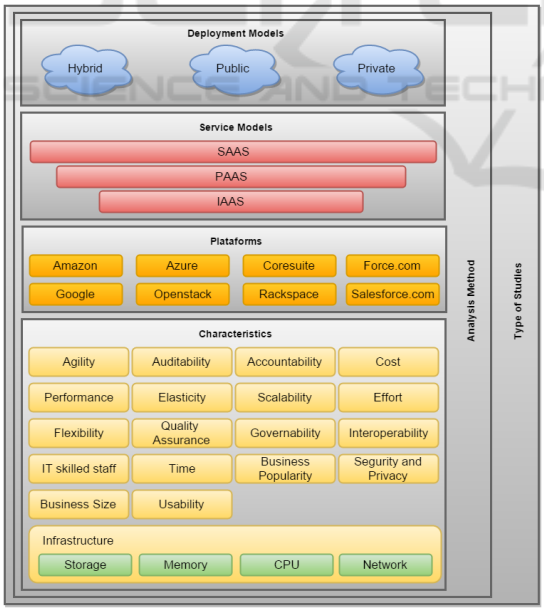

Figure 4: Level of Abstraction and Hierarchy of Elements in the Studies.

straction and hierarchy of elements in the studies presented in in Figure 4. based on the strategy presented before. We scrutinized the papers reporting the studies to identify relevant issues for analysis numbered according to the items presented in Figure 3.

Study S2: Cost Modeling Tool Evaluation. Goal: Evaluate a cost modeling tool called *Cloud Adoption Toolkit* through the comparison of three cost options: server acquisition, rental of equivalent infrastructure in the cloud, use of elasticity of demand in the cloud. In the S2 study, the authors evaluated the migration to a public cloud (1.1) using the IaaS service model (2.3). They also used the Amazon provider web services (3.1) to evaluate migration costs (4.4) using the cost modeling tool (6) as part of the Cloud Adoption Toolkit and hence the migration feasibility (5.1) of specific services from the St Andrews University to the cloud.

Study S8: Feasibility of Web Service Migration. Goal: Evaluate the feasibility (5.1) to migrate a web service solution to the cloud. For this end, the S8 study adopted a private cloud (1.2) with a IaaS (2.3) as a service model. The authors informed that OpenStack (3.6) was the chosen platform to migrate two server to the private cloud. The first server hosts a web service while the second hosts a database service. The servers were replaced by two virtual machines instances. The authors did not mentioned the characteristics as expected in the model presented in Figure 3. The study presented a feasibility study (5.1) to compare (6) the results.

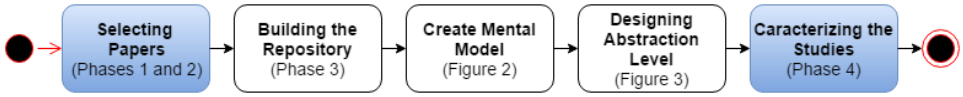

Figure 5: Adjusted Version of the Characterization Phases.

Study S9: Evaluation of ARTIST Project Tool. Goal: The S9 study reports a feasibility study of three tools aimed at evaluating the maturity, technical feasibility (5.1) and business feasibility (5) in the context of ARTIST project. The study describes the migration of a Java application called PetStore to the following scenario: public cloud (1.1) with the Google App Engine (3.5) as platform to evaluate cost (4.4) and effort (4.8) to migrate the PetStore to the cloud application in such a way that its users can access the application as a SaaS (2.2).

Study S11: Feasibility of FTP Server Migration. Goal: The S11 study reports a feasibility evaluation (5) of a FTP server migration to the cloud with corresponding advantages and challenges of this migration. For this end, a FTP server was configured in the public deployment model (1.1) using IaaS (2.3) through the Windows Azure provider (3.2) with elasticity resources (4.7). A performance (4.5) benchmarking (6.3) was performed aiming at identifying potential benefits and problems related with the migration of legacy systems to the cloud.

Study S13: Desktop-to-Cloud-Migration (D2CM) Tool Evaluation. Goal: The S13 study reports the evaluation of the D2CM Tool. The goal is to investigate the performance (4.5) and usability (4.19) of the tool. In the study, the authors adopted the public deployment model (1.1), the IaaS service model (2.3) and the tool D2CM to migrate an environment to the Amazon EC2 (3.1). The D2CM tool integrate a set of software libraries to support both the migration and the management of experiments in the cloud. The focus is the evaluation of the processor (4.12.2), memory (4.12.3) and cost (4.4).

Study S16: Feasibility Study and Difficult Analysis. Goal: The study focus on the evaluation of the migration of three legacy systems from the British Telecom to the Google App Engine (3.5). The study uses a compatibility checklist to guide the cost estimation (4.4) to migrate to the public deployment model (1.1) through the use of a IaaS (2.3) and PaaS (2.2) service models. In the case of the IaaS, the cost consisted basically in the management of resources without the need to change the code. However, when compared with the PaaS scenario, the cost is higher. The authors discussed the changes needed to migrate the three legacy systems to the Google App Engine (3.5) and the corresponding effort (4.8) and the feasibility (5.1) of the migration.

Study S31: Feasibility Study Goal: Perform a Feasibility Study (5.1) regarding the Migration of two legacy systems to the cloud. The authors compared the results (6.3) of the migration of Enterprise Resource Planning (ERP) systems of two companies to the public cloud (1.1). The first migration used both the SaaS (2.1) and PaaS (2.2) service models combined with the platforms Salesforce.com (3.8) and Force.com (3.4). On the other hand, the second migration used the PaaS (2.2) service model aimed at improving issues such as flexibility (4.9) and scalability (4.6) provided by the features of PaaS.

Study S32: Feasibility Analysis of a Migrating an Account System to the Cloud. Goal: Present an experience report regarding the selection of the effective service model for an accounting system. The feasibility analysis considered the following issues in the migration decision: public deployment model (1.1), the PaaS service model (2.2), flexibility (4.9), cost (4.4), business popularity (4.15), business size (4.18), security and privacy (4.17), timeframe (4.14), skill level of the IT staff (4.16). The authors did not mentioned the name of the selected platform (3).

Study S40: Selection of an Amazon EC2 Instance Configuration. Goal: Identify the best Amazon EC2 (3.1) Instance Configuration in a public cloud (1.1) using the IaaS (2.3) service model. The study used a Feature Model to analyze issues related to infrastructure (4.12) and cost (4.4) to compare a set of instances configuration to identify the one that best fit a specific scenario. The main contributions of the study is the list of the characteristics as well as configuration options of EC2 together with guidelines for the configuration of an EC2 instance using the Amazon EC2.

Study S44: Comparing the Performance of a Legacy System with Its Corresponding Version in the Cloud. Goal: Collect evidence of the performance of a legacy system after its migration to the cloud and compare with the previous legacy scenario. The legacy system executed in a .Net platform and in the cloud used the Microsoft Azure (3.2). The study concluded that the performance (4.5) does not deteriorate when migrating to the cloud. Moreover, the study presents potential advantages of the PaaS (2.2) service model in a public cloud (1.1).

Study S45: A Game-theoretic Approach to the Financial Benefits of Infrastructure-as-a-service. Goal: Compare the issues of cost (4.4) of an owned

data center with the cost of using the platform Amazon EC2 (3.1). The study considered costs per year for an owned data center as an investment cost amortization and running costs. Investments were considered as acquisition costs for server and network hardware together with operation system licenses (3 years write-off) as well as infrastructure and building costs (15 years write-off). Running costs were considered as maintenance, power, administration, and data transfer. The study discussed issues related to effects of hybrid clouds, reserved instances, economies of scale and market form, availability risk.

Study S46: Service Provider Selection. Goal: Select a Service Provider based on security and privacy (4.17) issues. The scenario is comprised of a company that aims at providing their point of sale services through a SaaS (2.1) in a private cloud (1.1). Due to confidentiality reasons, the paper does not list the providers (3) analyzed in the study.

Study S49: Service Provider Selection. Goal: Evaluate the effectiveness of the Fusion and Aggregation for Geospatial Information (FAGI) framework to select service providers. The study discussed the significance and ramifications of a structured selection of a Cloud Service Provider (CSP) in achieving the required assurance level based on an organization's specific security posture. The following issues were considered in the provider selection: security (4.17), auditability (4.2), portability (4.20), governability (4.11) and interoperability (4.13).

Study S50: Migrating Legacy Applications to the Cloud. Goal: this case study documents the migration of a text-mining application, acting as a proxy for any legacy application, through a set of stages progressing towards deployment in a cloud environment. The Private (1.1) deployment model and PaaS (2.2) Service Model were used. The Platform (3) was not mentioned. Performance (4.5) and cost (4.4) were also evaluated in the study.

Study S54: Benchmark of Cloud Computing Environments. Goal: Conduct a survey on a selection of Cloud providers, and propose a taxonomy of eight important Cloud computing elements covering service models (2), resource deployment, hardware/infrastructure (4.12), runtime tuning , business model (4.11), middleware, and performance (4.5).

Study S55: Evaluation of the CloudCmp Tool. Goal: Compare the performance (4.5) and cost (4.4) of AWS (3.1), Microsoft Azure 3.2), Google App Engine (3.5) and Rackspace (3.7) cloud providers. CloudCmp measures the elastic computing (4.7), persistent storage (4.12.1), and networking services (4.12.4) offered by a cloud along metrics that directly reflect their impact on the performance of customer applications. For this end, the study analyzed the deployment of three simple applications on the public cloud (1.1) using the IaaS (2.3) and PaaS (2.2) service models to check whether the benchmark (6.3) results from CloudCmp are consistent with the performance experienced by real applications. In this case, the study validated the conjecture that CloudCmps results can be used by customers to choose cloud providers in lieu of porting, deploying, and measuring their applications on each cloud. The applications included a storage intensive e-commerce website, a computation intensive application for DNA alignment, and a latency sensitive website that serves static objects.

S56 Study: Evaluate the Effectiveness of Google Compute Engine (GCE) and Amazon EC2 to Deploy Scientific Applications. Goal: Use the Cloud Evaluation Experiment Methodology (CEEM) to benchmark GCE and compare it with Amazon EC2, to help understand the elementary capability of GCE for dealing with scientific problems.The experimental results and analyses showed both potential advantages of, and possible threats to applying GCE to scientific computing. For example, compared to Amazons EC2 service, GCE may better suit applications that require frequent disk operations, while it may not be ready yet for single VM-based parallel computing. Based on the fundamental evaluation results, suitable GCE environments can be further established for studies focusing on real science problems.

Study S57: Evaluation of the SMICloud Framework. Goal: Evaluate the effectiveness of the Service Measurement Index Cloud (SMICloud) Framework to rank Cloud services based on QoS requirements. The SMICloud framework provides features such as service selection based on QoS requirements and ranking of services based on previous user experiences and performance of services. SMICloud uses the public cloud (1.1) and the IaaS service model (2.3) to rank the following providers: Amazon (3.1), Microsoft Azure (3.2) and Rackspace (3.7). The following characteristics were evaluated: Accountability (4.3), Agility (4.1), Quality Assurance (4.10), Cost (4.4), Performance (4.5), Security and Privacy (4.17), Usability (4.19), Elasticity (4.7) and Infrastructure issues Central Processing Unit (CPU) (4.12.2), Memory (4.12.3) and Storage (4.12.1).

5 RESULTS AND DISCUSSIONS

In this section, we followed the instructions described in the phase Characterization the Studies to answer the Specific Research Questions SRQ1, SRQ2 and

SRQ3.

We followed the instructions described in *"Phases for the Studies Characterization"* in section 3 to select the studies to answer the Specific Research Question 1 (SRQ1). The selected studies were then the reference to build a repository as presented in Table 2 to support the identification of elements and strategies used in studies focusing on cloud computing adoption. To answer SRQ2, we analyzed the data available in the repository (Table 2) to identify elements and strategies adopted in the selected studies. From this point, we were able to organize the data in four levels: deployment models, service model, platform and characteristics.

Transversely to these four levels, we included another two perspectives: type of studies and analysis method. To deal with SRQ3, to identify evidence of patterns and tendencies in the planning and execution of the selected studies, we analyzed separately each level previously described considering both the repository and the summary of each study presented in the previous section. In the following paragraphs, we present the results and discuss them.

Deployment Model Analysis. The deployment model scenario obtained from the selected studies is conveyed in Figure 6. As can be observed, there is a tendency for the use of the public deployment model in the studies, which corresponds to 68% of the 19 studies. This can be explained by the availability of the public providers and the myriad of instances types and profiles with corresponding pricing they offer which can meet different study needs and purposes.

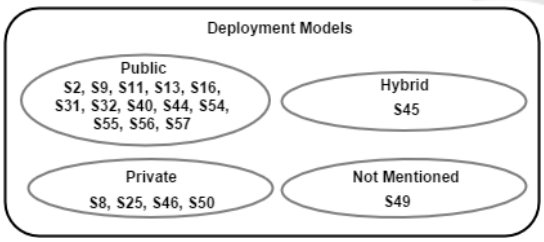

Figure 6: Deployment Models Identified.

Service Model Analysis. Similarly, the service model scenario obtained from the selected studies indicated that 68% of the 19 studies use the IaaS service model. The Figure 7 illustrates this tendency. This can be explained by the relatively deployment easy of IaaS (2.3) when compared to PaaS (2.2) service model. In the first case, the deployment can be executed through the use of a virtual machine in the cloud with the full stack of the legacy system to be analyzed in the study. In the case of PaaS service model, there is the need to configure the application in the cloud using the original platform resources such as operating systems, databases and drivers.

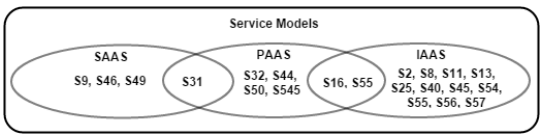

Figure 7: Service Models Identified in the Studies.

Platform Analysis. The Figure 8 indicates that 42% of the studies used the Amazon EC2 platform (3.1). It should be mentioned that five studies did not informed the service provider used in their respective studies. We could not find the reasons for the preference for the Amazon EC2. However, there is the possibility that this preference may be the result of the flexibility of pricing plans for the provider available instances.

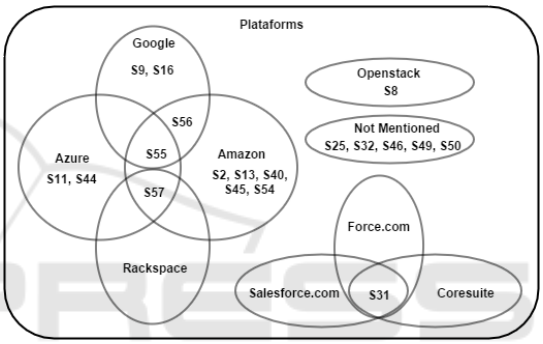

Figure 8: Platforms Identified in the Studies.

Characteristics Analysis. As can be seen in Table 3 and Figure 9, the characteristics that stood out in the selected studies were: costs (4.4), performance (4.5) and security/privacy (4.17). From the number of occurrences, it is possible to conclude that cost is by far the most influential characteristic in the cloud computing adoption. Companies that adopt cloud computing are willing to pay for resources that can be allocated in a pay-as-you-go fashion. This can lead to representative overall cost reduction as a result of several factors among the following: reduction of maintenance costs, of energy consumption, issues related to purchasing software licenses and depreciation allowances now in charge of the provider, just to mention some. The performance and security/privacy characteristics are issues also prioritized by users. With regard to security in a natural disaster event,for example, the servers continue operating normally since the security policy of the service providers located kilometers away from the headquarters. Regarding the performance, it is possible to allocate resources in the cloud changing settings in the provider and thereby allowing quick response to business needs while increasing performance at times of

peak processing. This is an important factor to lead to considerable stability in the services provided by a company. Moreover, due to elasticity, flexibility and interoperability, previous demand resources can return to their original configuration, contributing to possible reduction of costs. The infrastructure allocated to a specific instance (e.g. memory, storage and CPU) can vary according to different priorities depending on the profile of the type of service provided to the final user.

Table 3: Study evidence Consolidation.

Characteristics	Studies	Studies Quantity
Cost	S2, S9, S13, S16, S32, S40, S45, S50, S54, S55, S57	11
Performance	S11, S44, S50, S54, S55, S57	06
Security and Privacy	S25, S32, S46, S49, S57	05
Infrastructure (Memory)	S13, S56, S57	03
Infrastructure (CPU)	S13, S56, S57	03
Infrastructure (Storage)	S56, S57	02
Flexibility	S31, S32	02
Agility	S57	01
Auditability	S49	01
Accountability	S57	01
Scalability	S31	01
Elasticity	S57	01
Effort	S9	01
Quality Assurance	S57	01
Governability	S49	01
Infrastructure (Network)	S56	01
Interoperability	S49	01
Timeframe	S32	01
Business Popularity	S32	01
IT Skilled Staff	S32	01
Business Size	S32	01
Usability	S57	01

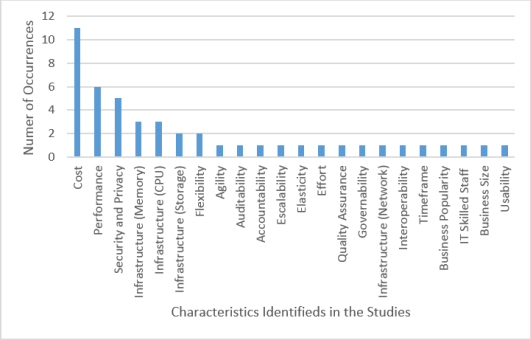

Figure 9: Characteristics Identified in the Studies.

Type of Study and Analysis Method. In Figure 10, we can observe that studies use with more frequency the strategy based on experience report. This is an interesting finding that show possibilities to share experience among potentially interested parties in issues related to cloud computing adoption and migration.

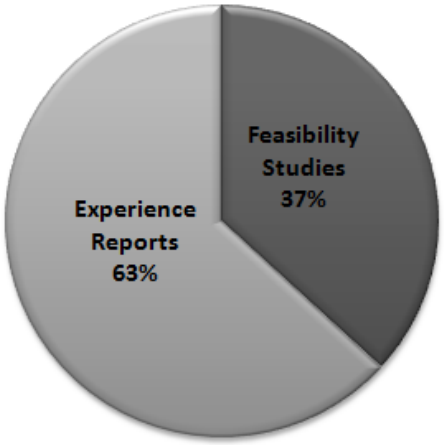

Figure 10: Types of Study.

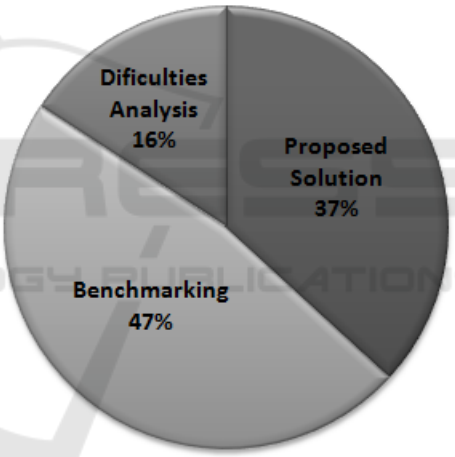

Figure 11: Analysis Method.

On the other hand, in Figure 11, we can observe a predominance of studies reporting difficulties, challenges and results obtained together with benchmarking and difficulties analysis. This lead to 63% of the occurrences in the studies, what brings possibilities of lessons learnt in the community that are prone to adopt the cloud computing paradigm.

6 THREATS TO VALIDITY

The following types of validity issues were considered when interpreting the results from this characterization. *Conclusion validity.* There may be bias in data extraction. However, this was addressed through defining a data extraction form to ensure consistent

extraction of relevant data to answering the research questions. The findings and implications are based on the extracted data. *Internal validity.* One possible threat is the selection bias. We have addressed this threat during the selection step as described in Figure 1, i.e. the studies included in the characterization were identified through a thorough selection process which comprises of multiple phases. *Construct validity.* The studies identified from a previous SLR conducted by the authors were accumulated from multiple literature databases covering relevant journals and proceedings. One possible threat is bias in the selection of publications. This was addressed through specifying a research protocol that defines the research questions and objectives of the study, inclusion and exclusion criteria, search strings that we intend to use, the search strategy and strategy for data extraction.

External Validity. The set of 19 papers selected in Phase 4 as described in Figure 1 is a potential external validity threat. In this case, there is a threat that the results so far obtained could not be generalized. However, the studies were selected having as a start point the ones published between 2005 and 2015 from a previous SLR conducted by the authors. For this reason, the set of the 19 studies are considered representative enough as a sampling for this characterization.

7 CONCLUSIONS

The analysis of data and the consequent identification of strategies, approaches and tools reported in the studies, could help in establishing knowledge on how the companies should adopt and migrate to the cloud, how the cost-benefit relationship can be evaluated as well as providers can be selected.

The selection of commercial cloud providers is a challenging task and depends on several factors. Among other reasons, cloud providers continually upgrade their hardware and software infrastructures. The result is that new commercial Cloud services, technologies and strategies gradually enter the market (Li et al., 2013). Studies have shown that successful migration to the cloud are usually driven by a set of criteria to select providers that best fit the company needs (Li et al., 2012b) (Li et al., 2010) (Garg et al., 2013). According to the results of the characterization presented in this paper, there is a tendency in the studies for the public deployment model (1.1). Another important finding is the perception of cost reduction. This fact is associated with the absence of the requirement to tie-up capital, to deal with technological obsolescence, hardware maintenance, as well as purchasing software licenses and depreciation allowances. In the cloud paradigm, these issues are now in charge of the provider. We also identified a tendency for the use of the IaaS model service. This can be explained due to the relative less migration complexity to the cloud that in this case is supported by virtual machines. On the other hand, the adoption of the PaaS model service has a potential drawback reported in the studies the need to adapt the application, including the need to rewrite parts of the code, replace libraries and APIs that can be not compatible with the cloud provider environment. All these factors together contribute to a higher migration effort and cost. However, the studies also highlighted the need to evaluate the cost-benefit relationship of both possibilities: IaaS and PaaS. Another finding was the emphasis of the studies in experience report format revealing opportunities of lessons learnt sharing. The opportunities of cloud migration and provider selection were conducted considering issues related to cost, performance and security/privacy. To sum up, it was possible to identify a tendency in the simultaneous use of public providers deployment model, the IaaS service model and the Amazon platform. As a future work, we plan to conduct a survey focusing on companies that migrated to the cloud to confirm the results of this characterization study.

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APPENDIX

Table 4: Studies included in the review.

ID	Author, Title	Venue	Year
S2	A. Khajeh-Hosseini, D. Greenwood, J. W. Smith and I. Sommerville, **The Cloud Adoption Toolkit: Supporting Cloud Adoption Decisions in the Enterprise.** ***Top Ten Cited Paper According to Google Scholar***	SPE	2012
S8	O. Sefraoui, M. Aissaoui and M. Eleuldj, **Cloud computing migration and IT resources rationalization.**	ICMCS	2014
S9	J. Alonso, L. Orue-Echevarria, M. Escalante, J. Gorronogoitia and D. Presenza, **Cloud modernization assessment framework: Analyzing the impact of a potential migration to Cloud.**	MESOCA	2013

Table 4: Studies included in the review (cont.).

ID	Author, Title	Venue	Year
S11	L. Zhou, **CloudFTP: A Case Study of Migrating Traditional Applications to the Cloud.**	ISDEA	2013
S13	S. N. Srirama, V. Ivanistsev, P. Jakovits, and C. Willmore, **Direct migration of scientific computing experiments to the cloud.**	HPCSim	2013
S16	Q. H. Vu and R. Asal, **Legacy Application Migration to the Cloud: Practicability and Methodology.**	SERVICES	2012
S25	A. Michalas, N. Paladi and C. Gehrmann, **Security aspects of e-Health systems migration to the cloud.**	HealthCom	2014
S31	T. Boillat and C. Legner, **Why Do Companies Migrate Towards Cloud Enterprise Systems? A Post-Implementation Perspective.**	CBI	2014
S32	M. Sadighi, **Accounting System on Cloud: A Case Study.**	ITNG	2014
S40	J. Garca-Galn, P. Trinidad, O. F. Rana and A. Ruiz-Corts**Automated configuration support for infrastructure migration to the cloud.**	FGCS	2015
S44	P. J. P. da Costa and A. M. R. da Cruz. **Migration to Windows Azure Analysis and Comparison.**	PROTCY	2012
S45	J. Knsemller and H. Karl **A game-theoretic approach to the financial benefits of infrastructure-as-a-service.**	FGCS	2014
S46	H. Mouratidis, S. Islam, C. Kalloniatis and S. Gritzalis. **A framework to support selection of cloud providers based on security and privacy requirements.**	JSS	2013
S49	C. Tang and J. Liu.**Selecting a trusted cloud service provider for your SaaS program.**	COSE	2015
S50	F. CRowe, J. Brinkley and N. Tabrizi.**Migrating Legacy Applications to the Cloud.**	CLOUDCOM	2013
S54	R. Prodan and S. Ostermann. **A Survey and Taxonomy of Infrastructure as a Service and Web Hosting Cloud Providers.** ***Top Ten Cited Paper According to Google Scholar***	IWGC	2009
S55	A. Li, X. Yang, S. Kandula and M. Zhang. **CloudCmp: Comparing Public Cloud Providers.** ***Top Ten Cited Paper According to Google Scholar***	IMC	2010
S56	Z. Li, L. OBrien, R. Ranjan and M. Zhang. **Early Observations on Performance of Google Compute Engine for Scientific Computing.**	CLOUDCOM	2013
S57	S. K. Garg, S. Versteeg and R. Buyya. **A framework for ranking of cloud computing services.** ***Top Ten Cited Paper According to Google Scholar***	FGCS	2013