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Challenges, Patterns and Sustainability Indicators for Cloud Computing

Desafios, padrões e indicadores de sustentabilidade para computação em nuvem

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ABSTRACT
Cloud computing has reshaped the way companies use computing. The delivery of everything as a service, which is the basis of this technology, allows the use of software, platforms, infrastructures, databases, etc. via remote connection. Due to its applicability, many organizations consider deploying their private cloud infrastructures to avoid relying on service providers. However, countless factors interfere negatively in this process, especially when we consider questions related to sustainability. This article presents the main challenges and concerns faced by companies that aim to migrate to cloud computing. A series of standards and indicators are listed which can serve as a basis for companies to achieve/contribute to environmental sustainability. The data presented is the result of an extension of a systematic literature review and much research on the mentioned topic.

Keywords: Cloud computing, Sustainability, Challenges, Concerns, Patterns, Indicators.

RESUMO
A computação em nuvem remodelou a maneira como as empresas usam a computação. A entrega de tudo em serviço, que está na base desta tecnologia, permite a utilização de software, plataformas, infraestruturas, bases de dados, etc. através de ligação remota. Devido à sua aplicabilidade, muitas organizações consideram a implantação de suas infraestruturas de nuvem privada para evitar a dependência de provedores de serviços. No entanto, inúmeros fatores interferem negativamente nesse processo, principalmente quando consideramos as questões relacionadas à sustentabilidade. Este artigo apresenta os principais desafios e preocupações enfrentados por empresas que desejam migrar para a computação em nuvem. Uma série de padrões e indicadores são listados que podem servir de

base para as empresas alcançarem / contribuírem para a sustentabilidade ambiental. Os dados apresentados são resultado de uma extensão de uma revisão sistemática da literatura e de muitas pesquisas sobre o tema mencionado.

Palavras-chave: Computação em nuvem, sustentabilidade, desafios, preocupações, padrões, indicadores.

1 INTRODUCTION

Currently, cloud computing is one of the constantly expanding technologies in the computing sector, allowing the use of computing infrastructure with different abstraction levels and offering on-demand services available on the [Jansen and Grance 2011]. GiveInternet in this reality, there is a strong expectation about the increase in demand for computational energy, which should be driven mainly by the large-scale construction of new data center infrastructures.

Data centers consume large amounts of electricity, thus contributing to carbon dioxide emissions (CO_2), they also demand high operating costs. This general structure presents a concern that stands out on a global scale: global warming. For this reason, energy efficiency is one of the aspects of (environmental) sustainability of great importance for IT. Several groups of organizations are striving to promote the implementation of greener computing, called Green Cloud Computing, and thus achieve a reduction in energy consumption from fossil fuels.

The rising economic costs and environmental damage caused by expensive data center infrastructures have increased interest in sustainable computing, leading companies to a reality that forces them to be concerned with various aspects of sustainability. This concern can be caused by contractual requirements, by law, or even by pressure from customers.

The planning of the energy, cooling, and IT infrastructures, considering the financial investments made, is one of the great challenges of the private cloud [Ahson and Ilyas 2010]. Planning IaaS sustainable ways costs much more than conventional models. Initiatives focused on propagating techniques to make data centers more sustainable consider IT equipment efficiency, energy efficiency, and cooling efficiency as well as clean energy alternatives.

Other issues that hinder the planning process for the implementation of IT infrastructures are the lack of standardization, the lack of legislation in general and that meets the needs of sustainability, control, and environmental management, as well as the difficulties to meet the requirements non-functional and quality requirements that make up service level agreements (SLAs).

In recent years, a lot of work has been done to address issues related to cloud computing. Researchers have used different approaches to deal with the various inherent problems of distributed computing, considering the problems of migration and deployment, performance, availability, sustainability, security, among others. The works described below present themes related to the context of this research.

In [dos Santos, et al. 2020] the authors evaluate the performance of three private cloud servers, presenting different test scenarios for evaluating the performance of CPU, memory and disk, to illustrate the applicability of these software in a low cost private cloud with easy management and high performance capacity.

In [Mohamed et al. 2015] the authors propose a project for a private university IaaS cloud, implementing two solutions to improve its security; especially the isolation of data in the IaaS and the isolation of the network, adopting the Tree-Rule Firewall approach.

In [Younge et al. 2010] a new structure is presented that provides efficient ecological improvements within a scalable cloud computing architecture, using energy-conscious scheduling techniques, variable resource management, live migration and a minimal virtual machine design.

In [Witkowski et al. 2015] the authors present the EOC Green Cloud prototype that serves as an operational demonstration that IT resources can be integrated with the dominant energy footprint of existing and dynamically controlled facilities to balance process production and server management.

Unlike the works presented, in this work, we make a diagnosis of sustainability in cloud computing to present the main challenges and concerns in the process of migration to private infrastructure. The results presented were generated based on a systematic review of the literature and research on the mentioned topic. In this way, we identify which aspects are the most important/critical to guarantee the delivery of services and the sustainability (environmental and financial) of the business. This article is presented as follows:

- In Section 2 we present the theoretical framework for the concepts that underlie our research, namely cloud computing, non-functional requirements, and sustainability. We also show the results of a systematic literature review, where we present as a contribution which are the aspects of sustainability that are in focus in the interests of cloud computing, in addition, we show which are the most cited problems in the area, which can be seen as gaps or opportunities for investigation.
- In Section 3 we present the sustainability guides and indicators. In this section, we think about contributing to companies so that they can be based on these standards, techniques, and indicators when they are going to design their private cloud infrastructure (data center). The idea is that companies can guarantee the delivery and provision of services while contributing to environmental sustainability.

- Finally, in Section 4 we present the final considerations and identify some proposals for future work.

2 BACKGROUND

This section presents the fundamental concepts of cloud computing, non-functional requirements, and sustainability. At the end of the section, we present the results of a systematic review of the literature and identify the aspects of sustainability that are being investigated in cloud computing, citing the problems and gaps found in this area.

2.1 CLOUD COMPUTING

A widely accepted definition for cloud computing, given by NIST in 2011, refers to it as a model for enabling on-demand, ubiquitous, and convenient network access to a shared pool of configurable computing resources that can be quickly provisioned and released with minimal management effort or interaction with your service provider [Cloud 2011].

In cloud computing resources are provided at different service levels, including software as a service (SaaS), which deals with the provision of applications; platform-as-a-service (PaaS) provides the capability for creating applications in the cloud; and infrastructure as a service (IaaS) that provides the infrastructure for processing, storage, network, and other resources. In a public cloud, the infrastructure is available for public use, external to the provider; the private cloud is used by a specific group of users, being able to be proprietary or of the service provider; a hybrid cloud is composed of two or more types of clouds, which are bound by some standardized technology; and in the community cloud the infrastructure is used by a set of organizations [Cloud 2011].

Cloud infrastructure computing can become a viable alternative for organizations only if these infrastructures provide adequate service levels. Factors such as resource grouping, elasticity, scalability, virtualization, availability, and performance should be considered. Providing functionality and adequate quality of service are the challenges of service-oriented computing. However, evaluating the performance of software and infrastructures can reveal effective information under workloads [John and Eeckhout 2018] to understand bottlenecks, need for improvements and adjustments of components [Jain 1991], [Menasce et al. 2004].

2.2 NON-FUNCTIONAL REQUIREMENTS

Non-functional requirements can be divided into two main categories: execution qualities, such as security and usability, which are observable at runtime; and evolution of qualities such as the ability to test, maintainability, extensibility, and scalability, which are incorporated into the static structure of the system. Availability, fault management, fault tolerance, maintainability, and performance are examples of NFRs [Chung et al. 2012]. Usability, maintainability, security, and performance are difficult to handle since the beginning of engineering requirements [Sommerville 2011].

There is no formal definition or a complete list of NFRs, nor is there a single universal classification scheme, and different people use different terminologies, which can make it harder to use certain classifications without customizing them. A variety of quality attributes and several classes of NFRs are presented, among which are: operational performance, life cycle, economic and political constraints [Chung et al. 2012].

NFRs may have different priorities and serve as selection criteria between different alternatives, however, they may affect each other. For example, improving performance can increase costs as well as improving security may decrease performance [Kazman et al. 1998]. In this way, it may be necessary to refine them into hierarchies through quantitative or qualitative comparisons and assign levels of importance to each of them [In et al. 2002].

2.3 SUSTAINABILITY

The concept of sustainability encompasses not only the impact of human beings on nature but also the technological capacity to produce more durable and less wasteful materials to avoid the planet degradation, which has always occurred, but which is accelerating with globalization and increasing due to consumption in societies as a whole. Sustainable development is what meets the needs of the present without compromising the ability of future generations to meet their own needs [WCE&D 1987].

The concept that has been widely disseminated in recent times for sustainability, as well as for sustainable development, is, however, supported by the economic, social, and environmental pillars. In general, a process or a system can be said to be sustainable when it presents conditions for its permanence, at a certain level, for the longest possible period, taking into account the conditions of economic, social and environmental viability.

However, a major cultural change is necessary, so that the focus of the discussion is on how technology can enable the production of efficient, durable, and less harmful goods to the environment. The production of this type of goods requires investments, mainly in research and technological innovation, changes in standardization, changes in the relationship with customers, in the production chain, in legislation, among other factors, which challenge companies to operate transparently and responsibly [Hart and Mark 2004].

Best corporate practices that regulate environmental responsibility meet Green IT governance requirements and benefit stakeholders. Among corporate-specific governance standards are the Global Report Initiative (GRI) and the International Organization for Standardization (ISO) with standard 14.001, which guides, specifies, and helps in the improvement of a system of environmental management [Makower 2009]. Greenpeace also regulates and recognizes environmentally friendly businesses.

The challenge is to find effective solutions to reduce the emission of greenhouse gases (GHG), which in turn absorb radiation in the infrared frequency, imprisoning heat in the atmosphere, thus contributing to global warming. Due to the increasing development of industrial processes, including information and communication technology (ICTs) and data centers, there has been an increase in energy consumption, which is partly responsible for a share of carbon dioxide (CO_2) emissions. Researchers say that intensive computing companies account for an average of 10% of CO_2 emissions and that computers directly consume too much electricity, but indirectly in their production and disposal, they impact the environment and collaborate in increasing GHG. Despite efforts to achieve sustainability, some statistics show that countries like China, Japan, and the United States that contribute heavily to global growth are large emitters of CO_2.

In this sense, the commitment to sustainability, the use of ecologically responsible practices, the use of alternative and clean energies, among other issues that corroborate with sustainable development open up numerous research and innovation opportunities, however, it is necessary that organizations and users can truly to apply these concepts so that they can achieve cost savings, to decrease energy consumption, and to reduce environmental damage [Murugesan 2008].

2.4 SYSTEMATIC LITERATURE REVIEW

A systematic literature review is a means of identifying, evaluating, and interpreting available relevant research to an area topic or phenomenon of interest, whether to synthesize evidence on a given area or to identify gaps for further investigation [Kitchenham 2004]. In this work, we follow the phases of a systematic review following the process of conducting by the proposed recommendations [Kitchenham 2004] and present new results for the LSR shown in [Camboim and Alencar 2018].

The main objective of the systematic review presented in [Camboim and Alencar 2018] was to identify whether there is standardization to support the migration to cloud computing in private infrastructure, considering non-functional requirements that support sustainability. For this investigation, the authors defined the following research questions:

1. Are there approaches to support migration to cloud computing?
2. Are there approaches to support migration to cloud computing that take into account non-functional requirements and sustainability?
3. Which open questions are related to the research area?

The results present the synthesis and analysis of the data from the primary studies to identify the important evidence within the researched context and some gaps were raised in the area. The authors realized that there is no research in the literature about non-functional requirements and quality aspects (such as performance, availability, reliability, etc.) that at the same time is concerned with sustainable aspects for private cloud infrastructure. Considering that NFRs promote the correct functioning of IT operations and that sustainability promotes environmental health and reduction of operating costs, these topics must be integrated to drive the evolution of technology in an economically responsible and ecologically correct manner.

The data presented correspond to the phases of the LSR completed in July 2017. The search bases chosen by the authors were IEEE Xplore, ACM Digital Library, and SCOPUS. In total 2373 articles returned from searches in these three databases, and after the eliminations followed by several stages of the process (elimination of duplicates, elimination by reading the title and summary, and elimination by reading the introduction and conclusion), a total of 51 articles were read in full, 18 of which were rejected because they were not the focus of the research. Of the 33 articles that remained, after the application of the quality criteria, 4 of them were rejected, leaving 29 articles for data collection and the results presented refer to these articles. Of these, only 14 articles deal with sustainability, of which only 3 identify a specific pillar for sustainability (which is environmental). The rest do not present any specific information about this definition. Although the majority did not highlight this point, they all identified which aspects of sustainability would be considered. Table 1 shows what these aspects are and shows how many studies refer to them.

Table 1. Sustainability aspects

Aspects	Number of papers
Energy efficiency (EE)	3
EE, Alternative energies (AE)	1
EE, Environmental concerns (EC)	4
EE, AE, EC	3

EE, EC, Refrigeration	1
EE, AE, EC, Refrigeration	1
EC, Water efficiency, Water footprint	1

Source [Camboim and Alencar 2018]

From the data presented, it was clear to define that for all articles that address sustainability, the pillar specifically considered was the environmental one. However, it is still necessary to analyze how these aspects influence the social and economic pillars, given that when energy efficiency is achieved, in a certain way and in the long run, there is an impact on cost reduction because the three are intrinsically related. Also, according to the authors [Camboim and Alencar 2018], 21 articles somehow addressed possible gaps that can be better investigated which may arise as an open problem for cloud computing. Regarding sustainability, the most cited problems were:

- lack of practical application;
- stagnant culture;
- inefficiency of inspection and collection;
- difficulties in the decision-making process;
- diversity and high level of complexity of techniques to assess aspects such as energy efficiency;
- rapid modification of techniques and the emergence of new needs;
- high cost of more efficient equipment; and
- delay in return on investment.

In addition to the problems, some opportunities were also identified that deserve further investigation, they are:

- exploring a scheduling system that is both energy conscious and thermal to maximize energy savings;
- to reduce energy costs in a cloud federation ecosystem;
- integrating energy storage techniques with sCloud for sustainable computing in green data centers;
- to evaluate the performance and electricity bills of operators in a green data center;

- measuring data center energy usage to predict factors like PUE (Power Utilization Effectiveness) and find trends in energy efficiency data; and
- to investigate NFRs like security and fault tolerance to devise specific metrics to evaluate those NFRs in cloud applications.

Many of these problems may serve, individually or collectively, as ideas for the development of future works.

3 SUSTAINABILITY GUIDES AND INDICATORS

In this section, we provide an overview of the main efforts to ensure effective quality in the provision of cloud computing and IT services. There are several standards and techniques that establish guidelines for defining requirements for the correct management of a company that provides IT services so that it is possible to guarantee the provision of quality services. These standards and techniques are used by organizations because they provide guidelines for gathering, evaluating, documenting and managing requirements in a way that can ensure consistency and good results throughout the organizational process. As environmental sustainability has been a focus due to global warming, there are countless efforts to support business growth and ensure economic sustainability.

According to [Schulz 2009], specific issues or combinations of issues vary by organization size, location, reliance on and complexity of IT applications, and servers, among other factors. IT organizations in general have not been placing a high priority on being perceived as green, focusing instead on seemingly nongreen PCFE (power, cooling, floor space, and environmental health and safety) issues. Part of the green gap is that many IT organizations are addressing (or need to address) PCFE issues without making the connection that, in fact; they are adopting green practices, directly or indirectly. Consequently, industry messaging is not effectively communicating the availability of green solutions to help IT organizations address their issues. By addressing IT issues today that include power, cooling, and floor space along with asset disposal and recycling, the by-products are economic and ecologically positive. Likewise, the shift in thinking from power avoidance to more efficient use of energy helps from both economic and ecological standpoints.

Considering all the issues involved and the difficulties faced in the process of planning and implementing private infrastructures, especially due to the lack of information on the part of the companies that build their private data centers - for security reasons, in this section we strive to present standards, techniques and indicators that can guide the first moment of planning, especially considering ecological sustainability. In the sequence we present some standards, followed by the standards and techniques ISO/IEC 22123, ITIL, ISO 9000, ISO 20000, ISO 14000, we follow with some guidelines for the planning of the infrastructure and finally, we present some indicators of environmental sustainability.

3.1 PATTERNS

To solve the problem of the lack of standardization for the implementation of private cloud infrastructures, considering aspects of quality and sustainability, this work intends to offer an approach that presents a set of sustainability guides and indicators, so that they can assist in the companies' decision-making process.

The deployment of cloud computing brings countless opportunities and one of them is the economic reduction for organizations that adopt this technology. The costs related to the use of resources and services, the maintenance of data centers and operational costs can be offset in the medium and long term. Given the significant reduction in the physical structures of companies, due to virtualization and capacity planning, the economic impact is positive in the long run. Thus, space and cost savings are sought, especially about high maintenance and energy costs.

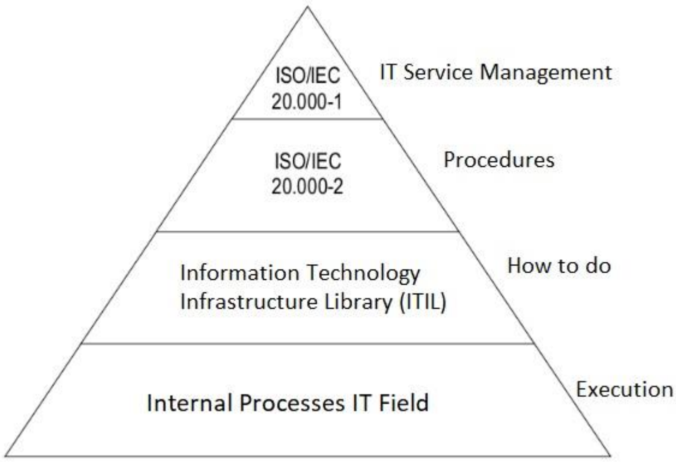
In order to better organize processes and ensure that the investment is returned, companies have to adapt to the new configurations of the service delivery model and adopt good strategies for all stages ranging from planning to the analysis of the services provided. In this sense, it is important to consider standardized approaches to facilitate success throughout the life cycle, which involves procedures for aligning operations geared to the organization's needs. A set of best practices is offered, which offer advantages to the organization both in terms of reducing costs by increasing the efficiency in the delivery and support of IT services and increasing the organization's capacity to generate revenue.

According to a study by Gartner Group, Inc., 80% of the causes of downtime of IT services are due to problems related to the operation of activities such as untested applications, poor management of changes, processing overhead, failures in procedures, failures in meeting requirements and errors related to security or backup routines. In another study, Gartner Group Inc. reports that 88% of financial services executives say that the operational efficiency of IT services is far more worrying than meeting the new IT needs of their organizations [Magalhães and Pinheiro 2007]

The management of IT services aims to properly allocate the available resources and manage them in an integrated manner, making the quality of the set perceived by its customers and users, avoiding the occurrence of problems in the delivery and operation of services. To ensure that this occurs, recommendations based on practices gathered in the Information Technology Infrastructure

Library (ITIL) and others presented by International Organization for Standardization (ISO) [Magalhães and Pinheiro 2007], as shown in Figure 1.

Figure 1. IT Service Management Strategies



Adapted from [Magalhães and Pinheiro 2007].

ISO is a non-governmental organization founded in 1947, in Geneva, and today present in about 189 countries. Its function is to promote the standardization of products and services so that their quality is permanently improved. Standards and norms have great benefits for demonstrating how best practices can be used. It is possible to point out some results resulting from its implementation, such as: defining the life cycles of the processes, analyzing errors, increasing the degree of safety, organizing working methods, generating continuous improvements, assessing the impacts of change, among others.

It is important to emphasize that the standards do not define the processes to be implemented and, in most cases, they are not mandatory or mandatory and are often adaptable. They present themselves as a facilitator to ensure that project needs are met and are in legal compliance. The following are some patterns of interest for this work.

3.2 ISO/IEC 22123 - CLOUD COMPUTING

This standard defines cloud computing, its terms, and definitions. A version made by ABNT in 2015, in Portuguese, is given by the NBR ISO/IEC 17788 standard [ABNT 2015]. The document establishes a reference for defining the scope and application of cloud computing, helping the development of national IT markets, serving as support to regulatory agencies.

Activities related to cloud computing can be categorized into three main groups: activities that they use, those that provide and those that support services. The customer belongs to a business relationship and its goal is to use the cloud. The business relationship is established with a provider or a partner. A cloud service partner may be engaged in supporting activities performed by either the provider or the customer, or both. A provider makes available and focuses on the activities necessary to provide and deliver customer services.

Cross-cutting aspects are the behaviors or capabilities that need to be coordinated and implemented consistently in a cloud computing system, including audibility, governance, interoperability, performance, portability, protection of personally identifiable information, regulatory, resilience, security and SLA. As security and governance aspects are considered most of the time as obstacles to the adoption of cloud computing.

Other efforts to standardize in the cloud computing area include:

- ISO/IEC DIS 19086-2 - Service Level Agreement (SLA).
- ISO/IEC FDIS 19941 - Interoperability and portability.
- ISO/IEC 19944 - Cloud services and devices: data flow, data categories, and data usage.
- ISO/IEC AWI 22123 - Concepts and terminology.
- ISO/AWI 22624 - Taxonomy-based data manipulation for cloud services.
- ISO/IEC NP TR 22678 - Guidance for policy development.
- ISO/IEC 30134-1 and ISO/IEC 30134-2 - Data centers - Main performance indicators.

However, most of these standards are in the process of development, which further confirms the immaturity of the technology and the need for investments in research to standardize and regulate its various processes and services. Due to this lack of standards for cloud computing, some other alternatives can guide, in general, the management processes of IT services and their assets, considering the standards made available for the IT area, defined next.

3.3 ITIL

ITIL was formed in the late 1980s by the Central Communications and Telecom Agency (CCTA), now the Office of Government Commerce (OGC), as an effort to discipline and allow comparison between the proposals of the various proponents of IT service providers for the British government. During the 1990s, the practices gathered at ITIL started to be adopted by European private organizations, since ITIL was conceived as an open standard, above all due to the great focus on quality, guaranteed by the definition of processes and the proposition of best practices for IT Service Management, enabling adherence to the ISO 9000 practice and the European Foundation for Quality Management (EFQM) reference model [Magalhães and Pinheiro 2007].

Among the motivating factors of the current race for the adoption of the practices gathered at ITIL, we can mention the increase in the following aspects [Magalhães and Pinheiro 2007]:

- Delivery and maintenance costs of IT services.
- Organizational requirements regarding the quality and cost/benefit of IT services.
- Demand to measure the return on IT investments.
- Complexity of IT infrastructure.
- Pace of changes in IT services.
- Need for availability of IT services.
- Aspects related to security.

ITIL is composed of a set of best practices for the definition of processes necessary for the functioning of an IT area, to allow maximum alignment between the IT area and the other business areas, to guarantee the generation of value to the organization [Magalhães and Pinheiro 2007]. ITIL seeks guidance for the management of IT services, describing the objectives, general activities, necessary prerequisites, and expected results of the various processes. Each process consists of a set of interrelated activities, based on a stipulated objective, performed to achieve the desired results. A process can become quite complex, depending on the organization, with a specific management method for each process. The proposed process reference model has two areas in which ITIL processes are fundamental for its full operation [Magalhães and Pinheiro 2007]:

- Service Delivery
- Service Level Management
- Capacity Management
- Finance Management
- Support Services
- Service Desk
- Incident Management
- Problem Management
- Configuration Management
- Change Management
- Version Management

In addition to the processes in these two main areas, described in ITIL, the process reference model includes others related to [Magalhães and Pinheiro 2007]:

- Application Management.
- Security Management.
- Communication Management.
- Relationship Management.

3.4 ISO 9000 - QUALITY MANAGEMENT

ISO 9000 designates a group of technical standards that establish a quality management model for organizations in general, whatever their type or dimension. It states the following: quality can be said when all the characteristics of a product or service required by the customer are being delivered to this customer. As far as quality management is concerned, it is stated that it means, then, that the organization guarantees that its products or services satisfy the customer's requirements and that they are in compliance with any regulations applicable to those products or services [ABNT 2015a], [VHP 2009].

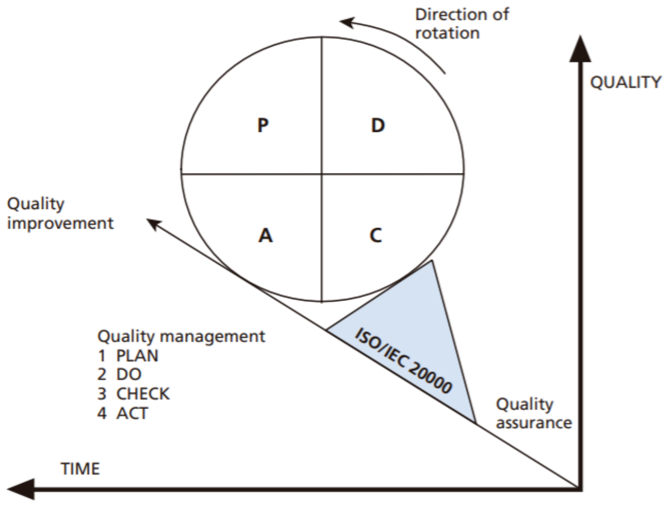
For the IT services department, quality management requires a business understanding of quality and value, and assurance that the service will be designed and managed to meet these specifications. Total Quality Management continually encourages everyone in the organization to meet the demands of the internal and external customers, in order to achieve a competitive advantage. It is a generic term used to describe a vast collection of philosophies, concepts, methods and tools [ABNT 2015a], [VHP 2009].

Willian E. Deming introduced to a diagram the methodology known as Plan-Do-Check-Act (PDCA), which can be seen in Figure 2, presenting the processes of planning and implementing services, which consists of four basic tasks:

- Plan - establishes the objectives and processes necessary to deliver quality services.
- Do - implements the processes established in the plan.
- Check - monitors and establishes metrics for the processes in order to confirm that they are being executed with quality.
- Act - takes actions aimed at the continuous improvement of processes and the results generated by them.

Both ISO 9000 and ISO/IEC 20000 [VHP 2009] include this cycle in their approach to continuous improvement.

Figure 2. Plan-Do-Check-Act Cycle



Source [VHP 2009]

ISO 9000 adopts the following principles for quality management: Customer focus, Leadership, People engagement, Process approach, Improvement, Evidence-based decision making, and Relationship management. The quality of an IT service is expressed as the specific characteristics of a service that satisfy customers' expectations, they can refer to behavioral aspects such as response time or more physical characteristics, they can be chosen relatively freely among the customer and the provider, but some attributes are more commonly accepted than others: availability, capacity, performance, security, confidentiality, scalability, adaptability, portability, etc. Service attributes can be dependent on each other, for example, the time of closure of the incident can directly impact availability [ABNT 2015a], [VHP 2009].

3.5 ISO 20000 - IT SERVICE MANAGEMENT

This standard does not formalize the inclusion of ITIL practices, although a set of management processes is described that are aligned with the processes defined within ITIL. ISO 20000 defines requirements for the correct management of a company providing IT services, guaranteeing customers the delivery of quality services. The requirements are the definition of policies, objectives, procedures, and management processes to ensure effective quality in the provision of IT services [VHP 2009].

The first activity of service delivery processes is the elaboration of service level agreements that are made between the requesting areas and the IT service management area. Like the ITIL delivery service, the service delivery processes in ISO 20000 also deal with issuing and reporting activities about service availability and continuity, budget and cost accounting, and capacity management. Besides, customer needs are identified and change management for those needs. Customer feedback should also be obtained by measuring their level of satisfaction [Magalhães and Pinheiro 2007].

IT Service Management (ITSM) is the management of all processes that cooperate to ensure the quality of IT services in production, according to the service levels agreed with the customer. The main benefit of ITSM is that it provides quality criteria for end-to-end customer-focused services. This is the only basis for the mature management of the IT infrastructure, represented by IT components, and non-IT, grouped into services in operation or at other stages of the service life [VHP 2009].

3.6 ISO 14000 - ENVIRONMENTAL MANAGEMENT

ISO 14000 [ABNT 2005] dictates rules for an Environmental Management System (EMS), to promote socio-economic balance in the face of current needs, thus providing organizations the assistance to achieve their environmental and economic objectives. This standard is also based on the PDCA methodology (see Figure 2). A technical committee was created and subdivided into several others to develop the 14000 series standards, responsible for:

- Subcommittee 1 - Standards on environmental management systems (EMS).
- Subcommittee 2 - Standards related to environmental audits.
- Subcommittee 3 - Rules on environmental labeling.
- Subcommittee 4 - Environmental performance standards.
- Subcommittee 5 - Life cycle analysis standards.
- Subcommittee 6 - Rules on definitions and concepts.
- Subcommittee 7 - Rules on the integration of environmental aspects in product design and development.
- Subcommittee 8 - Environmental Communication Standards.
- Subcommittee 9 - Rules on climate change.

Of the standards created, one of the best known is ISO 14001, it does not establish specific environmental performance criteria, but it does apply to any organization that wants to implement an EMS and ensure compliance with its environmental policy [ABNT 2005a]. Other well-known standards are:

- ISO 14004 – EMS for the internal part of the company.
- ISO 14010 - Environmental audit.
- ISO 14031 - Performance of the EMS.
- ISO 14020 - Product labeling and environmental declarations.

The EMS helps companies to control environmental issues holistically, to enable them to develop and implement a policy that considers the legal requirements on significant environmental aspects. Many organizations have carried out analyzes to assess their environmental performance, however, such analyzes may not be sufficient to provide an organization with meeting the legal requirements and those of its policy [Valle 2002].

The adoption and implementation, in a systematic way, of a set of environmental management techniques can contribute to obtaining optimal results for all interested parties, so that it is appropriate and economically viable and that the cost-benefit ratio of such techniques be taken fully into account [ABNT 2005a].

The standards presented guide the metrics and techniques that should be considered for better planning in terms of defining the private cloud infrastructure.

3.7 INFRASTRUCTURE PLANNING

Due to the rise of cloud computing in the corporate universe, three are the reasons that justify the huge scale migration to cloud computing: regulators are demanding new technologies, customers are wanting more ease and the competitive pressures are increasing. Certainly, the path will be shorter for some organizations and longer for others.

To implement a private cloud infrastructure, the starting point must be the planning of the IT architecture and its assets to align the resources and requirements following the services that it is intended to maintain and/or provide aligning the project with the available value for investment. It is important to think about the quality requirements for management, maintenance, and service provision, considering, among others, safety, availability, performance, reliability, compliance, maintainability, disaster recovery, business continuity and not least is to ensure economic and environmental sustainability.

Initially, the investment to ensure economic and environmental sustainability can be relatively high, but the long-term economic impact is positive, as the tendency for a significant reduction in the high expenses with maintenance, energy, and cooling is considered.

Capacity planning for new physical structures must consider space and cost savings, valuing the ability to scale the infrastructure when necessary, in other words, it is to plan the environment by estimating and enabling the possibility of long-term growth.

It is true that much still needs to be changed for cloud computing to reach its due maturity. First, a cultural change in society is necessary in the face of the paradox of achieving some dimension of sustainability considering the use of redundant resources and expensive data centers. The cloud environment is characterized by having redundant systems, which increases the availability of services. This tactic, by itself, is considered by many to be a waste, but when thinking about the practical side, who would like to try to access your data or services and be unable due to the provider's unavailability? How many organizations could fail to profit, or how many customers could be affected? It is important to note that the costs of IT resources such as servers and storage devices have decreased in terms of performance gains. It is still possible to state that IT is not an expensive resource, but the poor organization of internal processes in companies generates waste.

The private cloud implementation model is aimed at companies that want their infrastructure set up or have their own data center, considering that they have a large amount of data to perform their tasks. In this case, it is possible to achieve a higher level of security, as the data is under the domain of the company's infrastructure [Verderami and Rosa 2013]. Thus, there is greater control over policies for access to services, security management, maintenance, and updates. If compared to the public cloud where all resources and applications are managed by the service provider, in the private cloud these services are grouped and made available to users at the organizational level. Resources and applications are managed by the organization itself. Security is improved, as only users in organizations have access to the private cloud [Jadeja and Modi 2012].

3.8 SUSTAINABILITY INDICATORS

With the need to obtain relevant information on sustainable development, sustainability indexes were created. Sustainability indexes are tools that bring the ability to summarize and focus a large amount of information from a dynamic environment in a palpable amount of useful information, which serves to make decisions such as more appropriate technological routes or to prove the benefits of sustainable practices already used [Godfrey and Todd 2001]. By the way, an indicator does not say anything about sustainability unless there is a reference value or limits for it, it is necessary to compare at least two alternatives or compare with a model [Lancker and Nijkamp 2000].

The main aspects that the sustainability indicators consider are the social, economic, environmental, and safety aspects. Among the simplest indexes that can be used within the environmental area are CO_2 emissions, total energy consumed, and the relationship between the weight of waste and product produced. Toxicity information is available for most known chemical compounds and can also be considered as indicators of environmental issues.

According to [Azambuja 2013], another environmental indicator by ordering is the Indiana Relative Chemical Hazard Score (IRCHS), which indicates how one substance compares to another, in terms of its ability to cause impacts to human health, environmental, and ecosystem damage. Other examples of environmental indicators are:

- **Waste Reduction Algorithm (WAR) -** A theory has been constructed to quantify the potential environmental impact with something that can be quantified. The solution was to use something similar to the commonly used energy and mass balances. The pollution balance through the PEI is a quantitative indicator of the impact of these polluting agents on the process and how environmentally friendly a given production process is. The more efficient the process is, the lower the indexes and the lower the potential impacts that the process would have on the environment. Nor can the indexes be reset, as it would mean having no process [Azambuja 2013].
- **Life Cycle Assessment (LCA) -** LCA or life cycle analysis is a technique for assessing the environmental aspects and potential impacts associated with a product, process or service, through associated material and energy inventories since obtaining the raw material until the final destination, evaluating the impacts associated with each stage, identifying the inputs and outputs. All standardization of the LCA can be found in the ISO 14000 standards [ABNT 2005a], in which the LCA is described as the compilation of inputs and outputs, in addition to the potential environmental impacts of a production system throughout its life cycle. The LCA is, as far as possible, quantitative information. When this possibility does not exist, whenever possible, use qualitative aspects, to represent the evaluated process in the most complete way possible [Azambuja 2013].
- **Economic Indicators -** Economic indicators are the most common and widely used by industries and financial institutions. It is a way of describing the creation of value and wealth, assessing a company's ability to generate value while fulfilling its responsibilities. These indices can consider human and financial capital. Examples of such indicators include profitability, efficiency, and productivity [Azambuja 2013].

3.9 FINAL CONSIDERATIONS

According to [Schulz 2009], IT services consumers are increasingly looking for solutions and products that are delivered via companies with green supply chains and green ecosystems. Green supply chains extend beyond product logos with green backgrounds or pictures of green leaves on the packaging to simply make you feel good about going green. Regardless of stance or perception on green issues, the reality is that for business and IT sustainability, a focus on ecological and the corresponding economic aspects cannot be ignored. There are business benefits to aligning the most energy-efficient and low-power IT solutions combined with best practices to meet different data and application requirements in an economic and ecologically friendly manner.

4 CONCLUSION AND FUTURE WORK

The area of cloud computing has proven to be a technology that offers numerous benefits, but due to its inherent nature of distributed computing systems and because it is still an immature technology, many issues need improvement and there are concerns that are mainly focused on environmental sustainability. This is because this paradigm comes from expensive data center infrastructures, which are huge energy-consuming sources. For greater dissemination of this paradigm, a large increase in the construction of new data centers is expected, which generates concern on a global scale, due to global warming. Given this reality, the focus of this study is on a solution that allows meeting certain needs, considering aspects of sustainability. Therefore, standards were presented that aim to guide companies and users regarding the deployment and use of IT resources for private cloud infrastructures, where techniques were presented for the adoption of best practices regarding the quality and adherence of models, standards, and definitions for IT management and environmental management to promote environmental sustainability. As proposals for future work, some techniques will be used to perform the modeling of private cloud infrastructures that will be based on simulation, such techniques correspond to the reliability block diagrams, stochastic Petri nets, and Markov chains. To model the infrastructure several factors will be considered, among them are IT and energy infrastructure, capacity planning, virtualization, and reference model. It is intended to consider the best practices presented by the standards that are considered in this work.

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