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FINAL DEGREE PROJECT

ECONOMIC MODEL AND ANALYSIS OF THE CLOUD

SPANISH TITLE: **ANÁLISIS Y MODELADO ECONÓMICO DE LA NUBE**

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1. Introduction

1.1 Abstract

This final degree project analyzes the Cloud Computing situation in the world with a focus on the Spanish case, and models the Cloud Computing supply and demand. Different analysis about the Cloud Computing economic model have been carried before but either they focus on the general terms of Cloud, or they focus on specific service models. We tried to give a global perspective including all three main services.

In order to do that, it focuses on the definition of the Cloud Computing and its elements, and the factors that may influence the demand and supply. Then, some theories are considered, and a scenario-case has been calculated to help understand how the supply meets the demand and its applications.

At the final section, the conclusions about the different Cloud Computing elements, and factors that affect its adoption have been summarized and a forecast about future developments in the industry closes the paper.

Keywords: Cloud Computing, Network, SaaS, XaaS, Iaas, PaaS, Information Systems, Information Technologies, economic analysis

Palabras clave: SaaS, XaaS, Iaas, PaaS, Red, Tecnología en la Nube, sistemas de información, análisis económico

1.2 Introduction

Cloud Computing is a name given to the networked technology that, sharing resources in order to improve economies of scale with convergent infrastructures, reduces cost and simplifies and optimizes management. Basically, it is a transition from individual networks, storage facilities, and computing facilities, to the same services accessible from anywhere, with reduced costs and many more opportunities.

Cloud Computing are the Services and Solutions delivered and consumed by the customers over the internet in real time. It is a delivery model of computing services (understanding as "computing" every possible service related with computing and software engineering, information systems and technologies, and computer science).

Using an e-mail service, storing files in online shared folders, running web-based applications or hosting them, etc. all are Cloud Computing solutions or services that we use in daily basis without realizing it. Cloud Computing involves many concepts on its definition, so some stratification is needed in order to analyze the main characteristics of each part.

During the development of this project (June 2014- July 2016), different announcements have been made by some enterprises regarding future Cloud Computing projects. New improvements of the actual models appeared, and new services too. According to Forbes, there are 18.239.258 jobs related with Cloud Computing worldwide; in the US, there are 3.9 million, and from those, 384.478 are IT jobs (the others are related with Cloud Computing but not with IT). Cloud Computing is a developing industry with a growing market and without an actual limit on the scope of growth.

As new services and applications are launched, new professionals are needed. In 2012 the employment of Cloud Computing professionals in the US grew an 80%. This industry is a trend now, a good investment opportunity and because of that, something that many people talk about. With this scenario is not easy to focus in order to come up with a clear analysis of the industry with appropriate details and that is why this project's analysis focuses on the Public Cloud.

This Final Degree Project pretends to analyze the Cloud Computing market's situation and model it. There are different paradigms in the Cloud Computing: Public, Private or other kind of Cloud Computing models have different characteristics. Each paradigm has different customers, advantages and disadvantages, possibilities, etc.

We focused on the Public Cloud model, because it is the one that has more information available and allows comparison, there is a public marketplace from where data is available and there are many competitors and customers to obtain data from.

First, a literature review has been done for analyzing the situation of the Cloud Computing technology and market. At the information systems and computation field, new technologies and applications are created every day, so it is important to clarify what we are focusing on, in order to get a fixed image of a fast changing industry.

One of the points of this project is to analyze the market of Public Cloud model. To do so, both, supply and demand, have been considered, service providers have been analyzed, and their products and prices compared. Only three have been considered because even Cloud Computing is a fast growing market, many Public Cloud providers are still small, and few big corporations have large operations. With that said, many IT-related big companies are developing new products and services to enter this market in the following years.

The factors that influence Cloud adoption have been characterized and developed in the demand analysis, Small and Medium Enterprises (SMEs) do not follow the same criteria than large corporations, and new social media startups have not the same flexibility and needs than industrial factories.

And finally, two scenarios developed for comparing different cloud adoptions and the prices of the main cloud providers depending on the service model, trying to determine what is best for a company regarding its needs and situation.

The conclusion talks about the situation of the Cloud Market, and also introduces a forecast looking into the future of new technological developments that will bring new models and systems in the industry, replacing and changing the actual ones.

1.3 Objectives

The general objective of this project is to analyze the Cloud Computing market from the supply and demand perspectives.

In order to do that, the following objectives have been set:

-Define the supply and demand main factors that influence Cloud Computing market, through bibliography analysis and literature review

-Characterize the supply of Cloud Computing main providers

-Characterize the demand of Cloud Computing with the main buyers

-Model the Cloud Computing market supply and demand

-Analyze the decision-making process of a potential consumer through scenarios

-Identify future directions of the industry considering the main trends and the industry forums

2. Cloud Computing

This chapter pretends to define and explore Cloud Computing and all the terms that it involves, in order to clarify what we are analyzing and how to approach it. First, the most accepted definition, and the elements that characterize Cloud Computing, have been stated. And second, the different service and deployment models that are in place at the actual market, have been defined too with a higher degree of details and with some examples, to help understand the differences between them.

2.1 Definition

According to Amazon (aws.amazon.com), one of the first and major providers of those services, Cloud Computing is "the delivery on demand of computing resources and applications through internet with a low-price system based in the consumption"

The definition of the National Institute of Standards and Technology of the United States (NIST), is more accurate, technical and the most accepted within the community. It says that: "Cloud Computing is a model for enabling ubiquitous, 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 service provider interaction".

Once defined what is Cloud Computing in a general way, it is important to also define the relationship between the market participants. First categorizing the supply side, we have the cloud providers, like Amazon (among many others). On the demand side, we have the cloud consumer and the cloud customer.

Regarding that, Domènech et al. (2014) defined them as:

Cloud Provider: owner and/or manager of a cloud infrastructure. They can offer different kinds of service, that they make it available to the Cloud Consumers by series of price plans for different service configurations and using virtualization techniques. Their objective is to maximize the difference between

the revenues obtained from the cloud consumers and the cost of maintaining their operations.

Cloud providers are not directly bounded to the final users (Cloud Customers), but they are partially responsible for their satisfaction.

Cloud Consumer: company buying cloud services (infrastructure, software, platform or any combination of those). Their objective is to provide consumers with as much value as possible at a minimum cost. Cloud consumers have to trade off infrastructure, software and platform costs versus the costs of losing a customer. They play an intermediate role between customers and cloud providers.

Cloud Customers: web application users, considered as final users. When using an e-service, their objective is to obtain as much value as possible from it. The perceived value mainly depends on the services, contents and design offered, but it can be lessened by poor web server performance that causes long latencies or low availability.

Traditional computing services were based in private hardware systems that enterprises used as a fixed asset. This system did not allow SME to have access to great computing resources because costs were also great. With the development and consequently price reduction of technology, more enterprises started being able to access the computing services.

With the arrival of Cloud Computing, the reach has globalized, allowing any individual or enterprise to have access to services and tools that otherwise would not be possible to have. As the companies do not need to own the infrastructure or have the trained technicians to manage it by themselves, new opportunities arise.

2.2 Elements

Following NIST definition, Cloud Computing is formed by 5 essential characteristics that are:

On-demand self-service: A consumer can unilaterally provision computing capabilities, such as server time and network

storage, as needed automatically without requiring human interaction with each service provider.

Broad network access: Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations).

Resource pooling: The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence where the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or data center). Examples of resources include storage, processing, memory, and network bandwidth.

Rapid Elasticity: Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time

Measured Service: Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service.

All five characteristics are inherent of any Cloud Computing service, and allow us to establish the characteristics of the market that come with them. For example, if the supply and demand elasticity were high, the market would be flexible to fast changes in demand and supply, and everything would be controlled and counted to the minimum detail.

As we can observe from the main characteristics, and the definition, there are two main actors at the Cloud Computing market, the Cloud Provider and the Cloud Consumer.

The first is a company that offers some component of Cloud Computing services and solutions to other businesses or individuals via public or private network; the services it provides

may include hardware, software, infrastructure, assistance, and other related services.

The second is the individual or business that maintains a business relationship with the provider and uses the cloud computing services.

Depending on the relationship between the Cloud Provider and the Cloud Consumer, we can find different service models that are applied through different deployment models, adapting the product that the provider creates to the needs of the customer.

NIST defines three service models for Cloud Computing (SaaS, PaaS and IaaS).

2.3 Service Models

2.3.1 SaaS

Software as a Service (SaaS) enables the consumer to use the provider's applications running in a cloud infrastructure. Those applications are then, accessible from different client devices through a program interface (Google Earth) or a thin client interface (Webmail, Google Maps, Sabi, etc.). The consumer does not control or manages the underlying cloud infrastructure, including servers, storage, network, individual applications or OS, with the possible exception of user-specific and limited application configuration settings.

It is the most used service model, as it is used by millions of people directly through many services that require less personalization, as messaging apps or any social network game with or without a cost for the end-user. Due to the main five characteristics of the service models, there are many different pricing options, from upfront payment applications to freemium services (the usage is free until some quota, few users pay to have premium accounts with better service). For example, Dropbox offers a free version with 2 GB of data storage in the cloud with some features limitation, and has a premium version for individuals willing to pay and have much larger amounts of data storage and more features.

2.3.2 PaaS

Platform as a Service (PaaS) offers the implementation of consumer acquired or created applications over the cloud infrastructure. Those applications should be created using the specific libraries, tools, programming languages and services supported by the cloud provider. The consumer does not control or manage the underlying cloud infrastructure, including servers, storage, network, individual applications or Operating System, but does control the deployed applications and possible configuration settings of the application hosting environment.

Many corporations also use Platform as a Service service model for developing their own applications based on configurations established by the service provider, that allows them more freedom but, at the same time, they have to use the platform configuration for deploying their work. That, allows them to have flexibility and agility when developing their own products without spending time and money on building their own platform to work on. PaaS reduces the amount of code that users need to write, and saves time and money. PaaS is not a service for the general public or every corporation, only companies with qualified IT staff and the need of a system would be potential PaaS clients.

Some PaaS examples are Google App Engine, that allows users to build and run Apps with different codes on Google infrastructure; force.com, the platform that Salesforce.com uses for its CRM applications, but sells as PaaS to create applications over it, hosting them in Salesforce.com infrastructure; and Apprendra, a PaaS service that allows users to host their applications in a free cloud infrastructure or at their own premises (Private Cloud).

2.3.3 IaaS

Infrastructure as a Service (IaaS), provides processing, networks, storage, and other essential computing resources where the consumer can run and deploy software, which can include OS and applications. The consumer does not control or manage the underlying cloud infrastructure, but has control over storage, OS, implemented applications and possibly unlimited control over some networking components.

This is the most flexible and simple service model, just providing the storage, network and computing capabilities needed

at any time for the business, is the best option when high scalability is needed, the company does not have or want to spend money on active assets and there are temporal businesses or projects. From small start-ups to large corporations, they all benefit from the economies of scale of this service model.

An example could be the infrastructure needed by a company to host its website, it would need some virtual machines, CPUs, storage memory and disk memory (RAM) to host the website and run its applications; the company could change one or some of the infrastructure characteristics if needed at any time instantly increasing or reducing the bill and the service obtained. Some of the main IaaS providers are Microsoft Azure, Google Computing Engine, Amazon Web Services, Joyent, etc.

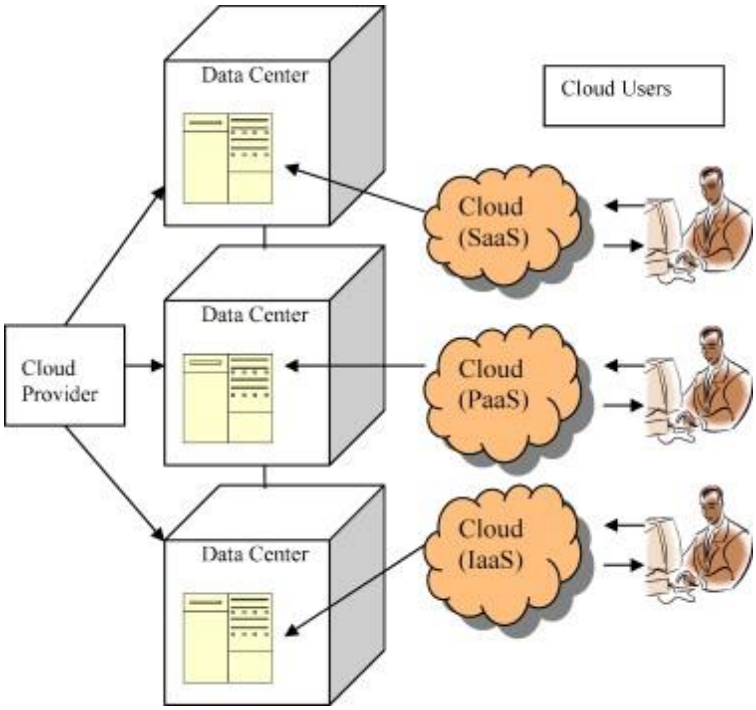
2.3.4 XaaS

There is a fourth service model that NIST definition does not include yet but that has been introduced recently and become popular at the literature.

The Everything as a Service (XaaS), is the aggregation of all service models, that appears as a market need in order to express the service model that combines the three previous service models. It is a service that provides infrastructure, software and platform at the same time. The end consumer only pays one bill even each sub-service may be provided by different companies specialized in different services.

An example could be a Desktop as a Service (DaaS), a virtual desktop running on a virtual environment with the OS, applications, etc. that the customer needs without the need of having the physical hardware in the same place (some hardware and software would be needed in order to interact with the virtual desktop, but they could be only minimal). So the customer may have a virtual computer on the Cloud, accessible from anywhere from a minimal interface, but accessing resources that will not be possible to have otherwise. Another one could be a Disaster Recovery as a Service (DRaaS), a service for recovering all information and infrastructure hosted in a cloud environment after a natural or human-made disaster happens (power shortage, sabotage, hacking…), in order to ensure business continuity. The service will provide the necessary resources and backup for a business to continue with regular or reduced service to its customers, having all its data secured and providing instantly the resources that were lost.

Figure 1 Cloud Computing Models



Source: Sultan, 2010, A simple representation of information communication via cloud computing.

2.4 Deployment models

According to the NIST, there are four different Deployment models regarding the kind of provider of the cloud service, as in the service models, we have introduced one more by our own.

A deployment model defines the way the services are owned and used. Here there are the main Cloud Computing deployment models:

2.4.1 Private Cloud

A cloud is said to be Private if one single organization (that incorporates multiple consumers) uses an infrastructure supplied for its exclusive use. It may be managed, owned and operated by a third party, the organization itself or a combination of both, and may exist on or off the premises.

Most of the enterprises use this model, because it is the first that appeared, it does not have dependence from others, and also because of the security and availability from the resources point of view, it provides better quality if they have the proper resources. Nowadays, even it is not the best option from the economic point

of view, it continues being chosen because the companies already have their systems built at their premises and changing the model would carry some costs and uncertainty.

Private Cloud is used widely but it is not compatible with all the Cloud services and applications developed. There are companies offering IaaS on the customer premises, managed by the provider, for PaaS and SaaS there are many options but the main problem usually is integration between the provider and the consumer systems.

2.4.2 Community Cloud

It is a Community Cloud when it is created for the exclusive use of consumers from different organizations that share concerns (policy, security requirements, mission, etc.). It may be managed, owned and operated by a third party, one or more of the organizations of the community or any combination of both, and may exist on or off the community premises.

This is not one of the most common models, but it has some advantages as the private cloud in terms of security, compliance, etc. and at the same time, sharing the resources between different organizations may save costs and give more flexibility and capabilities. It is a good option if different organizations have the same goals and are willing to share resources in order to obtain higher benefits.

2.4.3 Public Cloud

A Public Cloud is created for open use by the public. It may be managed, owned and operated by business, academic, or government organizations, or any combination of them, and exists on the premises of the cloud provider.

This is the model used by most customers, it has some problems with security and law compliance terms, but it is the one that provides higher scalability, flexibility and capabilities. It allows corporations with peak needs to save lots of money on investments and at the same time, reduces the barriers to use Cloud Computing.

2.4.4 Hybrid Cloud

A cloud is said to be Hybrid when it is created by any combination of two or more of the three previous models (private, community and public), that remain unique entities, but are

bounded by proprietary or standardized technology that allows application and data portability.

It is an option used by many corporations that need to have higher security standards or to comply with local laws and have their own private cloud on their premises, but at the same time, they want to benefit from the large scale of Public Cloud services. Merging both models is not easy but sometimes the services can be divided. It is the most used of the deployment models, that is because it combines the benefits of the two first models and provides the solutions that companies need right now.

2.4.5 Cloud Federation

Due to constant changes and innovations in the Cloud field, there is a fifth model, a new proposal of model combination, called Cloud Federation.

A Cloud Federation is the unionization of software, infrastructure and platform services from disparate networks that can be accessed by a client via the internet. The federation of cloud resources is facilitated through network gateways that connect public or external clouds, private or internal clouds (owned by a single entity) and/or community clouds (owned by several cooperating entities); creating a hybrid cloud computing environment.

3. Supply

The supply of Cloud Computing services and solutions worldwide is formed by thousands of providers of different sizes. As the regulations and accessibility may affect the decision of a customer to contract with one provider or another, and also to the providers to grow in different locations or stay where they are, most of the providers are located in certain areas, providing services to limited locations.

The Cloud Providers could be separated in different groups, for public cloud, large internet companies, telecoms, and governmental organizations.

Large internet companies have many large data centers around the world, and can provide any amount of resources to any customer with prices that small companies cannot compete with. Some of them are Amazon, Salesforce, Google, Microsoft, etc. They provide all kind of cloud related services, mostly the conventional IaaS, PaaS and SaaS, but it is in their platforms where other companies develop new services and applications, and some get integrated in the provider's portfolio.

Small and Medium Enterprises have no size to provide IaaS or PaaS service to most of the customers, they may operate with public cloud from large internet companies, or have their own data centers (or a mixture of both). They can offer their services worldwide but their prices cannot be as competitive as with large corporations.

Public sector agents can be universities, government entities, etc. They need to have their own cloud for their operations and users, and sometimes they can offer also their services to third parties. For example, UPV has its own data center and has developed its own platforms for HR, accountancy, research, library, e-learning, data recovery, multimedia, etc. All its users get access to an email service and an online data storage, also they can request access to a website creation SaaS that includes storage, etc. or a PaaS and IaaS, where they can develop their own projects.

Telecom companies offer also cloud services to their clients and to other enterprises. Most of them offer some email accounts and storage in the cloud for landline customers, and cloud storage for mobile ones. As they already have large data centers in their

premises, they also offer cloud services to enterprises or other customers. For example, Telefónica offers SaaS and IaaS, as well as DaaS and management of Private and Hybrid Cloud.

The prices and kind of services vary a lot and are not easy to compare and measure. In this industry, the quality of the hardware, the technicians or the technical support can affect the service delivery so, depending on the needs of the consumer, some providers may not be suitable for their needs.

So the comparable measures that one could consider in this industry are the objectified quantitative ones, as network transfer, storage, CPU, etc. costs for IaaS. In the case of PaaS and SaaS, as each service is unique in its own way, there is no possibility to have a general comparison. In PaaS each provider supports different programming languages, and in SaaS there are thousands of different applications (there may be a possibility to compare similar applications as Dropbox/iCloud/Box or Office365/Google Drive, but that is out of the scope of this project).

Comparison between providers in different locations and with different sizes will not produce results that could be of use for this project, a selection of the main global providers with similar services and locations has been done.

To illustrate the supply, only the three major providers have been selected. They own data centers around the globe with capacity to scale resources enough for any of its clients in a certain moment of time because of their size, and they have clear information about the kind of service, pricing model, and support service.

They provide the services through Service Level Agreements with the consumers, and those follow different models regarding the kind of service and the provider's policy. The different models are:

-**Pay per use**: It is the regular and most common option. The consumer pays periodically the bill of the services that has used during the period. The fractions for the service can be the same length of the period (for storage capacity, etc.) or may have shorter terms as minutes or hours (for computing, virtual memory, and so).

-**Spot/Pre-emptible instances**: This system allows customers with high needs in certain moments of time or with no need of

having a continuous service, to "bet" for the price of computing instances, and they get a cheaper price than with pay per use. This system is based on the premise that the provider will always have some free resources, then, that amount of resources (that varies on time) are "auctioned" continuously, and the customers that have higher needs at that time but want to pay a cheaper price, or the ones that do not need to have a continued service and want to save on costs, can get cheaper resources. The price changes as the offer and demand changes, but this system allows a more perfect market.

-**Reserved**: Even one of the main characteristics of Cloud Computing is scalability and on-demand resources, some customers may find their needs constant and may want to get long term SLA with the providers. As having part of the demand known in advance helps providers to predict and optimize their operations, they can offer discounts for the customers that commit to a minimum expenditure for a period of time, so the customer ensures the resources and gets a discount, and the provider ensures a continue income.

-**Free allowance**: Having some free services, without the full capabilities and with a limited use, as in the freemium models, allows companies to attract new customers, and allows possible customers to try different providers and services before deciding.

3.1 Amazon Web Services (AWS)

3.1.1 History

Amazon Web Services was created in 2006, and it has been one of the early adopters providing Cloud Service. Amazon started in 1997 as a digital bookstore, and after the internet crisis, instead of going bankrupt, it continued growing. Nowadays, it is one of the most important e-commerce companies in the world and it has developed its activity range to new industries as small electronic goods (eBooks, TV's, pen drives, cables, ...) and it is one of the major Cloud Computing providers.

In 2003, it started to develop its Cloud service that launched in 2006. It started because a worker realized that they were experts on building Private Cloud, so they could become a public cloud

provider by offering their expertise to new companies that wanted to enter the e-commerce and cloud through public cloud.

Nowadays, aside from the type of service, Amazon highlights because of their global presence and operation capabilities, having data centers that cover all geographical regions in the world.

Amazon Web Services, considered the greatest cloud provider (www.srgresearch.com) with more than 30% of the worldwide market share, provides IaaS, PaaS and SaaS services with a wide and increasing range of applications and specific services.

3.1.2 Pricing

Its pricing policy includes a 12-month free tier service with limited resources including most of its services. This allows potential customers to try its capabilities and functions before moving their business into it, or to start small beta versions for start-up and new projects. The limitations of each service are established by Amazon, and can be topped up by the customers if they need to increase the limit of any service.

Amazon offers a pay-per-use service in all their products and reserved instances in most of them, and it has per-hour billing in its computing services. The Spot Instances market for computing services is a first degree price discrimination marketplace where Amazon Web Services offers computing resources. The price is determined by the consumers' bids and the amount of resources Amazon Web Services can offer. The consumers set the amount of resources they want and the price they are willing to pay for them, and Amazon Web Services allocate the spare computing resources to the highest bids. If a customer successfully bids but during his use of the resources other customer sets a higher bid and there are no more available resources, the customer with the lower bid gets his service interrupted (but does not get charged by the last period lower than one hour). That price discrimination allows the more price-elastic costumers to find a better price for the resources they need.

For some services (compute, storage and data transfer), it has second degree price discrimination, that allows consumers with big accounts, to reduce their unitary cost for big volumes, replicating the economies of scale that they would have with a private cloud. At the same time, this second degree price

discrimination, allows Amazon to obtain higher profits and improve the relationship with its customers.

Figure 2 AWS S3 storage service price for Ireland

Data Transfer OUT From Amazon S3 To Internet

First 1 GB / month	$0.000 per GB
Up to 10 TB / month	$0.090 per GB
Next 40 TB / month	$0.085 per GB
Next 100 TB / month	$0.070 per GB
Next 350 TB / month	$0.050 per GB
Next 524 TB / month	Contact Us
Next 4 PB / month	Contact Us
Greater than 5 PB / month	Contact Us

Except as otherwise noted, our prices are exclusive of applicable taxes and duties, including VAT and applicable sales tax. For customers with a Japanese billing address, use of the Asia Pacific (Tokyo) Region is subject to Japanese Consumption Tax. Learn more.

Source: aws.amazon.com

For computing resources besides the second degree price discrimination for on-demand service, they allow pre-purchase of computing capacity for periods between 1 and 3 years. For the 1-year term, they allow three payment options: no capital upfront, partial capital upfront and total capital upfront, with different range of savings for each scheme.

As one can observe in the following table, price can vary up to 70% over on-demand cost.

Figure 3 AWS EC2 computing service payment options

hs1.8xlarge

1-YEAR TERM					
Payment Option	Upfront	Monthly*	Effective Hourly**	Savings over On-Demand	On-Demand Hourly
No Upfront	$0	$1,879.02	$2.574	44%	$4.600 per Hour
Partial Upfront	$11,213	$671.60	$2.200	52%	
All Upfront	$18,886	$0.00	$2.156	53%	
3-YEAR TERM					
Payment Option	Upfront	Monthly*	Effective Hourly**	Savings over On-Demand	On-Demand Hourly
Partial Upfront	$16,924	$554.80	$1.404	70%	$4.600 per Hour
All Upfront	$34,682	$0.00	$1.320	71%	

Source: aws.amazon.com

Also for Reserved Instances, there is a volume discount policy:

Table 1 Amazon Volume discount for Reserved Instances

Amazon Reserved Instances Volume Discounts			
Expenditure	<500K	<4M	<10M
Discount	5%	10%	Not disclosed

Source: Self-made from AWS

Reserved Instances allow much greater discounts than with the other providers' prices. But there is a fact that should be considered: reserved instances tie the customer to that minimum expenditure at the initial price during the period contracted, with the possible disadvantages that will be explained later.

3.2 Google Cloud Platform

3.2.1 History

Google is a tech Company, worldwide known for its search engine of the same name. It was created in 1996 at Stanford, and nowadays it is the search engine with the greatest use. Google has other businesses unknown for the general public, but it also owns many famous services globally used, such as Gmail, Google Earth, Google Maps, YouTube, and so on.

Google Cloud Platform started in 2008 with the Google App Engine, a PaaS service that enables the creation of application on Google infrastructure. Nowadays, it is formed by different innovative services (from hosting, computing, and storage, to big data, etc.).

Google Cloud Platform is the same infrastructure that Google uses for its owned services, and this is why many start-up enterprises and also large corporations use it.

3.2.2 Pricing

Google pricing system offers per-minute billing on their PaaS and IaaS services generally, but not in storage or network transfers; those services are charged as per use in a month. The minimum booking is 10 minutes for most services, and with few services the billing is done per hour. For the network usage they have tier prices (second degree price discrimination).

For computing services, it has sustained use discounts, applying discounts to the use during the month of non-overlapping instances of the same kind and at the same zone. The maximum average discount for sustained use for an instance or group of instances running over 100% of the month, is a 30%.

Table 2 GCP instances % of charge per monthly usage level

Usage Level (% of month)	% at which incremental is charged
0%-25%	100% of base rate
25%-50%	80% of base rate
50%-75%	60% of base rate
75%-100%	40% of base rate

Source: cloud.google.com

Google Cloud Platform has a service similar to Amazon Web Services Spot Instances called Pre-emptible Instances.

Pre-emptible Instances are a lower price option for computing instances that can be shut down at any time by Google Cloud Platform if needed. Their availability depends on Google Cloud Platform free resources (during peak periods usually they are not available). The main difference with Amazon Web Services product is that the price is fixed, so there is not a demand and supply market.

Table 3 GCP Pre-emptible Instances prices per hour

Machine type	Virtual CPUs	Memory	GCEU[1]	Lowest price[2] (USD) per hour with full sustained usage	Typical price[3] (USD) per hour	Full price[4] (USD) per hour without sustained use	Preemptible price[5] (USD) per hour
n1-highcpu-2	2	1.80GB	5.50	$0.053	$0.058	$0.076	$0.020
n1-highcpu-4	4	3.60GB	11	$0.106	$0.116	$0.152	$0.040
n1-highcpu-8	8	7.20GB	22	$0.212	$0.232	$0.304	$0.080
n1-highcpu-16	16	14.40GB	44	$0.424	$0.464	$0.608	$0.160
n1-highcpu-32[6] (Beta)	32	28.80GB	88	$0.848	$0.928	$1.216	$0.320

[1] See Google Compute Engine Units.
[2] **Lowest price (USD) per hour with full sustained usage**: This is the price per hour with full sustained-use discounts applied, when the instance runs for 100% of the month. To get a feel for how sustained usage pricing applies in your use cases, try the pricing calculator.
[3] **Typical price (USD) per hour**: This is the price paid per hour under average usage as calculated over all Compute Engine users, and includes partial sustained-use discounts.
[4] **Full price (USD) per hour without sustained use**: This is the price per hour of the machine type when the instance runs less than 25% of the month. No sustained-use discounts apply because the instance did not run for at least 25% of the month.
[5] **Preemptible price (USD) per hour**: This is the price per hour of the machine type when you set the instance to be preemptible. Preemptible instances do not receive sustained-use discounts.
[6] **32-core machine type availability**: 32-core machine types are available only in Ivy Bridge and Haswell zones.

Source: cloud.google.com

3.2.3 Cloud Computing Costs: Moore's Law

Regarding computing costs, Google Cloud Platform highlights Moore's Law as the cost/computing law that still applies to computing hardware.

Gordon Moore, an IBM co-founder, stated in 1965 that the number of transistors per square inch, that a chip could have, will double every year since their invention. Later in 1975, he changed the law's forecast time to two years, and recently he gave it an end date (2018).

Considering that, the computing capacity of any hardware grows a 100% every two years, depreciating the assets fast and demanding to any company with high computing needs to be flexible and change its hardware every few years, generating continuous costs and depreciation loses.

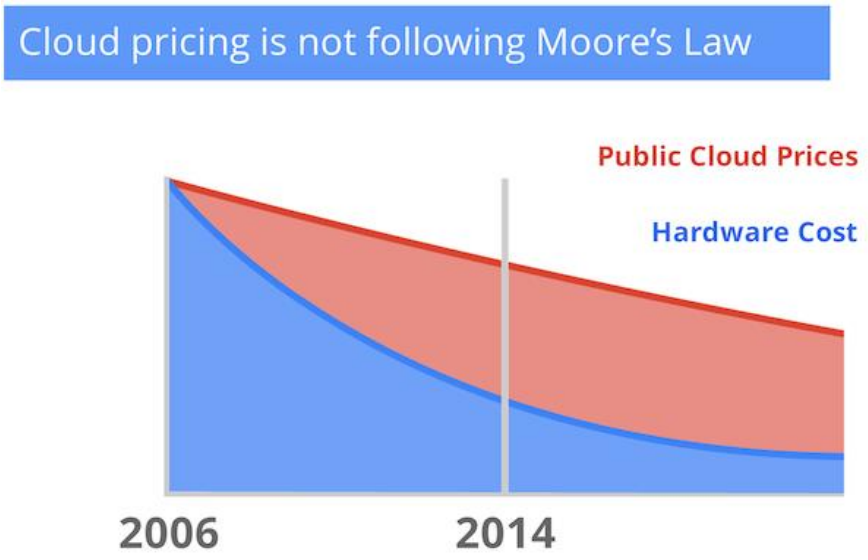
Cloud Computing helps the companies by eliminating the cost of acquisition of the hardware, improving its efficiency and

allowing to IT companies with dependence on those assets not to compromise their business activity because of those investments.

Google Cloud Platform made a commitment to follow Moore's Law for its Cloud services pricing. They recall that Cloud prices have decreased at a 6-8% rate annually while the price of the underlying hardware has fallen at 20-30% annual rate.

The cloud price reductions should be also taken into account when deciding which service adopt, because long term commitments will lose the market price reductions.

Figure 4 Graphic Cloud prices vs. Hardware Cost evolution



Source: cloud.google.com

3.3 Microsoft Azure

3.3.1 History

Microsoft Azure is Microsoft Cloud services platform. It started to develop in 2008 and, in 2010, the first commercial version was launched. They have been improving and adding services every year and now they have a range of services similar to Amazon Web Services or Google Cloud Platform. It is owned by Microsoft, the IT giant most known for developing the PCs, Windows, Microsoft Office, Messenger, etc.

Microsoft is not known as an early adopter of new technologies, but lately it has tried to be on the new innovation trends (entering the smartphone market, for example) and it is one of the three main public cloud services provider. It is the only one of the three main worldwide providers with physical presence in China, through a partnership with 21vianet, a Chinese data center provider.

3.3.2 Pricing

Microsoft Azure offers enterprise agreements that provide discounts (not disclosed), payment facilities (e.g., paying at the end of the year), and better management solutions. For example, an enterprise should do an upfront monetary commitment for three years in order to have an enterprise agreement, then there are flexible paying solutions for the upfront and for the amount that exceeds it.

They offer discounted rates and benefits (also undisclosed) to members of Microsoft programs (such as MSDN, BizSpark and Microsoft Partners Network). And for the regular customers, as Google Cloud Platform, they have a pay-as-you-go policy that bills the usage per minutes with monthly payment.

The discounts Azure offers are always on top of its policy to equal Amazon Web Services prices.

Table 4 Three major Cloud providers' services/pricing policies

Public Cloud Provider	Services provided	Pricing
Amazon Web Services	IaaS, PaaS and SaaS; Own enterprise solutions	Tier price, Volume discount, reservation discount, free tier
Google Cloud Platform	IaaS, PaaS and SaaS; Technology and Service partnerships	Tier price, Sustained Use discount, free cash coupon
Microsoft Azure	IaaS, PaaS and SaaS; Own enterprise solutions	Volume discount, Enterprise Agreement, Partners Discount, free cash coupon

Source: Self-Made with collected data from the providers' websites

3.4 Summary

The three major public cloud providers have some similarities and differences, all of them provide IaaS, PaaS and SaaS, and all together they combine 46% of the worldwide cloud market share (www.srgresearch.com).

Microsoft Azure and Amazon Web Services have parent companies with close relation with other big firms in different industries, and their services include enterprise solutions with added value beyond cloud service. Google Cloud Platform instead, has a flatter service, and partners with developers and other companies that create technology solutions and services for its platform.

Amazon Web Services bills its services per hour, and the other two do it per minute, allowing more flexibility to the consumers. Google Cloud Platform leads the lowest price, and Azure just equals Amazon Web Services price reductions.

Google Cloud Platform has discounts only by sustained use, they keep it simple for the costumers. Amazon Web Services and Azure have discounts subjected to long term agreements (in a fast growing IT environment, as it is in Cloud Computing, periods over a year can be considered long term, due to fast market changes).

Amazon Web Services provides a free tier with limitations, while Google Cloud Platform and Azure provide a cash coupon that the customer can allocate by his own criteria.

All three companies have more similarities than differences, but Google Cloud Platform is clearly more directed towards SMEs, start-up companies and customers who seek simple decisions for their services, and Azure and Amazon Web Services direct their services more to big corporations or customers with larger accounts that seek also a wider range of extra services in the same contract.

Table 5 AWS, GCP and Azure service comparison

Provider	AWS	GCP	Azure
Billing type	Hours	Minutes	Minutes
Customer Market	All, specialists in large corporations	SMEs and Start-up	Large corporations
Price reduction based on	Expenditure commitment	Incremental use	Expenditure commitment
Freemium Service?	Yes	Yes	Yes

Source: Self-made with Cloud providers' public information

4. Demand

4.1 Global aspects of Cloud Demand

There are many different factors companies should consider before to decide about moving to a private, public, or a hybrid cloud. It is clear that those factors will affect differently SMEs and large enterprises (also they will not affect the same way companies from different industries, but this study will focus on the company size, as most of the literature papers follow that differentiation).

4.2 Positive Factors

Some economic benefits of cloud adoption stated by Talukder et al. (2010), are:

-**Strategic Flexibility**: SMEs need flexibility for quickly getting to market and deploy their products; large enterprises can benefit too, if there are no software integration and data issues. It allows any company to keep IT costs as variable, allowing escalation when needed and drastically reduces the capital investment.

-**Cost reduction**: for SMEs, pay-as-you-go pricing can be critical if venture or operating capital is limited, and having current expenses instead of long term depreciation may provide tax advantages. For large enterprises, low setup costs allow quick and inexpensive explorations; non-critical applications can have better economic performance in reduced cost environments without jeopardizing the operations. For both, being able to raise or drop the IT expenditure at any time, reduces costs and optimizes the expenditure.

-**Software availability**: SaaS and PaaS provide software and infrastructure at a low cost, SMEs benefit from dramatic cost savings. Large enterprises usually with legacy desktop licenses may be reticent to move to SaaS versions with less functionalities (despite the cost difference). Through cloud solutions any software can be available anywhere, as only an interface is needed, from a tablet in one side of the world, a supercomputer can be managed remotely. Any software regardless of its needs, can be run in a cloud environment and accessed with a standard device.

-**Scalability**: it is one of the best benefits from cloud computing; all companies can auto scale their applications and

follow demand. Large enterprises may need to modify their software to adapt it to the cloud, but the scalability reduces the risk exposure of any business and may increase the profitability.

-**Skills and staffing**: both large enterprises and SMEs benefit from reduction of staff costs on any task or IT maintenance and support. Large enterprises will need to analyze their needs and adapt their structure to new models, so they may take longer to implement changes. Cloud solutions are replacing many repetitive tasks that are done by workers; also the related costs of owning IT infrastructure are eliminated and included on the cost of the service.

-**Energy efficiency**: cloud computing generates cost savings and environmental benefits for SMEs, and for large enterprises, but in the case they have private cloud they still have their own regular costs. Cloud providers locate their facilities in cost-efficient locations in terms of energy, transfer and land price.

-**System Redundancy and data backup**: hardware failure and disaster recovery are expensive for SMEs and large enterprises; both can benefit from cloud storage solutions that provide safer systems at lower costs, allowing them access to much more redundant solutions and indestructible backups.

4.3 Negative Factors

The main costs of adopting cloud are:

-**Data security**: Large enterprises consider data their most important IT asset, and uncertainty about the security that public cloud provides is one of the main barriers for public cloud adoption. For SMEs it is easier to use third-party security services, but even cloud solutions can provide better security standards than SMEs could afford on their premises. The externalization of the security of some data is not acceptable always. Large corporations face the same problems and therefore they will not adopt public cloud solutions for critical data.

-**Data confidentiality**: SMEs and large enterprises face the same issues with this point, but cloud computing allows encryption that adds safety to this aspect. As with the security, any system that is more accessible, can have more chances of being vulnerable.

-**Data regulations**: Depending on the industry and location of the company there may be regulatory issues that may prevent it to move part of its applications to the cloud (e.g. EU has restricted laws for personal data protection). Cloud providers comply with the legislation of the countries where they operate, but data protection laws may require to the owners of the data to hold their customers' data on their premises.

-**Data integrity**: Data corruption is likely to happen while moving data if protocols and systems are not consolidated. Cloud providers have redundant infrastructure in order to avoid errors, but this could be expensive for private clouds, and if the protocols fail or data is missed in a transfer, irreparable errors may occur.

-**Data transfer costs:** SMEs usually do not need to transfer large amounts of data. Large enterprises, on the other hand, could need to move large amounts of data if moving to public cloud with the consequent risk that this can carry. All three major cloud providers charge only outbound data transfers, and companies have to consider also their own network costs. If the service is outside the company premises, transfer costs will become more relevant and may be considered on the economic impact of adopting cloud.

-**Integration costs**: SMEs benefit from SaaS and PaaS services; large enterprises need to find solutions that fit their structure with no incremental cost over their previous enterprise agreements. Service providers largely have adopted cloud solutions and provide SaaS alternatives that can be integrated with private and public clouds. System integration can be costly and difficult some times.

-**Cloud availability**: Slow performance due to network or service problems, and service unavailability are serious concerns for SMEs and even more for large enterprises. This is because only big cloud providers can afford the standard demands of large enterprises that require 24/7 service covering all the globe and immediate technical service. A power or network shortage in the company or the cloud premises location can affect the business, and when more parties are involved, risk is increased if redundancies are not well managed.

Khajeh-Hosseini et Al. (2011) at their Cloud adoption toolkit paper, also mention **stakeholder impact** as a factor to consider due to sociopolitical benefits and risks associated.

4.4 Public vs Private Cloud

According to Cloudonomics theory, Weinman (2008); there are three main differences between **public** and **private** cloud services, and those differences affect the benefits they generate with their adoption.

The main differences are that public cloud provides true on demand services, operates in much larger scales than the greater private enterprises, and that the firsts reduce costs via dispersion and split, and the seconds, via concentration and consolidation.

Weinman collected these key competences that difference public and private cloud and he named them the 10 laws of Cloudonomics:

1st: Utility services cost less, even though they cost more.

Using a public cloud company, a company pays a higher cost per unit of time than if the resources are financed, leased or owned by them through a private cloud. But at the same time, they cost nothing when they are not needed. The higher the gap between the peak and average need, the greater the saving with a public cloud.

2nd: On-demand trumps forecasting.

The ability to react instantaneously to forecasting deviations, either increasing the provisions or decreasing them, saves costs and creates efficiency.

3rd: The peak of the sum is never greater than the sum of the peaks.

A single company can have really high peak needs in a certain moment of time, even many companies can have their peak periods at the same time, but a public cloud provider will never need to have enough capacity to provide peak service to all its

customers at the same time, so its investment can be considerably lower.

4th: Aggregate demand is smoother than individual.

By aggregating the demand, the coefficient of variation will be lower than the coefficient of variation of a single customer demand.

5th: Average unit costs are reduced by distributing fixed costs over more units of output.

Economies of scale benefit the private cloud, but benefit much more public cloud, as their volume of purchasing and operations is much higher.

6th: Superiority in numbers is the most important factor in the result of a combat (Clausewitz).

In case of being attacked by hackers or experiencing system failures, an enterprise solution will be beaten much faster than the same solution in a public cloud (the attack or failure should take down a much greater system).

7th: Space-time is a continuum (Einstein/Minkowski).

Nowadays, decision-making depends on computing (big data, Business Intelligence, risk analysis, etc.); having larger resources available allow business to respond to changing conditions and opportunities faster than the competition.

8th: Dispersion is the inverse square of latency.

Latency is the delay between making a request and getting a response, it is essential to have reduced latency in order to deliver fast enough services. To reduce the latency to half its value, needs four times more resources. Then, in order to be efficient and save resources, it is better to hire that capacity only when needed.

9th: Do not put all your eggs in one basket.

The reliability of a system with n redundant components, each with reliability r, is 1-(1-r)n. So if the reliability of a single data center is 99%, two data centers provide four nines (99.99%) and three data centers provide six nines (99.9999%). While no finite quantity of data centers will ever provide 100% reliability, we can come very close to an extremely high reliability architecture with only a few data centers. If a cloud provider wants to provide high availability services globally for latency-sensitive applications, there must be a few data centers in each region.

10th: An object at rest tends to stay at rest (Newton).

Data centers consume large amounts of power and need proper cooling systems, core network connection and cheap land. Public cloud providers locate their data centers in places that fulfill these needs. Enterprises, moreover, locate theirs at their headquarters or region offices, where the efficiency conditions are not generally met. Public cloud, then, would have lower performance costs and will be able to provide cheaper prices.

From those 10 "laws", we can conclude that there are significant differences between Public and Private Cloud; Public Cloud provides more opportunities than Private. It has a higher degree of flexibility that diminishes the costs and increases the efficiency and security.

4.5 Cloud situation in Spain

The Spanish Instituto Nacional de Estadística (INE), started to include Cloud Computing in its surveys three years ago. Table 9 collects the most relevant data.

Table 6 Spanish Cloud market situation (INE data)

	Enterprises			Households		
	2013*	2014	2015	2013	2014	2015
Internet use	98,00%	98,30%	98,40%	69,80%	74,40%	78,70%
Use of cloud solutions	19,80%	15,00%	15,40%	N/A	N/A	N/A
Storage	86,90%	69,00%	63,60%	N/A	32,40%	N/A
Databases	N/A	54,70%	56,50%	N/A	N/A	N/A
eMail	N/A	61,40%	70,60%	N/A	N/A	N/A
Paid use	N/A	N/A*	N/A*	N/A	6,40%	N/A

*Data from 2014 and 2015 from the enterprises, refers to companies with 10 or more employees that purchased any kind of solution during the last three months. Data from 2013 refers to companies that used any free or paid solution.

Source: Self-made from INE press releases

The data presented from the Instituto Nacional de Estadística (INE) from the Households, shows that internet use has grown from 70% to 79% from 2013 to 2015. Regarding the use of Storage Cloud Computing services, we only have data from 2014, when that module was added to the survey, but it was not continued in 2015. In 2014 the data collected also included the use of Storage Cloud Services and the reason to use/not to use them.

During 2014, 32.4% of the internet users used any cloud storage service during the last three months, and a 6.4% paid for them. Anyway, a 60.5% of the internet users that did not use any cloud storage service declared not to know its existence, but at the same time some declared to use the email as storage service.

The data presented from the Enterprises side shows that the internet use has grown from 98% to 98.4% from 2013 to 2015. In 2013, 20% of the enterprises with 10 or more employees used some kind of cloud solution, and 87% of those used storage solutions. In 2014 15% of the companies with 10 or more employees used some kind of paid cloud solution, and in 2015 they were a 15.4%. Out of those, 69% used Storage services in 2014 but only 64% did it in 2015. In 2014 also 61% of the enterprises that paid for Cloud services did it for email services, and 56% for Database services; in 2015 those numbers grew to 71% and 57% respectively.

The use of internet is not fully extended yet among the Households but it is growing firmly. Among the enterprises with 10 or more employees it is almost a 100%, showing that nowadays is a must have for any business.

From the data, it is clear that the information released by the INE is not standardized yet. Regarding the use of cloud by enterprises, data from 2013 says that 19.8% of the companies with more than 10 employees used Cloud solutions, and 2014 and 2015 data refers to the percentage of companies that purchased any cloud solution (15%). So on the enterprises side after 2013 we are getting data on paid cloud services only, as we have seen that some products are presented with a freemium model, and that some institutions provide free cloud services, … So the data from 2013 cannot be compared with the 2014 and 2015 ones.

The use of cloud solutions is a 32% at the Households, being the use of storage a 31% and the only one there is data from. We also have that 6% of the users paid for the service. The figures are lower than at the enterprise level, and that is understandable for the different needs of an individual and an enterprise.

We have that 87% of the enterprises in 2013 used cloud storage services; in 2014 and 2015 a 69% and 64% of the users that paid for cloud services used storage services, that is consistent with the models that Google, Microsoft or Dropbox have, giving a free storage of some GB and then charging for extra features and more capacity.

All this data makes sense considering a study by the National Observatory of IT and IS (ONTSI) that recognized in 2012 that a 15% of the companies used some kind of Cloud service. Also, a forecast from IDC set the percentage of Spanish companies that would use SaaS in 2012 at 18%.

This differs with the INE data, considering also that the lack of specific knowledge about Cloud Computing may lead surveys to miss data from free SaaS (as Gmail, Hotmail, Kindle, etc.). In 2013, a 42.99% of the Spanish companies with more than 10 employees manifested *not to have a high knowledge about Cloud technology*. In 2014, the percentage was 34.87%. That number could affect the results of the survey because of the companies that do not have a high knowledge about Cloud technology, but that use cloud based or directly Cloud technology without noticing it.

Considering the use of internet and Cloud solutions by the households, the numbers do not match. If 8.5 million people use some kind of Cloud Computing service in Spain (32% in 2014), but on that year 66.3% of the population used mail services to send attached files, and in the previous year 79.5% of the interviewed did the same, something is wrong. First, considering the technology gap, the survey may not be accurate to determine the number of real users, and second, having those percentages on the use of email and on sending files attached, probably they could use some Cloud Computing based or Cloud Computing solution without knowing it.

The changes in the survey from the INE do not help to determine the real number of Cloud solutions users in 2014 and 2015. Considering that the previous year almost a 20% of the Spanish companies recognized to use Cloud Computing, and considering that only a 6.3% of the users of storage systems paid for the services, it is not easy to think that a 15% of the Spanish companies used paid Cloud Computing solutions in 2014 (that would make 2/3 of the Cloud Computing solutions enterprise users in the previous year).

Having a 15% of Spanish companies paying for the service may be possible, but the number of companies using some kind of Cloud service would be much higher.

The problem resides in the understanding of Cloud service by the users, nowadays most of the Apps that the users have at their phones are connected to the cloud, Microsoft launched its Office 365 package based in the cloud that includes storage, data backup, voIP, etc. All public email users are using cloud based services, that usually include some storage service as well and some messaging/conference services as well, but as they are using the service for many years on daily basis and for free, they do not recognize it as a Cloud service.

So Spain is a country with high use of internet, and a growing number of paid cloud services, the use of free services is also extended but it could not be determined from the data collected. Anyway, considering social media, email, storage, photo sharing, etc services the number of Cloud services in Spain is also high and growing.

4.6 Cloud Computing situation in the world

The situation of the Cloud Computing market in the world is quite different, even Spain is considered a good location for IT companies because of the availability of resources and qualified technicians, it is not considered one of the most technological countries, Fons (2014).

In 2014, 28% of the expenditure on IT infrastructure was made in Public and Private Cloud Computing. In 2015, the forecast is 33%, and for 2018, it is a 44%.

Figure 5 2015 Users of Cloud Computing Worldwide

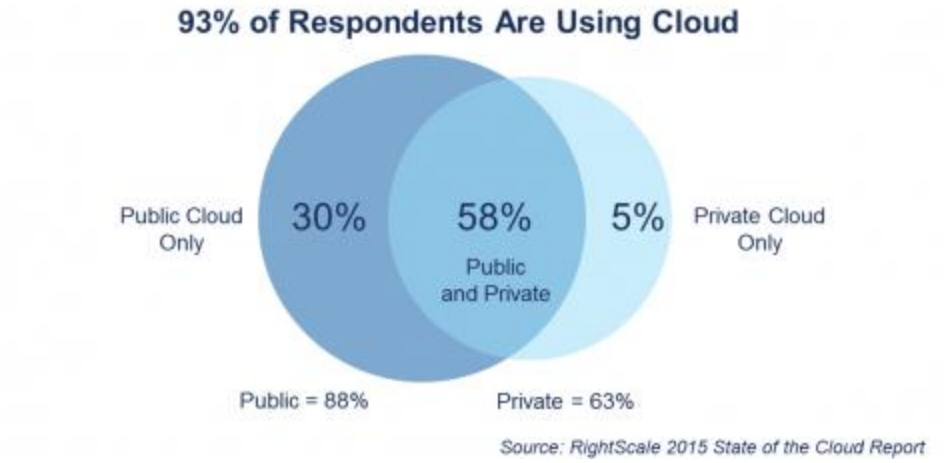
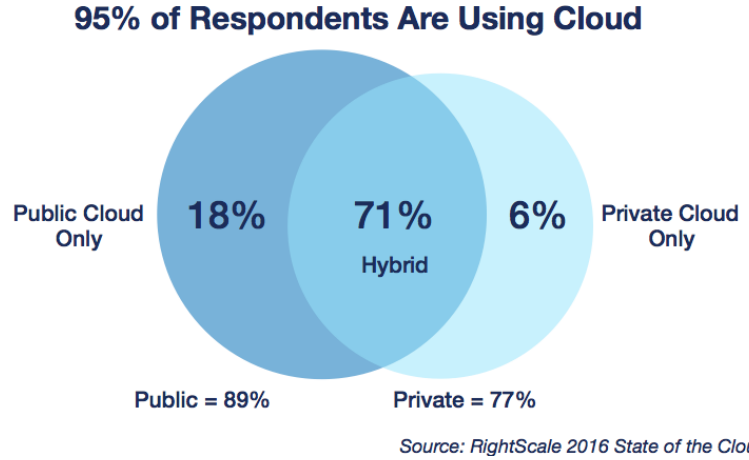


Figure 6 2016 Users of Cloud Computing Worldwide



According to the Right Scale 2015 State of the Cloud report, 93% of the surveyed companies used some Cloud solution. 88%

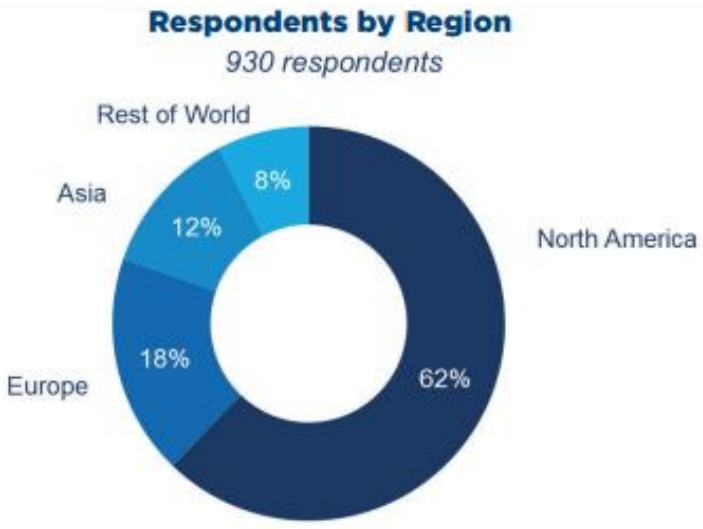
of them, used Public Cloud models, and 63%, Private ones (58% overall used some hybrid model, combining Public and Private Cloud).

In 2016, the users of Cloud grew to 95%, the highest growth was recorded in Private Cloud 77% from 63% on 2015; Public Cloud users also grew 1% to 89%; and Hybrid cloud use grew to 71% driven by the increase in Private Cloud implementation by former Public Cloud users.

The surveys were made by questioning technical professionals across a broad cross-section of organizations about their adoption of cloud infrastructure. In 2015, there were 930 respondents, 306 from companies with 1000 or more employees and 624 from companies with less than 1000 employees. The respondents included 24% of users and 76% of non-users of RightScale solutions, and ranged from technical executives to managers and practitioners from different industries.

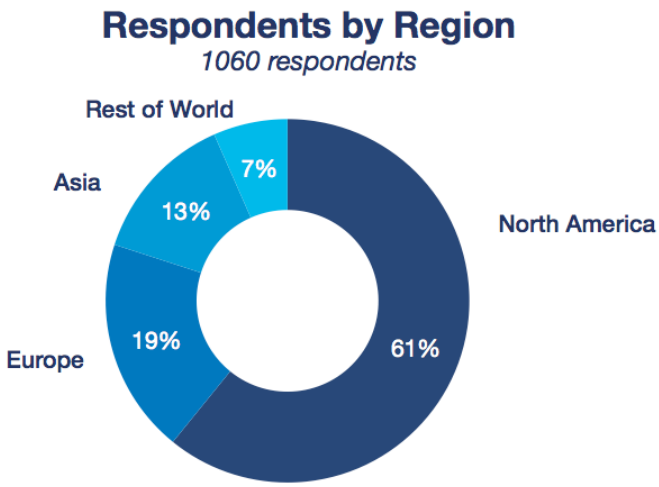
The 2016 survey included 1060 respondents, 433 from companies with over 999 employees and 627 from companies with less than 1000 employees. It included 17% of Cloud users and 83% of non-users.

Figure 7 2015 Respondents by Region



Source: RightScale 2015 State of the Cloud Report

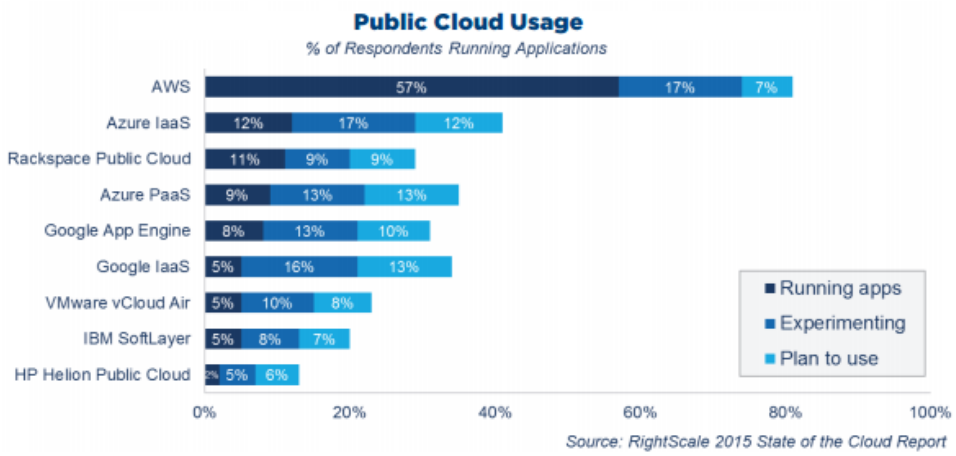
Figure 8 2016 Respondents by Region



Source: RightScale 2016 State of the Cloud Report

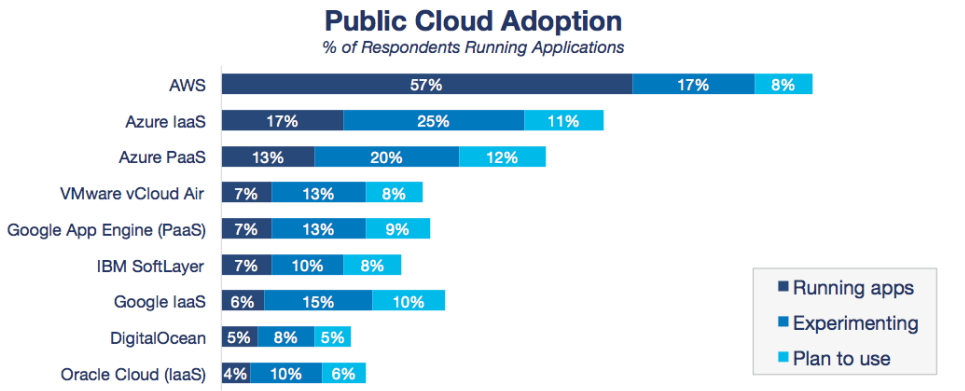
As we can observe, in both years the study was mainly focused in North America, where most of the Cloud Computing development has been done and where the biggest providers have their headquarters. But the conclusions from this report will not be representative for other regions, mostly the third world countries, where Cloud Computing is providing affordable solutions but they still do not have the same infrastructure and scalability as developed countries do.

Figure 9 2015 Public Cloud Usage



Source: RightScale 2015 State of the Cloud Report

Figure 10 2016 Public Cloud Usage

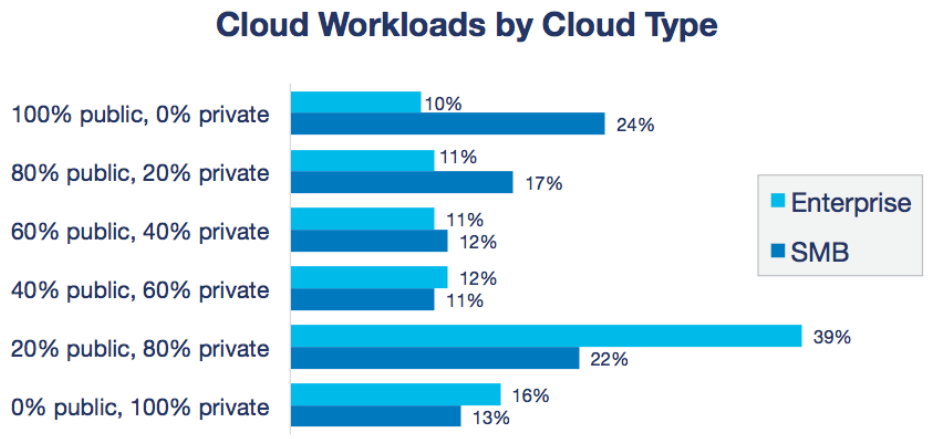


Source: RightScale 2016 State of the Cloud Report

The usage of Public Cloud services has three main providers that we have analyzed. Their target customers can be stratified in three main groups: the ones that plan to use their services, the ones experimenting, and the ones already working with them. As we can see, AWS has the major population of costumers already using their services. As we have said, they are the most mature provider, but Azure and Google have the higher number of possible future customers. That means that they are attracting more new companies with their products and prices, so in the future they will become stronger players.

The differences in the survey from 2015 and 2016 show that, AWS maintained its leadership position without increasing the market share, is used by 57% of the surveyed companies. Google Cloud use increased a bit, but the strongest growth has been at Azure IaaS and PaaS, that now holds a 20% use by the respondents.

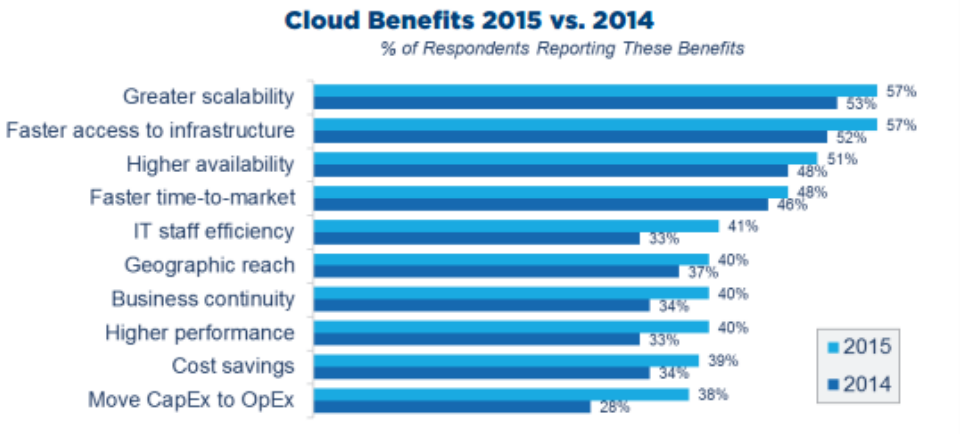
Figure 11 Public-Private Cloud Workload (Enterprise vs SMB)



Source: RightScale 2016 State of the Cloud Report

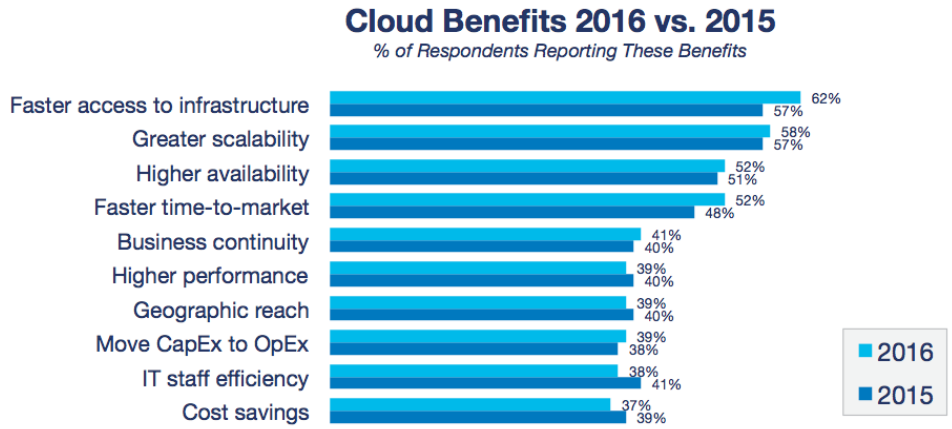
This table shows the different combinations of Public and Private Cloud workload used by Enterprises and SMB (Small and Medium Business). The most common combination for Enterprises is 20% Public and 80% Private, the table shows that Enterprises prefer to allocate higher workload to Private Cloud, and that rely less on Public one. On the other hand, SMB tend more to allocate higher proportion on Public Cloud.

Figure 12 Cloud Benefits (2015 vs. 2014)



Source: RightScale 2015 State of the Cloud Report

Figure 13 Cloud Benefits (2016 vs. 2015)

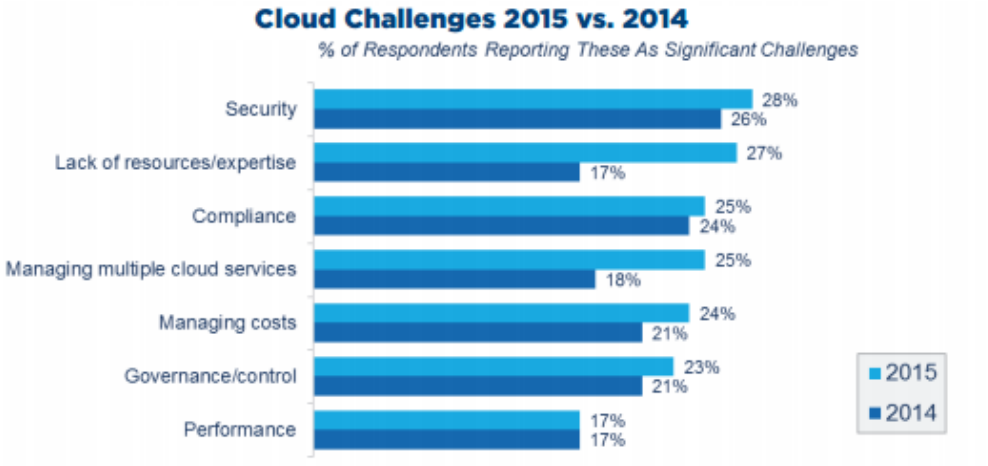


Source: RightScale 2016 State of the Cloud Report

The main benefits are, like we already said before, scalability, access, availability, ubiquity, and cost and performance improvements. More users feel those benefits from year to year. That means that the service quality improves and also the businesses get higher benefits.

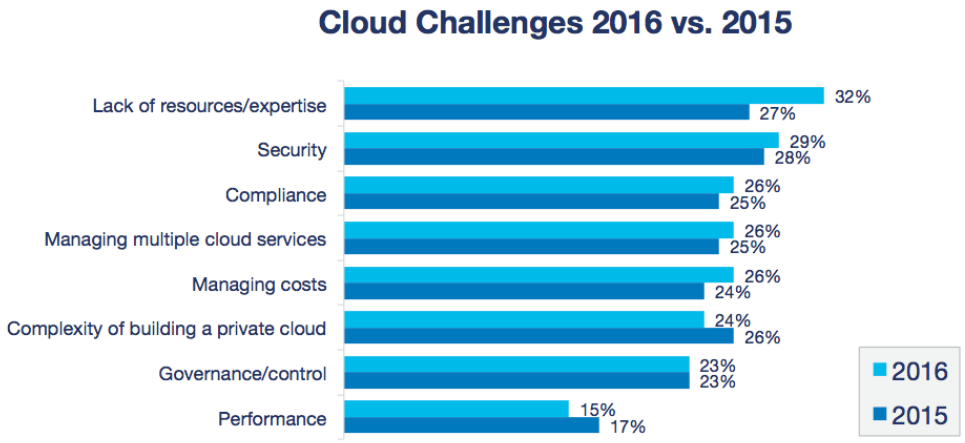
With the data from the last three years, we can see that cost savings, IT staff efficiency and higher performance decreased this year, but others like faster access to infrastructure grew over the average. Those changes of perception may mean that some parts of the market are reaching a maturity point and that new trends will appear and drive the market.

Figure 14 Cloud Challenges (2015 vs. 2014)



Source: RightScale 2015 State of the Cloud Report

Figure 15 Cloud Challenges (2016 vs. 2015)



Source: RightScale 2016 State of the Cloud Report

The challenges for the Cloud users are the matter of discussion of different forums, and the providers are trying to find suitable solutions to break the barrier of entry of many new possible customers.

Security was the main issue that concerns the customers in 2015, increasing from 2014 to 2015; but in 2016 the lack of resources and expertise overtook security as main issue. There were no main issues that have decreased the concern of the customers in 2015, and in 2016 only performance and complexity did it. The ones that increased most were the lack of resources/expertise, and managing multiple cloud services. Those are related with the lack of enough trained professionals, due to the fast evolution and changes of this technology. The continuous changes and the lack of standardization make it difficult for the companies to benefit completely from the new optimizations and changes, so for the following years, the demand of Could Computing professionals will continue growing, and the problems derived of managing multiple services or different ones, will be solved by Cloud Computing solutions that will make it easier for the IT technicians.

5. Scenarios

With the following scenarios, the author pretends to simulate different client demand situations in order to verify which cloud provider is more suitable to each kind of consumer and also, if Public Cloud adoption is more beneficial to the consumer.

The methodology used for the comparison is cost difference, because the value generation of the investment should be the same in all cases. Each provider defends that they provide extra quality service, and there are different additional services included in the price.

There are many qualitative factors that may difference one provider from other, but in order to simplify the model, we tried to reduce those factors by selecting similar services.

For the demand part, there are consumers that not only take in account the cost factor when deciding on moving their resources to cloud environments, or to choose one or other provider. Due to the complexity that introducing all those quantitative variables would affect the model, the author has decided not to take them in the economic decision, but to consider them as qualitative aspects to take in account by the consumer.

The prices for the public cloud services have been obtained from the cloud providers sites', the prices for the Private Cloud have been obtained using Amazon Web Services Total Cost of Ownership calculator, and the calculator assumptions and methodology have been reviewed by the author in order to verify that the service provided was similar.

Two different scenarios have been simulated in order to show the differences between different kinds of consumers and services.

5.1 Scenario 1

Public Sector Agent, Infrastructure as a Service

As a Public Sector Agent, the author has chosen a public university, the Universitat Politècnica de València in this case.

Universitat Politècnica de València (UPV) is a university located in the city of Valencia, Spain. It is a Top 10 university in the country, and the first technological university, with more than 39000 users between personnel and students, and an annual budget of more than 350M euros.

Many of its IT services are al already in a Private Grid Campus that provides computing, email, website and storage facilities to all its students and personnel.

As an Infrastructure as a Service, UPV could partner with any cloud provider and outsource most of its grid resources moving them to cloud solutions.

Considering the Infrastructure as a Service, a mixture of servers and storage should be considered. As the different servers' services that the main cloud providers offer have qualitative differences that are difficult to compare, a storage cost comparison has been done.

The university owns SAN and NAS Fujitsu data centers for providing services as online hard drive storage, the online file exchange or email.

In order to compare the cost of a private owned infrastructure and a public cloud one, using the Amazon Web Services calculator, only storage costs were accounted.

The assumptions are the following:

For the private data center, the following hardware needed for setting up the data center, has been accounted (from HDD to cables, with a 50% discount from the regular price, as industry policy).

Power, Cooling, and data center space costs have also been accounted, the price of the kWh used is the current commercial price at US (10c$/kWh). The Spanish industry, one with the actual currency exchange rate, would be almost the same (0.099*1.13=0.11$).

The private cloud storage needed in order to provide the same service that Cloud Providers provide, redundancy is needed, so available capacity is greater.

For example, with 100TB of physical memory, after the 7% of memory that the Operating System measures different than the disk manufacturer, plus the 50% loss that comes with the RAID 10 distribution, equals 46.5TB.

RAID distribution duplicates the data in different drives in order to obtain data redundancy or performance improvement, protecting the data from disk failure and unrecoverable errors.

For the simulation the UPV ASIC has been contacted regarding their systems and technology, and public prices have been obtained from Amazon, Google and Microsoft (see attachments).

Table 7 Total costs for 36 months of continuous service

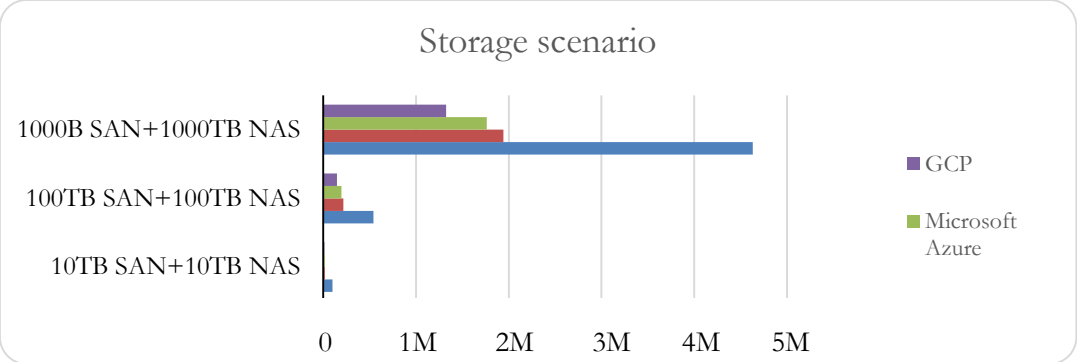
	3 year cost			
Resources	Private system	AWS	Microsoft Azure	GCP
10TB SAN + 10TB NAS	100.640,00 €	19.851,00 €	18.046,36 €	13.534,77 €
100TB SAN + 100TB NAS	543.640,00 €	217.367,04 €	197.606,40 €	148.204,80 €
1000B SAN + 1000TB NAS	4.629.800,00 €	1.941.771,65 €	1.765.246,95 €	1.323.935,22 €
Free resources	0	30GB	200$	300$

Source: *Author's calculations based on data provided by cloud providers.*

For the Private System and Amazon Web Services results, the AWS Total Cost of Ownership Calculator has been used (awstcocalculator.com). It considers, Server, Storage, Network and IT-labor costs, the calculator has been reviewed and certified by Frost & Sullivan.

For Microsoft Azure and Google Cloud Platform, their own service calculators have been used. As the service required is quantitative and the quality difference between different providers is not being analyzed, it is assumed to be the same level for all.

Figure 16 Graphic (Storage Scenario)



Source: Author's calculations based on data provided by cloud providers.

Table 8 Scenario 1, initial expenditures comparison cost

	Total cost	Monthly cost		
Resources	Private system	AWS	Microsoft Azure	GCP
10TB SAN + 10TB NAS	100.640,00 €	551,42 €	501,29 €	375,97 €
100TB SAN + 100TB NAS	543.640,00 €	6.037,97 €	5.489,07 €	4.116,80 €
1000B SAN + 1000TB NAS	4.629.800,00 €	53.938,10 €	49.034,64 €	36.775,98 €

Source: Author's calculations based on data provided by cloud providers.

A private system will require to acquire all the resources needed since the beginning, so if the assets are depreciated 1/3 yearly, it will require the same capital for one month, one year or three.

In the other hand, a cloud solution will cost according to the SLA, it will be paid on monthly basis and will have the possibility to upgrade or downgrade the resources regarding the needs of the business.

Table 9 Scenario 1, 3-year comparison table

	3-year cost savings for public cloud/private cloud			
Resources	Private system	AWS	Microsoft Azure	GCP
10TB SAN + 10TB NAS	100.640,00 €	80,28%	82,07%	86,55%
100TB SAN + 100TB NAS	543.640,00 €	60,02%	63,65%	72,74%
1000B SAN + 1000TB NAS	4.629.800,00 €	58,06%	61,87%	71,40%

Source: Author's calculations based on data provided by cloud providers.

According to the different prices that the cloud providers offer, and the cost of having a private cloud, the best economic option for the consumer should be contracting the service with a cloud provider. In this case, Google Cloud Platform is leading the prices of the market.

For this model, we had different assumptions: the first one, opposed to the 10 laws of Cloudonomics, is that storage needs are not being constant.

For example, at UPV, users start with 1GB of data storage in a virtual disk. If they reach the limit or if requested, they can increase the amount of space until 5GB. Also the course platform, PoliformaT, has storage peaks at the end of each academic year, and this is predictable.

Table 10 Scenario 1, initial investment comparison

	Total cost	Monthly cost		
Resources	Private system	AWS	Microsoft Azure	GCP
10TB SAN + 10TB NAS	100.640,00 €	0 €	0 €	0 €
100TB SAN + 100TB NAS	543.640,00 €	0 €	0 €	0 €
1000B SAN + 1000TB NAS	4.629.800,00 €	0 €	0 €	0 €

Source: Author's calculations based on data provided by cloud providers.

The private system will need the capital outlay at the beginning of the three-year period, unless agreements with the hardware

vendors are done (Dell provides a 3 years financing scheme with monthly payments), but this will increase the cost with the payment's interests.

The public cloud will allow a variable capacity that can be changed every month, in order to satisfy the needs of the customer and would not require a capital investment on the hardware.

Considering that, UPV would need to have enough storage capacity to provide users who need an increase (unpredictable storage increases), and that there are periods of the year with higher needs than others, using a public cloud solution will allow them to save costs when less resources are used.

If it was clear that there are constant resource needs, having a public cloud service will save costs, adding that there would be peak periods (so there would be under-used capacity during the non-peak periods), and that a larger amount of service is needed for unpredictable increases, a public cloud will be much more efficient and cost effective.

Table 11 Scenario 1, 3 years cost with 80% of use

	Total cost	3 years cost considering 80% of use		
Resources	Private system	AWS	Microsoft Azure	GCP
10TB SAN + 10TB NAS	100.640 €	15.880,80 €	14.437,09 €	10.827,8 €
100TB SAN + 100TB NAS	543.640 €	173.893,63 €	158.085,12 €	118.563,8 €
1000B SAN + 1000TB NAS	4.629.800 €	1.553.417,3 €	1.412.197,56 €	1.059.148,2 €

Source: Author's calculations based on data provided by cloud providers.

As mentioned before, Public Cloud allows business to afford peak needs without having unused resources during non-peak periods, if UPV uses only an 80% of its total capacity because its peak periods and contingency margins for possible storage increase requests from the users, the cost of public cloud will drop, but the private one will remain constant.

Table 12 Scenario 1, savings from 20% use reduction

	Savings from 20% use reduction			
Resources	Private system	AWS	Microsoft Azure	GCP
10TB SAN + 10TB NAS	0,00 €	3.970,20 €	3.609,27 €	2.706,95 €
100TB SAN + 100TB NAS	0,00 €	43.473,41 €	39.521,28 €	29.640,96 €
1000B SAN + 1000TB NAS	0,00 €	388.354,33 €	353.049,39 €	264.787,04 €

Source: Author's calculations based on data provided by cloud providers.

The savings obtained from using a public cloud and escalating the resources if needed, considering 3 years of use with a 20% of reduction from the first forecast, will produce a 20% of cost savings.

Storage costs have no discounts for continued use, pre-payment, etc. but all three major providers have enterprise discounts that may affect the price. As those discounts are not specified, we cannot conclude if this will change significantly the price difference between providers, so Google Cloud Platform would be the cheapest option.

Using Public Cloud services is cheaper than building Private Cloud ones, but this reason is not enough to make UPV move its storage and compute facilities to a public cloud service provided in Ireland or other country by a major cloud provider.

At the university, they value other benefits from having their own grid and computing facility at their premises (even if it is economically inefficient). Security is the main concern, they alleged that terms and conditions are not clear and that non-disclosure agreements are not clear either because, even the major cloud providers have data centers in EU countries, their headquarters may be in other non-EU countries where other laws apply.

Regarding to this, all three major Public Cloud providers have their headquarters in US, and according to US law, the US government can require any information to them, and they should comply.

5.2 Scenario 2

Introduction of SaaS to reduce human capital expenditure

Replacement of human capital by Software as a Service is happening today, and it manages repetitive, low qualification and huge time consuming activities with Cloud service solutions that replace workers. Cloud computing is changing the way of working for many corporations, from the invoicing system, payroll, accountancy, market analysis, incidence management, CRM or a call center; all can be managed with a SaaS and less headcount if the business has enough scale.

Some characteristics and needs to replace people by cloud based systems are:

In order to be feasible to be replaced by a cloud solution (by a Software as a Service), the task has to benefit from one or more of the main characteristics of Cloud Computing; broad access, on-demand, resource pooling, rapid elasticity and measured service.

For example, Microsoft lately is promoting its new Microsoft Office 365 product over its traditional Microsoft Office (Home/Professional/…) versions. With Microsoft 365, the user can access his documents and a cloud version of the program from any device and location. Also it includes email and videoconferencing services and 1TB of cloud storage, increasing the range of cloud services that come with the license.

Other major Cloud provider, Salesforce, is a company started as a SaaS services company that now also offers PaaS. Its main solution, Salesforce.com, is a CRM (Customer Relationship Manager), a tool that allows corporations to manage thousands of customers with their contracts, sales, etc from a system that organizes and virtualizes most of the interactions. So this tool, used by thousands of business worldwide, allows to have thousands of contracts from thousands of providers in a database integrated with the sales data from the clients and their respective contracts, reducing the employee interaction to minimal supervision and interpretation of the analytics provided by the system.

A company implementing Salesforce would require less administrative workload, allowing the employees to focus on more value added tasks. At the same time, it will require more IT staff and trained employees on handling the software and analyze data and make appropriate business decisions.

Entire departments are outsourced nowadays to specialized Business Process Outsourcing companies that reduce the expenses of non-core operations, from Payroll, IT, Finance or Customer Service. A billing department may be a suitable one, but instead of outsourcing it could be more profitable to improve it with Cloud solutions. For example, if the company has its sales system computerized, the bills can be automatically generated, so the customers can download them directly eliminating or reducing the interaction of employees from billing. Even the incidence management could be partially automated, keeping minimal personnel and ensuring that the task is done according to company standards in-house.

Organizations tend to leverage new technologies in order to provide better service and increase revenues and profit. Cloud computing helps corporations to transform legacy software into new efficient solutions that meet their business needs.

Call centers are a good example of operations that can be improved by introducing Cloud Computing. Nowadays call centers provide voice, email and social media channels to ensure customer service satisfaction, they are not anymore just a mean to get customer feedback and solve their issues.

For example, a SaaS improvement could introduce some software integrated that redirects the caller to the right department, so call center employees can be specialized and spend less time with each call and being more efficient. But if a company can identify and classify the different reasons of the calls and analyze which ones must be handled by persons (considering the value added, need of human handler, critical need, etc) and whose not, it may save many resources on that. It could purchase an automated solution that solves the call without the need of a call center agent to interact with.

Mark Allen and Mark Minorik, from Alsbridge (alsbridge.com), a consulting firm that helps corporations to transform their technology and business processes, state that the main reasons to consider Cloud Computing as a solution for a Call center are:

- To centralize technology and/or centers/operations, whether consolidating centers, outsourcing some functions, or controlling routing of inbound communications

- To simplify management of the center and its architecture – reduce the cost of support
- To improve business focus on deliverables, including enabling a better customer experience, and/or revenue – shift tactical operations to focus your teams on the customer or revenue
- To avoid capital outlays that will not produce returns on existing platforms that are at end or ending their support
- To lack functionality on the current solution or require significant upgrades
- To lack in-house talent to build or expand current solution to meet the business needs and desires
- To seek agility and speed of delivery
- To lack access to capital to invest
- To have a highly seasonal business (e.g., two months of the year drive 80% of contacts)

Call centers need also a centralized deployment with diversity and redundancies to ensure optimal transformation and operational continuity. Integration and federation of the cloud based solution are important to transition the operation without risking continuity and ensuring a higher level of service.

A Cloud Computing call center platform will allow SaaS solutions that can be escalated easily under real time demand. Those SaaS solutions may include features not available in legacy systems because their complexity or cost as speech analytics, social systems, etc

Also, from the financial perspective, converting capital expenditure into operational expenditure, reduces the risk and increases the attractiveness of any investment, besides allowing flexibility for peak cycles and increasing the efficiency and the alignment of the expenses with the needs.

Even Capex/Opex benefits may seem to drive Cloud adoption, the technological improvements, easiness of the functions and enhanced customer experience; are also interesting enough to consider migrating Call centers to the Cloud. As it will (hopefully) turn into greater revenues, higher speed to market, etc.

In order to ensure higher revenues, etc some customer service metrics have to be the business case of the Cloud Computing adoption. Also, Cloud Computing contact center solutions usually produce a ROI (Return On Investment) within 12 to 24 months.

By implementing Cloud Computing solutions in a Call center, the organization can improve the issue resolution rate, shorter the resolution average time, etc. With those improvements in the service delivered, customer service experience will improve the happiness and loyalty of the customer base, also benefiting the company brand value, differentiating them from the competition.

So process automation can be widely developed with SaaS that reduces, improves or replaces an actual process handled by employees. With the benefits of Cloud Computing the investment and costs are not a problem anymore, also scalability, on-demand, and broad network access are key points that add competitive advantages against traditional and legacy solutions.

6. Conclusions

6.1 Conclusions

Public service model is going to continue increasing its number of costumers, overtaking quota from Private clients, they will move to Public and Hybrid models leaving on their premises the most sensitive process and data, and they will move as soon as the cost gets lower, and they will need much higher expenditure in order to keep their Private systems. They will continue facing the problem of having qualified personnel, but the labour market is following the needs, and thousands of IT workers are being trained in Cloud solutions management.

Figure 17 Azure Statistics, October 2014

Source: Deutsche Bank, Microsoft

The market size has grown a lot during the last years, but new trends are appearing every season, and more industry forums are being held in order to share, test and show new initiatives, so there is still a long journey to go. According to Statista (statista.com), Public Cloud Market will grow from 5.8 to 159.3 $ bilion from 2008 to 2020 (that makes a 32% CAGR) and Enterprise Cloud Market will grow over 200% from 2013 to 2019 (that makes a 22% CAGR).

The main cloud providers are going to stay where they are, increasing their market quota, but as location and other factors may be of high importance for some companies, other smaller competitors will be able to absorb part of the increasing demand.

Companies that seek a short or long term service or solution, will choose public cloud providers because of flexibility and cost. Only those that continue facing legal obligation to hold their services at their premises or with core processes that may not be wise to use in Public Clouds, will choose Private models.

The market prices will continue dropping while the competition between the major providers continues, and they will continue with similar prices and will be differentiated by the customer service and the quality of the processes.

New types of services will be launched for testing to try to get more customers and fulfill needs and gaps for the customers. In Cloud Computing there are many really flexible customers that rely on the pay-as-you-go basis and the price changes, but others just externalize their capital expenses to operational expenses by moving from private to public Cloud. That trend will continue as it has fiscal incentives for the companies and, as the scenario has showed, it reduces the expenses in a considerable amount.

There are already few tools in order to help businesses decide whether to move to Cloud Computing or not, and to move to Private or Public Cloud. After this project, we can conclude that the decision has lots of individual points for every business but that some points are common and can help to have a snapshot of the main differences between Public and Private Cloud, and the attractiveness to the enterprises.

The following table resumes that:

Table 13 Decision-making table

Public Cloud	Decision aspects	Private Cloud
+	Cost	-
-	Security	+
+	Ubiquity	-
+	Fast Changing	-
+	Peaks	-
-	Capital Expenses	+
+	Operational Expenses	-
+	Elasticity	-
+	Redundancy	-
-	IT Staff needs	+
-	Customization	+
-	Maintenance	+
-	Regulation	+

Source: Self-made from this paper

Depending on where the business has more positive decision aspects towards Public or Private Cloud, there will be a more adequate choice to implement. In the case that none of them is clear, or that there are decision aspects that are primordial for the business, the best option would be a Hybrid model, combining both and obtaining their benefits at the same time.

6.2 The future of Cloud Computing

There are different theories about the future of Cloud Computing, following the development of the industry, and comparing it to other technologies' path, the author thinks that future of cloud is federated.

Cloud federation goes one step further, suggesting the unification of public, private, hybrid and community clouds in a cloud of clouds, where resources can be connected and shared (with the proper charge).

In the IEEE 3rd International Conference on Cloud Computing (2010), some professors from Universitat Politècnica de Catalunya presented a paper about Cloud Federation (Goiri et al. 2010) saying: "Cloud federation has been proposed as a new paradigm that allows providers to avoid the limitation of owning only a restricted amount of resources, which forces them to reject new customers when they have not enough local resources to fulfil their customers' requirements. Federation allows a provider to dynamically outsource resources to other providers in response to demand variations."

Cloud Federation concept was first used in 2007 by Kevin Kelly as a cloud of clouds, called Intercloud, as one machine comprised of all servers and attendant cloudbooks on the planet, and its characteristics are higher reliability, back up, available 24/7/365 from any terminal in the world, possibility to hold infinite apps and storage, and seamless sharing and collaboration possibilities. Until late 2014 there have not been real federation solutions, but lately, there have been few new solutions trying to enter the cloud market.

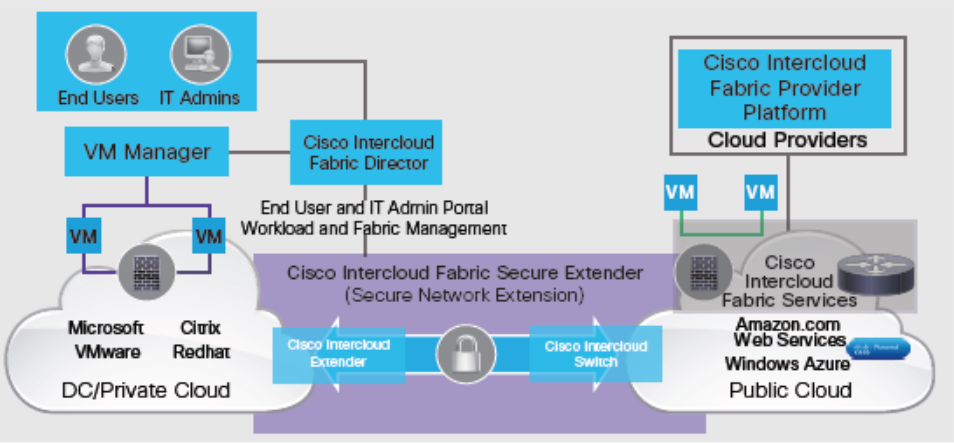
The main issues for cloud federation according to Al-Tehmani (2012) are the interoperability, security, trust, consumers, monitoring, legal issues, and quality of service.

Trust, security, legal, monitoring, and quality of service issues are also issues for regular cloud adoption. The interoperability is unique for cloud federation, and it has to do with the problem to connect different data centers and make them work as one together.

Each public cloud provider has his own protocols, and each private cloud is built in order to protect itself from outside attacks. Cloud Federation has to overcome all those problems and be able to connect any kind of public, private, hybrid, and community cloud, and make them work as one.

The following Cisco diagram shows how their product will work, enabling users to have access to different public and private cloud solutions at the same time.

Figure 18 Cisco Intercloud



Source: Cisco.com

In order to achieve that, their system should be able to access all those different platforms and manage their combined resources as a unique cloud. Cisco has not launched yet its Cloud Federation solution, but they are working towards it and made it public. Microsoft and HP also said that they intent to build an "interconnected set of interoperable clouds", and OnApp, a cloud management software developer, already launched that allows its customers to adopt a federative environment in their public or private clouds.

Being interoperability the major barrier for a real intercloud, the "interconnected set of interoperable clouds" solution is a step towards cloud federation that allows different clouds to adopt standards and be connected.

Cloud Federation claims to become a cloud of clouds, as internet did after the creation of the World Wide Web and the

TCP/IP protocols. First, the universities, army and big corporations, created their own internal networks, called intranets.

After that, some universities and research facilities connected their regional academic networks and created an "interconnected set of interoperable networks", and then, standards were created in order to adopt a global network of networks, known nowadays as internet.

Cloud Federation is expected to follow the same path, but for standards to be established, all cloud providers and owners should agree with that, but at the moment there is no solution accepted globally.

Benefits from Cloud Federation:

Cloud Federation allows a more efficient utilization of the resources. Theoretically, as in any market with perfect competition, welfare is at its maximum point because there are many buyers and sellers, and none of them has enough power to affect price.

Private Cloud owners, would benefit from federation by renting their underused resources to third parties, the owner would have the same fixed costs when buying the infrastructure but, if the cost of maintaining the resources operative is lower than the benefit from renting them, its revenue will improve.

On the other side, a provider who has not enough local resources to attend his workload, would be able to outsource his resource needs to other providers, but his expected revenue from the outsourced resources should be higher than the outsourcing cost.

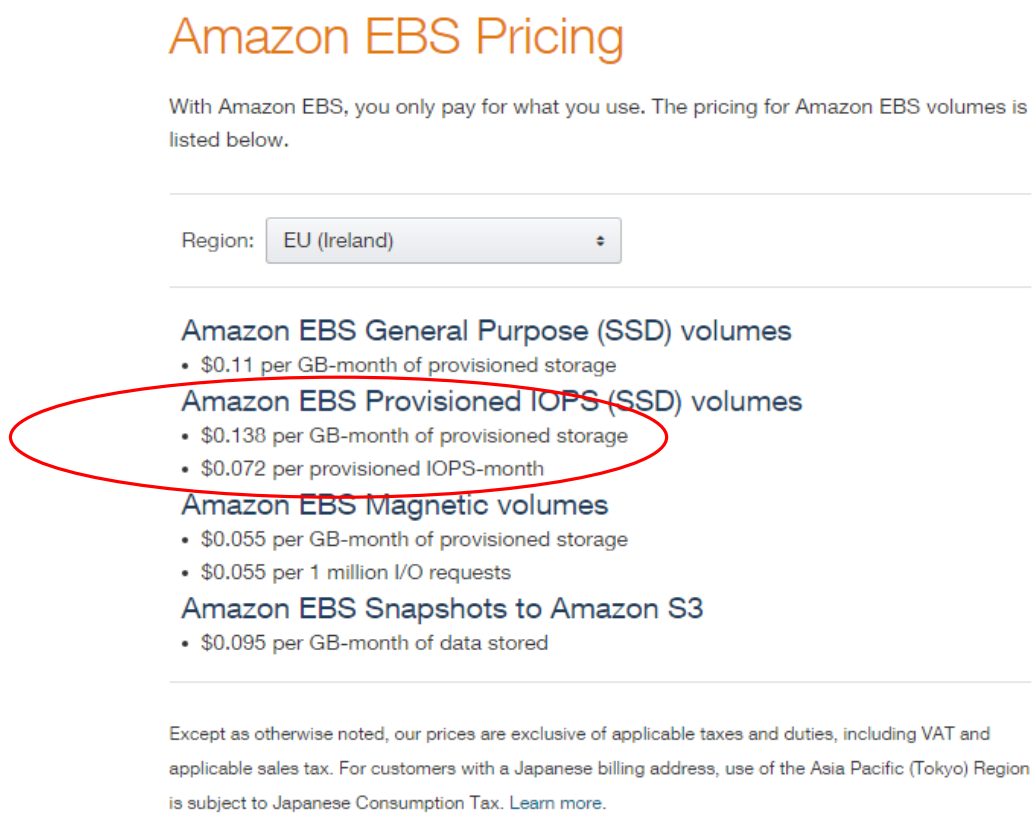
Cloud Federation way of providing resources is likely the electricity service market, where there are major service providers with standard prices and level of service, and the consumers can freely choose the provider they prefer. Also, it allows private producers of the resource to sell their resources to the network (in the electricity market could be solar panel owners when they sell their not-used electricity to the network, as in the federated cloud),

the private cloud owner sells its unused computing or storage capacity to third parties during a period of time.

Attachments

Price samples for Amazon Web Services, Google Cloud Platform and Microsoft Azure simulations for Scenario 1:

Figure 19 Amazon Web Services (HDD SAN+NAS)



Source: aws.amazon.com

Figure 20 Microsoft Azure (HDD SAN+NAS)

Page Blobs & Disks

Optimized for random read and write operations, page blobs are ideal for VHD images.

Learn more ▸

STORAGE CAPACITY	LRS	GRS	RA-GRS
First 1 TB / Month	$0.05 per GB	$0.095 per GB	$0.12 per GB
Next 49 TB (1 to 50 TB) / Month	$0.05 per GB	$0.08 per GB	$0.10 per GB
Next 450 TB (50 to 500 TB) / Month	$0.05 per GB	$0.07 per GB	$0.09 per GB
Next 500 TB (500 to 1,000 TB) / Month	$0.05 per GB	$0.065 per GB	$0.08 per GB
Next 4,000 TB (1,000 to 5,000 TB) / Month	$0.045 per GB	$0.06 per GB	$0.075 per GB
Over 5,000 TB / Month	Contact us	Contact us	Contact us

Source: azure.microsoft.com

Figure 21 Google Cloud Platform (HDD SAN+NAS)

Size, Price, and Performance Summary

Use the chart below as a quick reference for the performance and cost of some common Standard Persistent Disk volume sizes.

Volume Size (GB)	Monthly Price	Sustained Random Read IOPS Limit	Sustained Random Write IOPS Limit	Sustained Read Throughput Limit (MB/s)	Sustained Write Throughput Limit (MB/s)
10	$0.40	*	*	*	*
50	$2	15	75	6	4.5
100	$4	30	150	12	9
200	$8	60	300	24	18
500	$20	150	750	60	45
1000	$40	300	1500	120	90
2000	$80	600	3000	180	120
5000	$200	1500	7500	180	120
10000	$400	3000	15000	180	120

Source: cloud.google.com

Glossary

API: *The Application Programming Interface is a set of routines, protocols and tools for building software applications. It defines functionalities that are independent of its implementations, allowing definitions and implementations to vary without compromising the interface. It helps the programmers reduce the time they need to define and build their programs.*

CPU: *The Central Processing Unit, is the hardware component of a computer where most of the calculations take place. It is the brain of the computer, the most important element of a computing system, because determines its computing capabilities.*

CRM: *Customer Relationship Management, a software that helps companies to manage their relationship with customers and to manage the data from the sales, market, etc allowing the business to automate analysis for business decisions.*

Hardware: *It is defined as the physical components that form a computer, that define the capacity, speed and capabilities when combined with the software.*

HDD: *The Hard Disk Drive is the mechanism that controls the positioning, reading and writing of the hard disk, which furnishes the largest amount of data storage of a computer.*

Legacy: *An old method, technology, computer system, or application program, "of, relating to, or being a previous or outdated computer system." Often a pejorative term, referencing a system as "legacy" often implies that the system is out of date or in need of replacement.*

NAS: *A network-attached storage (NAS) device is a server that is dedicated to nothing more than file sharing. NAS does not provide any of the activities that a server in a server-centric system typically provides, such as email, authentication or file management.*

NAS allows more hard disk storage space to be added to a network that already utilizes servers without shutting them down for maintenance and upgrades. With a NAS device, storage is not an integral part of the server. Instead, in this storage-centric design, the server still handles all of the processing of data, but a NAS device delivers the data to the user.

A NAS device does not need to be located within the server, but can exist anywhere in a Local Area Network, and can be made up of multiple networked NAS devices.

OS: *The Operating System, is the most important program of a computer, as it is the one that manages all the other programs and applications, allocating the available resources and taking care of the security of the computer.*

RAID: *The Redundant Array of Independent Disks provides a way of storing in different places the same data, so the reading and writing speed of the operations can be carried on faster, and fault tolerance and redundancy are increased.*

SAN: *A storage area network (SAN) is a dedicated network that provides access to consolidated, block level data storage. SANs are primarily used to enhance storage devices, such as disk arrays, tape libraries, and optical jukeboxes, accessible to servers so that the devices appear like locally attached devices to the operating system. A SAN typically has its own network of storage devices that are generally not accessible through the local area network (LAN) by other devices.*

Software: *It is the variable part of a computer, formed by operating systems, programs and applications that run over the hardware.*

KB, MB, GB, TB: *All of them are units of measurement of information (network or storage capacity of a system), multipliers of the unit byte.*

	Approx. Bytes	Actual Bytes	Approx. Bits	Typical file/media
1B	1	1	8	Text email, SMS
1KB	$1000B = 10^3$	$1024B = 2^{10}$	8×10^3	Word document
1MB	$1000KB = 10^6$	$1024KB = 2^{20}$	8×10^6	Digital photo
1GB	$1000MB = 10^9$	$1024MB = 2^{30}$	8×10^9	DVD
1TB	$1000GB = 10^{12}$	$1024GB = 2^{40}$	8×10^{12}	Hard disk
1PB	$1000TB = 10^{15}$	$1024TB = 2^{50}$	8×10^{15}	Cloud?

References

Aguilar, Luis Joyanes. 2013. COMPUTACIÓN EN LA NUBE: Notas para una estrategia española en cloud computing. *Revista Del Instituto Español De Estudios Estratégicos* 1 (1).

ALACOT TORRES, MARCO. 2011. *Implantación De Una Plataforma De Cloud Computing*.

Alford, Ted, and Gwen Morton. 2009. The economics of cloud computing. *Booz Allen Hamilton*.

Al-Tehmazi, Dana. 2013. Inter-cloud trust model security: Issues and challenges. Paper presented at Proceedings of the International Conference on Security and Management (SAM), .

Altmann, Jö. 667. A marketplace and its market mechanism for trading commoditized computing resources. *Annals of Telecommunications - Annales Des Télécommunications* 65 (11): 653-67.

Grid economics and business models recurso electrónico-en línea] : 6th international workshop, GECON 2009, delft, the netherlands, august 24, 2009. proceedings, eds. Rajkumar editor Buyya, Omer F. editor Rana and SpringerLink (Servicio en línea). Berlin, Heidelberg: Berlin, Heidelberg : Springer Berlin Heidelberg, 2009.

Avram, Maricela-Georgiana. 2014. Advantages and challenges of adopting cloud computing from an enterprise perspective. *Procedia Technology* 12 : 529-34.

Boja, Cătălin, Paul Pocatilu, and Cristian Toma. 2013. The economics of cloud computing on educational services. *Procedia-Social and Behavioral Sciences* 93 : 1050-4.

Boja, Că. 1054. The economics of cloud computing on educational services. *Procedia - Social and Behavioral Sciences* 93 : 1050-4.

Brumec, Slaven, and Neven Vrček. 2013. Cost effectiveness of commercial computing clouds. *Information Systems* 38 (4): 495-508.

Chang, Victor, Robert John Walters, and Gary Wills. 2013. The development that leads to the cloud computing business framework. *International Journal of Information Management* 33 (3): 524-38.

Chen, Yao, and Radu Sion. 2011. *To cloud or not to cloud?: Musings on costs and viability*, eds. Jeffrey Chase S., Amr Abbadi ElACM.

De Alfonso, Carlos, Miguel Caballer, Fernando Alvarruiz, and Germán Moltó. 2013. An economic and energy-aware analysis of the viability of outsourcing cluster computing to a cloud. *Future Generation Computer Systems* 29 (3): 704-12.

de Los Ángeles López, María, and Ester Albanese. 2014. Gestión de riesgos para la adopción de la computación en nube en entidades financieras de la república argentina. *Contaduría y Administración* 59 (3) (, Vol.59(3), pp.61-88): 61-88.

R. Peña-Ortiz, J. Domènech, J.A. Gil, and A. Pont. 2014. *An approach for economic evaluation of cloud-based applications.*

Durkee, Dave. 2010. Why cloud computing will never be free. (practice)(essay). *Communications of the ACM* 53 (5) (, Vol.53(5), p.62(8)): 62.

FONS GÓMEZ, FERNANDO JOSÉ. 2014. *Cloud Computing: Caracterización De Los Impactos Positivos Obtenidos Por La Utilización Del Modelo Cloud Computing Por Las Pymes, Basado En La Tipología De Modelos De Negocio De Este Tipo De Empresas*.

Forrest, Will, and Charlie Barthold. 2009. Clearing the air on cloud computing. *Discussion Document from McKinsey and Company*.

García García, Andrés. 2011. *Cloud Computing PaaS Platform Cloud ComPaaS*.

Garcia Rodriguez, Pablo Jesus, Modesto Ramon Delgado Troya, and Giuseppe Blacio Abad. 2014. Centros de procesamientos de datos en la nube.

Gawai, NS, BV Chikte, VR Pandit, SM Ingale, and MS Burle. 2014. Application of cloud computing as hpc platform for embedded systems.

Géczy, Peter, Noriaki Izumi, and Kôiti Hasida. 2012. Cloudsourcing: Managing cloud adoption. *Global Journal of Business Research* 6 (2): 57-70.

Goiri, Inigo, Jordi Guitart, and Jordi Torres. 2010. Characterizing cloud federation for enhancing providers' profit. Paper presented at Cloud Computing (CLOUD), 2010 IEEE 3rd International Conference on, .

Gupta, Prashant, A. Seetharaman, and John Rudolph Raj. 2013. The usage and adoption of cloud computing by small and medium businesses. *International Journal of Information Management* 33 (5): 861-74.

Hou, Avus CY, Ching-Chin Chern, Houn-Gee Chen, and Yu-Chen Chen. 2011. 'Migrating to a new virtual world': Exploring MMORPG switching through human migration theory. *Computers in Human Behavior* 27 (5): 1892-903.

Hsu, Jack Shih-Chieh. 2014. Understanding the role of satisfaction in the formation of perceived switching value. *Decision Support Systems* 59 : 152-62.

Khajeh- Hosseini, Ali, David Greenwood, James W. Smith, and Ian Sommerville. 2012. The Cloud adoption toolkit: Supporting cloud adoption decisions in the enterprise. *Software: Practice and Experience* 42 (4): 447-65.

Kshetri, Nir. 2013. Privacy and security issues in cloud computing: The role of institutions and institutional evolution. *Telecommunications Policy* 37 (4): 372-86.

Kurze, Tobias, Markus Klems, David Bermbach, Alexander Lenk, Stefan Tai, and Marcel Kunze. 2011. Cloud federation. Paper presented at Proceedings of the 2nd International Conference on Cloud Computing, GRIDs, and Virtualization (CLOUD COMPUTING 2011), .

Kushida, Kenji, Jonathan Murray, and John Zysman. 237. Diffusing the cloud: Cloud computing and implications for public policy. *Journal of Industry, Competition and Trade* 11 (3): 209-37.

Li, Zheng, He Zhang, Liam O'Brien, Rainbow Cai, and Shayne Flint. 2013. On evaluating commercial cloud services: A systematic review. *Journal of Systems and Software* 86 (9): 2371-93.

Lin, Angela, and Nan-Chou Chen. 2012. Cloud computing as an innovation: Percepetion, attitude, and adoption. *International Journal of Information Management* 32 (6): 533-40.

Liu, Chung-Tzer, Yi Maggie Guo, and Chia-Hui Lee. 2011. The effects of relationship quality and switching barriers on customer loyalty. *International Journal of Information Management* 31 (1): 71-9.

Ma, Dan. 2007. The business model of" software-as-a-service". Paper presented at Services Computing, 2007. SCC 2007. IEEE International Conference on, .

Ma, Sugang. 2012. A review on cloud computing development. *Journal of Networks* 7 (2): 305-10.

Marston, Sean, Zhi Li, Subhajyoti Bandyopadhyay, Juheng Zhang, and Anand Ghalsasi. 2011. Cloud computing—The business perspective. *Decision Support Systems* 51 (1): 176-89.

Maurer, Michael, Vincent C. Emeakaroha, Ivona Brandic, and Jörn Altmann. 2012. Cost–benefit analysis of an SLA mapping approach for defining standardized cloud computing goods. *Future Generation Computer Systems* 28 (1): 39-47.

Mell, Peter, and Tim Grance. 2011. The NIST definition of cloud computing.

2009. The NIST definition of cloud computing. *National Institute of Standards and Technology* 53 (6): 50.

Misra, Subhas Chandra, and Arka Mondal. 2011. Identification of a company's suitability for the adoption of cloud computing and modelling its corresponding return on investment. *Mathematical and Computer Modelling* 53 (3): 504-21.

2011. Identification of a company's suitability for the adoption of cloud computing and modelling its corresponding return on investment. *Mathematical and Computer Modelling* 53 (3): 504-21.

Nisbet, B. 2011. *Monetizing the Cloud: XaaS Opportunities for Service Providers*.

Núñez, David, Isaac Agudo, Prokopios Drogkaris, and Stefanos Gritzalis. 2011. Identity management challenges for intercloud applications. In *Secure and trust computing, data management, and applications.*, 198-204Springer.

Nuseibeh, Hasan. 2011. Adoption of cloud computing in organizations. Paper presented at AMCIS, .

Oliveira, Tiago, Manoj Thomas, and Mariana Espadanal. 2014. Assessing the determinants of cloud computing adoption: An analysis of the manufacturing and services sectors. *Information & Management* 51 (5): 497-510.

Pal, Ranjan, and Pan Hui. 2013. Economic models for cloud service markets: Pricing and capacity planning. *Theoretical Computer Science* 496 : 113-24.

———. 2011. On the economics of cloud markets. *ArXiv Preprint arXiv:1103.0045*.

Palar, Roland Tumbelaka, Danny Manongga, and Wiranto H. Utomo. 2012. An appropriate cloud computing business model and its services for developing countries: A comparison of cloud computing business model in indonesia. *International Journal of Computer Applications* 43 (18): 32-8.

Park, Sang Cheol, and Sung Yul Ryoo. 2013. An empirical investigation of end-users' switching toward cloud computing: A two factor theory perspective. *Computers in Human Behavior* 29 (1): 160-70.

Ratten, Vanessa. 2013. Cloud computing: A social cognitive perspective of ethics, entrepreneurship, technology marketing, computer self-efficacy and outcome expectancy on behavioural intentions. *Australasian Marketing Journal (AMJ)* 21 (3): 137-46.

2012. Entrepreneurial and ethical adoption behaviour of cloud computing. *The Journal of High Technology Management Research* 23 (2): 155-64.

Rimal, Bhaskar Prasad, Eunmi Choi, and Ian Lumb. 2009. A taxonomy and survey of cloud computing systems. Paper presented at INC, IMS and IDC, 2009. NCM'09. Fifth International Joint Conference on, .

Stanoevska-Slabeva, Katarina. *Grid and cloud computing recurso electrónico-en línea] : A business perspective on technology and applications*, eds. Thomas Wozniak, Santi Ristol and SpringerLink (Servicio en línea). Berlin, Heidelberg: Berlin, Heidelberg : Springer Berlin Heidelberg, 2010.

Sultan, Nabil Ahmed. 2011. Reaching for the "cloud": How SMEs can manage. *International Journal of Information Management* 31 (3): 272-8.

Talukder, Asoke K., and Lawrence Zimmerman. 2010. Cloud economics: Principles, costs, and benefits. In *Cloud computing.*, 343-360Springer.

Toosi, Adel Nadjaran, Rodrigo N. Calheiros, and Rajkumar Buyya. 2014. Interconnected cloud computing environments: Challenges, taxonomy, and survey. *ACM Computing Surveys (CSUR)* 47 (1): 7.

Urueña, A., A. Ferrari, D. Blanco, and E. Valdecasa. 2012. Cloud computing. retos y oportunidades. *España, Pág* 18 .

Vanmechelen, Kurt. *Economics of grids, clouds, systems, and services recurso electrónico-en línea] : 9th international conference, GECON 2012, berlin, germany, november 27-28, 2012. proceedings*, eds. Jörn Altmann, Omer F. Rana and SpringerLink (Servicio en línea). Berlin, Heidelberg: Berlin, Heidelberg : Springer Berlin Heidelberg : Imprint: Springer, 2012.

Varian, Hal R. 1997. How to build an economic model in your spare time. *The American Economist*: 3-10.

Walters, Richard. 2012. The cloud challenge: Realising the benefits without increasing risk. *Computer Fraud & Security* 2012 (8): 5-12.

Wu, Wei-Wen. 2011. Developing an explorative model for SaaS adoption. *Expert Systems with Applications* 38 (12): 15057-64.

Wu, Wei-Wen, Lawrence W. Lan, and Yu-Ting Lee. 2011. Exploring decisive factors affecting an organization's SaaS adoption: A case study. *International Journal of Information Management* 31 (6): 556-63.

Xu, Xun. 2012. From cloud computing to cloud manufacturing. *Robotics and Computer-Integrated Manufacturing* 28 (1): 75-86.

Zissis, Dimitrios, and Dimitrios Lekkas. 2012. Addressing cloud computing security issues. *Future Generation Computer Systems* 28 (3): 583-92.