Master Thesis

The impact of Cloud Computing adoption on IT Service Accounting approaches – A Customer Perspective on IaaS Pricing Models

Submitted to

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Affidavit

I hereby declare that I wrote this thesis on my own and without the use of any other than the cited sources and tools and all explanations that I copied directly or in their sense are marked as such, as well as that the thesis has not yet been handed in neither in this nor in equal form at any other official commission.

Gerard Cots Salleras

Berlin, 11.09.2012

Foreword

This master thesis has been done in the "Teschnische Universität Berlin" during an Erasmus exchange between April and September of 2012. My host university, the "Universitat Politècnica de Catalunya", brought me the opportunity to study in Berlin for this last whole year of my studies. Within this year I managed to finish my degree on Industrial Engineering, and hence I wrote this thesis.

In the "TUBerlin" I visited on March 2012 the "Information and Communication Management" department as they were offering some interesting theses. After asking for some information I decided to focus my work on the economic perspective of Cloud Computing.

I would like to thank my tutor, professor Björn Schödwell for his patience, for answering all the emails and especially for his dedication to this project, helping me with the topic, with the results and for all information he has given me, which has made it easier to understand the essence of the study.

Moreover, I would like to express my gratitude to the international department. It has guided me in order to be able to write thesis, it has made my stage in Berlin easier and has helped me with all the paperwork and answering all kind of questions.

Then, I would like to make a special mention to Alvaro Masiá for his great job, as he has helped me editing the thesis.

Last but not least, I would like to thank my parents for giving me this great opportunity of study, because without them I would not have been able to live this great personal and scholar experience.

Abstract

Cloud computing has been recently a trending topic beyond the technological field, due to its implementation and expansion thanks to the internet revolution. Although it has reached end-users' hands during the past two years, the technology has been used for a longer period in the business world. In a scenario where cost-cutting strategies and start-up companies seem to have an increasing importance in global economy, cloud computing has been one of the pillars of many business' success in recent times. Companies like Netflix, Instagram or Spotify are recent examples of how an enterprise can grow spectacularly quick and become a market-leader basing its business activity on the cloud technology.

This master thesis tries to explain how companies should behave when acquiring a cloud service. Due to the wideness of the cloud market, the specific focus of the work is infrastructure as a service, and pay-as-you-go model was chosen for the study due to the novelty it introduces in the information technology market. Apart from technical details, the economic point of view of cloud computing has also been researched, as not only providers care about how their service have to be priced, but also companies want to predict the expenditure to make in their brand new information service.

Through the pages of the work, the predecessors of cloud computing are presented as well as the theories appeared to explain its costs and accounting aspects, to finally explain how cloud computing changed the role. After a brief introduction to cloud computing and its different service models, a market analysis of different providers is performed, to extract the patterns and peculiarities of the actual situation of cloud-market. Transferring the knowledge obtained in the market analysis, an accounting model is developed, based on costs categories and factors and a metering framework. Finally, a case study is performed applying the model to the market situation extracted from the market analysis.

Summary of Content

A. List of tables:

B. List of figures:

C. List of abbreviations:

ITIL	Information Technology Infrastructure Library
LAN	Local Area Network
PC	Personal Computer
CPU	Central processing Unit
GB	Gigabyte
GHz	Gigahertz
SLA	Service level Agreement
TCO	Total Cost of Ownership
TCS	Total Cost of Service
LCC	Life Cycle Cost
IS	Information Service
IT	Information Technology
IaaS	Infrastructure as a Service
SaaS	Software as a Service
PaaS	Platform as a Service
NIST	National (USA) Institute of Standards and Technology

1. Introduction

Motivation of this work arises from the interest in the new information technology wave based on the internet services and growing firmly and quickly during the last years. As the well-known information technology consultant “Gartner Group” reported, global information technology market growth in 2010 was 5.4% over the course of the year to total $3.4 trillion, and also predicted it to increase in 2011 by more than 5% with an anticipated total of $3.6 trillion worldwide (Nurik, 2012).

One of the most problematic aspects for enterprises investing in Information Systems has been historically the cost accounting. It is clear that, in most of the cases, knowing the benefits produced by an information system is much more difficult than accounting the costs of the investment, due the lack of time (long-term expected benefits) or because there could be no tangible gain (Willcocks & Lester, 1996). That is the reason why managers care about the costs and try to reduce the overall expenditure when acquiring, upgrading or updating their information systems, and also why this work is focused on the costs of information systems. Much research has historically been done on the topic and lots of models and theories can be found through the literature. However, information technology is in constant evolution and every few years, new opportunities appear. That’s why these theories and models need to be adapted to the new market tendencies of information systems.

Taking a brief view of the literature present in main journals and electronic databases, it is easy to notice that although cloud computing is a concurrent theme, the focus of the publications within this topic are mostly about engineering and technical aspects of the new technology wave. Despite, not many research have been done within the management, business, or accounting’s subject (Jäätmaa, 2010). Is in this field were most research is needed, and also in which this work is focused. Still, most of the literature covering accounting aspects and focused on cloud computing are centered on the provider-side, so caring about how the cloud technology should be priced (Mihoob et.al., 2010). The gap left in costumer-side accounting is attempted to fill in the next pages.

1.1. Objectives

In this thesis the state of the art in Information Technology, i.e. Cloud Computing, will be the focus, within the scope of cost identification and accounting, always from the point of view of the company investing in the information system. The main objective is to study how these companies should apply the traditional accounting approaches in the cloud scenario. The performed literature research gives the reader the ideal background to understand, further forward, the context in the new and changing technology and economy. The questions that this work tries to answer are:

- How cloud computing, and specifically infrastructure-as-a-service, differentiates from past information services solution in terms of costs incurred by costumers?
- How companies should account infrastructure-as-a-service following sound knowledge obtained from past information system services and products?

1.2. Structure of work

The work is structured in three main parts. The first part is strictly bibliographical and related to the literature found on defining the traditional accounting approaches and the actual information systems services available in the market, including in-house services and all the outsourcing possibilities in the market.

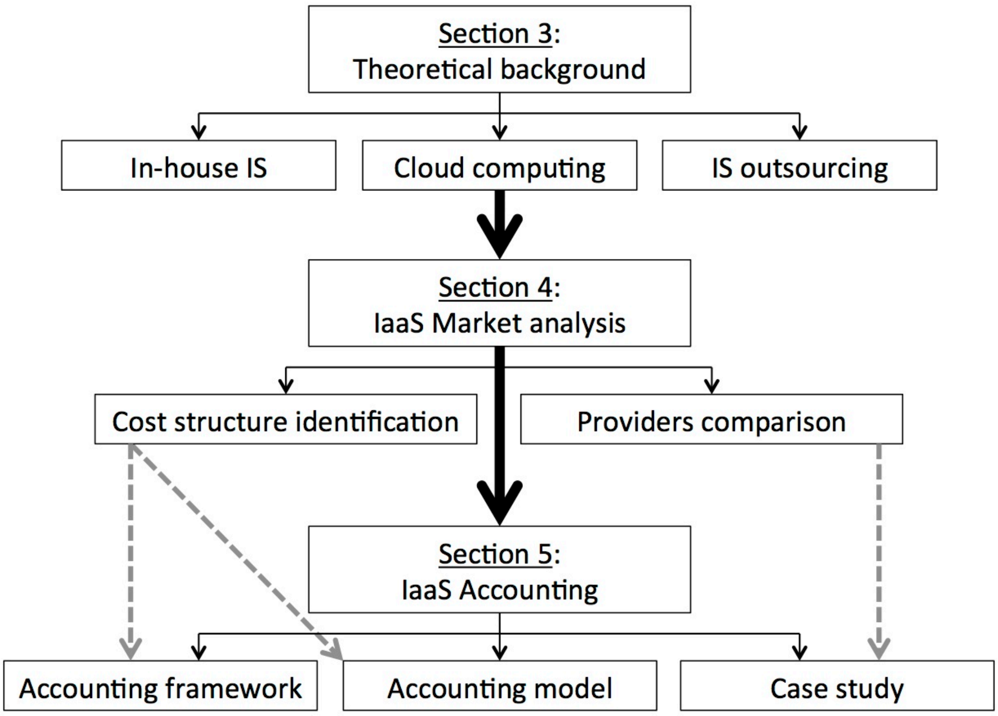

Figure 1: Structure of the work

The second one refers to the infrastructure-as-a-service actual market situation. In this section, a characterization of the actual market situation is performed by means of a market analysis.

The third part tries to explain how companies should react in terms of information technology accounting and allocating and an accounting model is presented. Figure 1 represents the structure of the parts and the information transfer (in grey lines) between them.

1.3. Research Methods Application

During the course of the thesis different methods are applied to obtain the desired results. The first one is a desk research method based on actual literature on the field. In further sections, a market analysis is performed to study the patterns and differences between providers in the actual infrastructure-as-a-service market. To complement the market analysis, a statistical study is performed based on the data transferred from the market analysis' information. In the last section, the literature information and the market analysis are used to design an accounting model and framework, and apply it to a hypothetical case study based on the market analysis to make the model more understandable. Further information about the used methodologies is presented in section 2.

2. Methodological approach

Three different methodologies are used in the course of this work, each one for each of the three main sections explained in section 1.2. Figure 2 presents graphically the succession of the three methodologies, which are widely presented below these lines, followed by the conclusions, which is the final section of the work.

Figure 2: Methodologic course of the work

2.1. Desk research

Due to the fact that this work required lots of investigation through the present literature about the topic, a research method had to be determined before starting to collect all the information.

The research was mostly based on documents, articles and journals found in Internet databases, as well as some books and websites that fitted the focus of the research. The method consisted of a keyword search in every database website including the most remarkable topics in the field. These keywords were annotated in a registry table, including also the databases consulted. Online databases consulted were *Ebscohost, IEEEdirect, Ais electronic library* and *science direct*. These databases cover both business and technical topics and are also the most used in scientifically research, so they were chosen among other available options in the Internet.

Keywords used during the research could fill a long list, as many specific topics are covered in some sections. In first searches, the main information technologies, i.e. *internal information system*, *information system outsourcing*, *cloud computing*, *infrastructure as a service*, were used as search inputs combined with keywords such as *costs, allocation*, *accounting*, *accounting models*, *pricing*, or *costing*. When obtaining a long list of search results, they were sorted by relevance (i.e. number of times the work is referred in other works) and the first 20 were selected. Search was also refined by adding a 10 years back-time period, so including only the ones written between 2002 and 2012[1]. After first the first research process, additional topics, such

[1]For some specific topics (like old accounting approaches and theories) this time period was not useful as all the remarkable literature was written before 2002.

as accounting and economic theories, were also documented to be presented in the thesis.

To select the useful documents among all the selected works, a quick review of the abstract was performed. The documents were stored in folders, creating subdivisions when a new topic was found. This folders-structure was used later on as a guide for the structure of the work. To find related documents to all that ones stored, a backward and forward search was used, as referred in (Webster & Watson, 2002).

2.2. Market analysis

In section 4, a study of the actual cloud market is performed, focusing on cloud infrastructure pay-as-you-go services. After the clear market segmentation, an external trend analysis is used to select the companies to include in the study, and all the data available in their websites and brochures is collected. This data is studied using a regression model and some descriptive statistics, with the aim of identifying the cost structure of the market. Also a comparison between providers is performed to identify the most beneficial option depending on the resources needed.

The regression analysis was performed using a least squares calculation on Minitab statistical software. The regression model was prior designed, based on cost elements observed in the data collection and on the research about the cloud technology (section 3.3). The descriptive analysis complements the results of the market analysis by giving a general outlook of the aggregated collected data from the different companies.

2.3. Design science methodology

In section 5, the design science methodology is followed to develop the resultant accounting model and framework. This methodology is a design-based procedure that aims to produce interesting new knowledge by improving the functional performance of an artifact, which in this case are all the known accounting methods and theories presented in section 3. Within this framework, the specific artifact has to be designed, constructed, analyzed and evaluated.

This design process takes advantage of all the information collected in previous sections. The most remarkable are the cost structure presented in section 4 as a result of the market analysis, and the found knowledge in information systems costs presented in section 3 through some accounting approaches and theories. All other concepts included in the construction phase are extracted from the knowledge gained during the course of the work.

In this thesis, the steps followed to design the artifact were the ones presented by Takeda et.al. In their paper, an accurate procedure of design development and knowledge gaining is argued, as well as a clarifying scheme where 5 steps are presented. These steps are drawn in Figure 3, except the final one, conclusions, which have been already included in Figure 2 (Takeda et.al., 1990).

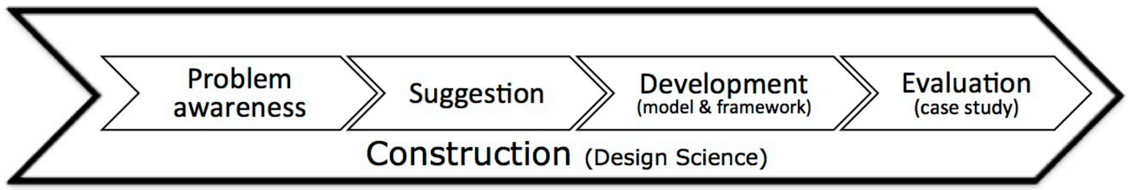

Figure 3: Takeda's steps of design science methodology

The first step is to identify the problem, which is early described in the first point of the work and later argued by presentencing actual market situation with introduction of cloud computing. Suggestion phase is the thinking and arguing process behind the design of the artifact, which is developed in the next step in form of an accounting framework and model. The last step in Takeda's procedure is to evaluate the designed artifact. In this work, a hypothetical case study is performed, as there was no possibility to prove the model in a realistic scenario.

As seen in some documents reviewed, the outputs of the design science can be, in general: constructs, models, methods, or instantiations (March & Smith, 1995). In this case, and as already commented, the output is a model that can be implemented to every infrastructure-as-a-service contracted by a company.

3. Theoretical background

The first big part of this thesis includes all the information extracted from the literature through a desk research method. Although this information is a review of the present literature, it is necessary to bear all the possibilities in the information system market in mind, and to understand the direction in which the actual research on information system accounting goes.

Actual accounting approaches and economic theories will be presented for both internal (section 3.1.2) and external (section 3.2.2) information systems, while also explaining the technology possibilities available for companies and the possible costs associated to them. The third part of this literature review introduces cloud computing and all the actual services for enterprises based on this brand-new and changeable information technology field. Finally, in the fourth part the dealt economic aspects found through information systems literature are integrated and adapted to the new market direction: information services[2] in the cloud.

3.1. Traditional internal information systems

Since the 1970s, lots of companies started to adopt information services as an important part of the organization's structure. They changed the paper-based processes into electronic databases and applications. At first glance, information systems are composed by hardware and software, which connected through a network, have the purpose of collecting and processing data that might be useful for the organization's functions or processes. Furthermore, "information systems are implemented within an organization for the purpose of improving the effectiveness and efficiency of that organization. Capabilities of the information system and characteristics of the organization, its work systems, its people, and its development and implementation methodologies together determine the extent to which that purpose is achieved" (Silver et.al., 1995).

More and more the companies started to depend on the new computer technology and its expansion was wide and fast. Since then, the information technology growth made

[2] Information services are defined in this work as a part of an information system which provides information, serves it to customers and collects it from contributors in order to manage and store it (Gängler, 2011).

companies take decisions in order to make their information systems more efficient and productive. As it has been considered one of the basic business processes, companies try to improve and use the technology as efficiently as possible, with the aim of being competitive. Thanks to the huge expansion, information systems turned to be available, in terms of costs, for almost every big or medium company. Although the costs of both hardware and software had been falling for many years, some studies claim that IT spending worldwide increased year-by-year since 2008, when the economic downturn stopped the progression of the budgets. Although the economic situation, IT budgets were expected to rebound after 2011 (Computer Ecnonomics Report, 2011). This growth situation forced companies to control their investments even more, but at the same time to continue investing to maintain their competitiveness.

An internal information system is that one kept inside the company. It is also called traditional because it was the first form of information systems working for companies. Once the concept of information system is understood, we can accept that lots of different costs are incurred when a company holds a whole information system within its boundaries. Obviously the process of adopting this new structure is neither quick nor easy, and nor cheap.

In a traditional information system there are some parts that are necessary to form the basic structure. The first part are the tangible assets, i.e. physical objects with added value, including hardware and other network machinery that allow the data to be collected, stored, processed and shown to the end-user. The second part are the intangible assets, such as software or know-how. The third part are the human resources, completely necessary to make the system work properly.

With the experience of the companies during the first years of information systems expansion, lots of concepts arose about how companies have to plan, manage, and control these types of investments, in order to make the right decision and to prevent running out of funds during the adoption, installation or using process. Hidden costs were found to be present during the life cycle of the assets implemented in the system, and some researchers and companies tried to explain and theorize these phenomena.

The process that companies follow to define their cost strategies towards the investment in information technology based on three steps: first of them is cost identification, which means to list and quantify all the possible expenditures that the company will have to face. The second step is to allocate these costs. At this point, lots of approaches can be used. The allocation is a basic process that helps the company understand what exactly causes the costs by structuring them, and later on be able to know where they have to focus to achieve a cost reduction or to recover them by pricing the costumer, which represents the final third step. The approaches presented below (sections 3.1.2 and 3.2.2) are focused in the two first steps of these process, which will be subsequently referred to as “accounting process”.

Accounting is considered in this work as the process of colleting, analyzing and communicating financial information about a business entity to users such as shareholders and managers. This information is generally in the form of financial statements that show in money terms the economic resources under the control of the management. This information can be used to predict and evaluate performance of the resources (Elliot & Elliot, 2004).

In the particular case of this work, the business entity is the information technology department inside a company, and includes all the activities performed within it, and hence all the costs incurred. The users who receive the resultant accounting information are the upper managerial teams inside the same company. To clearly establish the entire context in one go, the company contracting the information technology service will be referred as the **costume**r, and the one that offers the service, the **provider**.

The most well-known approaches to the cost accounting in information services are Total Cost of Ownership and Life Cycle Costing which are both going to be presented and explained in the next sections of the work. These approaches try to allocate and account the costs of the whole information system, helping that way enterprises to be conscious of the investment and the effort to be made with the purpose of an efficient and productive information system.

It might also be added that another strategy that leads to internal information system is called “Insourcing”. Hirschheim and Lacity (2000) describe insourcing as “the practice of evaluating the outsourcing option, but confirming the continued use of internal IT resources to achieve the same objectives of outsourcing”. In other words, the decision of discarding external opportunities, for strategic, cost or efficiency causes. The result of this decision can be a) continue using the existent internal information systems or b) transfer the information system contracted to another company and build it in-house.

3.1.1. Costs Identification and Classification

When a company wants to calculate the total cost of an internal information system, lots of costs factors and categories have to be taken into account. Among the literature, lots of categorizations, taxonomies and factors can be found. But the important point is to be conscious of the future costs of the information system. When purchasing or adopting a new information technology, acquisition costs tend to focus all the attention, though the most part of the cost of the investment will arise in future stages, like the installation, the adaptation or the operation processes. Normally these future costs are known as "hidden costs" (Drury, 2001).

When talking about costs allocation, it is important to clear the type of project being developed. The nature of the costs depends in part on the purpose and causes of the project in course. Also when evaluating the consequences (benefits) of the investments, it is important to realize which is the intention. A study by (Hochstrasser, 1990), divided the projects in 8 different groups, depending on their general objectives: *infrastructure, cost replacement, economy of scale, costumer support*, *quality support, information sharing and manipulating, new technology* projects.

Analyzing the different cost factors that appear in every kind of project, we can have a first list of all the costs that can appear in the process of adopting an information system. The next step is to categorize this extensive list, to make the accounting process easier. However, a common mechanism for cost identification and allocation does not exist, as every case differs from the others in many aspects.

What is particular in every information system project, and what really makes the difference when accounting costs compared to other types of project, is that an important human-organizational interface exist (Irani et.al., 2006). Although an information system seems to be just a technological change, the truth is that the end-user experience is what makes the difference between a good and a bad information system. In other words, in the adoption process of the system, all the staff in the company that has to use it plays a very important role. Not only the organization have to take care of the process in a technical and managerial way, but also has to take care that the implementation is useful and understandable for every end-user of the system. This phenomena tend to be a complicated step in the project process, and normally the one in which more hidden costs arise.

The cost types shown in Table 1 were defined by the information technology infrastructure library (ITIL) and are widely used to outline the cost structure of information systems. These cost types are understood as the highest level of category to which costs are assigned in budgeting and accounting.

Cost Type	Cost Elements (examples)
Hardware	Central processing units, LANs, disk storage, peripherals, wide area network, PCs, portables, local servers
Software	Operating systems, scheduling tools, applications, databases, personal productivity tools, monitoring tools, analysis packages
People	Payroll costs, benefit cars, re-location costs, expenses, overtime, consultancy
Accommodation	Offices, storage, secure areas, utilities
External Service	Security services, disaster recovery services, outsourcing services
Transfer	Internal charges from other cost centers within the organization

Table 1: Cost types and cost elements according to ITIL (Source: Office of Government Commerce, 2001)

Reviewing the literature, lots of taxonomies can be found. In a paper written by (Irani et.al., 2006), eight main taxonomies are presented, each one belonging to a different theory. A total of 58 cost factors are included in the eight theories. Some of these taxonomies are remarkable like the one dividing “Initial costs” and “ongoing costs”. As commented above, much part of costs arise on the ongoing phases of the process, after the initial acquisition. Also explained is the difference between “Development costs” and “hidden costs”. Another relevant perspective is the “Acquisition” versus “Administration” taxonomy. All the 58 cost factors seen in these main taxonomies can be found in appendix 6, as a source of further cost elements used during the process of the work, specially in section 5.4.

Among all the other taxonomies, the one conceived by (Love et.al., 2003) and known as “Direct/Indirect” costs seems to be the most accepted. Its usability and understandability makes one of the best examples to present the different costs factors that can appear. By *direct costs* they understand the expenditures attributed to the implementation and operation of Information Technology. Not only the initial acquisition of hardware and software are included, but also unexpected additional accessories, increases in processing power, memory and storage devices. Also installation and configuration are considered direct costs, and typically includes consultancy support, installation engineers and networking hardware and software.

Indirect costs are the ones comprised of human and organizational factors that address the issues of maintaining availability of the system to end users and keeping the system running (Piedad, 2001). Largest indirect costs are management time used to revise, approve and amend the information system strategy, the resources used to investigate the potential of the Information technology and to support and trouble-shooting of the system. Other human indirect costs can be lifetime support, which can multiply the cost of the original purchase, new skills developed by employees, which result in more contribution to the company and therefore revised pay scales.

An interesting classification of human indirect costs was written by (Irani & Mohamed, 2002). The following categories were presented:

- *Time*: used to transfer the knowledge from the management team to the staff
- *Learning costs*: training the personnel
- *Costs of resistance*: caused by some individuals or groups resisting the change initiative.
- *Effort and dedication*: time used to absorb the transition, exploring the capabilities and identifying integration issues.
- *Cost of redefinition of roles*: due to he organizational restructuring
- *Missed-Costs*: costs mis-assigned, or displacement costs
- *Reduction in knowledge base*: result of high-staff turnover when reducing labor costs to justify the investment in information technology
- *Moral hazard*: costs due to managers interested in gaining knowledge rather than being interested in organizational benefits
- *Deskilling*: means the inability to fully utilize the potential skills of employees.

As seen, the wide list of costs is difficult to summarize, mechanize or organize, but the important think is to review them and try to attend as many categories and factors as possible.

3.1.2. Internal Information Systems Accounting Approaches

After considering all the cost factors that can appear in information systems adoption projects, some theories can help to understand how this factors behave in the company environment, and which are the main principles learned during lots of years of practical experiences, researched theories, and studies performed. The two reviewed theories are Total Cost of Ownership and Life Cycle Costing. They have traditionally been used by most of the enterprises facing information system investments.

3.1.2.1. Total Cost of Ownership

Total Cost of Ownership (TCO) was first introduced in the information system field in 1987 by Gartner Group (Sultanesi & Schäfers, 2005). The total cost of ownership model tries to quantify the financial impact that an investment has in an organization. Although it is used in many industries, the first model developed by Gartner focused on the costs of a desktop personal computer. Years after, this model was adapted to any kind of information technology. Bill Kirwin of Gartner group defined total cost of ownership as "a holistic view of costs related to Information Technology acquisition and usage at an enterprise level" (Capuccio et.al., 1996). The purpose of the total cost of ownership model is to identify and structure the cost types, which helps to reduce overall costs, and therefore to maximize benefits. Also works as a strategic decision-maker and a tool to benchmark a system.

The structure presented by total cost of ownership model lies in 4 main cost categories. In one hand there are the information technology components' assets, which represent the 20% of the investment in average. In the other hand, *Technical support*, *administration of purchased goods* and *transfer of originary tasks of the IT-Department to the end-user* (plus downtime) (also known as hidden costs), represent all together the 80% of the investment (Capuccio et.al., 1996). The costs are also structured in direct costs (e.g. hardware and software, operations, maintenance and administration) and indirect costs (e.g. end-user operations, downtime…) (Sultanesi & Schäfers, 2005). Nowadays the 20% of total cost of ownership based on technology assets is a fixed price for almost every company, so is in the other 80% where they have to center their effort to have a competitive advantage, and it is over this part where they have great control (David & Schuff, 2002). A more detailed list of all cost that should be included in the total cost of ownership is presented in Appendix 1[3].

[3] Appendix 1 is presented in german, as it is information provided by the german tutor of the TUBerlin, so it needs further translation.

The procedure of the total cost of ownership model is to group all the costs into cost factors and include them in categories in order to control the costs more efficiently and gain transparency. When that is achieved, many strategies can help managers to reduce the total cost of ownership. The problem is that this reduction can affect negatively the services provided by the information system. The efficient strategies are the ones that decrease the total cost of ownership while maintaining or even improving the service level of the system. Among other strategies, the ones more followed when working with total cost of ownership models are *Standardization* and *Centralization*. (David & Schuff, 2002).

Standardization means to minimize the hardware- and software-configuration differences among individual workstations inside the company. In other words, the objective is to homogenize the system components. In that way, training costs and maintenance costs are severely reduced (indirect costs). Another benefit is the possibility to control the access of the end-users to non-convenient applications that produce a waste of time (downtime) or futzing[4].

Centralization seeks to consolidate software access, software distribution and network administration in a few central servers, to which all the end-user workstations connect. The aim of this strategy is to facilitate the software maintenance (e.g. updates or backups) and to make the work of the workstations lighter, improving the overall efficiency of the system, in terms of storage and computing capacity.

Some authors and companies developed forward total cost of ownership models. Singular are the ones taking in account not only the costs but also the efficiency of the investment. For example the Total Economic Impact, developed by Forrester Research, joins the total cost of ownership with utility, flexibility and risk factors to obtain a better-adjusted criteria (Sultanesi & Schäfers, 2005).

3.1.2.2. Life Cycle Costing

Life cycle costing theory tackles the cost accounting from another point of view. It was first introduced within the US department of defense in 1976 for procurement processes and further applied to many other fields such as information systems as an adaptation of the total cost of ownership theory (White & Ostwald, 1976). The idea of the theory is to calculate he cash flows that one asset will produce during its useful life.

[4] Futzing means to waste working time or effort on frivolities.

This quantification has to be made in a present value approach, so considering that costs in future years have a different value. This adds the complexity of assuming or estimating the inflation or interest rate. The life cycle cost of a physical asset begins when its acquisition is first considered, and ends when it is finally taken out of service or replaced by another physical asset, that will have a new Life Cycle Costing (Woodward, 1997).

An important aspect of the life cycle of a product or service are the phases it goes through during its useful life. Although there are many formulations and examples of life cycle stages, an appropriate classification that fits the life cycle of information systems is presented in Figure 4, where the costs related to each lifecycle are approximately represented in function of the lifetime.

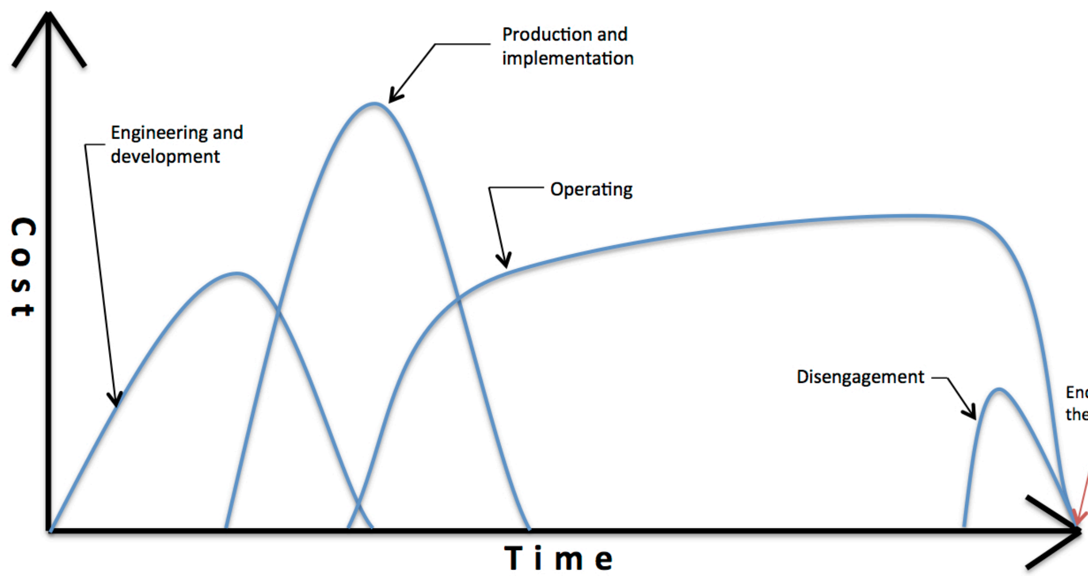

Figure 4: Stages of life cycle costs[5]

One of the most accepted procedures is the one proposed by Harvey, which includes four steps to reach the Life Cycle Costing of an asset. The first step is defining the *cost elements of interest*. That is all the expenditures incurred during the life of the asset. Secondly, the *cost structure to be used* has to be defined. That means grouping costs as it has been commented in above points of the work. The third step is to establish the *cost estimating relationships*, which means describing the cost of an item in function of some independent variables. The last step is *choosing the method of Life Cycle Costing* formulation (Harvey, 1976).

[5] Adaptation of Figure 2 in (Woodward, 1997), pg. 336

A very widespread formulation method is Kaufman's 8-steps approach (see detailed figure in appendix 2). The steps are 1) establish the operating profile, i.e. startup, operating and shutdown times, 2) establish the utilization factors under every operating profile, 3) identify the cost elements, 4) determine the critical cost parameters, 5) calculate all costs at current prices, 6) escalate costs at assumed inflation rate, 7) discount all costs to the base period and 8) sum discounted costs to establish the net present value. This last value is the total cost of the asset life cycle (Kaufman, 1970).

One of the sensitive points of the Life Cycle Costing analysis is the total *lifetime* of the asset. This time is the result of a forecast that has a big influence in the final result. The expected lifetime can be determined by the functional life, the physical life, the technological life, the economic life or the social or legal life. The *uncertainty* plays also an important role in the analysis. Although statistical data and historical records can be used, there's always a possibility that there could exist a deviation that invalidates the Life Cycle Costing final value.

In Table 2 a summary of the two explained approaches (TCO and LCC) is presented, given their main characteristics and making them comparable one to another. Common points and differences have to be clear in order to ensure a well use of the accounting model presented in section 5.4.

Total Cost of Ownership	Life Cycle Costing
Group costs in categories	Group costs in categories
Covers acquisition and utilization	Covers whole life cycle (failure and disposal)
Main objective is to help reducing costs	Main objective is to help estimating costs
Four major cost categories	Four major cost phases
Future and present costs at same value	Future costs at present value (interest rate)
Cost factors to convert business activities into costs	Cost estimating relationships to relate costs with processes

Table 2: Summary of traditional information systems' accounting approaches

3.1.3. Future Outlook

According to the IT Sourcing Europe's reports, the companies keeping the information systems in-house represented last year (2011) the 44% of the total number of companies using some type of information technology service. In a changing-technology environment, the traditional information systems still keep their role in the market and, although are no more the first option for companies, it is still not being exceeded by far by the outsourcing market, so it is not yet an obsolete solution (IT Sourcing Europe, 2011).

The actual situation, though, has changed in the point of view of accounting approaches. Normal evolution of computing and technology made enterprises to optimize the usage of their infrastructure in order to adjust the cost to their needs. Past solutions involving exaggerated computing power, storage or networking made way to more efficient systems, which can compete, in terms of cost, with the services provided by external companies. Due to this needs, new theories broke out to explain the phenomena and to present new ideas. Some of these new approaches are the usage-based accounting or the distributed IT infrastructures (Sultanesi & Schäfers, 2005), which seem to be the most popular and effective and are explained below these lines.

Resource consumption accounting is based on the Activity Based Costing and the "*Grenzplankostenrechnung*"[6] accounting approaches. It was established in the last decade and although it is a general accounting model, it is widely used in information systems decisions. Its principles are 1) the usage of many cost centers based on every operational cost, 2) a quantity-based model that always links a cause-effect relationship to the economic value, for example relating the final product with the hours invested, and 3) the nature of the costs, always separated into variable and fixed categories. This last principle allows the company to highlight the idle capacity, which in the case of actual information systems infrastructures is a critical issue (Polejewski, 2007).

Distributed information systems architectures refers to those systems where multiple applications and business units share the same infrastructure. In these systems, the consumption of the applications or the workload of every user is a significant cost driver (Brandl, Bichler, & Ströbel, 2007). To consider this cost driver, a usage-based model has to be used. The problem is that controlling the use of the resources is a complex solution, so the analysis has to be done under estimations, typically for the CPU time, storage input and output, and network traffic, for every service- or user-profile. The number of invocations multiplied by these estimations, can be the usage-based allocation model.

[6] Original german term for *Marginal Planned Cost Accounting*

3.2. Traditional Information Systems Outsourcing

Outsourcing has been a common solution for lots of business sectors for many decades. The idea of transferring uncritical activities to other companies seduced the market with lower costs and no need of specialized personnel, infrastructure or know-how. With the years, more processes with direct impact in the business activity were outsourced, e.g. logistics or distribution. According to Gartner group, worldwide information technology outsourcing revenue grew nearly 8% to $246.6 billion in 2011 from $228.7 billion a year ago (ET Bureau, 2012). This data shows the potentiality and size of this market.

In the early sixties, outsourcing was applied in the field of Information Technology Systems. The first outsourcing activities were base on timesharing of computers, used by companies to develop their information processes. In the late 1980s some consultant companies offered remotely controlled monitoring systems for information system's infrastructure (Dibbern et al. 2004). The first great well-known outsourcing alliance was formed by Eastman-Kodak and IBM in 1996, and it is considered the first example of "strategic outsourcing" (Hirschheim & Dibbern, 2006). Whereas all previous outsourcing contracts were done merely based on cost-efficiency criteria, Kodak outsourced its Information System in order to focus in its core Business, leaving in hands of an external firm all the activities that did not suppose a critical aspect. For the first time, outsourcing was considered a competitive advantage. At this point, we refer to provider as the external company and to costumer as the company using the information system.

From the perspective of information systems, the outsourcing is defined as "the execution of processes and activities related to the information technology of an organization by an external company that has its own structure, resources, decision capacity and management" (Sieber, Valor, & Porta, 2005). According to (Lacity, et.al., 1994), the reason why companies outsourced their information systems were: 1) to focus in core competences and 2) reduction of IT costs. Furthermore, the continuing technological change, lack of specialists in the field and the short life cycle of many technological products can also be considered essential causes of the outsourcing phenomena.

In the cost-accounting context, there are some clear direct advantages. First of all, the cost structure is now based on a contract between companies, guaranteeing complete transparency. In this new situation, cash flows are easy to determine for every time period, and the implementation costs, efforts, and time decrease drastically. Moreover, the maintenance and administration costs are transferred to the provider.

According to the degree of subcontracting, three main levels of outsourcing are described. When a company transfers the whole information systems department, we refer to total outsourcing. When it outsources only some processes, we refer to partial outsourcing. The lowest grade is called out-tasking and is based on transferring specific actions, e.g. printing or applications development. Another approach was proposed by (Lacity & Hirschheim, 1995). They argued an 80-20 division. Total Outsourcing represents more than 80% of the information technology budget transferred to external companies, total insourcing when this 80% was dedicated to in-house production, and selective outsourcing when the in-house allocation is comprised between 20% and 80%. Also single or multiple vendors may be included. At this moment, concepts as co-sourcing, collaborative outsourcing and multi-sourcing are of current interest.

In the next sections the different information systems outsourcing categories are presented, according to the market main possibilities, which offer to outsource different parts of the information system. Below, the most widely used economic theories in information systems outsourcing are explained.

3.2.1. Traditional outsourcing models

When talking about traditional outsourcing we refer to the first extended options available in the market for companies intending to outsource some part of their information system. These single options appeared through the years, due to the constant evolution of technical solutions.

Of course every option has its peculiarities that have to be studied in order to take the best decision for a company. Also in terms of costs, each option differs from the others in some aspects that will be set out in following sections. The three main options purchasable in the first outsourcing market were infrastructure outsourcing, application outsourcing and business process outsourcing.

3.2.1.1. Infrastructure Outsourcing

The first type of outsourcing was the first step on the outsourcing market. Companies that were worried about their spending on management and maintenance to support their information systems, saw on this outsourcing method a way to reduce costs. Infrastructure outsourcing consists in transferring partial or total control of the information system infrastructure to a specialized provider. This can include the distributed system, micro computing, processing centers and network communications (Factor, 2001).

Typically, the needs of an information system are the following:

- Local area networks (LANs) and wide area networks (WANs)
- Internet access
- Internet services (e-mail, Web sites, etc.)
- Hardware and software: servers, workstations, productivity software and specialized software
- User services: help desk, support, training

Infrastructure providers offer companies the day-to-day maintenance and administration, planning and design, or installation and upgrades for each of these categories (Murrain & Cohen, 2003). A multitude of different services are offered in the market, so it is difficult to categorize every market option.

Traditional outsourcing's scope is to take control of essential ongoing activities for the well functioning of the information system of the costumer. Thanks to these services, companies do not have to worry about solving problems affecting the infrastructure, and also con estimate costs more properly, due to the fact that some of the hidden costs presented in traditional information systems structures are now transferred to the provider.

Normally, enterprises used long-term contracts to acquire this type of services. Another characteristic of infrastructure outsourcing contracts was the high order volume. The provider adapted its solutions to every single costumer, fulfilling its needs and requirements (Braun & Winter, 2005).

At this point, a critical and common problem arose. The consequence of high-customized long-term contracts was that companies' possibility to change and improve their information systems was strictly restricted by the providers. This phenomenon was called the lock-in effect. This concept was observed in the outsourcing of both infrastructures and applications. The danger of lock-in is minimized when there are many suppliers in the market (Dibbern et.al., 2004).

3.2.1.2. Applications Outsourcing

Application outsourcing can be described as the transfer to an external company of the execution of certain processes. The idea is that software applications are licensed and implemented by the service provider. The first application outsourcing deals were run by external personnel using the costumer's infrastructure, and because of that they were known as *in-house* application outsourcing. The provider developed the application and was responsible of its maintenance. The application was exclusively used by the costumer (Liang et.al., 2000).

With the Internet revolution in the late 1990s, a new concept based on applications outsourcing arose: the *Application Service Provider*. In this case, the applications are run by the provider's personnel and in the provider's infrastructure, so *out of house* (Sieber et.al., 2005). These applications, as are run outside the costumer boundaries, can be shared with other companies that have same needs. The standardization, so, plays a big role in this new market activity. Additionally, distributed computing (section 3.1.3) takes on a big role from the point of view of the provider, as he has to share its infrastructure with all his costumers.

Through an application service center and a data center[7], the providers offer access to the end-user through an Internet-based software [8] (Liang et.al., 2000). These applications can be from complicated enterprise resource planning and e-commerce systems to simple e-mail or scheduling packages. One inconvenient is the low customization that costumers can apply to these applications. However, costumers benefit from this service obtaining always the last updates of the software and hardware.

With these new model, a basic cost concept of the traditional information systems disappears: now companies do not have to make a capital investment to start running

[7] The application servers are managed in a centrally controlled application service center. Data is stored and managed in a physically secured data center.
[8] This software can be a standard internet browser or a dedicated application owned by the service provider and installed in provider's boundaries

an efficient information system. No specific technology assets are needed, so that the information system can be run with only the normal desktop computers already used in the company. Also they do not have to make an effort to develop, implement or maintain the system. Companies no longer buy software; rather they rent it (Hirschheim & Dibbern, 2006). Typically, the service is acquired via a set-up fee and a monthly subscription or license. Like in the infrastructure outsourcing market, no standardized pricing models are observed across the industry.

The monthly fees usually cover the access to the application and ongoing technical support. These fees are based on the number of users or workstations accessing the application (Liang et.al., 2000). This quantification is called *licensing agreement*. Costumers have to predict the number of simultaneously users of the service in order to size the total number of licenses included in the contract. Also different classes of user can be assessed, so that two different licenses can be determined (e.g. light and standard). Another aspect to bear in mind when sizing the contract are the peak traffic demands, in which the system can be overload and, therefore, not work properly (Bontis & Chung, 2000).

3.2.1.3. Business Process Outsourcing

Business process outsourcing refers to the delegation of one or more technology enabled business processes to an external service provider (Rouse & Corbitt, 2006). These processes are basically non-core, or non-strategic activities for the company acquiring the services. These services are typically operative tasks and technological functions. Some of the business processes currently outsourced by companies fall in the areas of human resources, (e.g. payslip management, training and personnel selection) client relationship (e.g. costumer service center, sales promotion or special offers) and Finance and Accountability (e.g. purchase orders, bills, financial studies, planning and forecasting) (Sieber et.al., 2005).

As occurred in the application service provider model, the provider here takes on the full information system hardware and software to support the business process, as well as the operation and the maintenance activities. In addition, now includes also in the deal the management and execution of the process. This means that a higher grade of individualization may be applied to every service provided, which have to suit the company's specific environment (Braun & Winter, 2005). Due to this fact, companies have to develop their business process-outsourcing project meticulously in collaboration with the service provider, with the aim of formalizing a contract with the adequate level of service and also sufficient flexibility.

Economically, business process outsourcing lets the costumers reduce costs without decreasing efficiency or level of services. As seen on application service providing, costs are clear, fix costs are transformed into variable costs, and companies acquiring these service benefit from economies of scale created by sharing resources with other companies working with the same provider. Furthermore, the provider can invest in improving operation efficiency and continuous upgrades more aggressively, as they share costs between all the costumers. For a solo company, these expenditures would represent a huge and even unviable financial effort.

Another aspect to bear in mind when outsourcing these types of services is that the labor costs can be reduced when transferring the activities to low-wage countries like India or China. In 2008, India accounted for 55 per cent of information technology offshoring and about 35% of business process outsourcing (Fersht et.al., 2008). This phenomenon is recently referred to as offshore outsourcing or simply offshoring.

3.2.2. Outsourcing Economic Theories

In the economic point of view, many theories are applied to and thought for the information systems outsourcing. The most widespread theories, which are presented in the next points, are *Transaction Costs Theory, Resource Based View* and *Agency Theory*. Although they are not considered as accounting approaches, their application is directly related with the accounting process, and so will be useful for the accounting model presented in below sections.

Based on the relation between parties that interact in the outsourcing process, these theories identify concepts and costs that were not considered in accounting approaches seen in section 3.1.2. The main concepts that can be extracted from the theories presented below are focused on the decision process when externalizing an information service or process. In terms of cost, the theories can help to bring to light some hidden costs that arise when contracting an external provider, and also during the use of its service if the decision process is not correctly done. Further application of the next theories is presented in sections 5.1 and 5.3.

3.2.2.1. Transaction Costs Theory

This theory was first described by (Coase, 1937), and its purpose was to explain why firms exist and how firm boundaries are determined. Later on, it has been adapted and extended to explain and analyze the contractual relationships between organizations and markets. One of the big contributions to the theory was made by Williamson, who described transaction costs theory as a tool for analysis of the "*comparative costs of planning, adapting and monitoring task completion under alternative governance structure*" (Williamson, 1985).

Transactions costs refer to the effort, time and costs incurred in searching, creating, negotiating, monitoring and enforcing a service contract between buyers and suppliers (Coase, 1937). When these costs are higher than the costs of the internal production of the process (in our case, information system or service), companies may decide not to outsource the process. Transaction costs arise for *ex ante* reasons (i.e. drafting, negotiating and safeguarding agreements) and *ex post* reasons (i.e. maladaptation, haggling, establishment, operational and bonding costs) (Aubert & Weber, 2001).

Williamson (1985) presented in his theory two human factors and three environmental factors (also known in further research as dimensions of the transaction) to explain the outsourcing phenomena. The final target was to determine which governance mode should companies select in different situations. Not only insourcing or outsourcing is considered, but also different types of outsourcing governance. These governance forms are 1) simple contract on a spot market in which price, quantity and quality are known, 2) complex market arrangements using contracts and social norms, and 3) internal governance, preferred when transaction costs are high, that can even lead to an internal integration (employing the provider).

The two human factors are *Bounded Rationality* and *Opportunism*. *Bounded rationality* refers to the fact that humans are unlikely to have the abilities to consider every outcome that may arise during the transaction course. *Opportunism* is the human behavior that makes us act to further our own self-interests.

The three environmental factors or transaction's dimensions are *Uncertainty, Asset Specificity* and *Transaction Frequency*. *Uncertainty* exacerbates the problems that result from bounded rationality and opportunism (Aubert & Weber, 2001), and it is present in every transaction, as it is normally conducted under a certain level of imperfect information (Aubert et.al., 2004). It can be divided in two forms: environmental and behavioral. Behavioral uncertainty can create problems for performance evaluation, if the exchange partners perform inefficiently or ineffectively acting selfishly. Environmental uncertainty refers to all the factors out of the organization boundaries that can change the outcome predictions. If these changing circumstances are not covered by the contract, opportunism can result in a cost increase.

Asset specificity refers to the transferability of the assets included in the transaction. A specific asset is that one dedicated to a specific use (high customization), which may differ to other companies' use of the same asset. The specificity can be measured by the difference between the cost of the asset and the value of its second best use (Williamson, 1989). For example, money can be used in a transaction different than the best option without losing value. That makes money a non-specific asset. A good example of a specific asset is knowledge, which can be acquired but, if obsolete, cannot be sold for any value.

The last of the environmental factors is Frequency, which sorts transactions in recurrent or occasional. In combination with asset specificity, (Williamson, 1985) referred to an optimal set of governance structure, presented in Table 3. As shown in the framework, non-specific assets lead to low transaction costs. Thus, the use of standard, undifferentiated contracts is adequate for both frequencies. With higher asset specificity and occasional transactions, 'neo-classical' contracts (i.e. with "third party assistance) can be used to minimize transaction costs. For recurrent transactions, high specificity leads to high transaction costs, and therefore to insourcing. Lower levels of specificity are handled by 'relational' contracts, based on trust between parties.

	Asset specificity		
Frequency	**Non-specific**	**Mixed**	**Idiosyncratic**
Occasional	Outsource with classical contract	Outsource with neo-classical contract	
Recurrent		Relational contract	In-house

Table 3: Governance structure under Transaction Cost Economics, (Nagpal, 2004)

3.2.2.2. Resource Based View

While transaction costs theory focuses on the costs associated with transactions between organizations, resource based view theory concentrates on the factors that enable a firm to gain competitive advantage when outsourcing. The main contribution to the theory was made by (Barney, 1991), whose conceptual framework provides foundation for most of the already done research. The main idea of the theory is as follows: leveraging the resources and the core competences that a company possesses can generate a sustained competitive advantage, which, in turn, translates into better performance (Roy & Aubert, 2000). Resource based view argues that resources are heterogeneously distributed across firms and are imperfectly transferred between them (Barney, 1991).

Instead of assets (as shown in above section), this theory refers to "resources", which include assets, capabilities, knowledge and organizational processes that enable the firm to conceive of and implement strategies to its efficiency and effectiveness (Daft, 1983). A set of resources can only have value by means of the activities that they contribute to support or realize. Its strategic value depends on the value added to the product (Roy & Aubert, 2000). Strategic resources can produce competitive advantage and thus above-normal returns if they are 1) valuable, 2) rare, so that other firms can not obtain them, 3) imperfectly imitable, referring to aspects like casual ambiguity, social complexity that prevent competitors from understanding how the set of resources lead to the competitive advantage, and 4) non-substitutable, which means that other companies can not use alternative resources to gain the same advantage (Aubert & Weber, 2001). The higher the strategic value of the resources, the more the company is justified to exploiting them internally, and vice versa for outsourcing.

Strategic Value	Presence of appropriate resources	
	Low	High
High	Partnership	In-house
Low	Outsourcing	Recuperation

Table 4: Model of Information system sourcing under Resource Based View, Roy & Aubert, 2000

In terms of information systems sourcing, decisions and therefore costs involved depend in both the strategic value and the presence of the appropriate resource. As summarized in Table 4, companies may opt for different strategies when these two aspects change their level. *Partnership* refers to a contract in which both partners provide significant resources, and it is performed to have a better control of an important resource for the company. Recuperation means that the company shares the resources with competitors in order to recuperate the investment, due to the fact that the resource is no longer strategic.

3.2.2.3. Agency Theory

Agency theory was widely developed by (Eisenhardt, 1989), and focuses on the relationship between two parties when a process or task is transferred between them. According to (Jense & Meckling, 1976), an agency relationship is a contract under which one party (principal) engages another party (agent) to perform some service that involves delegating decision-making authority. The theory was firstly thought to understand the relation between employees (agency) and directives (principal) in organizational contexts, or the separation of ownership and management in a company, although it was later widely applied in outsourcing contracts. The theory was used in many fields, e.g. economics, marketing, society, finance or politics. It is clear that this type of business relationship is present in the information systems outsourcing phenomena, in which the agent is the provider and the principal is the company contracting the service.

The idea of the theory adds to the transaction costs theory the issue of risk aversion and information as a commodity, assuming information asymmetry (Gurbaxani & Kemerer, 1989). The agency problem is based in two fundamental concepts. First of them is related to information asymmetry, which causes that principal cannot perfectly and causelessly monitor the actions and the information of the agent. The second fundamental concept is the goal incongruence, meant as the different interests agent and principal can have although working toward the same goal (Delves & Patrick, 2010). This phenomenon is also known as the *agent-principal dilemma*. According to (Mitnick, 1973), principal's problem is to motivate the agent to act in a manner so that achieves the principal's goals. However, for the agent the problem is to decide to act either in principal's interest, own interest or some comprise between the two. Mitnick also presented policing mechanism as the mechanisms and incentives intended to limit the agent's discretion.

The principal way to limit agent to act for his own interest is the contract. Eisenhardt (1989) suggests that the type of contract between principal and agent impacts the quality of the work. The contract can be based on behavior or in outcomes. A behavior-based contract compensates agents for behaving in a certain way the principal considers positive for the work. An outcome-based contract compensates agents for achieving certain goals and may take the form of a commission, rewards, bonuses, or even fear of reprisals. These compensations can be considered *agency costs*[9], which are also present in case of behavior-based contract in form of monitoring and controlling mechanisms costs. All these costs have to be incurred in order to align the utility of the agent with the utility of the principal.

Other issues can incur costs in the agency relationship. Shirking, for example, meant as the agent eluding the responsibilities fixed by the principal, can incur costs due to the loss of productivity. Also privately-held information misrepresented by the agent or false-provided to the principal can lead to agency costs. Previous research suggests the more outcome-based the contract of the developers, the more monitoring by the project manager, the less shirking by the provider, and the less privately-held information by providers, the more successful the project can be (Kirsch, 1997). Moreover, agency costs are largely unquantifiable and very difficult to calculate, because they can appear in a large variety of forms, e.g. executive perks, drops in productivity, and loss of firm value.

3.3. Cloud Computing

In recent years, Internet revolution and technology evolution lead to new market opportunities in the outsourcing field. Now, Internet has lot more capacity to let users and companies interact with each other. The term "Cloud" refers metaphorically to the entire invisible infrastructure or network that the end-user cannot see because it is located in an external location, (i.e. Internet servers and network infrastructure). Although being another outsourcing model, it has been dealt separately from it in this work because it represents a bunch of new services that are presented below. The global cloud computing market will grow from $40.7 billion in 2011 to more than $241 billion in 2020, according to Forrester Group (Ried & Kisker, Sizing the cloud, 2011). Deloitte predicts that cloud-based applications will replace 2.34% of enterprise IT spending in 2014 rising to 14.49% in 2020 (Callewaert et.al., 2009).

Cloud Computing appeared in the late 2000s. Eric Schmidt, Google's CEO, was the first to use the term in a business context (Zhang et.al., 2010). But this is not an innovation coming from nowhere, rather an evolutionary development of many different technologies like, for example, the already presented application service providers or distributed information systems (Iyer & Henderson, 2010). Cloud computing is yet a

[9] Agency costs are costs incurred by the firm due to agency conflicts

growing industry and evolving technology. Many new services and possibilities arise in the market continuously. That is why many definitions can be found through the literature. One of the most accepted was written by the United States Institute of Standards and Technology:

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

Cloud computing's key characteristics like user friendliness, standardization, scalability, location independence, or ubiquitous access can be found in many articles (Iyer & Henderson, 2010) (Vaquero et.al., 2009). Also the NIST defined the five essential characteristics that define Cloud Computing:

- *On-demand self-service*. Computing capabilities can be acquired on-demand basis, without human interaction with providers.
- *Broad network access*. Capabilities can be accessed through standard mechanisms or platforms, as they are available over the network.
- *Resource pooling*. A multi-tenant [10] model is used by providers to pool capabilities to serve multiple costumers. This aspect is also known as virtualization: multiple applications may be hosted on a common set of servers, and providers offer virtual machines (virtual dedicated servers) as the resources for applications (Li et.al., 2009).
- *Rapid elasticity*. Capabilities can be rapidly provisioned and released.
- *Measured service*. Usage of capabilities can be transparently monitored, controlled, and reported.

Cloud computing services can be implemented following four deployment models: 1) *Public cloud*, when services offered by vendors can be accessed across the internet using systems shared among multiple customers, 2) *Private cloud*, which is built, managed, and used internally by an enterprise and uses a shared services model with variable usage of the system's resources, 3) *Hybrid cloud*, which is a combination of multiple internal computing resources and external cloud providers bound together,

[10] Multitenancy refers to software architecture where a single instance of the software runs on a server, serving multiple client organizations (tenants).

and 4) *Community cloud*, in which a cloud infrastructure is shared by a limited group of organizations (Callewaert et.al., 2009). This work is focused on the public cloud, as it offers lower costs and the easiest implementation process, and represents more tightly the essence of the cloud technology wave. From now on, we refer exclusively to public cloud services and not to other deployment models when talking about “cloud computing”.

In comparison with traditional outsourcing services, cloud computing solves some of the common problems that arose in past technologies. One of them is the wide-cited “free-rider problem”. It refers to the phenomenon in which some costumers pay more than what they use and some other pay less than what they use (Brandl et.al., 2007). With a usage-based acquisition, thanks to controlling and monitoring usage of resources, this problem is totally solved. However, it also represents a problem for companies subscribing these services, as described in section 5.2.

Another issue to solve was the frequent *downtime* of the services, which had a tremendous negative effect on the company performance. Nowadays, cloud-computing providers like Amazon or Google are reaching *uptimes* near 99.99% (Callewaert et.al., 2009). Stability and performance tend to prove better in the cloud given the scalability and abstraction of Cloud services, as well as the increasing use of web and service oriented architectures.

Also the lock-in issue is improved with the adoption of cloud computing services in the information services market. The high standardization of the services offered in the market, and the common short-term commitments make companies able to change their information technology strategies without having to handle the costs that in past technologies existed. Application portability and reduced switching costs are important values in the cloud market, and that is why more and more standards appear nowadays. However, service providers always attempt to capitalize long term through vendor lock-in, as they obtain more benefit (Orlando, 2011).

In economic terms, cloud sourcing, as cloud computing outsourcing is also known, shares economic aspects with the outsourcing methods, but in addition, the resource consumption plays a big role in order to benefit from the scalable services that companies can contract to cloud providers. Economies of scale make now a bigger difference. Cloud computing service providers seek to reduce costs by sharing their huge infrastructures with as many costumers as possible. That's also why standardization and virtualization are key factors and pillars of the cloud market.

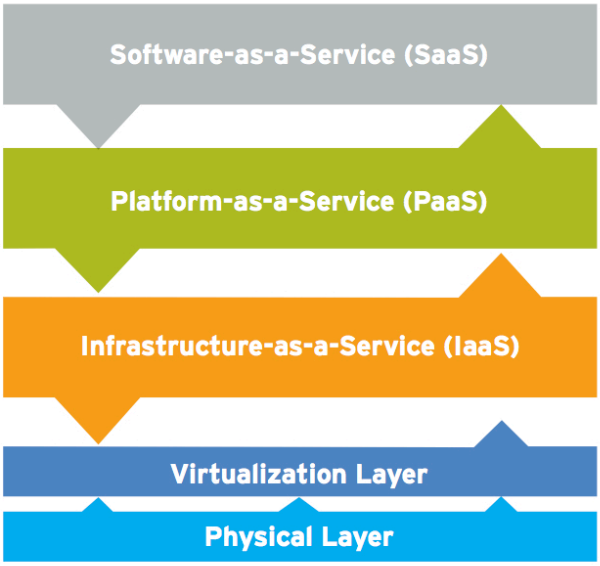

Figure 5: Cloud stack Framework, (Tata Communications, 2011)

Figure 5 represents the stack system in which cloud computing is based. The three service layers lean one on another and they are all borne on physical assets that are virtualized in order to make them accessible via the internet. Currently is accepted to categorize the cloud computing services using the SPI model, which refers to Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a service (IaaS). These are the three categories presented in next three sections, dealing with its particular characteristics and aspects affecting their costs.

3.3.1. Infrastructure as a Service

The first of the three cloud service models focuses on the infrastructure. The aim of infrastructure as a service (IaaS) is simple: to attract companies by lowering their total cost of ownership of the information system's assets. Contracting this service model, companies acquire processing, storage, networks, and other fundamental computing resources where they can deploy and run arbitrary software (e.g. operating systems or applications). The consumer cannot manage or control the cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of some networking components (e.g., host firewalls) (Mell & Grance, 2011).

The main advantages for enterprises contracting this type of services are considered to be instant deployment, ability to rapidly scale, lower total cost of ownership, and predictable uptime (Tata Communications, 2011). However, a key factor has been determinant for the expansion of the model: *cloud bursting*, which has been the greatest value for costumers. Cloud bursting is the process of off-loading tasks to the cloud during times when the most compute resources are needed. In other words, companies do not have to acquire assets to cover the most demanding runtimes, but transfer some of the running processes to cloud infrastructures when needed. In this way, businesses won't need to invest in additional servers that only run at high- or full-capacity two or three times in the year, which allows them to invest in more economical solutions (Rouse M. , 2011). In addition, IT departments must be able to build and implement the software that handles the ability to re-allocate processes to the cloud. Some companies, like IBM offer specialized cloud-bursting software for their cloud computing services (Orlando, 2011).

Mainly, the cloud-infrastructure services are based on three principal resources: computing power (equivalent to a CPU), computing memory (equivalent to RAM) and storage (equivalent to a Hard Disk Drive). All providers in the market offer these three characteristics. Many other attributes like software licensing, bandwidth, inbound or outbound transfer of files to the cloud, or accessible IP addresses also have to be included in the service. Offering more specific characteristics or adding them at attractive prices let infrastructure-as-a-service providers to differentiate from their rivals in the market.

The economic benefits[11] consumers can expect from infrastructure as a service are: 1) *Lower purchasing costs*, because providers often have greater purchasing power than single companies and the pooled resources are redistributed in the bandwidth, 2) *Avoiding technology obsolescence*, as providers are very likely to acquire the latest technologies, and 3) *Unparalleled expertise*, due to the fact that providers recruit top talents, which may be unavailable economically to some companies (Tata Communications, 2011).

At the moment, some of the most important infrastructure-as-a-service providers are Amazon, Terremark, IBM and CSC. Gartner estimated that in April 2011 the worldwide market value of infrastructure as a service was $3.7 billion, which is approximately 10%

[11] Economic benefits derive from economies of scale introduced by cloud computing technology.

of cloud computing market, and predicted it to increase to $10.5 billion by 2014 (Pettey & Stevens, 2011).

3.3.2. Platform as a Service

Platform as a service refers to a cloud-computing model in which the vendor provides the infrastructure to the costumer, who acquires the capability to deploy its own-made web applications or acquired ones, using programming languages, libraries, services, and tools supported by the provider. The user can configure settings for the application-hosting environment, but has no control on the underlying cloud infrastructure (Mell & Grance, 2011). In other words, offers developers the possibility to build and deploy web applications on a hosted infrastructure. Furthermore it can also be used to test, host and maintain applications, covering the complete life cycle of building and delivering web applications and services.

Platform as a service consists of two basic elements. The first one is the computing platform, place where software can be launched consistently as long as the code meets the standards of that platform, so that the applications deployed in the cloud fit the current computing platform of the provider. The second is the set of applications that will assist in the development process as well as the deployment of the application (Orlando, 2011b). In comparison to software as a service, this model allows customers to develop their own applications rather than acquiring them, achieving a higher level of customization.

The adoption of platform as a service has been slower compared to software as a service, because of the programming languages, that have different options among the main providers, but not a standardized solution. These phenomena can create a lock-in problem (3.2.1.1), typically seen in outsourcing, due to the difficult or even impossible transmission from one provider to another (each one uses its own developed programming language). Also the transition from traditional on-premise applications development platform can be a tough issue, as the new programming models have to be learned (Callewaert et.al., 2009).

The actual most important providers in the platform as a service market are Force, Caspio, Google app engine, and Microsoft azure. Gartner group argued that in 2008 the platform as a service market represents approximately 1,5% of the total application development market, and expected this value to grow up to 10% by 2013 (Callewaert et.al., 2009).

According to Forrester research, Platform-as-a-service will become a middleware platform alternative. Preintegrated and, in many cases, simplified platforms for the development of general-purpose business applications will become a serious alternative in the near future for developing custom applications. Also independent software vendors will also find them a highly attractive option for delivering software-as-a-service applications (Ried, 2011).

3.3.1. Software as a Service

Software as a service is a software delivery model, developed since the SaaS Conference offered by SDForum[12] took place in 2005, when it was for the first time accepted as a business model. It is defined as the provision of capabilities for the costumers to use the provider's applications running on the cloud infrastructure possessed also by the provider. Users can access the applications from either thin client interface (e.g. web browser), or a dedicated program interface. The costumer does not manage or control the underlying cloud infrastructure, which is mainly the information system infrastructure explained in above sections (3.1.). The only possible need for the company acquiring the services is a limited user-specific application configuration setting (Orlando, 2011c). The result is a cost-effective Internet-based service offered with a low-entry, zero infrastructure and low customization cost by providers. Most of the websites we visit daily are based on this model, for example Google docs, Zoho or any online mail website.

According to the definition, Software as a service has many similarities to application service provider's model. But also many differences. The first, and more important, is that software is developed by the service providers, instead of contracting or licensing it to a software vendor as seen in application service providing (3.2.1.2). Implementation time and usability are widely improved in software as a service. Also the Internet speed allows now data transfer levels unreachable in the time when application service providing was developed.

The main advantages companies can benefit of are: 1) Cost saving, because users can save information technology costs by renting just needed applications for their

[12] SDForum refers to Software Development Forum, while the organization changed its name recently to Silicon Valley Forum (SVForum)

business and purchasing and maintaining costs could be minimized, 2) Better resources utilization, referring to the use of the cost savings for more strategic processes, 3) Application access scalability, thanks to the multi-tenant structure that allows to scale up or down client's application access, and 4) The possibility of outsourcing more globally, allowing vendors to be located overseas (Chou & Chou, 2008).

According to Deloitte, the Software as a service market accounted in 2008 for 8,1 billion USD worldwide, which represents 7,7% of total enterprise application revenues and was the largest component of the Cloud computing market (89%) (Callewaert et.al., 2009). Last studies predict that by 2015 Software as a Service will represent the 13.1% of worldwide software spending, and that 14.4% of applications spending will be SaaS-based in the same time period (Mahowald et.al., 2011).

There are nowadays lots of services provided through this delivery model. Some of the most successful ones and with higher growing perspectives are customer relationship management, supply chain management, integration as a service (i.e. data transportation between enterprise wide systems and third parties), enterprise resource planning, and content, communication and collaboration software (e.g. web-conferencing, e-learning, e-mail or team collaboration) (Callewaert et.al., 2009).

3.4. Relating Traditional Economic Concepts to Cloud Computing Services

At this point of the work, both traditional information systems, as in-house model, and outsourcing phenomena have been described and some economic concepts, included in theories and methodologies, have been stated. As cloud computing have also been presented, the economic aspects of this new technology wave have to be argued. Not many new concepts arose in the costumer perspective with the implementation of this new technology, but the old concepts were developed and adapted.

During the rapid evolution on the field of the information systems, researchers and managers have consolidated many knowledge that now have to be used to understand any information technology strategy, acquisition or simple decision. Both accounting approaches for internal information systems (3.1.2) and outsourcing economic theories (3.2.2) have to be implemented in order to gain the correct information when making a sourcing decision, as generally both internal production and outsourcing have to be taken into account. In other words, the economic aspects described above are now complementary tools in the information system sourcing field.

Many concepts appearing in the total cost of ownership and life cycle costing, as seen for the internal production of information systems, are with the cloud technology (and also in some already seen outsourcing models) transferred to the provider of the service [13]. However, some aspects have been adopted and contributed to the development of cloud computing. While centralization is the basic idea for the outsourcing phenomena [14], trying to reduce operating and maintenance costs by reducing locations where hardware and software are installed, standardization was the next step towards the evolution to cloud computing. With its adoption, consumers have to select among several but standardized solutions, making easier the sourcing process, i.e. comparison and analysis. In conclusion, both concepts, thought to minimize the total cost of ownership of information systems, have been further applied and lead to modern information systems based on external servers and standardized software services.

From the point of view of the outsourcing economic theories, the majority of the concepts argued can be still applied to the cloud market, as it is a new market included in the outsourcing phenomena. Transaction costs and agency costs theories need to be adapted to understand the new market and to be useful for companies. This new relationship between providers and costumers is widely detailed in section 5.1.

In terms of contracts and pricing, cloud market is an evolution of the solution presented in the traditional outsourcing phenomena. Customized and long-term commitments gave way to a market with plenty of different offers with clear prices and contract specifications, among which the companies have to detect the best opportunity according to their needs. In the cloud industry the old contracting fees and subscriptions are known referred to as pricing models. The pricing models vary between cloud services categories. In this work, the most popular pricing models used in infrastructure as a service market are presented in section 4.2 as a result of an analysis of the actual market.

[13] When referring to a public cloud. Not applicable to other implementation models.
[14] Outsourcing is a centralization process at a higher level, as it creates a one-place infrastructure for several costumers or companies.

Another economic basis of the cloud market is the business model, which make it a more commercial business than its predecessor. In this new scenario, companies managed to create models that add value for the costumer, turning market opportunities into profit, and being able to capture the economic value from the new technology. In this new scenario, companies have to focus in user-related issues. In comparison with traditional outsourcing, providers have been able through cloud computing technology to create a remarkable commercial value, and form a large market with many different solutions, but with the sufficient structure to differentiate the different consumers' profiles. This level of unification was not present neither in internal information systems nor tradition outsourcing markets. In comparison to past information technology waves, the cloud is perceived increasingly from a business perspective and not only a technological advance (Iyer & Henderson, 2010).

4. The Infrastructure as a Service's actual market.

In this part of the work a study of the actual situation of the infrastructure as a service market will be performed. The purpose is to characterize this type of services in order to be able to apply the accounting approaches previously explained to the new market directions. A qualitative and quantitative study of the main cloud-infrastructure service providers is presented in the following sections.

Infrastructure as a service was chosen among the other widely developed cloud services or delivery models because it represents a natural solution for companies that want either to substitute an intern information system or to start up a business that needs an information infrastructure. Furthermore, cloud-infrastructure market is less scattered or divided than the other ones, as there are not many solution possibilities to offer to consumers. In other words, cloud-infrastructure services are more clearly defined and structured, and also their pricing models seem to be more mature than platform as a service and application as a service's ones.

4.1. Characteristics of the pricing models

Before starting to design the study of the infrastructure as a service market, the main points for every pricing model in the market have to be observed and defined. After a previous market overview and brief literature research on the topic, explained below are the main characteristics that can be found in the providers that will be further studied.

As argued by (Proden & Ostermann, 2009), the business model of the cloud market is based on three pillars: payment model, pricing, and service level agreement. The most important characteristic of cloud-service in general is its on-demand nature. That is why most of the providers, especially in infrastructure services, use consumption payment to charge their clients (also known as pay-as-you-go). However, some of the providers usually offer fixed solutions, known as monthly plans, which are paid on advance, and include a certain quantity of each of the characteristic resources that can be used by the costumer during a time period. These plans usually offer better prices compared to the pay-per-use one's, but don't allow the costumers to be charged just for the quantity of resources they use.

The pricing of the service is based on 1) virtual dedicated servers that can incur an activation cost and a time-usage cost, 2) the data (stored or transferred), and 3) the software licensing. Other cloud services charge also for a subscription fee, which is not observed to be a common practice in infrastructure as a service market. As seen in Osterwalder's work (2004), pricing mechanisms such as differential pricing and market pricing, which were applied to previous information system services, have been now replaced by the fixed pricing mechanism, which is one of the key values in cloud services. Inside fixed pricing can be included pay-per-use, subscription and list price methods (see complete list of pricing mechanism in appendix 2). Denne (2007) also discusses the types of pay-per-use methods and presents some different types of implementations (see appendix 3). Among different possibilities, time-based-pricing or subscription pricing is the most used in cloud-infrastructure market. It consists on charging the costumers per consumed time units.

Service level agreement (SLA) is a key characteristic for every company offering infrastructure as a service. It is a contract that specifies the minimum obligations of the provider to its clients, or the expected services costumers should receive in exchange of the price paid. Among other contractual aspects and clauses, the quality-of-service's aspect that has higher impact for clients is the up-time of the services. As has been previously explained, the tiny amount of time information systems are out of service is a key value for cloud computing compared to traditional outsourcing technologies. And it is: most of the companies guarantee a service level agreement in a range from 99,95 to 100%.

When observing the prices of most of the cloud-infrastructure providers, a common pattern is detected. Most of the companies offer their services in combined and defined quantities for each of the basic resources: computing, memory and storage. This phenomenon is called *price bundling*. Price bundling is defined as a strategy that markets two or more products or services as a specially priced package (Schmalensee, 1984). The aim of this marketing technic is to increase profits through price differentiation by segmenting customers and also to veil the prices of the characteristics of the bundle (Venkatesh & Mahajan, 2009). Bundling makes sense in infrastructure-as-a-service, as the costumers cannot operate with just one of the characteristics included in the bundles, so that they have to contract at least the three principal resources, and they also request different amount of resources depending on their profile.

What can be observed in company's price tables is a discrete set of predefined packages. Each provider presents this set in many different ways, with different nomenclatures for each of the packages. The opposite mechanism is price unbundling, which consists in fixing a price for each of the characteristics. It is also common that companies use a mixed methodology, bundling some of the characteristics and unbundling other ones. These phenomena create almost infinite pricing possibilities when contracting a cloud-infrastructure service.

Another key point of the pricing models is the duration of the contracts. As commented, the idea is to charge the user just for what he uses, and thus there is no minimum duration of the contract for most of the providers that have been observed. So the least quantity of service that can be acquired is a simple hour[15] of service at the required level. In some cases a discount is applied when subscribing some of the packages during a length of various months. In relation to monthly plans, usually short or mid-term contracts are required.

4.2. Infrastructure as a service market research

In this section a study of the actual infrastructure-as-a-service industry is performed. Following the general focus of the thesis, the study will cover the price models, strategies and quantities that providers use to charge the costumers, which are the center of attention of the work. The aim is to determine common patterns and differentiation aspects.

In order to simplify the lecture and understanding, the study is divided in an introductory part where the design is explained, and two central parts where strategies and prices are compared. A final part of discussion and summary will prepare the study results to be used in the following sections of the thesis.

4.2.1. Study design

The first step when designing the study is to determine which will be the studied population. In this case, lots of infrastructure-as-a-service providers are available in the market so in order to simplify the data collection, we have to select which ones should represent better the tendencies and values of the global market situation. First point to remark is that only providers offering public clouds were taken in account, as the public

[15] All providers charge their services per, at least, a complete hour of usage.

deployment model is the most accessible service for many of the companies, in terms of costs and also simplicity of acquisition. Companies providing private or hybrid cloud infrastructure solutions were not included in the study.

The population sample selection for the study was based on published rankings of the most well-known infrastructure-as-a-service providers. As it is difficult to determine exactly if one provider is better than another one (as they offer many different packages, prices, and service levels), different rankings were used. The main ranking followed to include providers in the sample was the "magic quadrant for public infrastructure as a service" recently published by Gartner Group (Figure 6). According to this ranking, the leaders of the market are Amazon Web Services, Savvis, CSC, Terremark and Bluelock. Also the providers close to the leaders' quadrant have been chosen.

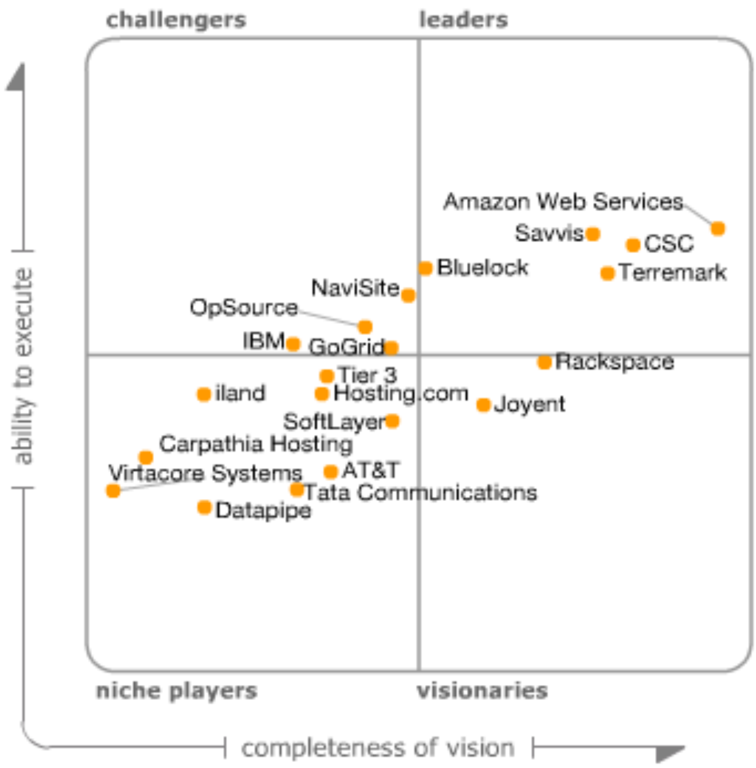

Figure 6: Magic quadrant for public infrastructure as a service[16]

To complete the providers' selection, a popularity survey by (Ahronovitz, 2011) and a specialized journal list of the most powerful companies in the market (Burns, 2012) were used. After selecting 12 providers crossing the three rankings, a quick review of the information shown in their websites was performed. Savvis, Bluelock and CSC do

16 (Lydia Leong, 2011)

not provide information about their pricing models, so they were removed of the list. The final list of 9 providers is, according to the name of their cloud-infrastructure service: Amazon Elastic cloud computing EC2 (subsequently referred to as Amazon), IBM Smartcloud Enterprise (IBM), Terremark vCloud Express (Terremark), Rackspace Cloud Servers (Rackspace), GoGrid Cloud Hosting (GoGrid), AT&T Synaptic Compute as a service (AT&T), Microsoft Windows Azure Virtual Machines (Microsoft), Cloudsigma and JoyentCloud (Joyent).

All the data used in the study was collected from the provider's websites or costumer support services in June 2012 (see complete collected data in appendix 5). A total of 76 different pricing models were included in the study, considering bundled packages and unbundled prices per resource.

With the purpose of standardizing the collected data, windows was chosen as the operating system, considering it a very common solution and also because when including windows in the acquisition, the license costs are incurred. For companies where different servers can be chosen[17], the closest to the European continent was selected. The prices were collected for unreserved resources, so that costs are reduced by sharing the providers' infrastructure with all other clients (i.e. elastic infrastructure). Also both 32 and 64 bits computing modes were included in the study.

The second step when designing the study is to define which variables will explain the results. In this particular case, the obvious response variable is the price charged to costumers. This variable will be the total amount in euros (€) for a whole month of service. Full-time usage is assumed for every provider, i.e. all the hours of a billing period (month), so that prices are comparable. In most of the pricing models observed, the prices are shown in euros or dollars per hour. To facilitate the study, these values were converted to euros per month, assuming a month is equivalent to 720 hours and that 1 dollar is equivalent to 0,794 euros[18].

The descriptive variables or predictors for our response are the characteristics that providers include in each of the pricing schemes. Obviously, the three main characteristics, i.e. computing power, memory and storage, have to be included in the study. Observing the most offered resources and services, following variables were

[17] Amazon lets users to choose among all the different servers located around the world
[18] Currency as market state for 29th of June, 2012

chosen to be part of the study, as seem to have the major impact on the pricing of the service:

1. **Computing power**, measured in GHz, which represents the frequency at which the processes can be performed and so the computing speed,
2. **Computing memory**, measured in gigabytes (GB),
3. **Storage capacity**, measured also in GB,
4. **Data transfer inbound**, measured in GB, and
5. **Data transfer outbound**, measured in GB[19].

Transfer amount was limited to 10TB as it is the maximum amount that providers are offering at a basic price (for amounts exceeding 10 TB, different pricing schemes are applied). All the variables are included in all the pricing tables of each provider, so that each subscribing option offer is presented in a homogenous way.

In the case of the CPU or computing power value, some companies do not provide an exact quantity of GHz but, instead, use different scales to quantify this resource. This issue is presented and argued in below sections, but in order to collect comparable values, the minimum CPU frequency is assigned, considering the worst case a costumer could have to face. This information is presented in the technical sheets offered by most of the providers included in the study.

In order to relate the response variable with the five predictive variables, the linear model in equation 1 was used. This model aims to divide a price amount into different smaller subparts, each of them referring to one of the resources included in a bundle. A very similar model was developed by Rosen (1974) and named Hedonic Pricing Model. The variable x_i represents the quantity of the i resource. It uses the units of the descriptive variables already listed (e.g. GHz, GB or 100GB). For a certain provider, the index i can range between 1 and *n*, being *n* the total number of resources included in the model for that provider. The parameter β_i is a factor that, when multiplied by the x_i variable, transforms the quantity into an economic amount. The units of this parameter are € per units of the x_i variable corresponding with the same i index (e.g. €/GB, €/GHz). A constant parameter β_0 is also included in the equation to make it ensure linearity.

[19] To simplify the numerical understandability of the results, the units for Storage capacity and data transfer in/outbound were calculated per 100GB

$$PRICE = \beta_0 + \sum_i \beta_i \cdot x_i \qquad i \in (1 \dots n) \qquad (1)$$

When applying the equation to our specific model, every descriptive variable has an assigned i index, as developed in equation 2. The indexes used are *CPU, RAM, and HDD* for computing power, memory and storage respectively, and *TrI* and *TrO* for transfer in and out of the server (n=5). The equation above has to be applied to every service provider including all the different pricing models that are offered. For unbundled prices, the β_i is just the price that providers set for the i resource. For bundled prices, a least-squares regression is used to determine each of the β_i parameters (Results in 4.2.3). This type of regression is used when approximating an over-determined system, i.e., set of equations in which there are more equations than unknowns. Many regressions as providers included in the study have to be calculated, i.e. 9.

$$PRICE = \beta_0 + \beta_{CPU} \cdot x_{CPU} + \beta_{RAM} \cdot x_{RAM} + \beta_{HDD} \cdot x_{HDD} + \beta_{TrI} \cdot x_{TrI} + \beta_{TrO} \cdot x_{TrO} \qquad (2)$$

When collecting data, it is firstly observed that not a single company bundles the data transfer, either inbound or outbound, with the computing resources, so the data transfer parameters can be easily determined directly with the values collected in providers' pricing sheets. The regression now does not need to include *TrI* or *TrO* indexes (n=3), so the final model applied to the data collected for each provider is the resulting equation 3.

$$PRICE = \beta_0 + \beta_{CPU} \cdot x_{CPU} + \beta_{RAM} \cdot x_{RAM} + \beta_{HDD} \cdot x_{HDD} \qquad (3)$$

4.2.2. Strategies Comparison

After determining the scope of the study, a first comparison will be performed. First objective is to compare the different pricing schemes that each provider uses. Pricing model is one of the key values providers use to differentiate their services from the ones offered by their competitors. Also the complementary services and the service level agreement help the costumer to distinguish which option is more suitable for its needs.

The first focus of this comparison is the pricing model. As already explained, one of the most spread technics is the price bundling. However, not all the providers use it in the same way. In Table 5 can be observed that the common pattern is to use a mixed bundled pricing model, although some companies opt for a totally unbundled solution.

As already argued, bundling the three basic resources is a logic decision, and all the providers charge for the data transfer separately. As it is commented in the next section of the study (4.2.3), most of the providers only charge for the outbound transfer of data.

The number of bundles included in the pricing sheets varies from one provider to another. Providers offering a higher number of bundles try to include more costumer profiles, so adapt to a larger number of required configurations of the resources. If a lower number of bundles are set, clients have to adapt to the resources configuration offered and possibly under-use the subscribed characteristics. The phenomena of dividing the resources charged in little parts is referred in some works as *granularity*, meant as the intervals of resource's amount for which providers change their pricing tariff (Repschlaeger, Wind, Zarnekow, & Turowski, 2012). For providers offering bundled prices, the granularity is in all cases measured as hour-periods for CPU and storage, and in GB for data transfer. On the other hand, unbundled prices granulate the resources per hour and GHz or hour per GB for CPU and ram or storage, respectively

<table>
<tr><th>Provider</th><th>Bundles</th><th>CPU</th><th>Memory</th><th>Storage</th><th>Transfer (I/O)</th></tr>
<tr><td>Amazon</td><td>11</td><td colspan="3">Bundled</td><td>Unbundled</td></tr>
<tr><td>IBM</td><td>9</td><td colspan="3">Bundled</td><td>Unbundled</td></tr>
<tr><td>Terremark</td><td>32</td><td colspan="2">Bundled</td><td>Unbundled</td><td>Unbundled</td></tr>
<tr><td>Rackspace</td><td>5</td><td colspan="3">Bundled</td><td>Unbundled</td></tr>
<tr><td>GoGrid</td><td>7</td><td colspan="3">Bundled</td><td>Unbundled</td></tr>
<tr><td>At&T</td><td>0</td><td>Unbundled</td><td>Unbundled</td><td>Unbundled</td><td>Unbundled</td></tr>
<tr><td>Microsoft</td><td>5</td><td colspan="3">Bundled</td><td>Unbundled</td></tr>
<tr><td>Cloudsigma</td><td>0</td><td>Unbundled</td><td>Unbundled</td><td>Unbundled</td><td>Unbundled</td></tr>
<tr><td>Joyent</td><td>4</td><td colspan="3">Bundled</td><td>Unbundled</td></tr>
</table>

Table 5: Provider's bundling strategy

Most of the providers that use price bundling show their pricing scheme as a table where each configuration has a price and an assigned amount of each resource. A singular case is Terremark, which scheme is a matrix where computing power and memory are included, assigning a price for each combination of both resources. In Terremark's case, so, storage is out of the bundle.

One of the most conflicting points when trying to compare the pricing models between providers is the computing power's nomenclature they use. Although computing memory and storage are quantified in clear units, there is no standard way to determine how much CPU[20] is offered in a priced package. Consider a small sample of the ways companies are characterizing compute resources: Amazon has ECU[21], Rackspace has no compute options, Terremark uses VPU[22], GoGrid uses cores and Joyent uses number of CPUs. Customers can buy on-premise computer equipment without a compute metric because the unit of compute is the physical processor itself. This is not the case with cloud computing where processor resources get sliced, in order to virtualize them (Beringer, 2010).

The low transparency of the prices due to the computing power different escalation makes it difficult for costumers to compare and evaluate the services they are going to acquire. From the point of view of providers, this phenomenon is a way to differentiate their services from competitors. Among many ways of avoiding this low transparency, the physic comparison of the resources and benchmarking of the systems are vastly used. In this study the different units presented in the provider's prices are converted to physical units that in case of computing power are GHz. Although most of the providers do not show the physical capacities of the CPUs offered in their pricing models, this information can be found in some technical forums inside provider's webpages or even in their technical specifications sheets. Among the providers studied, only IBM, Microsoft and Cloudsigma give clear information of the physical CPU resources in their pricing schemes. For all the others, as already explained, the minimum value provided by the provider is taken as the value to use, considering the worst-case scenario.

Apart from the already commented pay-per-use or pay-as-you-go models, some of the providers offer also prepaid monthly plans. GoGrid offers monthly subscriptions for different level of resources for both virtual servers and transfer data. IBM has a 6-month and a 12-month plans for high-capacity computing resources. Amazon's instances can be acquired for a 1-year or 3-years period including a subscription fee and an hourly charge at a lower price than for pay-per-use normal models. However, all these pricing plans are for reserved instances, and so are not taken in account in the study.

[20] CPU is meant in cloud computing as quantity of simulated computing power virtualized from a real CPU of a server.
[21] Refers to one EC2 (name of the service) Computer Unit
[22] Refers to Virtual processor units

Provider	Up-time(%)	SLA Up-time Strategy
Amazon	99,95	If up-time during 365 days is under agreement, client will receive a service credit equal to 10% of their bill (applicable to next purchases)
IBM	98,5-99,99	Uptime depends on the subscribed bundle. No additional info about compensations
Terremark	100	If uptime is below 100% during a month, clients receive one dollar (0,79€) for every 15 minutes of downtime, up to the 50% of their bill during that period.
Rackspace	100	Client receive a 5% of their billed amount back for every 30 minutes of network or infrastructure downtime, or for each additional hour of hosts or migration downtime, up to 100% of their bill.
GoGrid	100	Clients get a credit service equivalent to 10,000 times the downtime. The percentage is applied to the computing-memory hours acquired.
AT&T	99,99	for each thirty minute interval of service downtime during an applicable month, Customers receive a credit equal to 5% of the service fees for that month
Microsoft	99,95	Client receives a credit for next billing period (month) if the uptime is not reached. This credit equals to the 10% of the month bill if uptime is lower than 99,5% and 25% if it is lower than 99%.
Cloudsigma	100	Returns 50 times the costs for any period of lack of availability for a virtual server or network uptime lasting more than 15 minutes.
Joyent	100	Credit for the customer equal to 5% of the monthly fee for each 30 minutes of downtime, up to 100% of customer's monthly fee.

Table 6: Service level agreement's up-time information for each provider.

Regarding the service level agreement (SLA), each provider has a document or webpage where the contractual issues are explained. What is most significant for costumers is the up-time of the servers, for two reasons: it presents the guaranteed time the servers will be running, and also explains what happens when this guaranteed up-time is not achieved. Apart of the uptime agreement, many other technical aspects are included in the service level agreement, such as latency or response or the service, which are not considered in this work because they don't have a real impact in the final cost of the service. Each provider uses different methods to compensate the costumers when the agreement is not accomplished. In Table 6 the up-time agreement for every provider is presented, as also the strategy followed by each one. Most of the strategies are based on service credits. These credits are price discounts applicable to the next billing period. The uptime agreement is in most of the cases calculated per month, with the exception of Amazon, who uses a 365 days basis.

Another interesting point in the delivering strategies of the providers is to include some complementary services in their packages. Some of these are widely supported by most of the providers, but some other ones are specific for some of the vendors. The most offered complementary services are Public IP addresses and Load balancing. The first helps costumers to make their cloud accessible through the entire Internet network. The second is a computing tool that improves the resource utilization when using a high amount of resources. Other security options like Backups, Support and Firewall are also common offered services. A complete list of all the acquirable services for each provider is presented in Table 7.

Gogrid	Firewall, Load Balancer, Direct Connection, Content delivery network
IBM	Reserved IP, Virtual Private network, Premium Support, Pay-as-you-go Software, Cloud-bursting services
Microsoft	Virtual Private Netwok, SQL Database, Messaging, Content Delivery Network
Terremark	Public IP, Priority Support, SQL Templates
Rackspace	Backups, images, Public IP, Load Balancers
AT&T	Load Balancer, public IP, VPN
Joyent	Content Delivery Network
Cloudsigma	SSD storage
Amazon	Elastic Load Balancing, Cloudwatch supervision, Public IP, High-performance storage (Elastic Block Store)

Table 7: Complementary services by provider

4.2.3. Prices Comparison

In light of prices, the purpose of the study is to determine which are the critical characteristics when deciding to invest in infrastructure-as-a-service. A general analysis is performed to detect the patterns of the market in relation to the amount of resources to acquire. A comparative price study is also presented, facing all the providers included in the study. The purpose is to extract a general tendency of the pricing models, so that the accounting approaches can be applied in a more realistic market situation.

In a first study, all the data of the pricing models is aggregated in order to study the general characteristics of the packets offered by all the providers. The means and deviation of the main variables can give an idea of the general values present nowadays in the market. Like every technological resource, this values increase year-by-year, normally reducing the price per unit of resource or improving the amount of resources acquirable for the same price. The actual market values are shown in Table 8. A general idea of the variables included in the models can be obtained with the basic statistics shown in this table. Transfer data variables were not included, as they have no variation in quantity, but just one fixed price per provider, and thus are not included in the models. What is most useful in Table 8 is the range of values each variable has. It helps to understand the general amount of resources offered by providers, and thus required by clients.

Variable	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
CPU (GHz)	10,38	12,52	1	88
Memory (GB)	9,01	11,88	0,5	64,8
Storage (GB)	683	716	20	3370
Price (€/month)	353,1	374,8	11,4	1698,6

Table 8: Basic statistics of the main variables

Observing the mean and the deviation values for each resource and also for the price, we can have a general idea of the central value of all aggregated bundled services. Although the different bundles offered by each company differ in the quantity of resources, the results in table 8 can give a general idea of the size of market offers, which can affect in the decision of contracting a service, thinking of further upgrade or downgrade of the services.

Using a regression analysis for the linear model presented in equation 3, the parameters related to every resource per provider are presented in Table 9. These parameters give us an idea of how providers charge for each of the characteristics offered in their bundles. Not just the quantity charged per resource is an important value, but also the zeros or low negative values, which give an idea of the characteristic that do not have influence in the model, and thus do not affect the final price of the bundle. When one parameter is really close to 0, it means it is strongly correlated with some other variable, and therefore should not be included in the model. A good example is the GoGrid case, where only the RAM is significant in the pricing model.

R^2 is the coefficient of determination and shows how well the model fits the introduced data, which in this case is the charging schema for each company. According to the values, all models seem to work very well. The 100% for Cloudsigma and AT&T are due to the fact that their parameters were not calculated by regressions, but introduced directly from the providers pricing specification, as they do not apply bundling strategy. However, p-values, which show if the parameter for each variable is significant in the model, do not seem to give a good feedback, presenting values higher than 0,05[23] in most of the variables. This is mainly caused by the low quantity of data available for the analysis.

	const *(€)*	**CPU** *(€ per GHz)*	**Memory** *(€ per GB)*	**Storage** *(€ per 100GB)*	**Transfer In** *(€ per 100GB)*	**Transfer Out** *(€ per 100GB)*	R^2 *(%)*
Amazon	14,2	2,34	12,3*	22,7*	0	9,5	98,4
IBM	0,4	48,2*	-0,92	7,18	15	15	97,9
GoGrid	0	0	68,63*	0	0	9,5	100
Terremark	-10	3,55*	37,4*	19,86	14	14	97,9
Microsoft	0	-58,52*	91,1*	0	0	10	100
Rackspace	-2	3,87	38	0	0	14,2	99,9
Joyent	68,63*	47,76*	28,59*	-57,19*	0	0	100
Cloudsigma	31,5	12,6	16,42	100,8	0	5	100
AT&T	0	51,474	20,017	85,789	7,9	7,9	100

Table 9: Results of the multiple-variable model regression (p<0,05)*

According to the results, important to note is that only Amazon, Joyent and Cloudsigma charge a fix cost component, being Cloudsigma's constant value the price of the windows operating system license. It also looks clear that memory seems to be the most important driver in most of the models. The singular negative values in Microsoft's CPU and Joyent's storage are due to the low quantity of data available, and should need further research. In light of transfer, only Joyent does not charge for both inbound and outbound, and in general is the transfer out of the server the one that charges the clients.

Although we can obtain a general idea of which of the resources have a bigger impact on each provider's charging model, the statistical data does not assure that our conclusion is correct. In order to improve the wellness of the analysis, same regression was performed keeping only one of the variables, so performing one analysis for each bundled characteristic, whether it be CPU, RAM or HDD. Reducing the number of

[23] 0,05 represents the 5% confidence interval for the p-value

variables in the regressions makes the lack of data not to impact as much in the results' wellness.

With these one-variable regressions the amount charged per every extra unit of each resource can be calculated, as can be seen in the results in Table 10. In other words, the values show us how much money a costumer should have to pay if he wanted to get more computing power, memory or storage. Unbundled characteristics, as already seen, were directly extracted from provider's information and not calculated through regressions. Now, one coefficient of determination is obtained for every regression, and although these values are lower, the generally lower p-values make these results more relevant. Only Terremark's CPU has a singular low coefficient of determination, which indicates that the linear assumption is violated, but when its regression is performed including also memory, as seen in Table 9, p-values and determination's coefficient improve significantly.

	CPU *(€ per GHz)*	**Memory** *(€ per GB)*	**Storage** *(€ per100GB)*	**Transfer In** *(€ per 100GB)*	**Transfer Out** *(€ per 100GB)*
Amazon	18,40* (78%)	20,90* (87,4%)	49,72* (80,6%)	0	9,5
IBM	54,50* (98,1%)	53,30* (76,3%)	46,11* (82,1%)	15	15
GoGrid	35,14* (86,3%)	68,63* (100%)	174,07* (91,2%)	0	9,5
Terremark	3,55* (1,8%)	37,40 (96,1%)	19,86	14	14
Microsoft	42,38* (99,6%)	38,28* (99,9%)	25,45* (100%)	0	10
Rackspace	87,40* (93,5%)	39,70* (99,9%)	101,55* (99,9%)	0	14,2
Joyent	105,81 (92,4%)	27,10* (99,3%)	118,20* (98,1%)	0	0
Cloudsigma	12,60	16,42	100,80	0	5
AT&T	51,47	20,02	85,79	7,9	7,9
Average	45,69	35,75	80,17	4,1	9,456

Table 10: Results of the one-variable model regressions ($p<0,05$. Coefficients of determination are in parenthesis)*

The results in Table 10 shows clearly that Amazon, Terremark and Cloudsigma offer the lowest prices for CPU and memory, so they are more suitable for costumers that need high computing requirements. In terms of memory best prices are found in Amazon's, Joyent's, Cloudsigma's, and AT&T's bundles. Microsoft and Terremark offer the cheapest storage. Also important to notice is the average values, which give a general idea of the actual prices of the market, and could be used as a general pricing model for the set of providers studied.

Another point that should also grab attention is the transfer cost. Although inbound transfer is in some cases free, a high amount of data transfer could largely increase the costs. In case of a high amount of data transferred needed, Joyent is obviously the best option, but also Cloudsigma and Amazon offer attractive prices. Bearing all the resources in mind, Cloudsigma and Amazon have the most equilibrated and low prices.

4.3. Summary and conclusions

To conclude with the market research, a summary of the most significant information obtained from the study is detailed below. These market values can be used as general market tendency information, and are the basis for the infrastructure-as-a-service accounting approach detailed in below sections. In Table 11 the most useful results from the study are detailed. The acquirable amount and the significant prices (best and average) outline the market situation, though all other factors commented in the research's results have also to be covered.

	Minimum amount	Maximum amount	Lowest price	Average price
Computing power	1 GHz	88 GHz	3,55 €/GHz	45,69 €/GHz
Computing memory	0,5 GB	64,8 GB	16,42 €/GB	35,75 €/GB
Storage	20 GB	3370 GB	19,86 €/100GB	80,17 €/100GB
Transfer In	0 GB	10TB	0 €/100GB	4,1 €/100GB
Transfer Out	0 GB	10TB	5 €/100GB	9,46 €/100GB

Table 11: Summary of results from the market research

The average values include, as well as in Table 10, both bundled and unbundled pricing models. As in the actual market situation is mixed bundling the most widespread strategy, it is considered that including 7 unbundled plus 2 bundled schemes should represent in a reliable way the market values. Also expected in the average provider is to have CPU, memory and storage bundled and separate pricing per unit of transferred data, and even for complementary services, typically additional public IP addresses, or load balancing software.

One of the biggest problems when developing the statistical study was the lack of data, which turn out in some incongruence when using it to fit the designed model. The data was extracted from fixed pricing schemes and thus could not be extended. The final results seem to be statistically confident, but maybe expanding the study with more factors or a nonlinear specification of the resources could have improved the final values.

In light of the pricing strategies, though granularity is always meant as GB or hour intervals, what most catches the attention is the high ambiguity and low transparency providers apply to their computing power resource units. This phenomenon does not follow memory and storage's completely clear information. A determinant factor for this performance could be the structure's nature of cloud computing infrastructures, where CPUs are distributed and thus not easy to be established as an exact amount of physical resource. However, costumers' requirement of subscribing just for the exact resources they need should cause a change in this behavior. The cause this change is not happening is that providers need to differentiate their services, and making them not comparable to other alternatives is the easiest way. After all, some providers recently entering the market, such as Microsoft or Cloudsigma, do clarify the physical amount of CPU in their billing schemes.

In the study, a physical equivalency was used to mitigate the CPU ambiguity. In some well-known websites, benchmarks are published with the purpose of helping costumers when acquiring an infrastructure cloud service. In this study there was no possibility to contract the services with the aim of benchmarking them, but in further research benchmarking would surely offer more efficient and tight results.

5. Accounting the actual Infrastructure-as-a-service market

In this section the accounting approaches and theories already explained will be applied and adapted to the actual infrastructure-as-a-service market as presented in previous section keeping focus on public delivery model and pay-as-you-go pricing schemes. The purpose is to create an accounting approach that leans on well-known economic theories widely used in the field of information systems that focus on a realistic infrastructure-as-a-service market situation. The methodology used, as explained in section 2.3, is a design science model, following the steps argued by (Takeda, 1990).

As presented in Figure 7, the accounting process is the next step in a company organizational chain after acquiring the information service. In point 4 the pricing process between a cloud provider and an information technology team or department has been widely explained and argued, as well as in section 3 the tradition relationship between both parties has already been presented. In this section, the purpose is to explain how the IT department should present quantitative financial information that should be useful to report and predict the economic impact of an investment and also help to make economic decisions and reasoned choices. That is known, in fact, as the accounting process[24].

5.1. The new provider-costumer relation

In cloud computing in general, the relation between both parties taking place in the acquisition process has drastically changed when comparing it with in-house information systems or normal outsourcing. The negotiation power is now reduced to only big companies with an important market power. In cloud computing, providers offer their services and clients just subscribe to what they think is better for their interest. That means that negotiating costs, in form of travelling, communicating or time spending have disappeared. The new relationship can be considered unilateral, contrary to the contracting process, where a bilateral negotiation was needed. The three types of relation explained in this work are represented in Figure 7. As seen in section 3, the relation between providers and suppliers changed when the outsourcing phenomena started to take a bigger role in the information technology market. With the

[24] See section 3.1, page 17.

new cloud market, the relation between the two parties returns to its origins, because it is unilateral, but as the product is now a service and not an asset, contractual aspects that arose with outsourcing processes have also to be taken into account. The accounting process, as explained in above section 3.1.2, takes part when the information technology department of a company gives the managers the useful financial information to control the costs incurred by the subscribed cloud service.

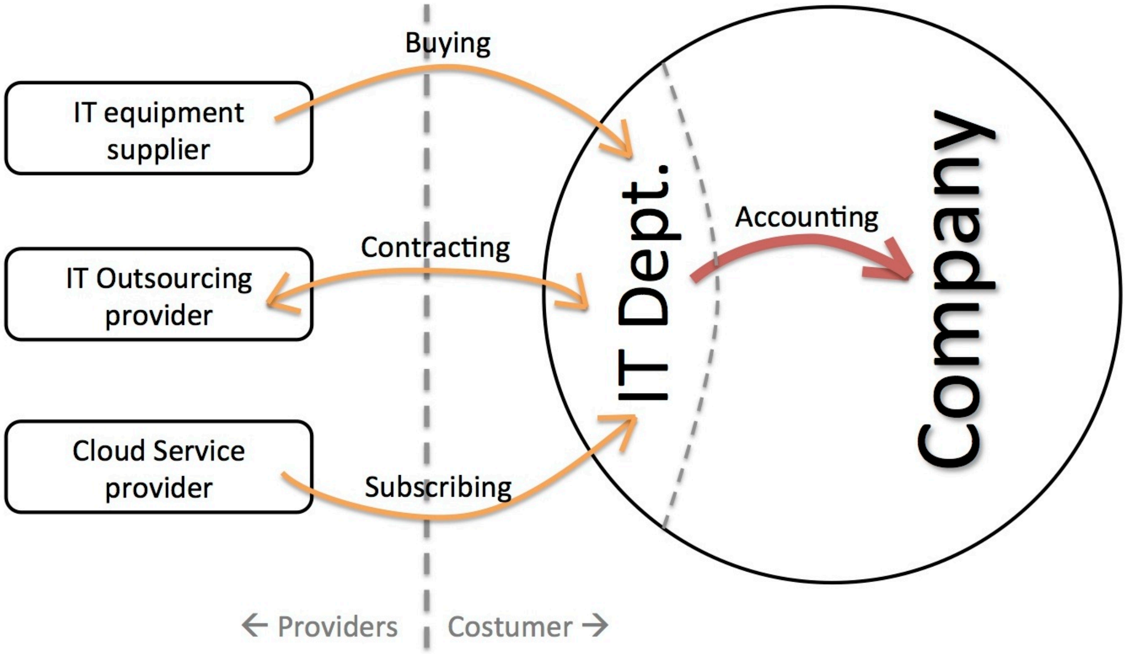

Figure 7: Costumer-provider relationships

According to agency theory, some of the costs incurred when outsourcing one of the processes of a company have disappeared with cloud adoption, but some others are still applicable and have to be accounted. Thanks to the service level agreement, the contracts are in the cloud market very standardized and less flexible than in past technologies. This new type of contract is considered by the agency theory as outcome-based, due to the fact that agent (provider) loses money when the agreement is not fulfilled. Another issue solved with the actual contracts is the goal incongruence. In service level agreement, all tasks and services providers have to bring to the client are clear. Now costumers know what to expect from the cloud service company. Also security problems like privately held information and shirking should not incur agency costs.

Despite all the facilities and improvements the service level agreement have entailed, there is one important aspect included in the agency theory that is still present in this new outsourcing scenario called cloud computing: the *information asymmetry*. Although many technical and economic aspects are highly detailed in the contracts, there is still some information that the client (principal) is not allowed to know. This information is basically the mechanisms that providers use to control and account the resources used by the costumers. This results in a huge headache for a company when trying to estimate what the cloud provider is charging for the services he thinks he has been using. The agency costs draw by this issue are monitoring and controlling costs, as more deeply explained in next section.

5.2. The Metering Issue

Taking a look at some traditional services that companies and also particulars can acquire through an external provider, such as water, gas or electricity, it is normal that costumers have access to clear information of what they are charged for. Although the charging process of the resources is developed by the provider, metering equipment is installed in costumer's premises so that he has the information about what the billing is based on. However, in Internet services such as cloud infrastructures, although this provider-side accounting is kept, clients do not normally have access to the metering information. In the market research performed in above sections, no resource-monitoring services are observed to be offered by any of the providers included in the study.

Cloud providers should make their services accountable for both provider and costumers, in order to settle possible discrepancies between them and their clients when monitoring the resources used. In actual market situation, cloud providers only offer ambiguous and light costs-calculators that do not precisely solve what is a main problem for enterprises catching up with the new internet-based services. Thinking of infrastructure-as-a-service, the pay-as-you-go nature makes monitoring a fundamental task. The necessary information to understand the billing process is based on three types of data: communication (internet data transfers in or out of the external server), computational (computing power resources), and information (data stored in the external server).

More precisely, the metering process should focus, as argued in section 3.3.1, on resource usage of CPU, memory, storage and data transfer (other particular services would need extra monitoring data). The data to collect in order to control the resource usage is based on time for CPU and memory, but on quantity-usage for storage and transfer, and also depends on whether the service acquired charges per amount of resource (unbundled) or simply per hour of usage (bundled). Anyway, all activities and systems to meter the usage will represent costs and thus have to be included in the accounting model.

In this work, the accounting model uses data that can be collected by the costumer or a trusted third party, which could be a monitoring-services provider. These types of accounting models are referred as strongly consumer-centric in (Mihoob, Molina-Jimenez, & Shrivastava, 2010), whereas weakly consumer-centric models are based on data queried from the provider.

Looking through the technical sheets and service level agreement documents of the providers, we can detect some patterns in the way they monitor the resources used by their clients and further used to charge them a monthly fee. For CPU and computing memory, as their resource amount is clearly quantified when selecting a bundle, the only variable that affects the final charge is the amount of time they are used. This amount of time is normally charged per whole hour intervals, so that if a company uses one hour and 30 minutes of the CPU acquired, it is charged for a total of 2 hours.

In light of storage, the resource is unlimited as extra storage capacity is normally available when reaching the limit of the subscribed bundle. Extra fees are charged when acquiring extra capacity. The problem with storage is that it has to be monitored as amount of data stored within the available storage space. Providers don't throw much information about how they proceed with this metering. Some of them seem to use a "checkpoint" method. This means that the stored data amount is collected a certain number of times per day. Cloud service companies do not provide this information because it could be misused by costumers to reduce their costs. Therefore, it is impossible to calculate the exact amount of resource the provider charges for the storage. The only thing clients can do is estimating this amount by monitoring the used capacity of their cloud server as many times as possible (accessing the server to calculate the capacity will result in an increase in transferred data). More detailed information about this issue can be found in (Mihoob, Molina-Jimenez, & Shrivastava, 2010).

Focusing on inbound and outbound data transfer, providers collect this information every time the client connects to the service, collecting and aggregating the quantity of data they are transferring in and out of the cloud server. This data includes files, metadata, and commandos used for the transaction. For both storage and data transfer, usage is charged per whole Gigabyte intervals.

The system to meter the resource usage should be included somehow into the accounting system, making available for the accounting model all the data necessary to compare the charges of the provider with the internal billing calculations. Moreover, this connected system can also be used to monitor performance, which in the case of infrastructure-as-a-service should be the up-time of the service (other variables like response time could also be metered), and compare it with the accorded up-time in the service level agreement of the provider in order to predict future discounts. With this purpose, the service level agreement's significant data as well as the pricing scheme of the provider should be included in the system, and be used to calculate the accounting data.

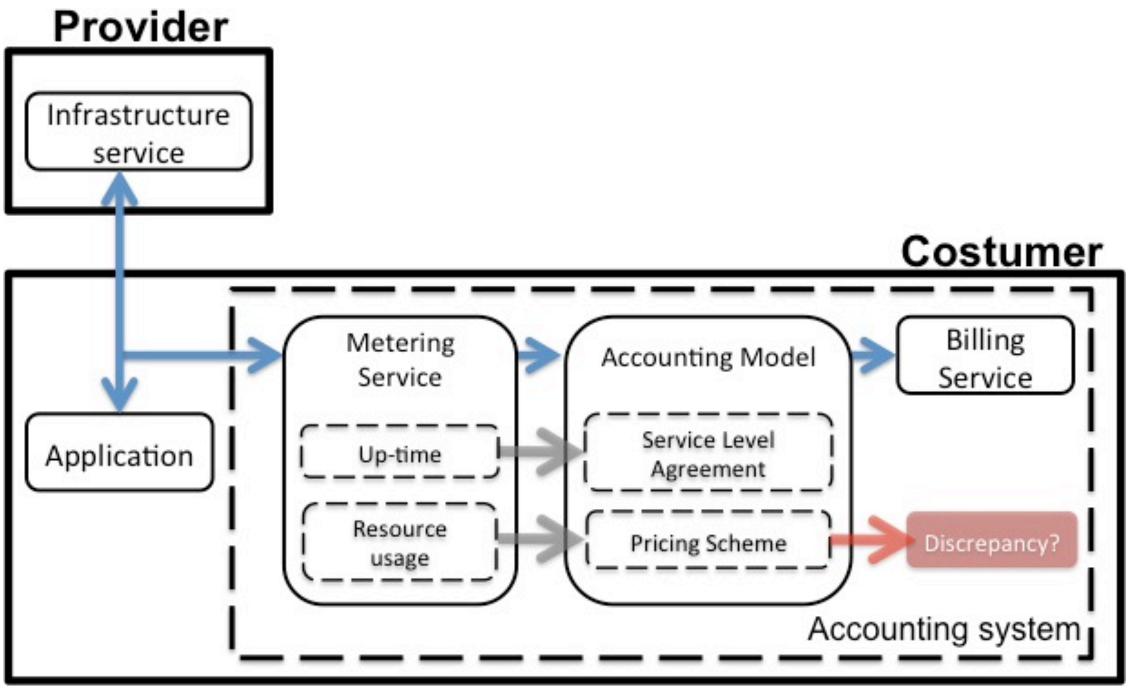

Figure 8: Framework for consumer-side resource accounting

In Figure 8, based on (Mihoob, Molina-Jimenez, & Shrivastava, 2011), a proposed framework for a consumer-side resource accounting system is represented, where data (represented by blue arrows) is intercepted from the internet connection between service and application and used to meter all the required variables' information. The accounting model is developed in section 5.4. The billing service aims to set the prices of the product or service offered by the client, which it is out of the focus of this work.

The discrepancy red box in the framework represents that when the charges calculated with the metering data of the resources used do not match with the monthly fee charged by the provider, the discrepancy should be solved contacting with the provider and revising his metering service or records. Although it should not happen frequently, because both metering services have to be based on same assumptions, the already commented lack of precise information (CPU and storage metering) could result in some deviation of the resultant metering data.

5.3. The decision process

One of the critical processes that has to be taken into account when defining the costs of the acquisition is the decision process. It influences the accounting system not just because it represents costs directly, but also because it will determine the future costs of the cloud infrastructure that a company is willing to acquire.

The decisions a company has to make before the acquisition of a cloud service are divided in two types. On one hand there is the strategic decision, based on whether a company should invest in cloud services or in other technologies, mainly in-house solutions. In this sense, transaction costs theory can be applied to assess the decision. In terms of this theory, we can define infrastructures for clients as assets with low specificity, and being nowadays the frequency of the transaction (cloud infrastructure acquisition) very high, theory would say to outsource to an external provider. Also low uncertainty in the market reasserts the decision. Other strategic decisions are the choice of provider and payment method, preceded by a clear definition of the technical, economical, and business requirements of the project.

On the other hand, operational decisions are based on the workload and the amount of resources needed. Although this is not a critical decision in other cloud services like for example software-as-a-service, it is very important in infrastructure cloud services. Companies need to scale their needs according to the amount of the resources available in every bundle offered by the selected provider, as seen in section 4.

Resource scaling can be a big headache for the consumers. The many different resource configurations seen in the market research prove that, and also indicate that in some cases it can influence the provider selection, so it can be also considered a strategic decision. In order to know how many CPU, memory, storage or data transfer a company is going to need, statistical performance data is usually used to estimate the resources required by a certain application. Also estimations of the future demand can help in the selection, as well as consulting companies that offer specialized know-how on the field, and will charge for their services. For companies starting an information system from zero, the scale-up and scale-down possibilities of the cloud infrastructures are invaluable. However, for a company migrating its existing information system to the cloud, performance analysis and calculations will represent a big effort and costs. All the costs in the selection process have to be included in the accounting model.

Taking a look in the resource-based view theory, some conclusions can also be extracted. First of all, none of the 4 characteristic a resource have to fulfill to be an strategic resource are applicable to the type of business activity companies are trying to outsource when contracting an infrastructure cloud service. However, it can be argued that in the opposite point of view, so in the perspective of the provider, the infrastructure he is offering to the costumers would be an important strategic resource, but this is out of the focus of this work. Aggregating, so, this low strategic value with a theoretical low presence of the resources inside the company (as infrastructure is contracted due to the lack of internal resources), resource-based view theory would result in a clear outsourcing decision.

5.4. The accounting model

In the next lines, an accounting model is proposed for companies willing to acquire an infrastructure over the cloud. The aim of this model is to record, report and analyze the financial transactions resulted of the usage of an infrastructure-as-a-service. The model tries to apply the main principles of the total cost of ownership model (*3.1.2.1*), though it is also based on some concepts that belong to life cycle costing and transaction costs theory, as well as cost factors arisen from other theories.

Before developing the model some assumptions have to be considered in order to simplify and clarify the model structure and applicability. The purpose of the accounting model is to see the change suffered in the accounting approach with the introduction of cloud technology, more precisely cloud infrastructure services. To keep this in focus, the model will only consider costs directly incurred by the acquisition of this type of services. We also consider both first-acquisition and migrating projects. The next assumptions are made to fulfill all these objectives.

- **Internal infrastructure for the Internet connection is available**: all potential users of the service have the necessary hardware and the infrastructure is ready to provide them with internet bandwidth. Thus, infrastructure costs and internet provider charges will not be included in the model.
- **No hybrid system is used**: the company subscribing to the infrastructure-as-a-service uses exclusively this service to cover the needs regarding the application for which the service is acquired.
- **Changing the service providers is equivalent to a new service acquisition**: the low interoperability and standardization of actual providers makes that changing to an alternative provider requires same steps and incurs same costs as a deployment of a new service.

The first step in the development of the model is to set the costs that will be included. As explained in total cost of ownership theory, not all the costs have to be considered, but they have to be grouped (also proposed in life cycle costing) in order to list the main cost categories. Taking a look at the main cost types, every company will be able to include all the important costs in the accounting model. Moreover, total costs theory suggests to list also the cost factors inside every cost category. These cost factors are defined in life cycle costs theory as independent variables that explain cost estimation relationships. The result of the accounting model is, so, a framework based on costs classification based on concepts used in the two most used accounting approaches.

The cost categories will be defined taking a look at all the cost taxonomies and types dealt through all the previous sections of the work, whether they belong to traditional information systems, traditional outsourcing services, or the actual cloud infrastructure market. Although the idea of cost categories is based on the total cost of ownership theory, the cost types included originally in it are not applicable to infrastructure as a service (e.g. information technology assets costs and infrastructure support or administration costs are in light of infrastructure-as-a-service no longer assumed by the company that uses the information system infrastructure).

Life Cycle Stage	Cost Category	Description
Engineering and development	Strategic and operational decisions (1)	Selection of information system (in-house, provider)
		Choice of cloud computing type (infrastructure, service or platform as a service) and delivery model (public, private, hybrid)
		Definition of service requirements (based on application)
	Provider and bundle selection (2)	Market providers evaluation and selection for required service
		Scale resources to choose the right bundle
		Service level agreement analysis: determine providers commitment, possible compensations and security requirements
Production and implementation	Implementation and configuration (3)	Implementation and configuration of the service (e.g. customization, access authorizations)
		Migration of the initially required data to the cloud server
		Merging with other systems present in the company
	Training (4)	Internal training by employees or
		External training through a third-party for users and administrative
Operating	Service charge (5)	Pay-as-you-go charging per resource
		Possible discounts for service level agreement compensations
	Support (6)	Internal support to end-users of the system
		External support acquired to the service provider
	Maintenance (7)	Modification or reescalation of the infrastructure service
		Monitoring of performance to control service level agreement
		Metering of resources used to control usage charges
Disengagement	System failure (8)	Loss of working time
		Client penalties for not being able to deliver service/product
		Loss of reputation
	Discarding (9)	Migration of data back from the cloud server
		Reestablishment of the service

Table 12: Cost categories and descriptions of the accounting model

Towards a significant and understandable classification, the life cycle approach has been used, including as main cost categories the different phases between the first time the acquisition is thought and the replacement or discard are considered. As seen in the Life Cycle Costing section (3.1.2.2), the main phases are: engineering and development, including decision, evaluation and selection; production and implementation, which includes configuration and training; operation, consisting of service charging, support and maintenance; and disengagement, meant as failure and discarding of the service. The different costs included in the model derive from above sections (decision, metering, and cloud provider's cost structure extracted from market analysis) and from different cost categories seen in section 3.1.1 and appendix 1. Also ex-post costs derived from transaction costs theory (3.2.2.1) were considered. Table 12 shows the detailed list of the identified cost categories representing the single phases of the life cycle.

Next step is to define the cost factors affecting each one of the cost categories. These cost factors are extracted from the description of each category and are mainly external acquisitions, time investments or internal costs. Important to notice is, that for the service charges, the cost factors were argued in section 4, and are the variables and parameters used to describe the pricing schemes of the infrastructure-as-a-service providers. The main common variables observed and also the costs for most widespread complementary services are included.

For every cost factor an abbreviation is assigned to use it in further calculations. Many cost factors are present in more than one category. That is why a separated account will be performed for each category. This account will help to differentiate the source of the costs and to aggregate costs related to similar business processes or activities.

All the cost factors presented in Table 13 are resource amounts that have to be converted into economic values. In order to do so, they have to be multiplied by parameters. As seen in the pricing models in section 3, most of the cost factors in the "service charge" category have to be multiplied by their price per unit, whether it be € per GB, € per GHz, or € per GB·h (applicable to cpu, ram, hdd, bun, tri, tro, ip). These cost factors have to be collected through the metering service and their parameters have to be extracted from the provider's pricing scheme, as shown in Figure 8. These parameters, as in section 3, are represented by β_i for each of the i cost factors (e.g. β_{cpu} for *cpu* or β_{ip} for *ip*).

Cost Category	Cost Factors
Strategic and operational decision (1)	Time invested (tim), consulting services (con), and information for decision-making (inf)
Provider and bundle selection (2)	Time invested (tim), consulting services (con), and information for decision-making (inf)
Implementation and configuration (3)	Time invested (tim) and data transferred to the server (tri)
Training (4)	Time invested by employees to train and be trained (tim), external training services (ets), and training material (mat)
Service charge (5)	Computing power (cpu), computing memory (ram), storage (hdd), bundle (bun), inbound transfer (tri), outbound transfer (tro), public IP addresses (ip), load balancer (loa), and service level agreement discounts (sla)
Support (6)	Time invested (tim) and support services cost (sup)
Maintenance (7)	Time invested (tim), performance monitoring (per), resource usage metering (res)
System failure (8)	Amount of loss (los)
Discarding (9)	Time invested (tim) and data transferred from the server (tro)

Table 13: Cost categories and cost factors of the accounting model

In all the cost factors based on time invested by employees of the company, the amount of time *tim* have to be multiplied by the salaries of these employees (β_{tim}), converting the time unit into a real cost. Some other factors, on the contrary, just represent the presence of a unique cost, so that their values are not the amount of resource but the exact price of the entity they represent (applicable to *con, inf, dat, loa, sup, ets, mat* or *los*). They only appear in the model if their related cost is incurred.

In the special case of metering services (*per* and *res*), their costs will depend on the system used. It can be acquired through a trusted third party (monthly or yearly fee) or done by internal software and/or hardware (asset cost), so their nature can vary. The data obtained by the metering service is used to determine possible discounts based on the service level agreement of the provider (*sla*), and also to prove if the charged services are correct. The accounting model is based in a total of 18 cost factors distributed among 9 cost categories.

If the total cost of ownership approach should be applied, a total sum per category of all the factors multiplied by their parameters should be performed. For the variables that represent a fixed cost, time is not significant, but it is when referring to monthly fees like the service charges. This is why we need to establish a total time for the service. This time was called in the life cycle costing theory the total lifetime of an asset, in this case a service. Although in cloud services the total lifetime loses its meaning because they work in a pay-as-you-go basis, a one-year period lifetime could be considered to calculate the total cost of ownership, which in the case of cloud infrastructure will be referred as total cost of service (TCS). To include all the monthly fees we have to consider 12 time periods inside the total lifetime.

An example of TCS calculation for "strategic and operational decision" would be the total sum of variable *tim* multiplied by the number of the affected employees (*m* variable from 1 to M total employees) and also by their salaries, plus the fixed cost amounts *con* and *inf*. If difference in salaries is assumed, the incurred cost of the time invested should be the total sum of the time expended by employee (tim^m variable) multiplied by the salary of each employee (β_{tim}^{m}). The resultant equation would be:

$$TCS_1 = \sum_{m=1}^{M} tim^m \cdot \beta_{tim}^{m} + con + inf$$

A more complex TCS calculation would be, for example, the one for the service charge, which have to be calculated for every time period (*t* represents each of the time intervals, generally months). In this case, a parameter for each of the computing resources is needed. Time variability is included for each resource's cost factor to indicate that the cost of the resource could increase or decrease if during a time period a different amount of resource is acquired. Time dependence is represented as the super index *t* (e.g. cpu^t, ram^t, hdd^t…). For the cost factor of the load balancer, although being a unique cost, is charged per month so it is also time-dependent. If unbundled services are acquired, the output of each cost factor is the amount of resource used multiplied by hours of usage (GB·h or GHz·h). In this case, the parameters, as seen in pricing schemes, have units such as €/GB·h or €/GHz·h, so that the multiplication results in €. The equation would be as follows:

$$TCS_5 \ without \ bundle = \sum_{t=1}^{12} (\beta_{cpu} \cdot cpu^t + \beta_{ram} \cdot ram^t + \beta_{hdd} \cdot hdd^t + \beta_{tri} \cdot tri^t + \beta_{tro} \cdot tro^t + \beta_{ip} \cdot ip^t - sla^t + loa^t)$$

Besides, if a bundle is acquired instead of each resource separately, the *cpu, ram* and *sto* variables are replaced by bun^t cost factor, also dependent of the time period. The output of this cost factor is just the hours of total usage, as the amount of resource is fixed in the selected bundle. In this case, as the pricing parameter would also change between periods, β_{bun}^t parameter is now also time dependent (e.g. when contracting a different bundle for a period of time where demand is expected to increase). Moreover, an *hdd* cost factor could be introduced with its own parameter to account the extra storage charged out of the bundle (at its corresponding price). The equation would be as follows:

$$TCS_5 with \ bundle = \sum_{t=1}^{12} (\beta_{bun}^t \cdot bun^t + \beta_{hdd} \cdot hdd^t + \beta_{tri} \cdot tri^t + \beta_{tro} \cdot tro^t + \beta_{ip} \cdot ip^t - sla^t + loa^t)$$

For further categories, the total cost of ownership would be analogously calculated. The total result for a year period would be the sum of the 9 TCSs calculated (9 cost categories). Instead of thinking the model as a total amount of costs, we can think it as a dynamical method to calculate, at the end of every time period (a month, a day or a year), the estimated costs of the service and keep up-to-date informs of the economic performance. Moreover, the total cost of ownership of the “service charge” category could be compared to the charges applied by the provider to control the wellness of its usage-based pricing scheme.

If, on the contrary, the life cycle costing should be applied, using for example, kaufmann’s model[25], same cost factors and categories could be used. The problem when using life cycle costing, which uses a long-term view of the resources’ costs, is that infrastructure-as-a-service future prices are difficult to estimate, as it is a growing technology and its costs could change in a short time period. Moreover, needs of bigger or better infrastructure cloud services are also hard to predict. However, if a time period is assumed and the acquisition of infrastructure-as-a-service is planned, the only thing left to do to calculate the life cycle cost is to group the costs per year and

[25] Please note section 3.1.2.2 and appendix 2

escalate every year total cost assuming a fix or variable interest rate to discount the money value variation from each yearly costs.

Assuming a fixed discount rate i and a time period of n years, we could calculate the total life cycle cost using the net present value equation. This equation uses the total cost per every year period (t), which should be calculated as a total cost of service, having a total of n TCSs. The cost category related with the disposal of the service is only considered one time in the lifetime and one yearly. The equation to gather all the TCSs calculated is as follows:

$$LCC = \sum_{t=0}^{n} \frac{TCS^t}{(1+i)^t} + TCS_9 \quad where \qquad TCS^t = \sum_{cat.=1}^{8} TCS_{category}$$

This accounting model can be used to apply a wide variety of accounting theories. However, it is mainly thought as a tool to keep a continuous record of the charged quantitates and to help companies predict what they are going to spend in their cloud infrastructure service, as it is necessary to set the prices of their final products and services without losing money. Although the accounting model is designed for a specific cloud type and delivery model, it could easily be extended to others.

5.4.1. Case study

To fully understand how the proposed accounting model works, a hypothetical example is presented in the following lines. To fully evaluate the model designed in above sections, a real case should be applied and studied, but no real enterprise's data was available for the development of this thesis. Making some assumptions and using the data collected in the market analysis in section 4.2.3, some calculations are done to obtain what would be a realistic market situation of costs incurred when contracting a cloud infrastructure service. Firstly, a total cost of service is calculated for 12 months, and the year total value is further used to estimate a 6 years life cycle cost.

The first assumption to make is considering the service and provider that is going to be acquired. According to the results of the analysis, it is normal to assume that the acquired service is bundled in price for CPU, memory and storage. The bundle selected for the case study is Microsoft Windows Azure large virtual machine[26] (see

[26] This service is chosen as it offers the amount of resources which best fit with mean values of the market presented in Table 8

specification in appendix 5). The yearly results of the calculations for each category are presented in Table 14.

Imagine a start-up web-services company with low capital and wanting to acquire an information system. They want to benefit from the scalable prices and resources and they have a demand estimation, which indicates that two months a year they need to subscribe the extra large bundle by Microsoft instead of the large one. The provider charges a fee for every hour of use of the resources, and also for the outbound transfer of data. The monthly data transfer out of the server is estimated to be 800GB. The company estimates that in average the cloud infrastructure will be used 650 hours per month, but in the two peak months it will be used at full time, i.e. 720 hours. Service level agreement discounts are not considered.

The salaries per hour are assumed to be the same for all the team and fixed at 30€ per hour. No consulting services are contracted as a cost-cutting strategy. The company only pays for the information used to take the important decisions and to estimate business activities, i.e. 150€ for strategic and operational decision. The time invested in strategic and operational decision is 40 hours, in provider and bundle selection 25 hours, and in implementing and configuring the service 80 hours. The data needed to start the web service amounts 500GB, but are not charged as the provider offers free inbound transfer.

The training is performed by internal employees with a total time expenditure of 60 hours. An external support and maintenance service is acquired every month with a cost of 100€. The monitoring and metering software are licensed for the whole year and represent a cost of 230€. The economic value of a loss in the service is estimated to be in average 50€ per period (based on 99,95% up time of the service). The time invested in a discarding situation would represent 30 hours of work and users data transfer out of the server would amount 200GB.

Cost Category	**Cost Factors**
Strategic and operational decision (TCS_1)	150€ + 40hours · 30€ = 1350€
Provider and bundle selection (TCS_2)	25hours · 30€ = 750€
Implementation and configuration (TCS_3)	80hours · 30€ = 2400€
Training (TCS_4)	60hours · 30€ = 1800€

Service charge (TCS_5)	10months · 650hours · 0,365€ + 2months · 720hours · 0,731€ + 800GB · 0,095€ · 12months = 4.337,14
Support (TCS_6)	100€*12months = 1200€
Maintenance (TCS_7)	230€
System failure (TCS_8)	50€ · 12 months = 600€
Discarding (TCS_9)	30hours · 30€ + 200GB · 0,095€ = 919€
TOTAL (TCS_{TOT})	13.586,14€
TOTAL (LCC_{TOT})	71.597,93€

Table 14: Results of the case study per category

To calculate the total cost of ownership for a year, the 9 category values have to be aggregated as follows:

$$TCO_{tot} = \sum_{cat.=1}^{9} TCO_{cat} = 13586{,}14$$

To proceed with the life cycle cost, assuming that for a six-year period (t=0 is first year) there is no charge in the costs, the value of the cost amount for each year have to be converted into the present value, so the interest rate have to be assumed at, for example i = 3%.

$$LCC_{tot} = \sum_{t=0}^{5} \frac{TCO_{TOT}^{t} - TCO_9}{(1+i)^t} + TCO_9 = 71597{,}93€$$

This hypothetical case study summarizes the finality of the model and shows a clear example of how it should be applied, although, as commented, many uses apart from the final cost results can be extracted from the model and framework. Furher application of the model has to be carried by companies and adapted to their necessities, although the model is considered to fulfill the main needs present in every company willing to acquire infrastructure-cloud services.

6. Analysis and conclusions

6.1. Discussion of the results

In this thesis I have presented a costumer perspective of the actual infrastructure-as-a-service situation from the costs' point of view based on well-known theories, approaches and sound knowledge. Once explained the base, a characterization of the market situation have been done by means of a providers research focused in their pricing strategies and presented schemes. The general information obtained from the research was used to present a solution for an accounting model for use in cloud infrastructure services based on resource-usage pricing. The designed accounting model and the market research are complementary and interdependent knowledge that companies should bear in mind when acquiring this type of service.

The focus of the work done so far has been the accounting process on incurred costs for enterprises that need an information system to perform their business activity. The roots of cloud computing have been described to understand how technology, market and business have evolved in last decades and ended up in the actual internet commercial services for companies. The resulting accounting approach summarizes all information acquired through the desk research and market analysis.

The presented accounting approach has an impact in infrastructure-as-a-service field, as a way of increasing the transparency for companies interested in it. Moreover, presents a variety of cost-based concepts that should influence the accounting process of cloud infrastructure services. The lack of publications in the field of cloud computing focused on business, management and accounting, draws the need for investigating how both providers and costumers are economically performing in this new scenario, beyond technical aspects and engineering concepts. As a technology with a promising future, further investigation will be done in coming years trying to understand and evaluate best practices for companies using and offering these services.

Limitations of this work are basically imposed by their own focus. As cloud market is experiencing a quick growth and its expansion has been in such a short time, diversification makes difficult to determine boundaries for a business research on the field. Many types of service, delivery models, and pricing strategies among a large number of providers force to reduce the scope of the work. The principal scope of the thesis is infrastructure-as-a-service market, specifically the usage-priced services available for companies that should beneficiate from cost reduction introduced by this easy way of contracting flexible and, in principle, cheaper information system.

The work is centered on infrastructure as it is the most similar cloud alternative to what companies have been doing in the past when they did not want or did not have the resources to build their own information technology structures. Compared to platform- and application-as-a-service, it looks like the most generic solution, so that can be used for a wider range of functionalities. For companies not interested in a concrete application, cloud infrastructures bring them the resources to use the cloud in a more flexible way. In addition, pay-as-you-go method looks like the way little and medium companies are entering into the cloud market, and proposes a completely different model form than what have been being used in the information market until the internet boom.

Other limitations were found while developing the work. In market research, the main limitation was the computing power measurement, as companies do not throw exact information. However, alternative solutions have been found and work was developed making some assumptions that at the end should not lead into inadequate results.

A relevant conclusion is the lock-in issue that infrastructure-as-a-service market is experiencing. Lack of transparency providers apply in their pricing schemes and service level agreements, as well as the lack of standardization in the service's models, makes it difficult for costumers to discern between all the available solutions in a market that, in nature, offers an standardized service for all type of clients. Standardization is, though, only observed inside providers' schemes and not between companies. Hence, interoperability between providers is a concept that nowadays seems difficult to reach, as providers try to differentiate their services from their rivals.

6.2. Related work

As already commented, most of the literature related to the economics of cloud computing and infrastructure-as-a-service focus on how to charge services from the point of view of the providers. However, some papers are focused on costumer-side economies of cloud computing, although not specifically in infrastructure-as-a-service.

Kondo et.al. compared the costs of a cloud solution based on Amazon EC2 services and a Desktop Grid system (group of powerful computers interconnected through the internet network). Their focus is scientific computation used in universities to investigate in new fields. They also compare performance of both solutions to estimate benefits, so their work uses some technical benchmarking methods.

Mihoob et.al. (2010) (2011) focused their works on costumer-centric resource accounting methods based on amazon EC2 cloud services. Their work is based in measurement technics of the resources used by companies subscribing amazon's infrastructure cloud services. Their description of the charging schemes is very precise and they argue some new concepts obtained from some performance experiments they did on the cloud servers.

Strebel and Stage (2010) developed an optimization model to minimize costs for companies using cloud services and in-house systems at the same time. Their work focuses on the workloads transferred to the cloud server to evict an overload of their own information system. They also use a statistical analysis to determine the variables in the model that have a strong relationship. The work's focus is application deployment, which is a specific case among all cloud computing capabilities.

6.3. Research needs

Further research in the field should include more pricing schemes other than pay-as-you-go. The monthly plans offered by providers, although not being the most representative pricing model of cloud computing, are claimed to have a strong position in the market as companies start to establish their information systems in the cloud. With further development of the technology and expansion of the infrastructure service, as well as other types of cloud services, companies will be more confident with them and costs will continue decreasing. In terms of cost, mid-term contracts represent an overall discount that for sure will seduce lots of companies willing to base their information applications in cloud infrastructures.

Other types of cloud services should also include. Although the market for platforms and applications in the cloud is more atomized, the patterns of charging schemes and accounting models should also be studied to have a more general vision of how cloud computing is charged. For other delivery models the accounting should more or less similar to the one used for information technology outsourcing, as it is based on dedicated high-customized solutions for both private and hybrid clouds.

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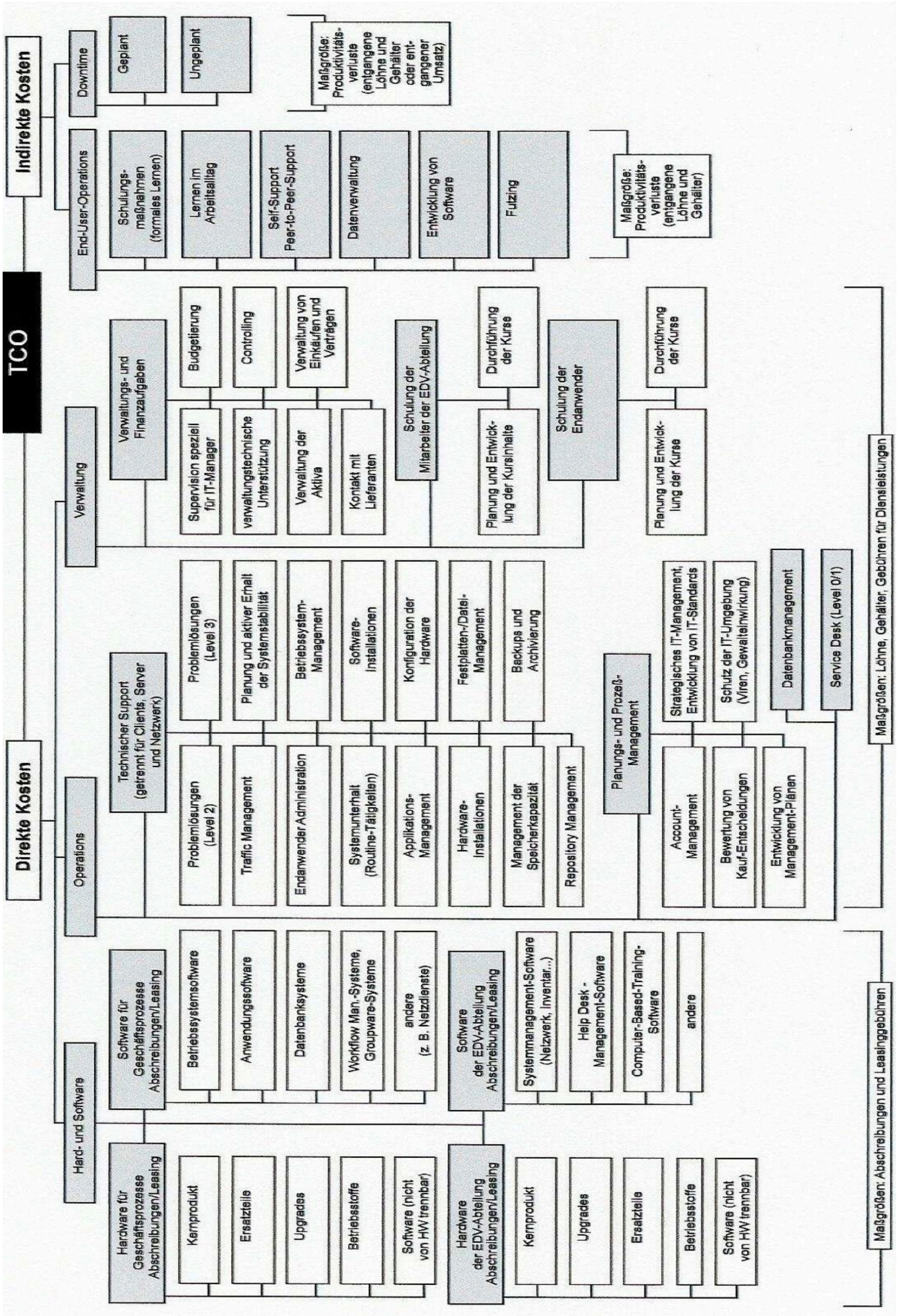
Appendices

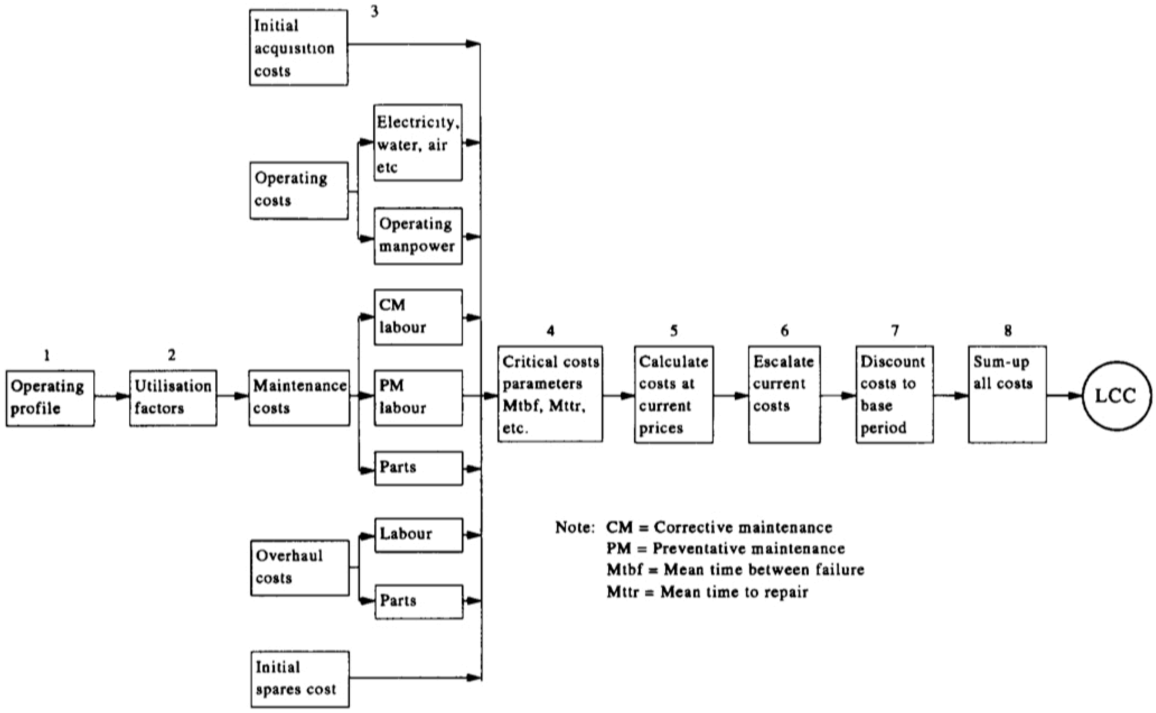
Appendix 1:

Information system's Total Cost of Ownership categories structure (Sultanesi & Schäfers, 2005)



Appendix 2:

Kaufmann's Process for life cycle costing (David G. Woodward, 1997)



Appendix 3:

Classification of pricing mechanisms (Jaakko Jäätmaa, 2010)

Category	Pricing Mechanism	Description
Fixed pricing	Pay per use	Customer pays in function of the time or quantity he consumes of a specific service.
	Subscription	Customer pays a flat fee in order to access the use of a product or to profit from a service.
	List price / menu price	A fixed price that is often found in a list or catalog.
Differential pricing	Service feature dependant	Price is set according to service configuration. Includes also bundling of different services.
	Customer characteristic dependant	Price is tailored to the characteristics of every single customer.
	Volume dependant	Differentiates prices on the basis of purchased volumes.
	Value-based	The final price will strongly depend on the customer's valua- tion of a value proposition.
Market pricing	Bargaining	The price outcome depends on the existing power relationships between the parties involved.
	Yield management	The best pricing policy for optimizing profits is calculated based on real-time modeling and

		forecasting of demand behav- ior.
	Auction	Price is set as buyers bid in increasing increments of price.
	Reverse auction	Price is set as sellers bid in decreasing decrements of price.
	Dynamic market	Price is the outcome of a large number of buyers and sellers that have indicated their price preference, but are not able to influence this price as individual sellers.

Appendix 4:

Classification of different provider's pricing schemes (Jaakko Jäätmaa, 2010)

Implementation	Description
Time-based pricing (Subscription pricing)	Pricing is based on consumed time units. The difference to the actual subscription pricing mechanisms discussed below is that customer does not sign a fixed con- tract.
Peak-level pricing	Pricing is based on peak consumption within a defined window.
User-based pricing	Pricing is based on the number of distinct users presenting themselves to the sys- tem.
Ticked-based pricing	Pricing is based on fixed price electronic tickets that services provider issues for use of the service (for a specific period of time).
Integral pricing ("under the curve")	Pricing is based on peak utilization of defined capacity unit divided by average utilization.
Overage charges	Pricing changes if customer exceeds the average consumption of the service.
Consumption commitments	Pricing is based on estimated average consumption and exceeding or undercutting the consumption commitment affects the price.

Appendix 5:

Collected data of providers pricing schemes for the market research

1. Amazon: (Amazon, 2012)

Provider and Service	Amazon Elasctic Cloud Computing EC2			
Bundled	CPU, RAM, Storage			
Number of bundles:	11			
SLA	99,95%			
Cost Transfer Inbound	0 €/GB			
Cost Transfer Outbound	0,10 €/GB			
Service Bundle	**CPU (Ghz)**	**Memory (GB)**	**Storage (GB)**	**Price/hour**

Small	1	1,7	160	€ 0,09
Medium	2	3,75	410	€ 0,18
Large	4	7,5	850	€ 0,37
Extralarge	8	15	1690	€ 0,73
High-Memory extralarge	6,5	17,1	420	€ 0,45
High-Memory double extralarge	13	34,2	850	€ 0,91
High-Memory quadruple extralarge	26	64,8	1690	€ 1,81
High-CPU medium	5	1,7	350	€ 0,23
High-CPU extralarge	20	7	1690	€ 0,91
Cluster Eight Extra Large	88	60,5	3370	€ 2,36

2. IBM: (IBM, 2012)

Provider and Service	IBM Smartcloud enterprise			
Bundled	CPU, RAM and Storage			
Number of bundles:	9			
SLA	99,99%			
Cost Transfer Inbound	0,15 €/GB			
Cost Transfer Outbound	0,15 €/GB			
Service Bundle	**CPU (Ghz)**	**Memory (GB)**	**Storage (GB)**	**Price/hour**
32 bits copper	1,25	2	60	€ 0,08
32 bits bronze	1,25	2	235	€ 0,09
32 bits silver	2,5	4	410	€ 0,19
32 bits gold	5	4	410	€ 0,29
64 bits copper	2,5	4	60	€ 0,27
64 bits bronze	2,5	4	910	€ 0,31
64 bits silver	5	8	1084	€ 0,39
64 bits gold	10	16	1084	€ 0,75
65 bits platinum	20	16	2108	€ 1,55

3. Terremark: (Terremark, 2012)

Provider and Service	Terremark vCLoud Express
Bundled	CPU, RAM
Number of bundles:	32
SLA	100,00%
Cost Transfer Inbound	0,135 €/GB
Cost Transfer Outbound	0,135 €/GB

Storage	0,198 €/GB		
Service Bundle	**CPU (Ghz)**	**Memory (GB)**	**Price/hour**
TER1	2,9	0,5	€ 0,03
TER2	5,8	0,5	€ 0,04
TER3	11,6	0,5	€ 0,04
TER4	23,2	0,5	€ 0,05
TER5	2,9	1	€ 0,06
TER6	5,8	1	€ 0,07
TER7	11,6	1	€ 0,08
TER8	23,2	1	€ 0,10
TER9	2,9	1,5	€ 0,09
TER10	5,8	1,5	€ 0,10
TER11	11,6	1,5	€ 0,11
TER12	23,2	1,5	€ 0,13
TER13	2,9	2	€ 0,11
TER14	5,8	2	€ 0,14
TER15	11,6	2	€ 0,15
TER16	23,2	2	€ 0,19
TER17	2,9	4	€ 0,21
TER18	5,8	4	€ 0,26
TER19	11,6	4	€ 0,29
TER20	23,2	4	€ 0,34
TER21	2,9	8	€ 0,38
TER22	5,8	8	€ 0,46
TER23	11,6	8	€ 0,54
TER24	23,2	8	€ 0,60
TER25	2,9	12	€ 0,57
TER26	5,8	12	€ 0,65
TER27	11,6	12	€ 0,73
TER28	23,2	12	€ 0,79
TER29	2,9	16	€ 0,77
TER30	5,8	16	€ 0,80
TER31	11,6	16	€ 0,86
TER32	23,2	16	€ 0,89

4. Rackspace: (Rackspace, 2012)

Provider and Service	Rackspace Cloud Servers
Bundled	CPU, RAM, Storage
Number of bundles:	5
SLA	100,00%

Cost Transfer Inbound	0 €/GB			
Cost Transfer Outbound	0,142 €/GB			
Service Bundle	**CPU (Ghz)**	**Memory (GB)**	**Storage (GB)**	**Price/hour**
RAC1	2	1,024	40	€ 0,06
RAC2	4	2,048	80	€ 0,13
RAC3	4	4,096	160	€ 0,25
RAC4	8	8,192	320	€ 0,46
RAC5	8	15,872	620	€ 0,86
RAC6	16	30,720	1200	€ 1,72

5. Gogrid: (GoGrid, 2012)

Provider and Service	GoGrid Cloud Hosting Pay-as-you-go			
Bundled	CPU, Memory, Storage			
Number of bundles:	7			
SLA	100,00%			
Cost Transfer Inbound	0 €/GB			
Cost Transfer Outbound	0,095 €/GB			
Service Bundle	**CPU (Ghz)**	**Memory (GB)**	**Storage (GB)**	**Price/hour**
X-Small	1	0,5	25	€ 0,05
Small	2	1	50	€ 0,10
Medium	4	2	100	€ 0,19
Large	8	4	200	€ 0,38
X-Large	16	8	400	€ 0,76
XX-Large	16	16	800	€ 1,53
XXX-Large	48	24	800	€ 2,29

6. AT&T: (AT&T, 2012)

Provider and Service	AT&T
Bundled	No
Number of bundles:	-
SLA	99.9%
Cost Transfer Inbound	0,079 €/GB
Cost Transfer Outbound	0,079 €/GB
CPU	51,47 €/GHz·h
RAM	20,017 €/GB·h

HDD	85,79 €/GB·h

7. Microsoft: (Microsoft, 2012)

Provider and Service	Microsoft Windows Azure Virtual Machines			
Bundled	CPU, RAM, Storage			
Number of bundles:	5			
SLA	99,95%			
Cost Transfer Inbound	0 €/GB			
Cost Transfer Outbound	0,095 €/GB			
Service Bundle	**CPU (Ghz)**	**Memory (GB)**	**Storage (GB)**	**Price/hour**
Extra Small	1	0,768	20	€ 0,02
Small	1,6	1,75	225	€ 0,09
Medium	3,2	3,5	490	€ 0,18
Large	6,4	7	1000	€ 0,37
Extra Large	12,8	14	2040	€ 0,73

8. Cloudsigma: (Cloudsigma, 2012)

Provider and Service	Cloudsigma
Bundled	No
Number of bundles:	-
SLA	100,00%
Cost Transfer Inbound	0 €/GB
Cost Transfer Outbound	0,0455 €/GB
CPU	0,0175 €/GHz·h
RAM	0,0228 €/GB·h
HDD	0,14 €/GB·h

9. Joyent: (Joyent, 2012)

Provider and Service	Joyentcloud Windows			
Bundled	CPU RAM HDD			
Number of bundles:	4			
SLA	100,00%			
Cost Transfer Inbound	0 €/GB			
Cost Transfer Outbound	0 €/GB			
Service Bundle	**CPU**	**Memory**	**Storage**	**Price/hour**

	(Ghz)	(GB)	(GB)	
Medium	2,4	4	120	€ 0,32
Large 8	4,8	8	240	€ 0,54
Large 16	7,2	16	480	€ 0,83
XL	9,6	32	760	€ 1,40

Appendix 6:

The list of 58 cost factors identified by (Irani, Ghoneim, & Love, 2006) within their taxonomies research.

Categories	References							
	Dier and Mooney [5]	Kusters et al. [16]	Remenyi et al. [23]	Anandarajan and Wen [1]	Ryan and Harrison [26]	Irani et al. [13]	Mohamed and Irani [19]	David et al. [4]
Development		•		•	•			
Training	•	•		•	•	•	•	•
Implementation		•						
Operations		•						•
Maintenance	•	•	•	•		•		
Security		•						
Phasing out		•		•				
Communication	•			•	•	•		
Hardware	•	•	•	•	•	•		•
Package software	•		•	•	•	•		•
Custom software	•			•				
System software	•							•
Cabling/building	•							
Project management	•							
Licenses	•							
Support	•			•				•
Modification	•				•			
Upgrades	•				•			•
Overheads	•					•		
Installation and configuration		•				•		•
Management/staff resources						•	•	
Management time						•	•	
Cost of ownership: system support				•		•		
Management effort and dedication						•	•	
Employee motivation						•		
Employee time				•	•	•	•	
Personnel issues						•		
Software disposal						•		
Productivity loss						•	•	
Strains on resources						•		
Business Process Re-engineering (BPR)		•				•	•	
Organizational re-structuring		•				•		
Implementation risks (covert resistance)		•		•	•	•	•	
Opportunity costs and risks						•		
Hardware disposal						•		
Data communication			•					
Commissioning			•					
Infrastructure			•		•			
Staff related costs (changes in salaries)	•	•	•				•	•
Accommodation/travel		•	•					
General expenses			•					
Tangible			•					
Intangible			•					
Conversion		•						
Data conversion	•							
Environmental						•		
Data preparation and collection				•				
Displacement and disruption				•			•	
Evaluation								•
Futz								•
Downtime								•
Integration							•	
Learning					•		•	
Moral hazard							•	
Knowledge reduction							•	
Employees redundancy							•	
Change management					•			