Cloud Computing economics

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ABSTRACT

Cloud services and technologies are currently receiving increased attention from the industry mostly due to business-driven promises and expectations. Significant innovations in virtualization and distributed computing, as well as improved access to high-speed Internet and a weak economy, have accelerated interest in cloud computing. But, is the migration to the Cloud the most profitable option for every business? Enterprise adoption of cloud computing often requires a significant transformation of existing information technology (IT) systems and processes. To justify such a change, a viable business case must be made based on the economics of transformation. This chapter presents a study of the basic parameters for estimating the potential infrastructure and software costs deriving from building and deploying applications on cloud and on-premise assets. Estimated user demand and desired quality attributes related to an application are also addressed in this chapter as they are aspects of the decision problem that also influence the choice between cloud and in-house solutions.

INTRODUCTION

Cloud computing has become the buzzword in the industry today. Cloud computing enables the use of common business applications online using the providers' software and hardware resources and finally paying on-demand Although it is not an entirely new concept significant innovations in virtualization and distributed computing, as well as improved access to high-speed Internet and a weak economy, have accelerated the interest in cloud computing. This model opens a new horizon of opportunity for enterprises as it introduces new business models that allow customers to pay for the resources they effectively use instead of making upfront investments. This fact raises the question of whether such a technology reduces IT costs and the situations under which cost is actually a motive for migrating to cloud computing technologies.

As cloud computing services are maturing, they are becoming an attractive alternative to traditional in-house or on premise development.. Cloud computing promises to increase the velocity with which applications are deployed, increase innovation, and lower costs, all while increasing business agility..The variable costs calculated on scalable use of resources, the support of enterprise growth through on demand instant infrastructure provisioning and the shift of maintenance, administration and monitoring operations to third parties are among the compelling benefits of the cloud. Still a quantitative analysis of the relevant aspects of the potential IT problem is required before making a decision on the appropriate development and infrastructure model.

IT managers are recently faced with the problem of making a selection between cloud computing and on-premise development and deployment. Cloud computing option is attractive, especially if the quality delivered and the total cost is satisfying and the risks are reasonable. The real question for many IT departments is whether the cost of transition to an external computing cloud will be low enough to benefit from any medium-term savings (Armbrust et al., 2008), (Cloud Computing Congress, 2010). In order to be able to provide answers to the above question, a formal cost analysis of cloud and on-premise deployment should be performed in order to compare thoroughly the two alternatives.

A thorough analysis of the estimated costs and quality associated with the two alternatives will help an IT manager define the pros and cons of each solution. Such an analysis will point out which is the right combination of cloud and premise based assets and can indeed provide the optimal solution. As mentioned by Knight, (2009) the key is not choosing between the two solutions but being strategic about where to deploy various hardware and software components of a total solution.

Although there is a lot of research dedicated to cloud computing software engineering issues, economics and cost estimation drivers for adopting such a technology are not systematically addressed. This chapter presents basic parameters for estimating the potential benefits from Cloud computing and provides an estimation framework for determining if it is a technology that offers a long term profitable solution to IT business problems. Basic parameters for estimating the potential costs deriving from building and deploying applications on cloud and on premise assets are presented.

The assessment of cloud computing costs is more evident compared to the assessment of on premises development and deployment. The cost of cloud computing services initially depends on the usage of three types of delivery models; namely, software-as-a-service, platform-as-a-service and infrastructure-as-a-service. The usage is counted and billed based on the committed resources per hour or the number of users per hour. As the cloud technology is offered from types of providers from giants like Amazon to small re-sellers, measurement standards are not yet fully defined and consistent for each model. The usage metrics should be carefully selected in order to provision and receive effective services (Dikaiakos et al., 2009). The metrics that nowadays are frequently used are bandwidth, CPU, memory and applications usage, per hour. These metrics will also be used to estimate the cost of an application moving or being developed over the cloud. Other important parameters that should be taken into account in order to evaluate cloud computing adoption is the business domain and objectives of the application considered, demand behaviour in the particular field and technical requirements (Klems et al., 2009). Of course this estimation would help in order to approximately predict the cost of cloud computing adoption, but still one should be able to estimate the costs of the alternative privately owned solution in order to compare them and make a justifiable choice.

Estimating the cost of software development and deployment based on on-premise assets is a more complex procedure. On–premises application development includes a variety of different costs associated with IT infrastructure and software development. Estimating in-house development and deployment of software is a difficult task, as there are different cost drivers related to personnel, product, process, hardware and operation expenses. Developing applications on privately owned IT infrastructure comprise, apart from software development and maintenance costs which remain the same in both cases, a series of cost drivers associated with physical attributes, performance factors and functional expenses (McRitsie et.al., 2008). Physical attributes, that may affect the in-source development, are related to the operating environment such as facility requirements, systems hardware and software costs and end users equipment. Performance attributes involve the technical non-functional requirements of the application relevant to the required reliability, transaction- rate, safety, accuracy. The non-functional requirements have an impact on the selected infrastructure. Finally the functional expenses of the company may involve years of operation, labor rates, size of the development and support team and replacement and upgrade policies.

These factors affect the total cost of an IT investment and may define the feasibility of a certain application development and the potential benefits of developing it in-sourcing or out-sourcing over the cloud.

This chapter is an overview of possible billing measures and metrics related to infrastructure and software either they are deployed in the cloud or in house. It is addressed to IT managers that face the dilemma of selecting to deploy applications on the cloud or on premise, to cloud providers that want to effectively bill their provisions and to Independent Service Vendors that want to offer to potential customers both of the two alternatives, clarifying long term benefits of each of the two. Specifically, in the sequel we pursue three main goals:

a) to analyze the different types of costs related to adopting cloud technologies and in house development. Our approach is based on the discussion of general cost categories that are taken into account by “cloud” providers and the traditional cost drivers considered in estimating in-source software and systems applications;
b) to provide an analytic comparison example for the deployment of a CRM system based on current economic status. The analysis is based using commercial data from software development coming from the International Standards Benchmarking Group (ISBSG, 2010) and from (Yankee, 2005) report.
c) to define quality attributes and levels of demand behaviour that may affect the final choice. User demand is an indicator of the load of a system and the estimated traffic that greatly affects infrastructure costs. Desired quality attributes and the level these attributes are incorporated into on premise and on cloud solutions can also affect the final decision.

The rest of the chapter is organized as follows: The next Section provides an analysis of the background and the related work. Section entitled “Choose the right deployment model” describes cloud computing and traditional software and system costs and provides a three step procedure that will assist IT managers to understand the benefits of each solution. The two last sections discuss future work and conclude the Chapter.

BACKGROUND

There is fairly broad general interest on the benefits and drawbacks of moving or deploying an application to the cloud. Cost is recognized as an important factor that may motivate the transitioning of IT operations to cloud computing. Practitioners show an increased interest on the costs related to cloud computing however monetary cost- benefits are not yet fully recorded, assessed and analyzed by the scientific community.

Armbrust et. al. (2009) in their technical report, include a chapter devoted to cloud computing economics. Three issues are mentioned in (Armbrust et al., 2009) that should participate in cloud computing economic models. These issues are related to long-term cost benefits, hardware resource costs declines and resource utilization. A host service in the cloud should offer benefits over the long term. This means that one has to estimate the utilization over the cloud for a significant period of time. In these estimations the “pay as you go” billing system offered by cloud computing providers is evaluated in terms of elasticity measured in resource utilization. An IT manager will predict daily average and peak demand measured for example as the number of servers required and then he will be able to compare utility computing versus privately owned infrastructure. Also hardware expenditures should be taken into consideration into economic models. Hardware resource costs decline at variable rates a fact that may lead to unjustifiable expenditures compared to actual resource usage. Cloud computing can track changes to hardware costs and pass them through the client more cost effectively.

Klems et al. (2009) propose a framework for determining the benefits of cloud computing as an alternative to privately owned IT infrastructure. The model presented is based on the business scenario and the comparison of costs between the two alternatives. The business scenario is defined by the business domain and objectives, the demand behavior and the technical requirements. For example, the business domain defines whether an application will be used at a Business to Business level or Business to Client level, or for internal use. The business goals will point out particular benefits coming from web hosting in the cloud such as short time to market, reduced costs, and software licenses violations. Demand behavior also is an important factor that affects the performance of services and applications in the Web according to Kleims (2009). Demand behavior can be seasonal, temporary or caused by batch processing jobs.

In Bibi et.al (2010) the cost factors of on premise and hosted solutions are addressed while in Bibi et al. (2012) a cost model is introduced for assessing costs of on premise, SaaS and hybrid solutions (IaaS). In the last study a case study is presented utilizing data from a company that assessed all three solutions. The TCO analysis pointed that the SaaS solution has benefits with respect to the in-house solution, but the gain tends to decrease over a 20-year period, while the IaaS solution benefits over the in-house solution remain practically stable.

The key factors that must be considered in determining the economic soundness of any transformation to cloud computing are presented by Beaty et al (2011). The paper discusses the aspects that should be taken into consideration for performing sensible ROI analysis that captures the relevant factors affecting the economics of cloud transformation. The type of IT costs considered are: infrastructure and software costs, energy costs and labor for system management.

A few studies addressed the issue of pricing models that would help cloud providers be competitive and challenge potential customers. Samimi and Patel (2011) introduced a review and comparison of the recent pricing models in grid and cloud computing and their economic models. They also highlighted the differences in grid and cloud computing by comparing their usage, standardization, virtualization, and SLAs. They studied pricing models thoroughly in grid computing and compared them to those in cloud computing. . Sharma et al., (2012) suggested a financial model for cloud providers capable of bringing high level of QoS to customers with competitive price. The authors employed the financial option theory and captured the realistic value of cloud resources. The price appointed by this model represented the optimal price that the service provider should charge its customers to recover the initial costs. The financial option theory gave a lower boundary of the price that should be charged to customers. The upper boundary of the price was determined using Moore's law. The authors suggested that, if the price was set between these two boundaries, it would be beneficial for both customers and service providers.

Related studies that discuss the cost of familiar to cloud computing models like grid computing are (Kondol et. al., 2009) and (Optitz et al., 2008). Performance trade- offs and monetary costs of cloud computing compared to desktop grids are analyzed in (Kondol et. al., 2009). The above comparison involves two relevant architectural platforms, cloud computing and volunteer computing, that present similar principles. Performance comparison is quantified in terms of execution, platform construction, application deployment and completion times. Cost comparison is performed in terms of technical requirements such as project resource usage. The costs of relevant aspects of cloud computing such as grid computing is addressed also in (Optitz et al., 2008). The study analyzes different types of costs and determines the total costs of a resource provider. Relevant cost for resource providers include hardware, business premises, software, personnel and data communication expenses.

Practitioners on the other hand seem to be bigot supporters of utility computing. Miller (2009) states that cloud computing is a type of web-based computing that allows easy and constant access to applications and data from all over the world through an internet connection and facilitates group collaboration. Though he mentions that cloud computing is not suitable for any case, stressing the advantages and disadvantages of cloud computing. Regarding costs he refers that cloud computing reduces hardware and software costs and increases the productivity of the employees as they have access to their files and applications from home as well. Among the disadvantages of cloud computing related to costs Miller

(2009) mentions that cloud computing requires fast and instant internet connections. Also data confidentiality in the cloud is a subject under examination that may cause economic loss (McGowan, 2009). Gupta et al. (2013) analyze five factors that affect the decision of an SME to adopt cloud services: usability, convenience, security, privacy and costs. According to the findings of the study, contrary to the generic belief, cost reduction is not among the top two factors for SMEs to move to cloud. Usability and convenience are the two main factors that can urge the migration to the cloud. Reliability seems to be the main concern of SMEs that prevents sharing and collaboration to the cloud.

Knight (2009) argues that the dilemma between cloud computing and on-premise development is wrong and should be substituted by the question of which is the right combination of cloud and premise based assets. The combination of the two approaches can indeed exploit the best of both worlds.

CHOOSE THE RIGHT DEPLOYMENT MODEL

In this Section our goal is to clarify which services are offered by cloud computing and how they are related to on-premise software and system costs. We record and analyze thoroughly all relevant costs related to cloud deployment and in-house development and finally suggest a three step decision model that will support the decision of migrating or not to the clouds.

Cloud Utilities

The main purpose of Cloud Computing is to provide a platform to develop, test, deploy and maintain Web-scale applications and services. A formal definition of cloud computing is not found in literature but most resources refer to this term for anything that involves the delivery of hosted services over the Internet. These services are broadly divided into three categories (Dikaiakos et al., 2009), (Lenk et al., 2009): Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). Figure 1 depicts the services offered by the cloud.

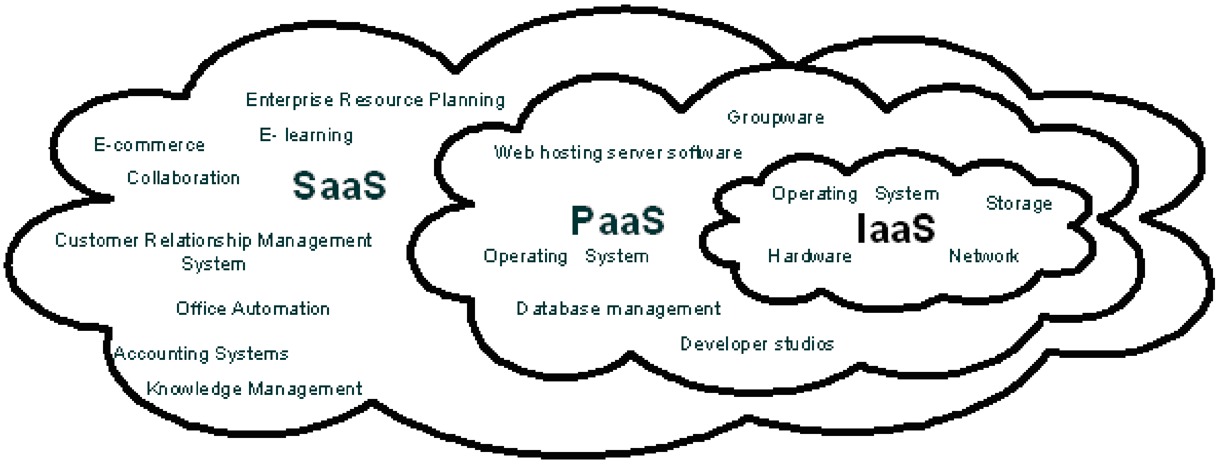

Figure 1. Cloud services

A. Software as a Service

Software as a Service is a software distribution and usage model that is available via a network to the customers. Both horizontal and vertical market software are offered by SaaS. Typical examples of horizontal SaaS are subscription management software, mail servers, search engines and office suites. Examples of vertical SaaS are more specialized software such as Accounting software, Management Information systems and Customer Relationship Management systems.

SaaS software is leased through Service Level Agreements (SLAs). An SLA (SLA definition, 2010) is a contractual service commitment. An SLA is a document that describes the minimum performance criteria a provider promises to meet while delivering a service. It typically also sets out the remedial action and any penalties that will take effect if performance falls below the promised standard. It is an essential component of the legal contract between a service consumer and the provider. SaaS investment is typically limited to the subscription fee. This pricing model provides a predictable investment that follows a pay per usage billing scheme. Usually costs are calculated considering user licenses, customizations costs and end user support and training costs (CRM Landmark, 2009). The last three types of cost refer mostly to software for vertical needs. All these costs are determined in SLAs that define the pay-on-demand rates.

Defining the billing model of SaaS is a challenging task for potential customers, providers and Independent Software Vendors. Many Independent Software Vendors (ISVs) have developed their SaaS solutions offered in parallel with the corresponding commercial products. Among the challenges ISVs are confronted is the re-structuring of pricing models. In order to establish attractive pay- as- you go subscription fees, the understanding of the differences in cost between software products and services is required. These differences need also to be clearly presented to candidate customers.

Major SaaS providers bid very low prices hoping that perpetual licensing will lead to upfront earnings. SaaS providers usually provide scalable types of licensing based on the number of users or on the number of applications accessible to the user. One pricing model may not be appropriate for all types of applications and software services. For example, eCommerce or supply-chain SaaS solutions could be priced based on the number of transactions or volume of data transmitted. Customer relationship management (CRM) or Salesforce Automation (SFA) solutions can be priced based on the number of accounts, prospects, or bookings they support. Determining customers' price-sensitivity when it comes to SaaS is especially difficult for providers who need to balance their new solution pricing against existing product pricing schedules. (Le Cayla, 2006).

SaaS providers are faced with the problem of metering and billing their services in order to establish competitive offers that will at first attract potential customers, and offer long term benefits to both of the two parties. A provider is faced with the following three problems:

- Which usage data to collect and record?
- Based on which metrics to charge?
- Should process and ratings be flexible per customer? Per contract?

Answering the first question we can say that the relevant data collected so far by providers generally falls into three categories, resource data, transactional data and workflow data.

Resource data most of the times describe the customers usage of the premises offered by the provider. Relevant data that can be recorded is the number of users, or connections to the application that can be 'per use' or per 'concurrent use'. The number of registered users of a product per month is an increasingly popular method of pricing SaaS. SalesForce, (2010) is a major SaaS provider that use among others this model for most of its offerings. This billing model has different prices for each level usage based on the number of users. The payment per user is appropriate for software that serves internal needs of the customers company. In that case the customer needs to isolate and record the number of employees that will actually utilize the SaaS software. The number of registered users is a good indicator of the value that a group derives from the product (Rothbart, 2009). Risks deriving from this method involve possible user's abandonment. The customer company needs to control, manage and remove users that do not regularly use the software.

Another way of pricing resource usage is based on per- user page view fees counted as the number of users that access a page. This kind of pricing model is mostly appropriate for products that are destined for large external customer and partner communities. In that case, the number of users that access and browse a website is recorded as the basis to charge customers. Theoretically this metric is indicative of the number of users that visit a website and actually may use or buy a product, but still there is no guarantee that a high page view presents the proportional benefits to the SaaS customer and its clients. The page view does not always reflect how much users are using a product. The “concurrent use” on the other hand can be an alternative metric in the cases of SaaS products that require concurrent user intensive functions. Examples of such SaaS products may be teleconferencing applications, discussion forums, calendars, or even information portals. Concurrent user is an industry standard term that refers to the total number of people (as measured by network connections), that are connected to a server or online service at any one point in time. The term “concurrent user” is analogous to “port” or “line” with respect to a telephone branch exchange (Nefsis, 2010). In general, the pricing based on number of users or user licences may be combined with additional fees for extra bandwidth and storage.

Transactional data refer to the interaction between a subscribed customer and the SaaS provider and usually are one –time fees based on the needs of the customer. For example, SaaS Optics (2010) define several types of transaction items within the subscription life cycle. In essence, these transaction items are the events that can occur with regard to a term agreement over time. Such transactions may involve *New Subscription, Upgrade, Downgrade, Adjustment, Renewal, Cancellation*. New Subscription service is a one time fee that can break down to license and professional services fees. License costs are related to the initial subscription to the SaaS service. Professional services fees may include consultancy, training, user support and several other customer needs that may occur. Upgrade, Downgrade or Adjustment are three services that can be offered to a single customer subscription that allow the customization of the application to the customers needs. The fees charged are based on the level, the costs and the time required for the incorporated changes. Renewal charges include the fees related to the continuation of the services to the customer while cancellation fees include penalties to the customer in case of cancelling the contract based on the time period of the notification.

Workflow data may involve usage metrics involving process oriented activities. Such metrics are relative to the specific SaaS application and are forced by the business goals. For example an E-commerce system may count the number of sales or invoices send, an Advertising& Marketing system may count the number of emails or forms received. The usage of a document management system is reflected by the number of documents download or uploaded. Workflow metrics are defined by the procedures and user tasks incorporated in the SaaS software and are indicators of the level of successful usage of a system. A high level of workflow metrics is associated with relevant economic benefits of the SaaS customer.

We mentioned possible data and metrics that can be used to bill SaaS based on the type of the application and the customer’s needs. As with any variation of products available to market there should be differences in pricing taking into consideration the basic marketing mix: the four P’s of product, price, promotion, and place (Lovelock, 2007). Depending on the potential customer the SaaS services might be different, the price might be different, the hosted place and the product might be different. Table 1 summarises the metrics that are currently used by SaaS providers to charge their services. Still the pricing models of SaaS are in their infancy at a lot of research is devoted to capturing the correct price model that will better reflect the usage and value of SaaS.

Type of Metric	Metric	Explanation	Unit of measurement	Charges and current SaaS vendors
Resource metrics				
	Number of	Internal	# of licences	Based on ranges of # licences

	users	enterprise employees		www.salesforce.com www.salesboom.com
	Pay per user	External community users, potential customers	# of page views per month	Based on usage per search http://www.ppcsaas.com/ (for a Search Engine SaaS is the number of searches per month)
	Pay per concurrent user	Systems of high concurrence	# of concurrent users per month	Teleconferecing and knowledge sharing systems http://www.nefsis.com
	Number of user + additional bandwidth and storage	Low prices for small number of users because of additional bandwidth and storage charging	# of users + infrastructure charges	Based on ranges of # number of users + ranges of infrastructure usage
Trasactional metrics				
	New Subscription	Licence fees + Professional services	Standard subscription fee, training costs, consultancy costs, user support costs	Subjective monetary costs by SaaS provider
	Upgrade	Cost of upgrading current application	Based on the level of upgrade. (time, infrastructure, labour costs are counted)	Subjective monetary costs by SaaS provider
	Downgrade	Cost of downgrading current application	Based on the level of degrade	Subjective monetary costs by SaaS provider
	Adjustment	Cost of adjustment of current application	Based on the level of adjustment	Subjective monetary costs by SaaS provider
	Renewal	Cost of renewing SaaS agreement	Subjective monetary costs by SaaS provider	Subjective monetary costs by SaaS provider
	Cancellation	Penalty costs of cancelling a SaaS SLA		

Workflow metrics				
	Successful business scenarios that show the benefit of the customer using a SaaS	Invoices (proofs of sales), Emails (proof of marketing and advertisment)	# business metric/ month	Measure business successful usage http://www.verticalresponse.com/ http://www.zoho.com/invoice/index.html

Table 1. SaaS billing metrics

B. Platform as a Service

Platform as a Service (PaaS) includes the delivery of operating systems and associated desktop services over the Internet without download or installation. PaaS is an outgrowth of Software as a Service targeted to middleware distribution. Platform as a service is a development platform hosted to the cloud and accessed via a network. The functionality that PaaS offers involves at least the following: operating systems, developer studios that include all necessary tools to build a web application, seamless deployment to hosted runtime environment and management and monitoring tools. PaaS offers the potential for general developers to build web applications without having any tools installed in their own space. PaaS applications are hosted to infrastructure offered as a service by cloud computing providers. Therefore, the costs of PaaS are connected to the costs of Infrastructure as a Service and will be analytically addressed in the next section.

C. Infrastructure as a Service

Infrastructure as a Service is a provision model in which the customer outsources the equipment used to support operations, including storage, hardware, servers and networking components. In that case the provider is the owner of the hardware equipment and all relevant resources and expenses related to housing, constant operation and maintenance are his own responsibility. The client typically pays on a per-use basis. Infrastructure as a Service involves the physical storage space and processing capabilities that enable the use of SaaS and PaaS if wanted otherwise these services are used autonomously by the customer. Virtualization enables IaaS providers to offer almost unlimited instances of servers to customers and make cost-effective use of the hosting hardware.

IaaS can be exploited by enterprises that chase quick time to market. The customer enterprise can accelerate the development time required to build new versions of applications or environments without having to worry about ordering, waiting, paying and configuring new hardware equipment. The most popular use of IaaS is website hosting. Website hosting is a convenient way for enterprises to shift the relevant IT resources away from an internal infrastructure whose primary purpose is to run the business, not the website. In this case the availability and the monitoring of the website are in the concerns of the IaaS provider.

IaaS offers relatively simple infrastructure as it includes basic hardware and operating services. Customers select software servers with operating systems that match their needs and then they load up their own libraries, applications and data and finally configure them themselves. This process requires that the in-house personnel possess considerable IT skills. In the case that the customer enterprise personnel is relatively inexperienced IaaS may not be enough to cover the needs of the customer and can be combined with PaaS. IaaS is then enriched with platform services such as database management systems, web hosting server software, batch processing software and application development environments that are installed in the relevant infrastructure. PaaS and IaaS costs in that case are interrelated.

IaaS and PaaS are billed based on the services delivered to the customer. The billing model is produced considering the level of usage of hardware, application, storage and networking components. Hardware and application components are usually charged simultaneously. These costs most of the times are calculated as on-demand instances per hour. On-Demand instances refer to the number of servers used. The prices differ according to the operating systems and middleware applications loaded to the offered servers. The payment is then processed based on per use instances that are indicative of the compute capacity. Additional metrics that can be used derive from the technical attributes of the server such as the hard disk size of the server, the cpu and the memory capacity. The usage of the servers may also be charged measured in bandwidth or as a daily percentage usage, along with additional IP generation. Also full back ups of cloud servers may be charged separately. PaaS services that may be included in the prices involve databases, web servers, application development environments and servers and video encoding and streaming software.

Storage services are billed based on the hard disk demands, the data transfer and the requests. Initially the data storage is measured in terabytes committed in the hard disk. The price depends on the level of hard disk usage. Data transfer involves transferring the data into databases. Data transfer may be charged autonomously, or is included in data storage fees or may be for free based on the regions of transfer. Data requests involve operations such as copy, get, put, list and other requests regarding the data. Data requests involve inquiries in the data set.

Networking services involves the possibility of establishing a virtual private cloud (Amazon, VPC) that will be the bridge between a company's existing IT infrastructure and the cloud. A private cloud enables enterprises to connect their existing infrastructure to a set of isolated cloud compute resources via a Virtual Private Network (VPN) connection, and to extend their existing management capabilities such as security services, firewalls, and intrusion detection systems to include their cloud resources. The billing of such services is based on the number of VPN connections per hour and the data transferred.
The metrics used to bill IaaS and PaaS services are presented in Table 2.

Type of Metric	Metric	Explanation	Charges and current SaaS vendors
Hardware and application metrics			
	No Instances of servers	Number of servers.	The prices are based on the operating system and the software installed on the server. The pricing models depend on the provider and can be calculated based on the usage per hour or per month.
	CPU	Level of CPU usage	The CPU usage may is calculated in hours or cores.
	Bandwidth	Incoming, outgoing bandwidth	The gigabytes transferred from and to the cloud measured in gb/ per unit of time
	RAM	Megabytes, Gigabytes	RAM memory committed measured in MB or GB /per unit of time

Storage metrics			
	Data Storage	Hard disk storage, Terabytes	GB or TB/ per unit of time
	Data transfer	Amount of data transferred in different regions	GB or TB/ per unit of time
	Data requests	Copy, get, put, list	Number of requests per month
Networking services			
	No of VPN connections	Virtual Private Network that will bridge the cloud to private infrastructure	Number of VPN connections per hour
	Monitoring operations	Monitor the cloud computing resources, statistics	A charge based on the number of instances monitored per hour
	IP addresses	Additional public IP adresses	Number of IP addresses generated

Table 2. IaaS and PaaS billing metrics

Traditional software and systems costs

This Section discusses the costs related to IT infrastructure and software development for an application based on on–premise assets. Companies that possess their own IT department have the dilemma of selecting between in-house and hosted SaaS solutions will find very useful to predict software development costs, as these costs define all relevant on-going costs such as maintenance, training, upgrades and also costs related to infrastructure.

A. IT Infrastructure Costs

When estimating software development and maintenance costs, IT infrastructure costs should also be accounted. IT costs are non-negligible as usually they stand up to 60% of Total Ownership costs (Gray, 2003), (McRitsie, 2008). Unlike software development estimation, IT estimation is a simpler process as infrastructure and services are more tangible. The cost drivers that influence IT costs as mentioned in (McRitsie, 2008), (Optitz, 2008) and (TechAmerica, 2008) can be operational attributes and business premises.

	Drivers
	Operational Drivers
New resources	Servers, Laptops, PCs
	Peripheral devices, CPU, memory
	WAN/LAN equipment

	Drivers
	Operational Drivers
Maintenance and replacement costs	CPU
	Hard Disk
	Power supply
	CPU Cooler
License fees	Application Software (office applications, mail)
	System Software (Operating system)
	Database (Licences for end users)

Table 3. Operational Drivers

	Drivers
	Business Premises
Personnel Expenses	Labor Rates
	Training expenses
Electricity costs	Electricity consumption
Physical Locations	Rental expenses

Table 4. Business Premises

Operational attributes refer to hardware costs, software and system license fees. Hardware costs include new resources acquisition, replacement and maintenance of existing resources. Hardware acquisition costs depend on the infrastructure hardware list (servers) and the end user hardware list (laptops, CPU, printers). Hardware maintenance costs usually are estimated using measures that compute the Mean Time To Failure (MTTF) or Mean Time Between Failures (MTBF). Software, system and database license fees refer to operational software that will be installed in computer systems necessary for the operation of the new application. License costs are defined by the number of inbound and outbound workstations in which the new application will be installed. The number of users usually affects cost mainly through the number of software licenses needed and recruitment and training costs.

Several performance factors are associated with the non-functional requirements of an application that apart from the need to incorporate them in the software also rise the need for business premises. The average transaction rate, the storage needs, security issues and reliability factors require computational power and capacities. Computational power in low level is related to electricity costs. Other business premises that are necessary for IT development and are associated to total costs involve labor rates, outsourcing agreements and operational locations. Labor rates are related to the personnel expenses and training procedures. Outsourcing agreements may include hardware/software leasing or development. Different physical locations of the organization and different access points to the application are associated to rental or leasing expenses. Tables 3 and 4 summarize in-house infrastructure costs.

B. Software Costs

Software development costs are divided into four groups. Product, platform, process and personnel drivers are pointed out by literature (Boehm, 1981) as the most important aspects that determine software costs. Tables 5 to 8 summarize in-house software development cost drivers.

Product attributes related to a software project include descriptive variables and size indicators. The aggregation of variables of both categories is indicative of the complexity of the new projects and the expected difficulties that might rise. Descriptive variables provide information regarding the development type of the project, the application type (IT project type ERP, MIS, CRM or Web applications, etc.) and the user type of the application (professional, amateur, concurrent, casual. In order to estimate size attributes an initial assessment of functional requirements is necessary. From functional requirements we can provide a size estimate measured in function points (Albrecht, 1979) or in Lines of Code (Boehm, 1981). Accurate size estimation is a very important task as it is considered to directly affect the amount of effort required to complete a software project.

	Drivers	
	Product Drivers	Metric
Type of project	Application Type	ERP, Telecommunications, Logistics, etc.
	Business Type	Medical, Public Sector, Transports, Media, etc.
	Development Type	New Development, Re-development, Enhancement
User type	Level of usage	Amateur, Professional, Casual
	Number of Users	1-50, 50-200, 200-1000, >1000
Size	Source Code Lines	Lines of Code (LOC)
	Function Points	Number of Function Points

Table 5. Product Drivers

Table Head	Drivers	
	Platform Drivers	Metric
Technical attributes	Distributed Databases	1-5 Scale that depicts the necessity of the attribute.
	On-line Processing	1-5 Scale
	Data communications	1-5 Scale
	Back-ups	1-5 Scale
	Memory constraints	1-5 Scale
	Use of new or immature technologies	1-5 Scale
Non-functional requirements	Reliability	1-5 Scale
	Performance	1-5 Scale
	Installation Ease	1-5 Scale
	Usability	1-5 Scale
	Security	1-5 Scale

Table 6. Platform Drivers

Non-functional requirements affect the values of platform drivers and can oppose certain constraints or lead to conflicting interests. Examples of non-functional requirements are software reliability, database size, security issues, performance standards, usability issues and transaction rates. Other drivers that directly affect platform costs are incremented memory needs, increased storage facilities and maintenance of back up files. All the above parameters capture platform complexity of the software under development.

Process attributes refer to all project supplements that may be used and enable the development and delivery of quality software within cost and time limitations. Among these characteristics the use of CASE (Computer Aided Software Engineering), the utilization of methods, techniques and standards are the main aspects that define the level of support and observation of the development procedure. Productive development teams usually follow a well-defined and guided process. Proven best practices, methodologies and the selection of the appropriate lifecycle processes are aspects that a development team should rely on to complete a project. The success of a project, the time and cost required for its completion depends on the existence of a well-managed process.

Table Head	Drivers	
	Process Drivers	Metric
Use of Case Tools	Versioning tools	% of usage
	Analysis & Design Tools	% of usage
	Testing Tools	% of usage
Management Process	Use of lifecycle models	Yes or No
	Managed development Schedule	1-5 Scale
Methodologies	Existance of best practices	1-5 Scale
	Software Reuse	% of the total LOC

Table 7. Process Drivers

Software costs are also dependant on personnel team attributes. Typical examples of this group of cost drivers are the experience of the team, the analysts' capabilities, the familiarity with the programming language and the application. Recent studies also point out that cultural characteristics also determine software costs. Well structured teams that encourage communication allow knowledge exchange and support reward mechanisms are more productive compared to impersonal teams. The capabilities of the personnel and the motivation of the environment affect directly the productivity of a development team thus the total developments costs.

Table Head	Drivers	
	Personnel Drivers	Metric
Experience	Analysts cababilities	1-5 Scale
	Programmers experience	1-5 Scale
	Familiarity with the problem domain	1-5 Scale
Cultural issues	Reward mechanism	1-5 Scale
	Collaboration	1-5 Scale
	Cabable leadership	1-5 Scale

Table 8. Personnel Drivers

Estimating cloud computing migration

IT managers are faced with the problem of selecting how and where to develop and deploy their applications. The requirements of an application will determine the choice between cloud computing and development on premises or even a combination of both (Armbrust, 2008). Each of the two different options presents advantages and disadvantages on various fields. The business goals and priorities of the application will determine the level of usage of cloud or premise assets. IT decision making often requires trading between innovation and time-to-value advantages of cloud computing against performance and compliance advantages of development on-premise. For this reason we propose a three step procedure that will assist in decision making:

A) Assess software and infrastructure development costs.
B) Define quality characteristics.
C) Estimate user demand.

The issue of deciding whether to develop and deploy the applications in the cloud was also addressed in (Klems et al., 2009), but our three-step process is somewhat more generic as it includes detailed recording of relevant parameters.

A. Assess Software and Infrastructure Development Costs

This procedure involves costs assessment of the two alternative solutions. The previous sections will be useful to keep in mind all the relevant aspects of the problem. A five year total cost of ownership projection will be useful to determine long-term benefits of each solution.

We will discuss the deployment of Customer Relationship Management Systems; a common business application that is becoming popular on the cloud. We will focus on software development costs of such an application.

Customer Relationship Management (CRM) is an information industry term for methodologies, software, and Internet capabilities that help an enterprise manage customer relationships in an organized and efficient manner (Laudon & Laudon, 2009). CRM functionality may include product plans and offerings, customer notifications, design of special offers, e.t.c.

Development and cost data for CRM applications built in-house can be found in the International Standards and Benchmarking Group (ISBSG, 2010) data base. Based on data coming from ISBSG , CRM systems on the average require 1867 total effort hours for completion. Keeping in mind average US salaries (4141 US$), 1867 effort hours correspond to 233 workdays, 11,65 months and 48242$. Analyzing the projects that include development data we can see that 56% of the projects require development teams larger than 9 people. All CRM projects developed in-house followed a particular methodology while only 33% of projects that presented values for that field were supported by the use of CASE tools. Cost and development data for CRM applications developed in-house are presented in tables 9 and 10.

Cost data	Average value
Effort (hours)	1867 h.
Size (function points)	181.5 fp
Cost (US $)	48242 $

Table 9. Cost data statistics for on-premise CRM applications

Development data	Values and percentages
Development Team Size	> 9 people. (56%)

Use of CASE tools	Yes (33%)
Programming Languages	C, C#, Cobol, Visual basic and Oracle (65%)
Platform	PCs (39%), clients and servers (15%).
Database	Oracle (41,1%.

Table 10. Development data statistics for on-premise CRM applications

On the other hand CRM cloud applications with Zoho (Zoho, 2010) and Salesforce (Salesforce, 2010) leading providers charge based on the number of users and the number of applications accessed. The prices range from 12$ per month to 75$ per month, per user. Considering in that case 5 potential users that will use a sublist of the product features charged 50$ per month the annual costs are calculated to be 3000$.

In both cases analyzed previously costs associated to software development and usage are recorded. In order to calculate infrastructure, maintenance and deployment costs we consider certain assumptions made by the analysis presented in (Yankee, 2005). In Table 11 we present a five year cost analysis including infrastructure and software costs for in-house and hosted to the cloud solution for a CRM application; the costs presented are only indicative and they may vary from case to case. Figure 2 summarizes the 5year costs.

	Cost Category	Cost driver	Year 1	Year 2	Year 3	Year 4	Year 5
Hosted	Infrastructure Costs		included	included	included	included	included
	Software Costs	Number of Users	7800$	7800$	7800$	7800$	7800$
		Professional Services	5850$	1950$	1950$	1950$	1950$
		Customization	5850$	780$	780$	780$	780$
TOTALS			19500$	10530$	10530$	10530$	10530$
On premise	Infrastructure costs	Hardware + middleware	30000$	1500$	1500$	1500$	1500$
		Network Infrastructure (including internet)	19000$	19000$	19000$	19000$	19000$
		Power, Electricity	12000$	12000$	12000$	12000$	12000$
		Floor Space	12000$	12000$	12000$	12000$	12000$
	Software Costs	Development costs	48242$	0	0	0	0 $
		Application support and maintenance	8683$	8683$	8683$	8683$	8683$
		Customization and Integration	36182$	4824$	4824$	4824$	4824$
		User Training	1500$	750$	750$	750$	750$
TOTALS			167607$	58757$	58757$	58757$	58757$
TCO							61620$

Hosted							
Tco On premise							402635$

Table 11. 5 year cost analysis of hosted and on premise software deployment

We make the following assumptions (These assumptions and costs cannot be generalized in all possible deployment models but still provide an initial support to enterprises that want to calculate relevant costs):

- The number of end users of the CRM application is 10. This number was selected in order to simulate real world situation for a Small Medium Enterprise (SME). Keeping in mind that each employee serves from 50 to 100 clients we consider that the guest list of a SME is 500-1000 people.
- The functionalities of the CRM support Sales, Marketing and Relationship management.
- The price per user for the hosted solution is calculated based on the Professional support offer of Salesforce 65$ per user per month. (The prices of other providers present slight differences that do not distort the results).
- The number of in-house servers is considered to be three; data base server, application server and web server. Three- tier architecture is a popular model adopted by many similar applications, therefore selected in this study. In all of the servers the appropriate middleware is installed and the relevant costs should be considered. Considering that the middleware can be either open source software or commercial solutions, the total infrastructure costs can range from 9000$ (3000$ per server machine considering no costs for middleware) to 70000$ when using commercial middleware (for example Oracle database server (47500$) and Windows (400$) or other commercial products). An average price considered in the analysis is 30000$.
- Application support and maintenance costs in an on premise solution are calculated as 18% of the development costs. Professional Services are calculated as 75% of the development costs. For the next four years they are calculated as 25% of the development costs. Customization and integration costs for the first year are calculated as 75% of the development costs and for the next four years they are calculated as 10% of the development costs. The percentages used in the calculations are based on the analysis of the Yankee Group(Yankee, 2006).
- Hardware costs for the second to the fifth year are calculated as 5% of the costs of the first year.
- Training costs varies based on the number of users.

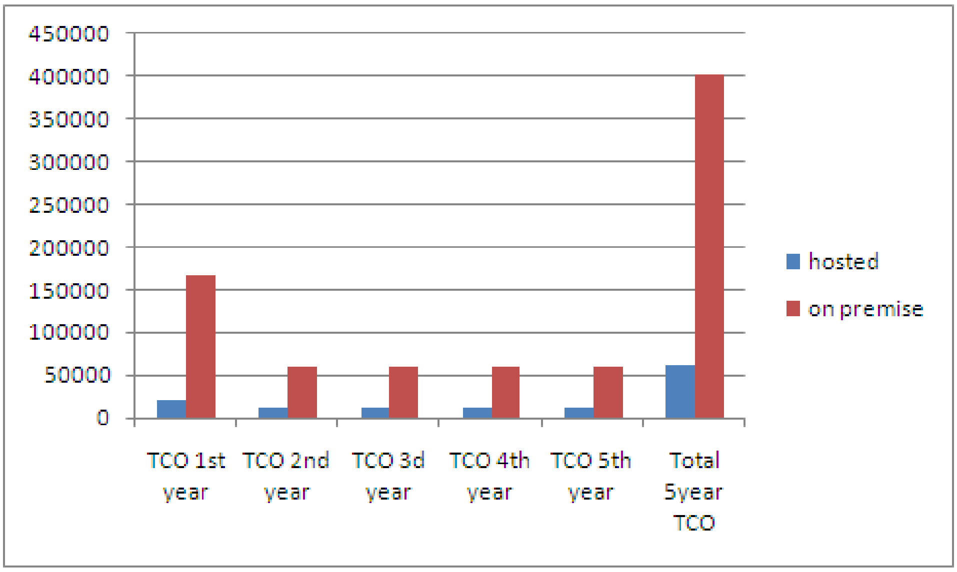

Figure 2. TCO for on premise and hosted solution.

B. Define Quality Characteristics

Quality characteristics are closely associated to business goals and most of the times are defined as non-functional requirements. An initial assessment involves the definition of non functional requirements and their priority. Table 12 summarizes quality attributes and which of the two solutions best incorporates them.

Among the quality characteristics that are incorporated in cloud computing is improved performance. Computers in a cloud computing system boot and run faster because they have fewer programs and processes loaded into memory (Miller, 2009). Compatibility is another attribute that is supported by cloud computing. Documents created in a Web application can be read and processed without any special installation on the users PCs. Increased data reliability is also ensured as cloud is considered the ultimate back-up. Interoperability and availability are two other quality characteristics of cloud computing. Interoperability and availability allow user to have access to the system any time, anywhere by any computer or network.

On premise software advantages involve data accessibility, ownership and safety. The biggest advantage of on-premise software is that businesses have complete control over their critical business data (MacGowan, 2006). This is also a main benefit for data intensive applications that should support high volumes of transactions. Other advantage of the on-premise software is that it allows integration with existing software/hardware resources. Customization is one more quality characteristic of in–premise software.

CRM systems usually store, handle and process sensitive private data of customers that should not in any case leak to competitors. Therefore safety is an important non functional requirement. Other important features involve the back-up file storage, and online any-time, any where immediate access to the system. Usability is another important feature for such an application. A customer should be able to navigate through different functionalities and access the information he needs easily and quickly. Prioritizing non functional requirements is an indicator that will help managers take a decision regarding the development and deployment of a system.

Quality Attribute	Cloud vs On premise?

Reliability	Reliability is an indicator of the ability of system to perform its required functions. Cloud-based providers are usually better equipped to recover from a failure. Most providers guarantee their uptime and have built-in continuity systems to ensure continuity of the operations.
Availability	Cloud solutions offer instant and universal access to the data and the applications of the customer thorough an internet connection. On the other hand cloud computing is impossible if you can't connect to the Internet or you have low connection speed.
Flexibility & Customization	Customization and integration are considered to be better addressed in on premise solutions. With the software running on its premises, a business retains complete control over its entire hardware and software environment, including the flexibility to select the peripherals and third-party applications that best complement and support its processes (McGowan, 2006).
Data confidentiality	The biggest advantage of on-premise software is that businesses have complete control over their critical business data. This data is physically located on a business's premises and does not require the transmission and storage of data off-site. Owning the hardware and supporting systems provides a business with maximum control.
Back ups	Cloud-based solutions are generally considered to ensure a more secure backup of data and data recovery as data stored in the cloud are replicated across multiple machines. Still there are arguments in case of data loss in cloud you have no physical or local backup.
Interoperability	The ultimate cloud computing advantage is device independence (McGowan,). Existing applications and documents are visible even if local systems and devices alter.
Maintenance and upgrades	Maintenance and upgrade is an intensive and time consuming task especially for web applications where servers, storage, software, backup systems and network are in constant operation. In case of hosted applications this burden is transferred to the provider and usually agreed upon SLAs.
Usability	McGowan states that many web-based applications do not provide the same functionality and features compared to their desktop-based brethren. Users that are tight with existing desktop applications might find interesting the learning curve of the web based corresponding applications.

Table 12. Quality characteristics

C. Estimate User Demand

Estimating the expected demand of the application is also very important in order to assess costs. Expected demand is associated with the number of users. The number of users affects licensing costs and hardware costs. Licensing costs are considered for users that access the applications and make changes of any kind. On the other hand, for hardware as the number of users increases, the hardware must also be improved or performance becomes unacceptable. Centralized database models present reasonable costs for 5-10 users, but present exponential growth of costs as the number of users increases. Distributed models are a solution to such problems shifting costs to PCs. Administration fees are also affected by the number of users as normally one administrator is considered every 5-10 users.

While estimating the number of users according to (Klems et al., 2009), one should keep in mind four types of demand.

- Expected Demand: Seasonal demand. This type of demand is associated with consumers' interest in particular products only during a specific period within the calendar year. For example, Christmas ornaments and snow ski equipment are subject to seasonal demand.
- Expected demand: Temporary effect. Expected temporary demand may be caused due to offers, or low prices, or clearance period.
- Expected Demand: Batch processing. Batch processing demands involve computational intensive tasks that demand execution of a series of programs. Usually such batch processing procedures may be cost, time consuming or even unfeasible tasks when in house resources are considered.
- Unexpected Demand: Temporal Effect. The unexpected demand as mentioned by Klems et al, (2009) is similar to Expected temporary effect but the demand behavior cannot be predicted at all or only in short time in advance.

For the CRM system seasonal demand refers to sales and retails periods that usually present increased demand volume. In that case the number of in-house users may increase as the sales are increased. Temporary effect may refer to clearance period or possible relocation that are seldom events that may cause extra demands. Expected demands: Batch processing may involve for the CRM a period that massive advertisements are shifted. Finally, unexpected demands for the CRM may occur when a new product of the company becomes very popular unexpectedly.

FUTURE WORK

As future work we aim to evaluate the proposed model on real world applications deployment and compare the three alternatives (cloud, on–premise, a combination of the two) based on data coming from both in-house development and cloud hosting. In particular for the hybrid of the two worlds, we plan to elaborate on the cases where it is more profitable and derive appropriate "rules-of-thumb", since we argue that this model will be the one that will finally dominate the market.

In general, for companies it will be a big mind change to give up the convenience and comfort of local deployment, control, and operation to cloud computing vendors but the advantages of cost reduction, scalability, speed to market and high powered computing will allow them to return to their core business and differentiate themselves from their competitors. For the cloud computing vendor the key success factors will be to get the variable pricing right, ensure sustainability of the services provided, coordinate a smooth evolution of the services and that the quality of the services needs to be of a high value. Based on these, we understand that a broad horizon of research topics open up as described in the June 2009 issue of ACM SIGACT News magazine.

CONCLUSION

In this chapter we have taken a first step towards identifying all relevant costs of cloud computing and on-premises infrastructure and software. We proposed a three step decision model for evaluating the two alternatives. Software development and infrastructure costs, desired quality characteristics of the application and expected number of users are the main aspects that a software manager has to consider. The final choice may be the deployment of an application on the cloud, on business premises or by adopting a combination of the two aforementioned alternatives.

A thorough analysis of the costs of cloud computing solutions has been performed. All costs, metrics and measurements related to Software as a Service, Platform as a Service and Infrastructure as a Service has been recorded in order to help potential providers and ISVs bill and provision their services and potential customers calculate their expenses. SaaS costs do not only include the subscription fee but the customization and other professional services fees as well. The subscription fee can be charged based on the number of users, on number of page views or based on metrics coming from business oriented goals. PaaS and IaaS costs are related to the infrastructure and middleware utilized. The level of data storage and transfer, networking, server and middleware utilization are some of the measurements used by providers to charge a customer.

On premise costs on the other hand are split into software development costs and infrastructure costs. Software development costs are related to product drivers, such as the type of the application, the process maturity, ability of the development team to follow standard procedures, platform drivers, related to non functional requirements of the applications and personnel capabilities drivers. Companies possessing their own IT department and have the dilemma of selecting between in-house and hosted SaaS solutions will find very useful to predict software development costs, as these costs define all relevant on-going costs such as maintenance, training, upgrades and also costs related to infrastructure. Infrastructure costs are split into operational costs such as hardware, maintenance and networking and business premises costs such as personnel, physical locations and electricity costs. Infrastructure costs are tangible assets and can be estimated more accurately compared to software costs.

The choice of selecting between in house development and cloud deployment is a dilemma that nowadays concerns an increasing number of companies. Cloud computing is a term covering a wide range of online services and seems an attractive proposition for small medium companies that seek to exploit IT services at lower costs, instant time to market and limited risk. As mentioned the initial investment remains to relatively low levels compared to on premise development, the total cost of ownership is reduced and maintenance burden is shifted to providers. On the other hand on premise supporters argue about security, systems' redundancy, functionality and data privacy as obstacles to cloud computing. Aspects that can point out the way to IT deployment are potential costs, user demand and desired quality attributes. User demand is an indicator of the load of a system and the estimated traffic that greatly affects infrastructure costs. A thorough five year cost analysis will enlighten potential long term cost benefits of both solutions. Desired quality attributes on the other hand and the level these attributes are incorporated into on premise and on cloud solutions can also affect the final decision.

Today, most organizations tend to adopt exclusively one of the two solutions limiting the possibilities that a combined solution can offer. An hybrid approach can provide the best of both worlds by allowing the customer organizations to maximize the benefits of both a hosted delivery model and those of the on-premise model. Such a model may exploit just IaaS combined with on premise software applications to avoid infrastructure costs. An alternative is to use SaaS on VPNs to minimize potential data privacy risks. Or even a company can use PaaS service to build each own applications and deploy them using IaaS or private infrastructure. Services offered by the cloud cover a wide variety of IT needs. A potential customer can find the optimal development and deployment solution keeping in mind all relevant aspects of his own specific IT problem and how these are incorporated in the two models.

Closing, as future work we aim to evaluate the proposed model on real world applications deployment and compare the three alternatives (cloud, on–premise, a combination of the two) based on data coming from both in-house development and cloud hosting. In particular for the hybrid of the two worlds, we plan to elaborate on the cases where it is more profitable and derive appropriate "rules-of-thumb", since we argue that this model will be the one that will finally dominate the market.

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KEY TERMS & DEFINITIONS

SaaS: Software as a Service is a software distribution and usage model that is available via a network to the customers.

PaaS: Platform as a Service (PaaS) includes the delivery of operating systems and associated desktop services over the Internet without download or installation

IaaS: Infrastructure as a Service is a provision model in which the customer outsources the equipment used to support operations, including storage, hardware, servers and networking components.

Infrastructure Costs: Hardware, networking, and physical location costs

Software Development Costs: Development costs that are affected by the process, the product, the platform the personnel

SLA: Service Level Agreements (SLA) is a contractual service commitment.

TCO: Total Cost of Ownership, direct and indirect costs and benefits related to the purchase of any IT component