

## **Cost Break-Even Model for Cloud Computing**

نموذج تعادل الكلفة في الحوسبة السحابية

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**Master Thesis**

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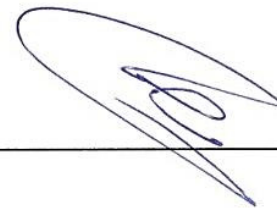
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## Dedication

I would like to express my sincere appreciation to Dr. Ahmad Kayed for his guidance, support and motivation throughout my Master's Thesis.

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## LIST OF ABBREVIATIONS

# U	Number of users
ACC	Average cost of cloud computing
ACT	Average cost of traditional
CC saas(h)	Cost Cloud for SAAS
CC paas (h)	Cost Cloud for PAAS
CC iaas (h)	Cost Cloud for IAAS
CT saas(h)	Cost Traditional for SAAS
CT paas (h)	Cost Traditional for PAAS
CT iaas (h)	Cost Traditional for IAAS
CCO	Cost of Cooling.
CWL(h)	Cost Windows License in hour
# VM	Number of Virtual Machine
CC(h)	Cost Cloud computing in hour
CT(h)	Cost of Traditional in hour
CU(h)	Cost of User in hour
T(h)	Time in hour
CS (h)	Cost Server fee in hour
CM(h)	Cost of Maintenance in hour
CRM	Customer Relationship Management
CBA	Cost Benefit Analysis
CU(h)	Cost of User in Hour
GUI	Graphical User Interface
IAAS	Infrastructure as a Service

<b>IT</b>	<b>Information Technology</b>
<b>PAAS</b>	<b>Platform as a Service</b>
<b>RAM</b>	<b>Random Access Memory</b>
<b>SAAS</b>	<b>Software as a Service</b>
<b>SLA</b>	<b>Service Level Agreement</b>
<b>TCO</b>	<b>Total Cost of Ownership</b>
<b>VM</b>	<b>Virtual Machine</b>
<b>CSP</b>	<b>Cloud Services Provider</b>
<b>ROI</b>	<b>Return On Investment</b>
<b>CSE (h)</b>	<b>Cost of Server in hour</b>

# Cost Break-Even Model for Cloud Computing

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## ABSTRACT

Cloud computing is one of the important inventions that have occurred in our life for providing solutions in the field of information technology (IT) through the Internet. Also it enables users to access applications and their own resources using a web browser, which reduces the cost of software, hardware and the maintenance costs. However provide datacenters with thousands of servers that costs a large of money, therefore some companies moved to cloud computing.

Identifying the parameters that influence the software and hardware costs, and the calculation of the traditional computing costs, as compared to that of the cloud computing are not simple problems. As such, this study comes as an attempt to identify the main parameters that may affect the costs of both the traditional and cloud computing paradigms, it proposes a cost break-even model to decide when to use the cloud or traditional.

For the purpose of this study, we carried out simulation of certain experiments, to identify the influence degree of a number of parameters on the total cost of each of the traditional computing and cloud computing. This was made through forming many

equations for each of the two paradigms; these equations can be used in any simulation model and support decision makers to analyze the cost for both paradigms.

Experiments and simulation were carried out to obtain the break-even point in different cases. Through study and analysis, it was found in all cases that the cost of the software and hardware in the cloud computing is less than that of the traditional computing; and that the break-even point is obtained in case of software as a service only provided when the number of the users is small. As well as, the study attempted to identify the parameters that affect the cost of both the traditional and cloud computing paradigms.

## نموذج تعادل الكلفه في الحوسبه السحابيه

اعداد: رغداء عبد الباقي مغير

اشراف: أ.د احمد الكايد

### الملخص

تعتبر الحوسبة السحابية هي واحدة من الاختراعات الهامة التي حدثت في حياتنا لتوفير الحلول في مجال تكنولوجيا المعلومات عبر الإنترنت. كما أنها تمكن المستخدمين من الوصول إلى التطبيقات ومواردها الخاصة باستخدام متصفح الإنترنت، الأمر الذي قلل من تكلفة شراء البرامج والأجهزة وتقليل تكاليف الصيانة. ان توفير مراكز البيانات مع الآلاف من الخوادم تكلف الكثير من المال، لذلك انتقلت بعض الشركات إلى الحوسبة السحابية.

ان تحديد العوامل التي تؤثر على تكلفه البرامج والأجهزة، واحتساب تكاليف الحوسبة التقليدية بالمقارنة بالحوسبه السحابيه ليست بالمساله البسيطه. لذلك تأتي هذه الدراسة بأنها محاولة للتعرف على العوامل الرئيسية التي قد تؤثر على التكلفة لكل من الحوسبة التقليدية والسحابية، وذلك عن طريق ايجاد نقطه تعادل الكلفه لتقرر متى تستخدم نموذج الحوسبه السحابه أو التقليديه.

لغرض اجراء هذه الدراسة، أجرينا محاكاة لبعض التجارب، وذلك للتعرف على مدى تأثير مجموعه من العوامل على التكلفة الكليه لكل من الحوسبة السحابية والتقليدية. من خلال صياغه مجموعه من المعادلات لكلا النموذجين. مع الاخذ بالاعتبار امكانية استخدام هذه المعادلات في اي نموذج محاكاة لحساب التكاليف، والذي يمكن ان يساعد متخذ القرار في عملية التحليل لكلا الاسلوبين.

تم اجراء التجارب والمحاكاة من اجل التوصل الى نقطة التعادل في حالات مختلفة. ومن خلال الدراسة والتحليل تم التوصل الى ان معظم الحالات تكون فيها تكلفة الاجهزة والبرامج في اسلوب الحوسبة السحابية اقل منها في اسلوب الحوسبة التقليدية، وان نقطة التعادل تحصل في حالة البرامج كخدمه فقط عندما يكون عدد المستخدمين قليل، كما حاولت الدراسة التعرف على العوامل التي تؤثر في التكلفة لكلا الاسلوبين التقليدي والسحابي .

# CHAPTER ONE

## INTRODUCTION

### 1.1. Overview

This chapter provides preface about cloud computing, and identifies the problem statement of this research, author's contribution, and the outline of thesis chapters.

### 1.2. Preface

Nowadays, one of the most promising sectors in the future of computing is the cloud model; this model provides information technology solutions as a service over the internet. According to the National Institute of Science and Technology (NIST), Cloud computing is "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction"(Mell, P. and Grance,T., 2011).

Cloud computing is available as subscription services (pay as you go) to consumers, these services such as Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). (Buyya R. et al. 2010)

Today people are moving from traditional computing to cloud computing because it gives a higher level of dependability, fault tolerance, access to extensive network, and use on demand. The main factor for moving to cloud is the cost. Nowadays, many companies start working in the range of cloud computing, that provides cloud computing services to customer, such as Google, IBM, and Microsoft,

Rackspace. In USA, university of California, Washington state universities are examples of institutions that have adopted cloud service. (Sultan N. 2010).

One of the clouds computing issues of interest is its cost model, also known as pay-as you-go. In this model, IT resources are offered in an unlimited way and one pays an amount according to the actual resources used for a certain period (Barbosa F. and Charao A. 2012).

In terms of cost, there are many methods to compute cost such as total cost of ownership (TCO), which is a financial estimate that aims to help customers and enterprise managers in determining direct and indirect costs of a product, the purpose of TCO is to compute the financial effects of deploying an information technology product over its life cycle. These technologies include software and hardware (Kornevs M. et al 2012).

Kristekova has defined the simulation model to compute cost in cloud computing and in-house datacenter based on system dynamic methods, as that system is used to understand the behaviour of complex system with numerical values (kristekova Z. et al. 2012).walker has presented the idea of computation the cost of CPU hour in case of leasing and purchasing in cloud computing by using Net Present Value (NPV), which is a financial estimate to calculate the profit over its expected life time including all direct and indirect cost. (Walker E 2009).

It is important to know the total cost of cloud and traditional paradigm and the parameters that affect the cost and computation of break- even point in three layers such as software as a service, platform as a service and infrastructure as a service.

The break-even point is directly related to the fixed costs, reducing these costs assists the business to get a lower break-even point in order to achieve profitability (Aswal P. et al. 2013).



We should not focus only on the cost break-even model but we also have to get a clear image of the parameters that affect costs in both cloud and traditional paradigms. To understand the potential role of cloud computing to cost analysis, cost analysis is required.

Several studies were conducted to ensure savings in cost, where in this research we used different sources to gather information and get results in order to build cost estimation model for cloud and traditional paradigms.

We considered several cost parameters that has a significant affect on the cost for traditional and cloud paradigms, and we used several formulas to our findings between both paradigms. Depending on these results, we could formulate a relation between cloud and traditional and then the break-even model between them can be obtained.

The purpose of this thesis is to build a cost break-even for cloud computing and traditional, to find the parameters that have effects on cost in cloud and traditional paradigms, and to suggest a simulation model that covers the cost, which therefore will support decision makers to analyze cost for both paradigms.

### **1.3. Research Problem**

People today are shifting from traditional computing toward cloud computing where cloud is one of the good solutions. The main problem of this research is to propose a cost break-even model to compute cost that will be defined when shifting from traditional paradigm to cloud paradigm. This model should define the main parameters such as payment method, Time periods, number of users, network, Hardware, Software, etc, in addition to the effect of these parameters on the cost model. Goal of the research will be accomplished by answering the following questions:

1. What are the main parameters that affect the cost for cloud and traditional paradigms?
2. How to build break-even model to move from traditional to cloud?
3. How can we build the cost formulae for both cloud and traditional paradigms?
4. How can we generalize the findings of this study?

#### **1.4. Research Objectives**

The objective of this research is to identify the main parameters that affect the total cost for traditional and cloud paradigms, and to find a break-even model that can help decision makers in identifying the cost in moving from traditional to cloud paradigm. The second objective is to build formulas for cloud and traditional computing which could be utilized in any cost simulation model for cloud and traditional.

#### **1.5. Research Motivation**

Today people are moving from traditional computing to cloud computing because it decreases the cost of hardware and software. Most businesses try to minimize its expenses and expand its profits, therefore, the decision to study the cost for cloud and traditional paradigms are very important. There are many studies about cost in cloud computing and traditional computing, but most of these studies do not determine the main parameters that affect the cost of the two paradigms. Therefore, the one of the most important motivations that led us to study this research is to identify the parameters that affect the cost for cloud and traditional paradigms which help the businesses to decide when to move for cloud computing.

## 1.6. Research Methodology

Based on the problem statement which was mentioned earlier, the main aim of this research is to find the proper model to estimate the cost in the cloud and traditional paradigm. In this model, we can know when to move from traditional to cloud paradigm. To achieve the goal of this thesis, the following methodology has been followed (figure 1.1):

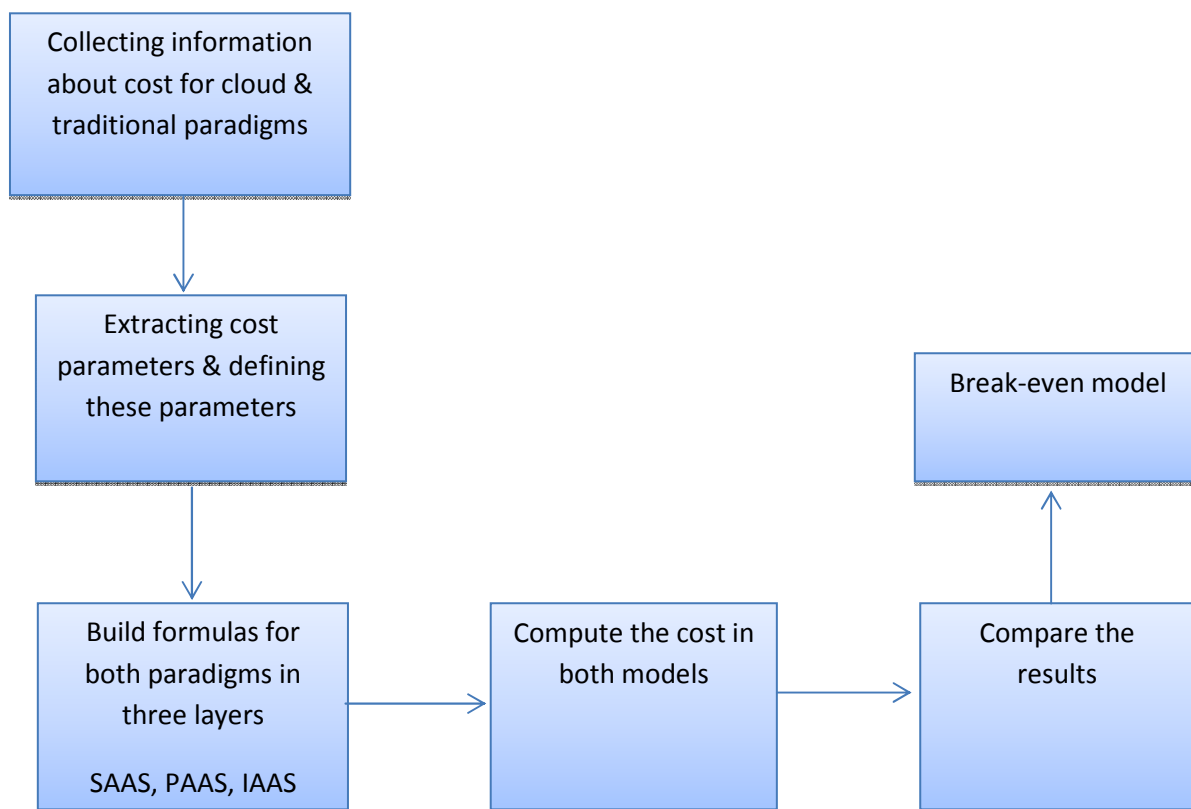


Figure 1.1: Research Methodology

The first step is collecting information about cost for cloud computing and traditional paradigms and defining cost parameters, and this means defining the parameters that affect the total cost such as (payment model, number of user, time, hardware, software, and network) in both paradigms based on previous research. After

that we collect the data on these parameters and build many formulae in three layers SAAS, PAAS and IAAS and compute the cost of both traditional and cloud. This information that comes from many companies such as (Microsoft dynamics CRM, Sage CRM, Microsoft Windows server, Windows Azure, Google app engine, HP, Rackspace) is based on the previous research. Then, computing the cost in both models and building a cost break-even model until reaching the better investment in cloud computing or traditional paradigm. Finally, generalizing the results to other domains in cloud computing.

## 1.7. Outline of Thesis

The outline of this thesis corresponds to the structure of the work, as undertaken throughout the study. This thesis includes five chapters, presented below:

Chapter 2 provides the summary of the literature review and related works that are related to problem statement. It displays the subjects that are related with cost and parameters effecting on cost in cloud and traditional. In addition, this chapter also highlights the main literature review.

Chapter 3 provides the main parameters for both cloud and traditional and suggests many formulas that will be used in experiments design. Furthermore, it includes the procedure that was followed to compute cost in cloud computing and traditional computing.

Chapter 4 presents the method and the main outcome of the cases, these cases were carried out based on the effect of the parameters for computing cost for cloud and traditional, in order to determine the results for experiments details in chapter three. Then the discussions for this thesis are presented.

Chapter 5 presents the conclusion and provides directions for future work in order to improve the final work.

## CHAPTER TWO

### BACKGROUND AND LITERATURE REVIEW

#### 2.1 Introduction

This chapter provides a background and literature review on the main concepts covered by this research, It is divided into three sections. Section 2.2 discusses the necessary background information that is needed to better understand topics related with cloud computing. Section 2.3 presents a range of tools that are used to measuring the cost in cloud paradigm and traditional paradigm. Section 2.4 discusses the related studies in the field of cost cloud computing. Finally, section 2.5 presents a summary.

#### 2.2. Background

##### 2.2.1 Cloud Computing

Cloud computing is a re-discovered technology which gained popularity, and expanding rapidly in service deployment environments. The idea was invented by John McCarthy in 1961, including sharing hardware, software and information through the Internet.

The cloud computing is a set of datacenter from hardware and software, which is responsible for providing services to the clients. The cloud service provider offers hardware, software, infrastructure, and application to its clients on demand basis. (Sharma M. et al. 2014).

The fundamental goal of cloud computing is to reduce cost; the users of cloud computing can use applications without setup of special software and access their specific information from any machine over the Internet.

The most important factors for adopting cloud computing s that you do not need any investment in software, hardware nor any software maintenance, it reduces the work as administrator, It is user friendly, the user pays for what actually used. And there is not a HW lifetime period limit (Němeček J.& Vaňková L. 2011 ).

### 2.2.2 Types of Cloud

Cloud computing is categorized into three types:-

- 1- **Public cloud**: in this type, resources dynamically provide services to public people through the Internet. These resources are owned by a cloud service provider (Abuakibash M. and Elleithy K. 2012).
- 2- **Private cloud**: in this type, resources are provided and operated only for a single organization.
- 3- **Hybrid cloud**: is a collection of public and private cloud that offers the benefits to multiple users and clients (Sharma M. et al. 2014).

### 2.2.3 Types of cloud providers

It contains various components, features, abilities and measurements coverage numerous regions, including Infrastructure as a Service (IAAS), Platform as a Service (PAAS) and software as a service (SAAS):

**1-Infrastructure as a Service (IAAS):** is a strategy in which enterprises rent equipment, for example, servers and network tools instead of buying from service providers through the internet. Examples of IAAS providers include windows azure, HP, Rackspace, etc. (Malhotra R. and Jain P 2013).

**2-Platform as a Service (PAAS):** Platform as a Service is a method whereby customers can lease resources such as determining the equipment type of operating systems to develop and run applications through the Internet. Examples of PAAS providers include Google app engine, windows azure, force.com, etc. (Duipmans E. and Pires L 2012).

**3-Software as a Service (SAAS):** allows users to use the cloud computing providers' applications through the web browser. In this model, software applications are installed in the cloud and the end user accesses the software from cloud clients. The end users charged a flat fee monthly or yearly. Examples of SAAS providers include Google apps and CRM and etc. (Samimi P. and Patel A. 2011).



## 2.2.4 Advantages of cloud Computing

- 1- Cloud computing works with higher efficiencies and it includes more use; therefore, the cost is less.
- 2- Depending on the type of service provided, you may find that you do not need a hardware or software licenses to implement the service.
- 3- Quality of service: The Quality of Service is something that you can obtain under contract from your vendor.
- 4- Reliability: The size of the cloud computing networks and their ability to provide load balancing and failover makes it highly reliable.
- 5- The use of cloud computing permits another person to deal with your computing in order to reduce the cost of IT staff (Sosinsky B., 2010).

## 2.2.5 Disadvantage of Cloud Computing

Cloud computing requires a Constant Internet Connection. Because if you do not have an Internet connection, you cannot access anything even your own documents. This might be a more significant disadvantage than you might think. Also it does not work well with Low-Speed Connections. A low-speed Internet connection like Dial up types, web based apps often require a lot of bandwidth to download for large documents. Stored data might not be secured: With cloud computing, all your data is stored on the cloud (Miller M. 2008).

## 2.2.6 The Relationship between User and Provider for Cloud

### Computing

The traditional method of purchasing software requires the consumer to locally install an application on their computer and use licenses to authorize the usage (Foster I et al. 2008). With SaaS, the consumers pay for the software on a subscription level and do not need to install any software on their computers. An example of this is Google Docs, a word processing application offered online. The user can access the application through a Web browser, create documents and use all the features of the application. What differentiate SAAS from PAAS and IAAS is that the user will not alter the application itself, nor the hardware that the application runs on, or the network configuration (Goyal S. 2014). Figure 2.1 shows the relationships between providers and customers.

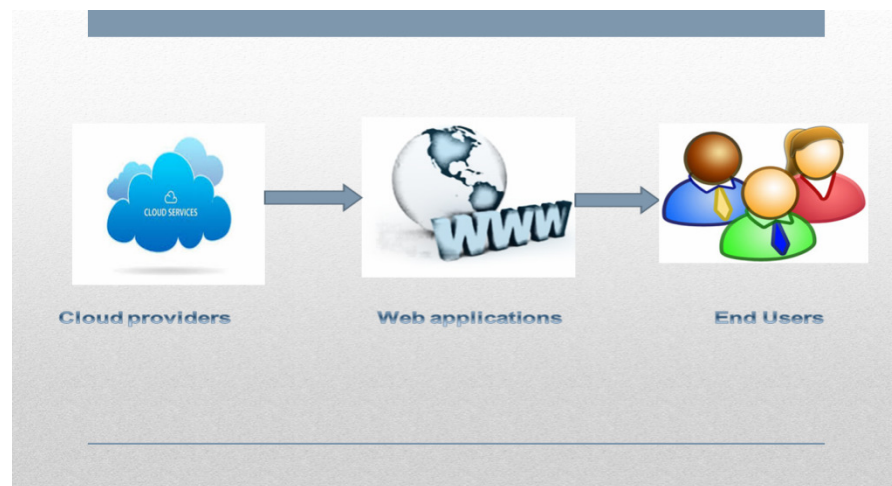


Figure 2.1 Relationship between providers and users

## 2.2.7 Reasons of Adopting Cloud Computing

The most important reason behind moving to cloud computing paradigm is cost savings which is the first among other factors, this is achieved through increasing gain by lowering operational and capital costs and increasing productivity through better scalability and flexibility cloud offers. As shown in figure 2.2 below (Kwofie B. 2013).

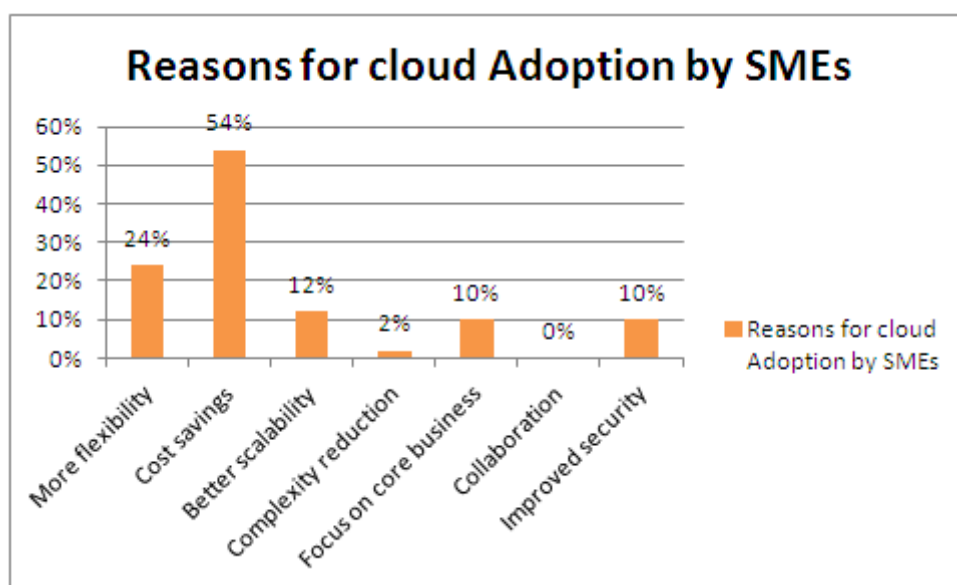


Figure 2.2: Reasons for cloud adoption by SMEs by Kwofie B. 2013.

## 2.2.8 Cost associated with Cloud Computing

Cloud computing involves hosting applications on servers and delivering software and services through the internet, and pays for services based on usage. By adapting cloud services, it is not required by the organization to purchase IT infrastructure, because all IT infrastructure, software, will be hosted in the cloud provider servers. This approach will reduce the cost associated with hardware purchase, software licensing, electric power, cooling and salaries for IT support staff ( Mtebe, J. S., & Raisamo, R. 2014).

## 2.2.9 Compute Cost for Cloud Computing

The costs associated with the cloud model are calculated almost differently. Each resource has its own specific cost and many resources can be provisioned independently from one another, therefore, the cost cloud is better represented by the equation:

$$\text{Cost cloud} = \Sigma (\text{UnitCostcloud} \times (\text{Revenue} - \text{Costcloud})) \dots \dots \dots (1)$$

Cloud providers offer packages of machine instances with a fixed relationship between a machine instance, memory allocation (RAM), and network bandwidth. Storage and transactions are unbundled and variable. (Sosinsky B. 2010).

## 2.2. 10 Parameters that affect on Pricing in Cloud Computing

1. The amount of money that the service provider spends annually to buy resources.
2. The period in which the customer will lease resources from the service provider. Service providers usually offer lower unit prices for longer subscription periods.
3. The set of technologies and techniques offered by the service provider to enhance the user experience in the cloud.
4. The age of the resources employed by the service provider, the older the resources, the lower the price charged.
5. The amount of money that the service provider spends on maintaining and securing the cloud annually (Al-Roomi M etal. 2013).

## Payment Methods (fixed price)

- 1- **Pay as you go:** Customers pay for just the use and for just the required time for specific service. (Carlin S. & Curran K. 2011).
- 2- **Subscription** Customer pays a flat fee in order to access the use of a product or to a profit from a service.
- 3- **Fixed pricing List price/ menu price** /a fixed price that is often found in a list or catalog. (jaatmaa J. 2010)

There are many payment methods in cloud computing, we took two payment methods such as pay as you go and subscription but these are two methods which give us the same price, if they are measured for month or in an hour by multiplying by number of hours or number of months or number of years.

## 2.3 Type of Tools to Compute the Cost

There are several tools that support companies to analyse and compute cost such as:

### 2.3.1 System Dynamics

System dynamics modelling is used to understand the structure and behaviour of complex systems, with numerical values. Jay Forrester (1961) is the inventor of system dynamics. The methods used feedback, and process used in computer is based on technologies to design a model. This methods is used simplicity in networking of variables, this model can grow in complexity and size, and the result appears completely it does not show the key structure for the model briefly, this model is user-friendly graphic interfaces and modelling is always easy done

by click on mouse, the result of this model is complex, and the feedback loops may not correspond to the great model behaviour in the real world life (Kelly R et al. 2013).

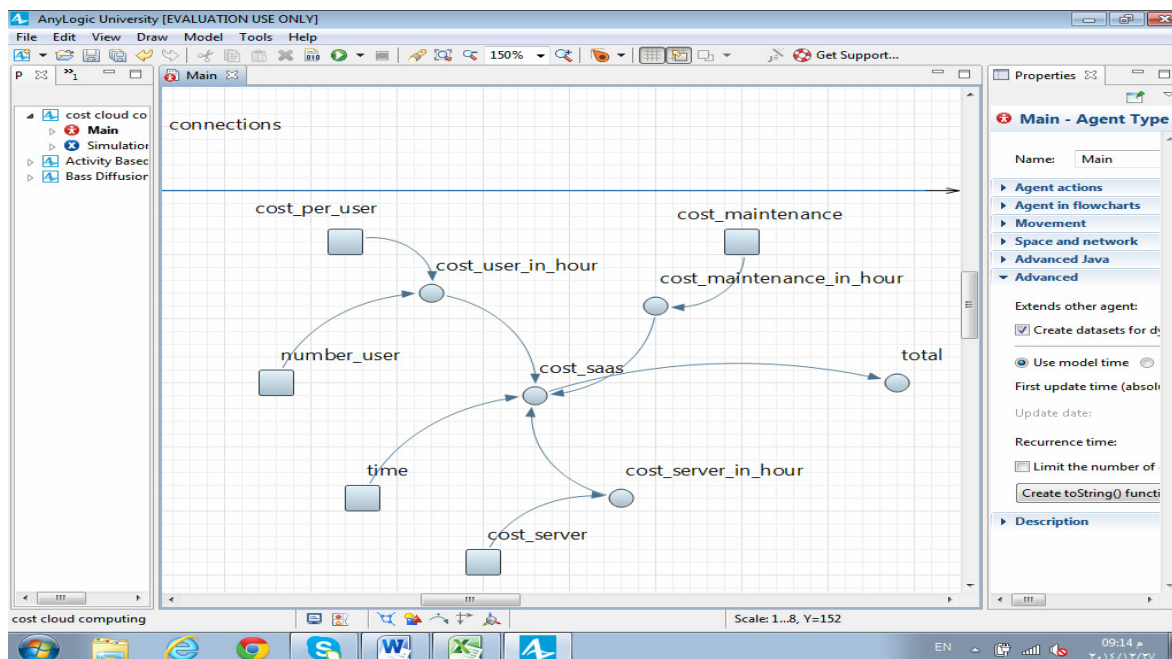


Figure 2.3 system dynamics interface

## How to use system dynamics

This application describes the system behaviour as a number of interacting feedback loops, and represented in terms of stocks such as material, knowledge, people, money, flows between these stocks, and also represented by information that determines the values of the flows.

This application uses variables and parameters. A variable represents a model state, and may change during simulation. A parameter is commonly used to describe objects statically. A parameter is normally a constant in a single simulation, and is changed only when one need to adjust the model behaviour (Kelly R et al. 2013).

### 2.3.2. Total Cost of Ownership (TCO)

Is a widely method used to compute the real cost (capital and operational cost) and to assist the customers and managers to determine the direct and indirect costs of a product, this method is used in both cloud and traditional paradigm. For software and hardware industries, TCO tries to compute cost of product over its life cycle (Kornevs, M. et al 2012). Cost can be calculated according to the following formulae:

$$TCO(T) = \text{initial cost} + \sum_{i=1}^T (\text{Direct costs} + \text{Indired costs}) \dots\dots(2)$$

### 2.3.3 Net Present Value (NPV)

Is a popular method in cost analysis, used to compute the profitability of investment over expecting lifetime of product considering all the cash inflows and outflows. Many researchers used this method such as Walker and Byung (2011). In this method the cost is computed as shown in the following formulae:

$$NPV = \sum_{t=0}^{Y-1} \frac{Ct}{(1+r)^t} \dots\dots\dots(3)$$

Where r: is the discount rate, Ct the cost at time t. (Walker E 2011).

### 2.3.4 Cloudsim and Cloud Reports

Cloudsim is a famous tool, that support for modeling and simulation of large cloud computing environments, including datacenters on single computing node (kumar R. and Sahoo G. 2014)

This tool shows how to create data center with number of hosts, in each host there is numbers of virtual machine, cloudsims defines the cost of processing, cost of using memory and bandwidth for each virtual machine (Calheiros R. et al. 2010).

The cost of processing and memory and bandwidth are used in this tool as input only, and do not give the total cost of these resources. Therefore we do not use this tool.

There are another tool for cloud computing, which is cloud reports tool, this tool opens source and user friendly interface (GUI), and it is easy for users to display a reports of graphics, The application simulates an infrastructure as a service provider with an number of data centers entirely customizable, user can easily set the amount of computational nodes and their resource configuration includes processing capacity amount of RAM of available bandwidth power consumption.

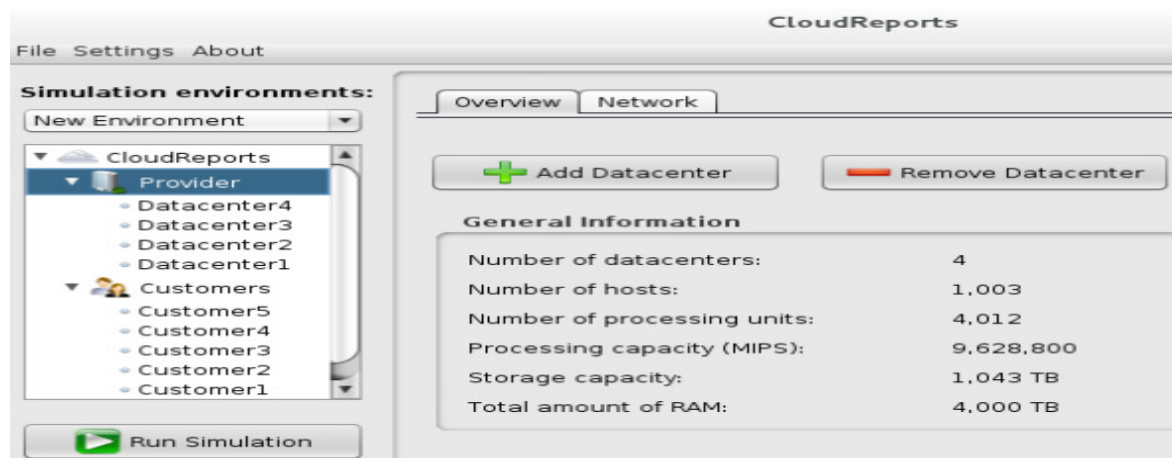


Figure 2.4 Cloud Reports Interface

Figure 2.4 shows the interface of cloud reports and how datacentre works with number of hosts and virtual machine.

Datacenter Characteristics represent static properties of a resource such as resource architecture, Operating System (OS), management policy (time- or space-



shared), cost and time zone at which the resource is located along resource configuration. (Vadicharla R et al. 2013).

### 2.3.5 Amazon Simple Monthly Calculator

Pricing models for elastic compute cloud (EC2) as follows:

- On-Demand Instance: this offers for hour with short period of commitment.
- Reserved Instances: this offers built on a purchase of a contract for each instance lower hourly usage charge after you have paid for the reservation.
- Spot Instance: This is a method for bidding on unused EC2 capacity based on the current spot

Figure 2.5 shows the AWS Simple Monthly Calculator and you can find this calculator on this website <sup>1(1)</sup> that helps to estimate the charges value.

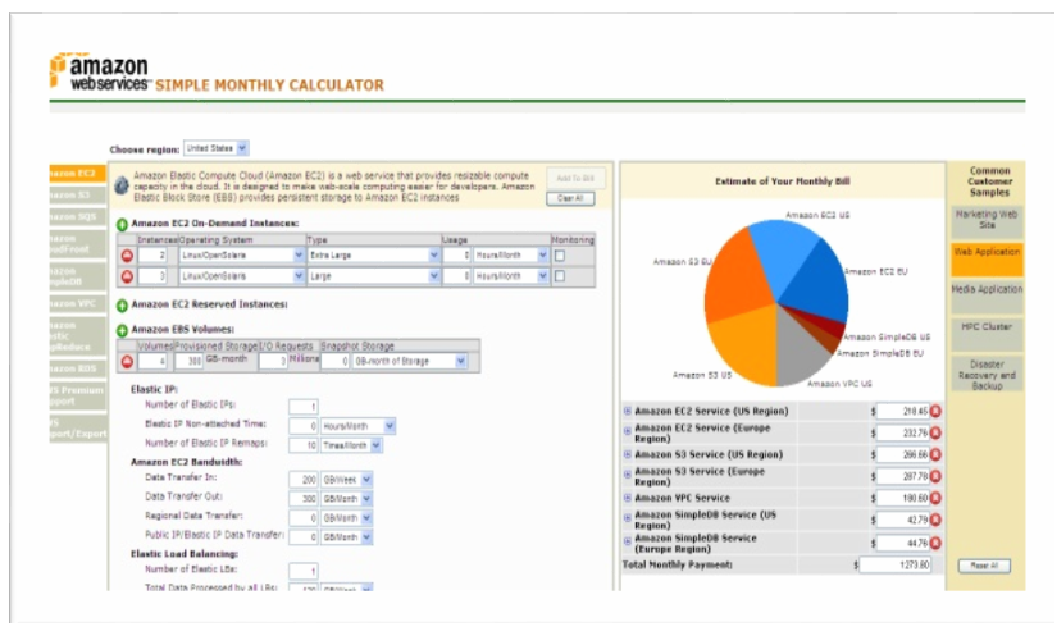


Figure2.5 Amazon simple monthly calculators

<sup>1</sup> <http://calculator.s3.amazonaws.com/calc5.html>

## 2.4 PREVIOUS STUDIES

Buyya defined cloud computing and provided the architecture for creating Clouds with market-oriented resource allocation by leveraging technologies such as Virtual Machines (VMs). Also, provided visions on market-based resource management plans that include both customer-driven service management and computational threat management to sustain Service Level Agreement (SLA)-oriented resource allocation. The cloud computing supports negotiation of QoS between users and providers in order to establish SLAs for providers who can meet QoS expectations, and payment management and accounting infrastructure for trading services (Buyya R. et al. 2008).

Kristekova planned and created a simulation model that shows the dynamic viewpoints and helps leaders to analyse expenses and profits of cloud computing versus its own datacentre, by using system dynamic. The general outcomes show that the experts discovered that the simulation model is useful, instinctive, and complete. All interviewees like the particular division of user interface, want the separation between cloud computing and its own datacenter, since this permits them to utilize the model just for particular space. We used the formulae of this study in system dynamic simulation and reached to same results by using these formulae in excel sheet (kristekova Z. et al. 2012).

Han presented cloud computing providers such as Amazon Web Services, Microsoft Azure, and Google App Engine, along with case studies of implementing web applications on IAAS and PAAS using AWS, and discussed costs and technology analysis by comparing cloud computing with local managed storage and servers through

five years of life cycle of products. The total cost of ownership of an AWS is used, Han also claimed that the cloud computing providers have huge advantages in offering high availability to minimize hardware failure, natural disasters, network failure, and human error, while the locally managed server and storage approach have to be spent a lot to reduce these risks. We followed this study by taking the life time of hardware (Han Y. 2011).

Barbosa presented cloud computing that concerns to the pay-as-you-go pricing model. Where one pays according to the amount of resources consumed. Some cloud platforms already over the pay-as-you-go model .we address the effect of this new approach in software by evaluating and software improvement. Our theory is that hardware consumption may affect specifically on the software vendor profit and therefore it could be important to adjust some software development practices. Also, what was discussed is the need to review well-established models such as COCOMO II and a few angles identified with requirements engineering and benchmarking tools. (Barbosa F. 2012).

Tak B. et al recognized an initial set of key factors influencing the cost of a deployment choice. Using Net Present Value (NPV) representing to two separate applications through ten years of life of software, it was also examined the development of expenses for typical organization decisions indirectly to that applications characteristics, such as, workload force, development rate, storing limit and software licensing costs produce complex that joined together to have impact on general expenses, we followed this study by taking the life time of software (Tak B. et al. 2011).

Buyya proposed Cloudsim: an extensible simulation toolkit that enables modeling and simulation of Cloud computing environments. The cloudsim toolkit supports modeling and creates one or more virtual machines (VMs) on a simulated node of a Data Center, jobs, and their mapping to suitable VMs. It also allows simulation of multiple Data Centers to enable a study on federation and associated policies for migration of VMs for reliability and automatic scaling of applications. We can use some parameters of this study as inputs in the cloudsim tools but not all other parameters (Buyya R. 2009).

Kornevs and Minkevica assessed Distributed computing and focused around financial measurements which represent some basic money related measurements, for example, CBA, ROI and TCO that represent how they could be connected to assess distributed computing. In this study, it was presented the methods to compute cost for cloud computing and in our study we took the prices of hardware and software for both cloud and traditional and the cost break-even point for both paradigms was presented (Kornevs M. and Minkevica V. 2012).

Boillat plan enterprise software's movement towards the cloud is still in its beginning. For software vendors, the move towards cloud computing implies deep changes in their value-creation logic. Not only are they required to deliver fully web-enabled solutions and to replace their license model with service fees, they also need to build the competencies to host and manage business-critical applications for their customers, they find that moving from on-premise software to cloud services affected on all business model components (Boillat T. and Legner C. 2013).

Walker examined the storage services in cloud computing used for leasing disk storage. A new modelling tool, formulated from empirical data that spanning many years, organizations rationally evaluate the benefit of using storage clouds versus purchasing hard disk drives. It was proposed a model to assist consumers, researchers, and policy makers in estimating the benefit of leasing from storage clouds, buying or leasing for an expected storage life of six years, the result shows storage life of less than four years and leasing is always best, and if the storage life more than four years, purchasing is the best solution. The difference with our study is by taking the storage cost only as a parameters and we uses the cost of other parameters for cloud and traditional to compute the hardware and software cost (Walker E. 2010).

Linlin introduces in chapter three from the Doctoral dissertation three algorithms for SaaS providers to maximize profit by minimizing cost and increase market part by increasing number of users requests, and the use of simulations is by taking VM price only in cloudsim and the results show large enhancement (up to 40%) for cost saving. The difference with our study is by taking cost of virtual machine as input parameters for cloud only, therefore we took cost of others parameters such as cost of software and hardware for cloud and traditional (Wu L. 2014).

Walker has observed issues related to the financial side of purchasing or leasing CPU hours by using the net present value concept. The reason of this work is to provide a methodology that can assist in deciding to buy or lease the CPU capacity from the organizations side by using Net Present Value as a method to calculate the cost for 10 years of hardware expect life time. The difference with our study is that computation of

the CPU hour cost only annually and we study the other parameters such as license cost of software, bandwidth and other parameters (Walker E 2009).

Mtebe and Raisamo has studied the adoption of cloud computing in higher educational in sub-Saharan countries. They presented the cost of hosting e-learning service between cloud-hosted and on-premise approaches in higher educations by taking Tanzania as a case study. The Total Cost of Ownership (TCO) represents the methods to compute the cost of cloud and on-premise, the cloud-hosted is better than on-primes approaches. The estimated cost is based on prices in Tanzania. The requirement of this study for one month with two server are four virtual machine, 30GB bandwidth, and 800GB hard drive. The difference with our studies is that we used other parameters such as license cost and software cost with different cases specifications (Mtebe, J. S., & Raisamo, R. (2014).

## **2.5 SUMMARY**

Based on previous studies; there are few studies to compute cost for cloud computing and to compare with traditional to moving to cloud computing, most of the studies used the TCO total cost of ownership in both model cloud computing and traditional paradigms, and amazon monthly calculator online to analyse cost in cloud computing, there is no model that available to compute cost in both cloud and traditional paradigms.

The next chapter provides the information about companies in cloud computing and traditional for three layer (SAAS, PAAS, IAAS), and extracts the data about the parameters that have effect on the cost for both paradigms, and proposes many formulas to compute cost in both paradigms.

## CHAPTER THREE

### The Cost Break-Even Model and Experiments

#### 3.1. Introduction

Several research have been reviewed to find out the cost in both cloud and traditional paradigms by using many methods such as Total Cost of Ownerships (TCO) and Net Present Value (NPV), taking into consideration total cost only. This chapter discusses how to define the main parameters that affect the cost of cloud and traditional paradigms as well as proposed many formulas for both paradigms to define the cost break-even model. Also, this chapter discusses the experiments details in order to generalize the results in different layers (SAAS, PAAS and IAAS) in both paradigms.

#### 3.2. The Cost Formulas

This section defines the main parameters that affect the cost for the purpose of determination of cost break-even point, so gathering information from many companies about prices was done, and then many formulas were built. These formulas will be used to calculate the cost for both paradigms, then these formulas will be used to find in which layer break- even point will be given in cloud and traditional computing; also these formulas can be used in any simulator model.

There are many companies that supply hardware and software for cloud and traditional; therefore this research was conducted on many companies to collect the prices with the following criteria:

- 1- These companies provide the prices for cloud and traditional.

- 2- These companies are global and set their prices in case of purchase or lease.
- 3- These companies provide software, hardware and multiple computing services through the internet.

The companies were chosen based on the previous criteria. However, these companies provided hardware and software such as:

1- Microsoft and Sage for software, one product was selected from these companies which is Customer Relationship Management (CRM) systems and these systems are a combination of people, processes, and technology that seek to provide understanding of a company's customer and to support a business strategy in the field of the relationship with customers. This software is a famous software and many enterprises using it (Nemecek J.&Vankova L. 2011 ).

There are many other companies that provide CRM such as Sales Force and Sugar but these companies provide cloud only; therefore Microsoft and Sage were selected as cloud and traditional are provided in them.

2- Microsoft Windows Azure, Google app engine, Rackspace and HP for hardware, many products were selected form these companies. These products such as servers, bandwidth, storage and operating system windows 2012 (Duipmans E and Pirres L 2012). These companies were selected because they provide resources to customers, and they are well-known companies that provide services to customers.

Depending on the above companies and their products, the prices were collected for several products from these companies. It was found that each product has a different way of computing the prices. For example Microsoft, the price of software has



been computed on monthly subscription and, in traditional we can purchase by paying the total cost and maintenance cost.

Due to the cost differences between each company and also in traditional in case of purchase, the life expects of time for products were considered, for the software. There are many studies that consider to the life expect for product such as (Tak B. et al 2011) study which presented the life expect of software for 10 years and, (Bucholtz, C. 2011) study which computed the total cost of software for 3 years.

For the hardware, (Han Y. 2011) study computed the cost of hardware for life expects 5 years. (Walker E 2009), study computed the cost of CPU hour for 10 years.

For these different units, we decided to compute the cost for cloud and traditional for an hour by taking the life expect of software for 3 years and hardware for 5 years.

We decided to use one hour as a basis for calculation. This is due to the fact that we can compute the price for other times units such as weeks, months, years and days. In all layers, we convert cost of HW, SW to one hour basis to be able to make comparison between two paradigms as shown in these formulas:

$$CC(h) = Total\ cost\ (M\ month) / (M * 24 * 30) \dots \dots \dots formula\ (1)$$

$$CT(h) = Total\ cost\ (N\ years) / (N * 24 * 365) \dots \dots \dots formula\ (2)$$

Where CC (h) cost of cloud computing in one hour. CT (h) cost of traditional in one hour. N: number of years. M: number of months.

The formula (1) converts the total cost in M months to hour by dividing the total cost to M months which is  $(M * 24 \text{ hours} * 30 \text{ days})$ . This formula is applied on all parameters in each layer in case of cloud computing. In this formula, we used M month because in cloud you will lease monthly and sometimes hourly.

The formula (2) converts the total cost for N years to hour by dividing the total cost to N years which as  $(N \text{ years} * 365 \text{ days} * 24 \text{ hours})$ . This formula is applied on all parameters in each layer in case of traditional. In this formula, we used N years because you will purchase the product for a certain time life period.

To be able to compute the cost for cloud and traditional, the cost was divided into three parts; each part will define the cost for hardware and software.

The following parts, will discuss the cost of each layer in details, will explain the main parameters, and will find the formula for each layer. Layer can be classified as follows:

## **1- Software as a Service**

This layer allows users to access application about Web browser. A customer is not buying any software, but pay for the use of the software as a subscription; therefore there is no cost of maintenance and investment in the applications. This term appears in cloud computing by providing many services via the Internet.

In this layer, we selected software from two companies such as CRM as mentioned previously, these companies offer different prices in both cloud and traditional. The mixing is not easy to compare the prices in both cloud and traditional,

In cloud, you have to pay monthly according to the number of users. While in traditional, you have to buy for the software and can use this software for certain of time; therefore we face a problem of how to compare the prices with each other so we decided to compute the cost on an hour basis as shown in previous formulas (1), (2).

The two companies for software provide CRM in different editions with different number of users. The details about offers for company's software are presented in the following sections.

- Regarding CRM in Microsoft, traditional introduces two editions, for unlimited users; however you pay for Client Access License (CAL) for each user with server fee and cost of maintenance. For limited user; there are five users the pricing of limited users; you pay one price for all users without purchase a (CAL) for users. In cloud, you do not pay for cost of maintenance and server fees, you only pay for number of users in a monthly subscription.
- Regarding CRM in Sage, traditional introduces two editions for unlimited users, you pay for (CAL) for each user with cost of maintenance. For limited user, there are 30 users. In the pricing of limited users, you pay for each user with less cost in case of unlimited users. In cloud, you do not pay for cost of maintenance and server fees, you only pay for number of users in monthly subscription. All prices of these two companies are available in website(1),(2),(3)<sup>1</sup>

<sup>1</sup> (1) Retrieved from: <http://crm.dynamics.com>. Date accessed 28/10/2014.

(2) Retrieved from: [Dynamics CRM 2013 On-Premises Licensing Guide](#)pdf. Date accessed 28/10/2014.

(3) Retrieved from:[www.blytheco.com/sagecrm/price.asp](http://www.blytheco.com/sagecrm/price.asp). Date accessed 31/10/2014.

The prices of these two companies are collected and presented in table (1) / appendix (1).

In this layer (SAAS), the parameter that affect the cost for cloud and traditional is number of user as stated previously for the two companies; in cloud you lease monthly and that depending on number of users. In traditional you purchase the Client Access License (CAL) for each user with cost of maintenance and server fee; therefore we formed two formulas as shown below:

$$CC(h)saas = CU(h) * \#U * T(h) \dots \dots \dots formula (3).$$

$$CT(h)saas = CS(h) * T(h) + \#U(h) * T(h) + CM(h) * T(h) \dots \dots \dots formula(4)$$

Where CC (h) saas: cost of cloud computing for software as a services in hour, CT (h) saas: cost of traditional in hour for software as a services, CU (h) cost of user in hour, #U number of user, T (h): time in hours, CS (h) cost of server fee in hour, CM (h) cost of maintenance in hour.

In the formulae (3) and (4) we took cost of maintenance, server fee and of user license and followed the formula (1) and (2) to convert these cost to hour, and multiplying by time T(h) as mention in formulae (3) and (4).

In formula (3) that related to cloud, we compute cost per user in a month and convert that cost to hour by using formula (1) then multiplying by number of users and time required because in cloud, we pay only to number of users. Where in the formula (4) that related to traditional we pay for licenses per user, server fee and maintenance cost after converting cost per each to one hour, then multiplying by number of required hour T (h). We used these formulas in SAAS layer for both cloud and traditional.

## 2- Platform as a Service

(PAAS) allows users to deploy their own applications under the provider's environment such as programming language, operating system and tools. In this layer, there are many companies that provide platform such as Microsoft which provides enterprise server and platform, and that company lets you build and run applications in both cloud and traditional and provides user to access from anywhere. Microsoft provides operating system platform such as windows server 2012 standard edition licenses and windows server 2012 datacenter edition licenses, that available in many editions so it is easy for customers to choose the right editions for their needs, the editions are as follows:

- Datacenter edition for highly-virtualized cloud environment.
- Standard edition for no virtualized or lightly environment.

Datacenter edition and standard edition differs only by virtualized rights, where two virtual instances for standard editions and unlimited virtual instances for datacenter editions. The prices of these editions are available in website <sup>(1)</sup>. We will use the prices of windows server 2012 for datacenter with unlimited virtualized. In cloud ,we do not need to purchase operating system license due to the provider provides the virtual machine with operating system and the provided bears the expenses of the cost of license for operating system. In traditional, we need to purchase operating system for datacenter edition with unlimited virtual instances and standard editions with two virtual

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(1) Retrieved from: <http://www.microsoft.com/en-us/server-cloud/windows-server/buy.aspx>, date access 24/9/2014.

instances. The parameter that affects the cost in traditional is the Client Access License (CAL) for operating system.

To be able to compute cost in cloud and traditional ,we formed one formula in this layer and the prices of these licenses are provided in table (1) /appendix (1).We will compute cost in cloud and traditional, depending on number of VM, the calculations will be based on the formula below:

$$CC(h)/CT(h)_{paas} = \#VM * CWL(h) * T(h) \dots \dots \dots formula(5)$$

Where CC (h)PAAS: cost of cloud computing for platform as a services in hour, CT (h)PAAS: cost of traditional in hour for platform as a services in hour, #VM: number of virtual machine, T (h) time in hour, CWL(h) cost of windows license for virtual machine.

Regarding cloud in formula (5), the cost of operating system is zero due to the lease of virtual machine and the cost of license is included in the virtual machines cost. Regarding traditional in formula (5), we will purchase windows edition license for every virtual machine and multiplying them by number of virtual machine and purchase for unlimited numbers of virtual machine.

### 3- Infrastructure as a Service

IAAS layer provides the storage, network, virtual machine and other computing resources as a service to customers about the internet. There are many companies that provide infrastructure (servers, storage, network), such as HP, Rackspace, windows azure and we selected these companies because they provide the infrastructure for both cloud and traditional.

In cloud, we collected data about virtual machine prices with specification of CPU and RAM, bandwidth and storage from many companies as shown in appendix (1)/ table (1), and website (1), (2),(3),(4)<sup>1</sup> these prices are in hour and per month. Therefore we will convert the cost per month to hour. Because the unit is in hour.

In traditional, we collected data about cost of server, bandwidth, internal hard drive, 20% of maintenance, cost backup server and cooling for server from many companies as shown in appendix (1), table (1), we converted the cost of server to hour by using formula (2), to compare with cloud prices, in cloud the cost of virtual machine is in hour as shown in appendix(1), table(1), we took cost for virtual machine with (1CPU and 1.75 RAM) specifications only because the cost with other virtual machine specifications are multiplied by numbers of CPU. For example cost of virtual machine with 4CPU is multiplied by the cost of 1CPU by 4, due to dependence on number of CPU in each virtual machine. Therefore we took one virtual machine with 1 CPU and 1.57 RAM. These formulas compute the cost of server and virtual machine as shown in formula (6) (7) below:

$$CVM(h) = \#VM * CVM(h) * T(h) \dots \dots \dots \text{formula (6)}$$

$$CSE(h) = \#SE * CSE(h) * T(h) + CM(h) * T(h) + CCO(h) * T(h) + CSB(h) * T(h) \dots \dots \text{formula (7)}$$

<sup>11</sup>(1) Retrieved from: <http://azure.microsoft.com/en-us/pricing/details/data-transfers>. Date access 21/10/2014.

(2) Retrieved from: <https://cloud.google.com/products/compute-engine>, Date accessed 21/10/2014.

(2) Retrieved from: <http://www.rackspace.co.uk> date accessed 28/10/2014.

(3) Retrieved from: <https://cloud.google.com/products/compute-engine/>, Date accessed 28/10/2014.

(4) Retrieved from: <http://azure.microsoft.com/en-us/pricing/details/data-transfers>. Date accessed 21/10/2014.

Where CVM(h): Cost of virtual machine in hour, #VM: number of virtual machine  
 T(h): time in hour, CVM: cost of VM per hour, CM(h) cost of maintenance in hour,  
 CCO(h): cost of cooling in hour, CSB(h) cost of backup server in hour, CSE (h): cost of  
 server in hour, #SE: number of server.

To compute the cost of bandwidth in traditional and in cloud , we take the cost of one GB per month, and convert it to one hour depending on formula (1), then multiplying by number of GB, and the required time is in hour T(h) as shown in formula (9):

$$CBW(h) = \#GB * CGB(h) * T(h) \dots \dots \dots formula (8)$$

Where CBW (h): cost bandwidth in hour, #GB: number of GB, T (h): time in hour,  
 CGB (h): cost of GB in hour.

In traditional and in term of bandwidth, we take the prices of bandwidth for zain company in Jordan, we convert the price from Jordanian Dinar (JOD) to United States Dollar (USD) by (1 JOD= 1.4108 USD), these prices are provided in website (1)<sup>1</sup>We compute price per GB by dividing on number of GB, for example 10 GB=25.51, cost per GB = 25.51/10=2.551 as shown in appendix (1). These prices are on monthly basis we compute on hour basis as shown in formula (1). In cloud, the average cost of many companies per GB is in month, these prices are presented in appendix (1)/ table(1). The prices are different by increasing the number of GB, where one more GB will lead to less cost of GB for two paradigms.

<sup>1</sup>(1)Retrieved from: <http://www.jo.zain.com/arabic/consumer/broadband/ZMAXOffers/Pages/default.aspx>, date accessed 28/10/2014.



To compute the cost of hard disk in traditional and storage in cloud computing, we took the average prices for many companies. The price for 1 GB is multiplied by number of GB then converting to hour by using formulas (1), (2).

In traditional, we took cost for hard disk (Lenovo 1-Inch 500 GB 2 MB Cache Internal Hard Drive 0A89473) from website <sup>(2)</sup><sup>1</sup>, the cost of this hard is 170\$ for two year, the cost of this hard disk for 5 years is about (425\$), we convert this price of hard disk to hour by using formula (1).

$$CSR(h) = \#GB * CGB(h) * T(h) \dots \dots \dots \text{formula (9)}$$

Where CSR (h) cost storage, #GB number of GB , T(h) time in hour, CGB (h) cost of GB in hour.

To compute cost of infrastructure in cloud and traditional; we sum the formula (6, 7, 8, 9) as follows:

$$CC(h)iaas = \sum CVM(h) + CBW(h) + CSR(h) \dots \dots \dots \text{formula (10)}.$$

$$CT(h)iaas = \sum CSE(h) + CBW(h) + CSR(h) \dots \dots \dots \text{formula(11)}.$$

Where CC (h)iaas :cost of infrastructure for cloud, CT(h)iaas :cost of infrastructure for traditional.

The average cost in cloud computing (ACC) is obtained from summation of formulas (3, 5, 10), and the average cost in traditional (ACT) is obtained from summation of formulas (4, 5, 11).

$$ACC = \sum CC(h)saas + CC(h)paas + CC(h)iaas \dots \dots \dots \text{formulae (12)}.$$

<sup>1</sup>(2) Retrieved from: <http://www.amazon.com/Lenovo-1-Inch-Cache-Internal>, date accessed 15/12/2014.



Case 5	CC5	100 users from Microsoft CRM and Sage CRM	Operating system windows license	128 virtual machine, 300 GB bandwidth, 500 GB storage.
	CT5	100 users from Microsoft CRM and Sage CRM, with server fee and maintenance cost.	Operating system license for unlimited virtual machine.	16 servers with 8 cores, 300GB bandwidth, 500GB internal hard drive. Cost of maintenance, cooling and backup server.

In table 3.1, we presented five cases for cloud and five cases for traditional in three layers, so we started with software, the pricing in SAAS layer is based on CRM in two companies and these companies know how many users' licenses, we took limited and unlimited numbers of users, server fee and maintenance cost. According to licensing viewpoint, the pricing in PAAS layer is based on operating system windows server 2012 standard edition with limited number of virtual machine, and datacenter edition is for unlimited number of virtual machine. For hardware, we took small virtual machine (a small VM consist of 1 CPU and 1.75 RAM), and physical servers with 8 cores, the cost of server out of average of many companies is shown in in appendix (1)/ table (1). For bandwidth, we took different numbers of GB in each case with different prices as shown in table (1) / appendix (1). For storage, we took 500GB for cloud and hard disk with 500GB for traditional.

In the first case, we took a few specifications in all layers with the expansion of the specifications in the other cases; to compare the results between cases in cloud computing and traditional.

The details about the cases are summarized as follows:

- SAAS: We started with software with limited and unlimited number of users, in cloud, the pay is on monthly basis and per each user, we used the formula (1) to convert this cost to hour due to that the used unit is in hour, In traditional the cost of license per user, cost of server fee and maintenance are converted to

hour by using formula (2), after converting to hour. The total cost of cloud in SAAS layer is provided by using formula (3) and (4).

- PAAS: For PAAS layer, the operating system that used mostly will be windows server 2012 therefore, our work will be based on windows 2012 standard and datacenter editions. In cloud ,the cost of operating system is (0\$) due to that the windows server 2012 license is included as a part of virtual machine price, in traditional we take the prices of license for two editions and convert them to hour by using formula (2). The total cost of cloud in PAAS layer is calculated by using formula (5).
- IAAS: For IAAS layer, we took numbers of virtual machine, the cost of these VMs is on one hour basis, and multiply that cost by numbers of VMs without converting to hour. The number of servers is multiplied by the cost of server for five years, which is calculated by using formula (2), converting this cost to hour, and then making a comparison between them. For bandwidth in cloud and traditional, the cost per GB is in month, by using formula (1) ,then converting to hour and using formula (8) to multiply the resulted value by number of GB and required time T(h). with regard to storage ,the cost is presented in one GB per month, we use formula (1) to convert to hour, and cost of hard dish for five years is obtained using formula (2) and that formula convert to hour then we use formula (9) and the resulted value will be multiplied by required time. The total cost for cloud and traditional in IAAS layer is provided by using formula (10) and (11).

In the following sections, we will deal with the details about the first case for three layer, the other cases are same as this case with different specifications.

### First case: Case Cloud1 (CC1) and Case Traditional1 (CT1)

In this case, we will compute the cost for hardware and software in each layer SAAS, PAAS and IAAS for both cloud and traditional paradigms, then we will compute the total cost for all layer. The cost of first case in cloud and traditional for three layers is illustrated as follows:

**SAAS layer:** The (table 3.2) show how to compute cost for SAAS layer for two CRM in case one for both paradigms.

**Table 3.2 Compute Cost of SAAS layer**

Parameters	Formula convert to hour for cloud and traditional	Formulas in each layer for required numbers of hours.
Cost per user for cloud (CU) \$65/user/month *5 user for CRM1  Cost per user for cloud (CU) \$69/user/month *5 user for CRM2	Formula (1)  $CC(h)CRM1 = 325/30*24 = \$0.451$  $CC(h)CRM2 = 345/30*24 = \$0.479$	Formula 3  $CC1(h)saas = \#U*CU(h)*T(h)$  $CC CRM1 = 0.451*720 = \$325$  $CC CRM2 = 0.479*720 = \$345$  Average cost of SAAS layer is $(325+345/2) = \$335$ per hour for one month.
Cost server fee(CS) (2,462\$) CRM1  Cost server fee(CS) (1,495\$) CRM2  Cost maintenance(CM) 20% (2,462*0.20)CRM1  Cost maintenance (CM)18% from total user cost (2,973*0.18)  Cost user licenses (CU=\$0) the cost of five users with the cost of server fee in this case only. CRM1  Cost user licenses (CU= \$595)	Formula (2)  $CS(h)CRM1 = 2,462/3*24*365 = \$0.094$  $CS(h)CRM2 = 1,495/3*24*365 = \$0.057$  $CM(h)CRM1 = 492/3*365*24 = \$0.056$  $CM(h) CRM2 = 536/3*365*24 = \$0.061$  $CU(h)CRM2 = 2,975/3*365*24 = \$0.113$	Formula (4)  $CT1(h)saas = \#U*CU(h)*T(h) + CS(h)*T(h) + CM(h)*T(h)$  $CT(h)$  $CT CRM1 = 0.094*720 + 0.056*720 = \$108$  $CT CRM2 = 0.057*720 + 0.061*720 + 0.113*720 = \$166$  Average cost of SAAS = $(108+166/2) = \$137$ per hour for one month

CRM2 *5 users		
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In the case cloud1 (CC1) for SAAS layer, from table 3.1, we will compute the cost of software (CRM) in cloud and traditional then obtained the prices form CRM in the mentioned two companies and the prices are provided in appendix (1) table (1), the first company is Microsoft Dynamic that has CRM. In cloud, you pay monthly subscription for each user, the cost of user is about \$65 for limited user, In this case, we will take 5 users, the cost of 5 users is about (\$325) by using formula (1) (this formula divided the total cost as (30 days\*24 hours). We convert this cost to hour, this cost in hour CU (h) is about (\$0.451), and the T (h) in all cases in one month and 24 hours is (720) by using formula (3). We multiply the CU (h) by T (h), this cost is about (\$325) and this cost for CRM in Microsoft Dynamic for limited users. The second company is Sage CRM. In cloud you pay monthly subscription for each user, the cost for one user is about \$69, in this case we will take 5 users, the cost for 5 user is about (\$345) by using formula (1)(this formula divides the total cost on (30 days\*24 hours), we convert this cost to hour, this cost in hour CU(h) is about (\$0.479) and the T (h) in all cases is one month and 24 hours is (720) by using formula (3) we multiply the CU(h) by T (h), this cost is about (\$345), and this is cost for Sage CRM of five users. The average cost of cloud of SAAS layer (CC (h) SAAS) for two companies is about (\$335). For unlimited user the cost for one user is about (\$30), for cases of more than 30 users for Sage CRM company. The cost per user is about (30\$) per user we took this cost for more than 5users for Microsoft dynamic CRM company.

In Traditional Case for the first company, the offer is for five users therefore you will pay only the cost of server fee and cost of maintenance, the cost of server fee is about (\$2,462) for three years, which is considered the standard life of a software by using formula (2) and which divides the total cost on (3years\*365days\*24hours). We

convert this cost to hour, the cost of server fee CS (h) is about (\$0.094). In traditional you pay the cost of maintenance; this cost is about 20% from total cost. The cost of maintenance (CM) is obtained by multiply server fee by 20% ( $2,462 \times 0.20$ ) which is (\$492), the cost CM(h) for three years in hour is about (\$0.056), the T (h) for one month and 24 hours is (720) by using formula (4), we multiple the CS(h) and CM(h) by T (h), this cost is about (\$108) for CRM in Microsoft Dynamic for five users.

Regarding traditional in CRM of Sage, you will purchase the license for each user and pay the server fee and cost of maintenance. The cost of server fee is about (\$1,495) for three years which is considered the standard life of a software by using formula (2) and by dividing the total cost on ( $3\text{years} \times 365\text{days} \times 24\text{hours}$ ). We convert this cost to hour, the server fee in hour CS (h) is about (\$0.057), the cost of license for one user (CU) is about (595\$), in this case we take 5 user; therefore we multiply the cost of one user by 5 users, this cost is about (\$2,975). By using formula (2), the cost for 5 users in hour CU (h) is about (\$0.113). In traditional, you pay the cost of maintenance, this cost is about 18% from the total cost; cost maintenance (CM) is obtained by multiplying the cost of 5 users (CU) by 18% ( $2,975 \times 0.18$ ) which is about (\$536), the cost CM(h) for three years in hour is about (\$0.061), the T (h) for one month is obtained by multiplying one month by 24 hours, which is (720) . by using formula (4) we multiply the CS(h) by T(h) and sum the resulted value with  $CM(h) \times T(h)$  and  $CU(h) \times T(h)$ , this cost is about (\$166) for CRM in Sage, the average cost for SAAS layer in traditional (CT(h)SAAS) for two companies is  $(\$108 + \$166 / 2) = (\$137)$ . For

**PAAS layer:** The (table 3.3) show how to compute cost for PAAS layer for operating system windows licenses in case one for both paradigms.

**Table 3.3 Compute Cost of PAAS layer**

Parameters	Formulas in each layer for required numbers of hours.	Formula convert to hour for cloud and traditional
The cost of operating system with cost of VM	Formula 1 $CC(h)=\$0$	Formula 5 $CC(h)=\$0$
Cost of limited virtual machine (\$440) *8 VM  Cost of unlimited virtual machine (\$6155)	Formula 2 $CT(h)= 440/3*24*365 =\$0.134$	Formula 5 $CT1(h)paas= \#VM*CWL(h)*T(h)$  $CT1 (h)paas= 0.134*720 = \$96$ per hour for one month.

Regarding cloud, from table 3.3, The (CC1) for platform as a services (PAAS) layer is about (\$0). in cloud, the cost of operating system is included with cost of renting virtual machine. The total cost in cloud (CC (h) PAAS) is 0.

The CT1 for platform is the cost of operating system Windows server 2012. The windows server 2012 is provided in two edition as mentioned previously, in this case we purchase the windows license for 8 virtual machine, the cost of one VM is (\$440), the cost of windows license for 8 VM in hour CWL(h) is about (\$0.134) by using the formula (5), this formula is obtained by multiply the CWL(h) by T(h)), then the total cost for 270 hour is (\$96) and this is the total cost for PAAS layer (CT (h)PAAS).

**IAAS layer:** The (table 3.4) show how to compute cost for PAAS layer for operating system windows licenses in case one for both paradigms.



Table 3.4 Compute Cost of IAAS layer

Parameters	Formulas in each layer for required numbers of hours.	Formula convert to hour for cloud and traditional
The cost of VM (0.08\$/h)* 8VM	Formula 1 $CC(h)=0.08*8= 0.64\$$	Formula 6 $CVM(h)=\#VM *CVM(h)*T(h)$ $=0.64*720=460\$$
The cost of BW per one GB=0.12\$/month, number of GB in case one 10 GB	Formula 1 $CC(h)=0.12*10/30*24=0.002$	Formula 8 $CBW(h)= \#GB*CGB*T(h)$ $=0.002 * 720 = 14.4\$$
Cost of storage per one GB =0.101\$/month, number of GB	$CC(h)=0.101*500/30*24=0.070$	Formula 9 $CSR(h)= CSR(h)*T(h)$ $=0.070*720=50.4$
		Formula 10 $CC(h)_{iaas}=\sum CVM(h)+CBW(h)+CSR(h)$ $=460+14+50=513\$$ per hour for one month.
Cost of server with 8 core is about (7,572\$)* one server	Formula 2 $CT(h)=7,572/5*365*24=0.173\$$	Formula 7 $CT1(h)=$ $\#SE(h)*T(h)+CCO(h)*T(h)+CSB(h)*T(h)$
The cost of BW per one GB=2.551\$/month, number of GB in case one 10 GB	Formula 1 $CT(h)= 2.551*10 /30*24$ $=0.035\$$	Formula 8 $CBW(h)= \#GB*CGB*T(h)$

<p>The cost of cooling is about (6000\$)</p> <p>Cost of backup server is about (7,572\$)</p> <p>Cost of maintenance 20% from total cost of server and backup server and cost of operating system 9,526\$=(440+7,572+7,7572*0.20)</p>	<p>Formula 2</p> $=6000/5*24*365=0.137\$$ <p>Formula 2</p> $=9.526/5*365*24=1.087$	<p>Formula 11</p> <p>CT1 (h)iaas= 0.173*720+0.137*720+1.087*720=1,163\$ per hour for one month.</p>
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Regarding (CC1) for infrastructure as a services (IAAS) layer, from table 3.4 we compute cost for renting virtual machine, Bandwidth and Storage, the renting of virtual machine per hour, the average cost for many companies is shown in appendix (1), the cost of 1VM with 1CPU and 1.75 RAM per hour is (\$0.08) . For 8VM, the cost in hour (CVM (h) is about (\$0.64). For bandwidth, the average of many companies is shown in appendix (1), the cost for one GB in month is (\$0.12).in this case we get 10 GB, the cost for 10 GB is about (\$1.2), the cost of bandwidth in hour CBW(h) is about (\$0.002). The cost of storage for one gigabyte in month from average companies is shown in appendix (1) and that cost is about (\$0.101). in all cases, we multiply 500 GB storage by cost for one gigabyte 500GB and dividing on (30day \*24 hour) by using formula (1) to get the cost of storage in hour CSO (h) and this about is (\$0.070). The total cost of cloud for infrastructure (CC (h) IAAS is about (\$513) by using formula (10), we compute the total cost of IAAS for 24 hour, by multiplying the (CVM (h)\*T (h) +CBW (h)\*T (h) + CSO (h) by T (h).

Regarding (CT1) for infrastructure as a services (IAAS) layer, we compute cost for purchasing servers, backup server, maintenance, cooling and bower consumption bandwidth and internal hard disk. Purchasing hardware is based on 5years which is considered as life of hardware. In this case, we will get one server and this cost is

about (\$7,572), we convert this cost by using formula 2 to convert the total cost for 5 years to hour. The cost of server (CSE(h) is about (\$0.1734) and it is the cost of this server that extracted from the average cost of many companies as shown in appendix (1) this server with 8 core in traditional . in cloud , we took 8VM and each one have 1CPU. For bandwidth in Zain prices in Jordan as shown in appendix (1), table (1), the cost for one GB in month is (\$2.551), in this case we get 10 GB, the cost for bandwidth for 10 GB in hour CBW (h) is about (\$0.035). The cost of internal hard disk is (\$425) by using formula (2) to get the cost of storage in hour CSO (h) and this is about (\$0.010). The cost of maintenance is 20% from total cost of server and license operating system and cost of number of servers and cost of backup server  $(440+7,572+7,572*0.20)$ , the cost of maintenance CM (h) in hour is about (\$0.223).

The cost of cooling and power is about (\$6000) and this cost for 5 years, the cost of cooling and power in hour CCP (h) is about (\$0.137) and the cost of backup server CBS is (\$7,572), this cost in hour CBS (h) is about (\$0.137).

The total cost for infrastructure in traditional (CT (h) IAAS) is about (\$541) by using formula (11), we compute the total cost of IAAS for 24 hour, by multiplying as follows:  
 $(CSE(h)*T(h)+CBW(h)*T(h)+CSO(h)*T(h)+CM(h)*T(h)+CBS(h)*T(h)+CCP(h)*T(h)$

In the final stage of the first case, we will compute the average of the three layer in both cloud and traditional by using formula (12), the average cost of cloud ACC is about (\$848) by summing the cost of CCsaas, CCpaas, CCiaas  $(335\$+0\$+513\$)$ . The average cost of traditional ACT is about (\$774) by summing the cost of CTSAAS, CTPAAS, CTIAAS  $(\$137+\$96+\$541)$ .

### 3.4 Summary

In this chapter, we proposed many formulae in cloud and traditional, and described the parameters that affect the cost for both paradigms.

To define the main parameters, we presented many companies in three layer to compare between cloud and traditional, and extracted the prices from these companies. Then we found the parameters in each layer.

We described the cases specifications that we presented to know the parameters and to find cost for hardware and software.

In chapter four, we will present the results of these cases, and then we will define the effect of these parameters on cost and the break-even point in these cases.

## CHAPTER FOUR

### RESULTS AND ANALYSIS

#### 4.1. Introduction

This chapter discusses the results of the cases that were explained in chapter three. The results have shown the differences between cloud and traditional cost in each layer, under different data. This analysis explains break-even in SAAS layer, including the different cases in cloud and traditional, which had been explained in details in the previous chapter. Moreover, we conducted analyses of the results that are related to the difference for all cases in all layers for both paradigms.

#### 4.2 Cases Results

In order to find break-even point for both cloud and traditional, many cases are executed in cloud and traditional. The prices for many companies were taken while executing cases for these companies. The cases are categorized into SAAS, PAAS, and IAAS layers. The extracted results are represented the average of 80 cases for both cloud and traditional.

The results in this chapter will be discussed as follows:

- Discuss the cost break-even point for cloud and traditional in SAAS layer.
- Discuss the cost of hardware/ software in cloud and traditional in PAAS, IAAS layer.
- Average cost for all cases in all layers for cloud and traditional.

### 4.3 Cost of Cloud and Traditional over Different Cases.

In this section, we will discuss the results for SAAS, PAAS and IAAS layer in cloud and traditional

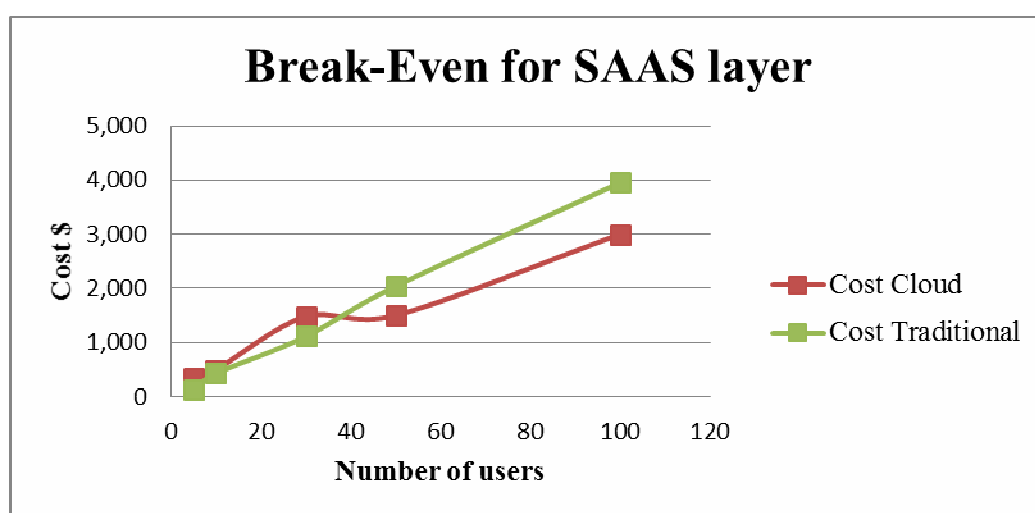
#### 4.3.1 Results of Cloud and Traditional in SAAS Layer

From SAAS cost, the main aim behind testing this layer; is to find the parameters affecting the cost in both paradigms. Table 4.1 shows the results of SAAS layer for average of two companies. The details about results for the cases are shown in appendix (1)/ table (2).

**Table 4.1 SAAS Results for Cloud and Traditional**

Layer	Software as a services		
Cases	Number of user (#U)	Cost Cloud CC	Cost Traditional CT
Case1	5	\$335 per hour	\$137 per one month
Case2	10	\$459 per hour	\$429 per one month
Case3	30	\$1,485 per hour	\$1,111 per one month
Case4	50	\$1,500 per hour	\$2,037 per one month
Case5	100	\$3000 per hour	\$3,953 per one month

These results show the difference in cost after executing many cases in this layer. In case one, two and three, the cost of traditional is best than cloud. In case four and five, the cost of cloud is best than traditional. The number of users has an effect on both paradigms, when the number of users increased the cost increased too in both paradigms, and the cost of cloud is better than traditional when the number of user unlimited due to the affect of many parameters such as (license per user, and cost of maintenance) in traditional, but in cloud the cost of leasing is per user only, therefore the cost in cloud is lesser than traditional and break-even is obtained when the number of user is limited. Figure 4.1 shows the break-even point for cloud and traditional in SAAS layer



**Figure 4.1 Break-Even for SAAS layer.**

Figure 4.1, summarized the results of cases for SAAS layer, the break-even point is obtained when number of users is less than 40 user, and the cost of traditional is less than cloud due to the cost of limited number of users which is less than unlimited users and the cost of maintenance is less too. For unlimited number of users the cost of cloud become less than traditional due to that the cost of cloud is less per user only. It is

expected that the cloud computing is best because of the cost of maintenance and server fees borne by the provider of cloud computing.

### 4.3.2 Results of Cloud and Traditional in PAAS and IAAS Layer

From PAAS and IAAS cost, the main aim behind testing this layer; is to determine the effect of many parameters on cost in both paradigms. The average of results for cost of operating system license and servers, bandwidth for many companies in these layers are shown in Table 4.2 which represents the results of PAAS and IAAS layer for average of many companies. The details about cases are shown in appendix (1)/table (3).

**Table 4.2 PAAS and IAAS Results for Cloud and Traditional**

Layer	Platform as a services		Infrastructure as a services	
Cases	Cost Cloud CC	Cost Traditional CT	Cost Cloud CC	Cost Traditional CT
Case1	0	96	\$513 per hour	\$541 per one month
Case2	0	193	\$977 per hour	\$1,920 per one month
Case3	0	169	\$1,382 per hour	\$3,916 per one month
Case4	0	169	\$3,751 per hour	\$6,971 per one month
Case5	0	169	\$7,459 per hour	\$13,575 per one month

These results show the difference in cost after executing many cases in these layers. we get number of virtual machine, servers, operating system license, number of GB bandwidth with 500 GB storages mentioned in chapter three for IAAS layer, but in PAAS the cost of operating system is (\$0) because when you lease the virtual machine, the price of operating system is included but in traditional when you purchase server you will purchase operating system license for number of VM that you need to make



virtualization on the server. The cost of cloud is best than traditional in all cases in these two layers. the cost of maintenance , cooling and backup server in traditional is higher, but in cloud you pay only the cost of leasing and the provider is responsible about cost of maintenance ,cooling and responsible also about backup for the data. Therefore the cost in cloud is better than traditional. In these two layers, the break-even point for cloud and traditional cannot be obtained because the cost of traditional always is higher than cloud. The cost of maintenance, cooling and license are other parameters that affect the cost in traditional, when the number of server, number of GB for bandwidth and cost of storage increased the cost increased too in both paradigms, but the cost of cloud is lesser than traditional and break-even cannot be obtained for the two layers. Figure 4.2 shows the chart for cost of cloud and traditional in PAAS, IAAS layer.

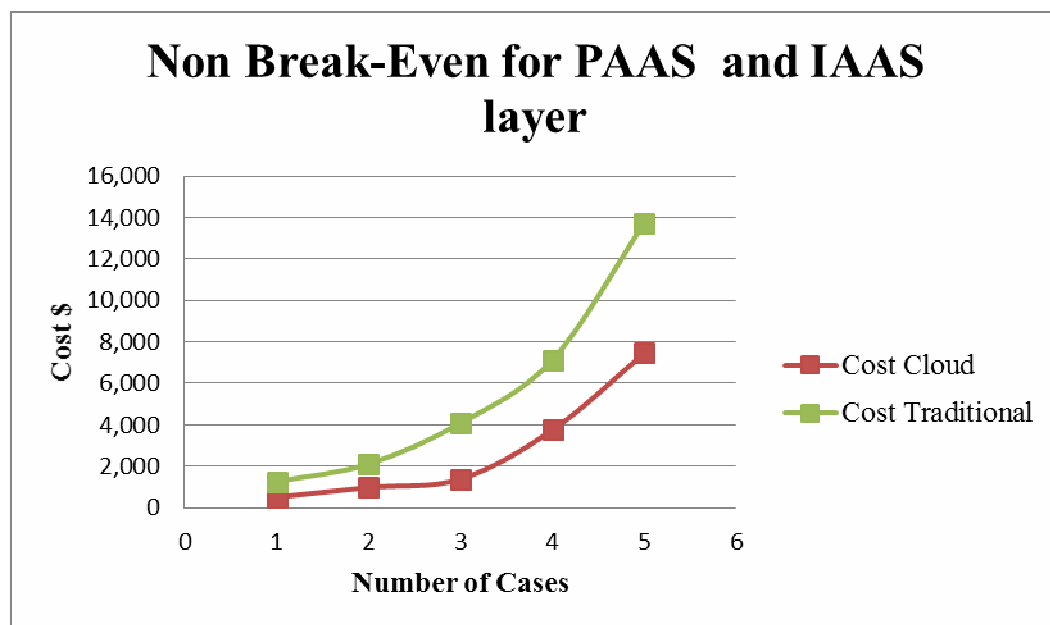


Figure 4.2 Non Break-Even for PAAS and IAAS layer

In the figure 4.2, we note that cost traditional is always higher than cloud. The cost cloud is better than traditional in PAAS and IAAS layer. It is expected to be the best

cloud computing due to the affect of cost of license ,maintenance and cooling in traditional, because of the cost of maintenance and server fees borne by provider of cloud computing.

### 4.3.3 Average Results of Cloud and Traditional in Three Layers for all Cases:

Table 4.3 shows the average for all cases results in all layers for cloud and traditional as well as differences between them.

**Table 4.3 Average Results for Cloud and Traditional for all cases**

Layer	Software as a services		Platform as a services		Infrastructure as a services		Average cost cloud	Average cost traditional	Difference
	Cost Cloud CC	Cost Traditional CT	Cost Cloud CC	Cost Traditional CT	Cost Cloud CC	Cost Traditional CT	(ACC)	(ACT)	ACC-ACT
Case1	335	137	0	96	513	1,163	848	1,397	-549
Case2	459	429	0	193	977	1,920	1,472	2,542	-1,069
Case3	1,485	1,111	0	169	1,901	3,916	3,386	5,195	-1,809
Case4	1,500	2,037	0	169	3,751	6,971	5,251	9,177	-3,926
Case5	3000	3,953	0	169	7,459	13,575	10,459	17,697	-7,238
Case 6	335	137	0	96	513	1,163	848	1,397	-549
Case 7	459	429	0	96	513	1,163	1,008	1,688	-681
Case 8	1,485	1,111	0	96	513	1,163	1,998	2,370	-373
Case 9	1,500	2,037	0	96	513	1,163	2,013	3,297	-1,284
Case 10	3000	3,953	0	96	513	1,163	3,513	5,213	-1,700
Case 11	335	137	0	193	977	1,920	1,312	2,250	-938
Case 12	459	429	0	193	977	1,920	1,472	2,542	-1,069

Case 13	1,485	1,111	0	193	977	1,920	2,462	3,223	-761
Case 14	1,500	2,037	0	193	977	1,920	2,477	4,150	-1,673
Case 15	3000	3,953	0	193	977	1,920	3,977	6,066	-2,089
case16	335	137	0	169	1,901	3,916	2,236	4,222	-1,986
Case 17	459	429	0	169	1,901	3,916	2,369	4,513	-2,118
Case 18	1,485	1,111	0	169	1,901	3,916	3,386	5,195	-1,809
Case 19	1,500	2,037	0	169	1,901	3,916	3,401	6,122	-2,721
Case 20	3000	3,953	0	169	1,901	4,901	4,901	8,038	-3,137
Case 21	335	137	0	169	3,901	6,971	4,086	7,277	-3,191
Case 22	459	429	0	169	3,751	6,971	4,246	7,569	-3,323
Case 23	1,485	1,111	0	169	3,751	6,971	5,236	8,251	-3,015
Case 24	1,500	2,037	0	169	3,751	6,971	5,251	9,177	-3,926
Case 25	3000	3,953	0	169	3,751	6,971	6,571	11,093	-4,342
Case 26	335	137	0	169	7,459	13,575	7,794	13,881	-6,087
Case 27	459	429	0	169	7,459	13,575	7,954	14,172	-6,218
Case 28	1,485	1,111	0	169	7,459	13,575	8,944	14,854	-5,910
Case 29	1,500	2,037	0	169	7,459	13,575	8,959	15,781	-6,822
Case 30	3000	3,953	0	169	7,459	13,575	10,459	17,697	-7,238
Case 31	335	137	0	0	0	0	335	137	-198
Case 32	137	495	0	0	0	0	495	429	-66
Case 33	495	429	0	0	0	0	1,485	1,111	-374
Case 34	429	1,485	0	0	0	0	1,500	2,037	-537
Case 35	1,485	1,111	0	0	0	0	3,000	3,953	-953
Case 36	0	0	0	96	513	1,163	513	1,259	-747
Case 37	0	0	0	139	1,163	977	977	2,113	-1,136
Case 38	0	0	0	169	977	1,920	1,901	4,084	-2,184
Case 39	0	0	0	169	1,920	1,901	3,751	7,140	-3,389
Case 40	0	0	0	169	1,901	3,916	7,459	13,744	-6,284

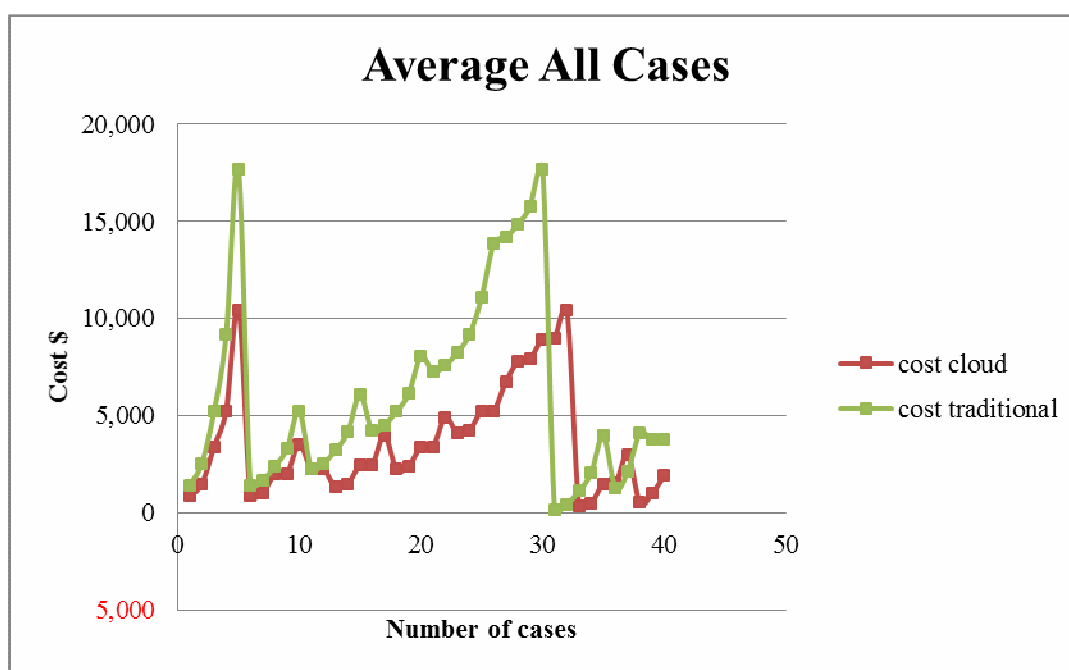
In table 4.3, the average cost for cloud is lesser than traditional in all cases. In order to answer the causes of these results. The following points illustrate the results for many cases:

- For SAAS layer the cost of cloud is better than traditional for unlimited users, for example the case (14) for SAAS layer, the cost of cloud is about (\$1,500) and in traditional the cost is about (\$2,037) ,due to that in this case there are 50 users, each user is 30\$ in cloud you only pay the cost for 50 user only, but in traditional you pay license per user which is about (\$983) and 20% cost of maintenance from total cost of 50 users. In all cases for SAAS layer we notice that the cost of cloud is better than traditional and the number of users affects the cost for both paradigms but the cloud is lesser in cost comparing to traditional. So the best choice is cloud computing.
- For PAAS layer, the cost of cloud is (\$0) and the cost of traditional has different costs, this layer does not affect the total cost for both paradigms. Because the cost of operating system license is lesser than the cost of hardware and software in the other layers.
- For IAAS layer, the cost of cloud is better than traditional, for example case (26), in this case the cost of hardware for cloud is about (\$7,459) and for traditional the cost of hardware is about (\$13,575), the cost of traditional is higher than cloud because the cost of 16 server with one backup server and cooling and maintenance is very higher comparing with cloud. Therefore, the cloud is best than traditional in term of cost.

- For Average of cost cloud and average of cost traditional, we found the average cost in cloud computing is always lesser than traditional computing, and more layers impact on the total cost of hardware in the infrastructure as a service layer for traditional.
- cases (6,7,8,9, and 10) , we presented the results for five cases of SAAS layer with the results of case 1 for PAAS and IAAS layer with 8VM and 10GB bandwidth and 500GB storage.
- cases (11,12,13,14, and 15), we presented the results for five cases of SAAS layer with the results of case 2 for PAAS and IAAS layer with 16 VM with 50GB bandwidth and 500 GB storage.
- cases (16,17,18,19, and 20) , we presented the results for five cases of SAAS layer with the results of case 3 for PAAS and IAAS layer with (32 VM with 100GB bandwidth and 500 GB storage.
- cases (21,22, 23,24, and 25), we presented the results for five cases of SAAS layer with the results of case 4 for PAAS layer with 64 VM with 200GB bandwidth and 500 GB storage.
- cases (26, 27, 28, 29, and 30), we presented the results of five cases of SAAS layer with the results of case 5 for PAAS and IAAS layer with 128 VM with 200GB bandwidth and 500GB storage.
- Case (31, 32, 33, 34, and 35) , we presented the results for SAAS layer only.
- Cases (36, 37, 38, 39, and 40), we presented the results for PAAS and IAAS layer only.

We can conclude in this chapter that the cost for cloud will be best in all layers. The more details about the cases are shown in table (3,4) in appendix.

Figure (4.3) shows the average for all case that presented in table 4.3



**Figure 4.3 Average Results for Cloud and Traditional for all cases**

Figure (4.3) shows the average cost between both paradigms for all cases, this figure shows the 80 cases for both cloud and traditional. We note in all cases the cloud is better than traditional in term of cost of hardware and software in all layers.

#### 4.4 Discussions

There are some models that support organization in analyzing cost such as:

- 1- **Amazon monthly calculator**, this model considered static and do not consider dynamic in using cloud computing. Therefore, it is used to define the static parameters to compute cost.
- 2- **Cloudsim**: is a famous tool support for modeling and simulation of large cloud computing environments, including datacenters on single computing node (kumar R. and Sahoo G. 2014)

This tool shows how to create data center with numbers of host, in each host there are numbers of virtual machine, clouds define the cost of processing, cost of using memory and bandwidth for each virtual machine (Calheiros R. et al. 2010), the cost of processing, memory and bandwidth use in this tool are inputs for cost, and do not provide the total cost of these resources. Therefore we do not use this tool.

- 3- **System dynamic**: this tool is used to study the behavior of the complex system, we can use this tool by using the formulas mentioned in this thesis and then we can obtain the same results.

We propose several formulas for cost analysis of cloud and traditional paradigms. These formulas can be used in any simulator model in order to define the cost of cloud and traditional as well as to analyze the different scenarios before transferring them into real world. These formulas:

- 1- Formula for cloud computing that converts the cost per month to hour:

$$CC(h) = \text{Total cost (M month)} / (M * 24 * 30) \dots \dots \dots \text{formula (1)}.$$

Where CC (h): cost of cloud in hour. M: numbers of months.

2- Formula for traditional that converts the total cost per number of years to hour:

$$CT(h) = \text{Total cost (N years)} / (N * 24 * 365) \dots \text{formula (2)}$$

Where CT (h): cost of traditional in hour. Y: numbers of years.

3- Formula for cost of software for cloud computing(SAAS):

$$CC(h)_{saas} = CU(h) * \#U * T(h) \dots \text{formula (3)}$$

Where CC (h)<sub>saas</sub> cost of software for cloud. CU(h): cost of user per hour. T (h): required time in hour.

4- Formula for cost of software for traditional(SAAS):

$$CT(h)_{saas} = CS(h) * T(h) + \#U * CU(h) * T(h) + CM(h) * T(h) \dots \text{formula(4)}$$

Where CC (h)<sub>saas</sub> cost of software for cloud. CU (h): cost of user per hour. T (h): required time in hour. CM (h): cost of maintenance.

5- Formula for cost of operating system for traditional(PAAS):

$$CC/CT(h)_{paas} = \#VM * CWL(h) * T(h) \dots \text{formula (5)}$$

Where the #VM: number of virtual machine. CWL (h): cost windows license in hour.

6- Formula for cost of VM for cloud(IAAS) layer:

$$CVM(h) = \#VM * CVM(h) * T(h) \dots \text{formula(6)}$$

Where #VM: number of virtual machine. CVM (h): cost of virtual machine in hour.

7- Formula for cost of server for traditional(IAAS)layer:



**$SE(h) = \#SE * CSE(h) * T(h) + CM(h) * T(h) + CCO(h) * T(h) + CSB(h) * T(h) \dots \text{formula}$**

**(7).**

Where #SE: number of server. CSE (h): cost of server in hour CCO (h): cost of cooling. CSB: cost backup server. CM (h): cost of maintenance.

8- Formula to find cost of bandwidth in hour(IAAS):

**$CBW(h) = \#GB * CGB(h) * T(h) \dots \text{formula (8)}$**

Where CBW (h): cost bandwidth in hour. #GB: number of gigabytes. CGB: cost per GB in hour.

9- Formula to find cost of storage in hour(IAAS):

**$CSR(h) = \#GB * CGB(h) * T(h) \dots \text{formula (9)}$**

Where CSR (h): cost storage in hour. #GB: number of gigabytes. CGB: cost per GB in hour.

10- Formula to find cost of (IAAS) layer:

**$CC(h)_{iaas} = \sum CVM(h) + CBW(h) + CSR(h) \dots \text{formula (10)}$**

**$CT(h)_{iaas} = \sum CSE(h) + CBW(h) + CSR(h) \dots \text{formula (11)}$**

These two formula are extracted from sum of formula (6,8,9) for cloud , and formula (7,8,9) for traditional.

11- Formula to find the Average Cost Cloud (ACC) and Average Cost

Traditional(ACT):

**$ACC = \sum CC(h)_{saas} + CC(h)_{paas} + CC(h)_{iaas} \dots \text{formula (12)}$**

$$ACT = \sum CT(h)_{saas} + CT(h)_{paas} + CT(h)_{iaas} \dots \dots \dots \text{formula(13)}$$

Where ACC: is sum of formula 3, 5, 10, ACT and sum formula 4, 5, 11.

#### 4.5 Contribution to Knowledge

After conducting this research, several contributions were reached. This research contributes in defining the most important parameters that affect the cost for cloud computing and traditional paradigm, and it also contributes in defining the relationship between these parameters, the formulas had been proposed to compute the total cost for both models, these formulas can be used in any simulations models, after series of testing and experiments of studying the effect on several parameters, and break-even model can be built , as a result we could obtain this point and define these parameters.

We can summarize the points as follows:

- Survey the field of cost in cloud computing and traditional.
- Studying the impact of several parameters in cost-cloud and cost-traditional.
- We found most of the cases have a cloud less than traditional, and the break-even point can be obtained only in the case of limited users in SAAS layer.
- Propose many formulas to compute cost in cloud and traditional.
- These formulas could be used in existing tool such as system dynamics, and we can use them in this tool and any another simulators.
- We found that the payment methods do not affect the cost because we use one measure for measuring hours, and when there are multiple price for number of hours and number of months and number of years, we find the same result.

#### 4.6 Discussion the Results:

The benefits from this research are to identify the main parameters that affect the cost for both cloud and traditional and to find break-even point between them by searching on many prices for hardware and software. Hence, the findings of this research were summarized in recommendations as follows:

- From software cost, it is recommended to select traditional when number of users is limited only. But in case of unlimited user the cloud is better.
- From hardware cost, it is recommended to select cloud in all cases due to the cost of hardware, cost of maintenance; cooling and power are higher in cloud. The cost in leasing hardware is better than purchasing in traditional.
- Moving to cloud today is attractive in term of saving money, in addition to the providers have multiple data center in different regions therefore one can avoid many factors such as software and hardware failure, natural disasters and network failure and human errors.
- This research can offer the best in cloud than traditional. It is recommended that the companies starting a new business to use cloud computing because it saves money and reduce many parameters that affect negatively on cost.
- It was founded there is no simulator to simulate the cost for both cloud and traditional, and these formulas can be used for any another simulator to define these parameters.

## CHAPTER FIVE

### CONCLUSION AND FUTURE WORK

#### 5.1. Conclusion

The general purpose of this thesis is to study the main parameters that affect the cost for both cloud computing and traditional paradigms, and to define the cost break-even model in three layers for SAAS, PAAS and IAAS.

This study is based on providing the formulas for both paradigms. We found that most cases which have cloud is less than traditional, and the break-even point is obtained only in the case of limit users in SAAS layer. Also we defined the parameters that affect the cost for cloud and traditional. The simulation model was carried out to calculate the cost break-even model in three layers with different cases.

The main outcome showed that there is cost break-even model only is SAAS layer. In addition, the outcomes of this study presented the parameters such as number of users, client access license and cost on maintenance that affect on cost in both paradigms.

In summary, the result and point of this research is the work related to analysis and previous studies in cloud computing field for facilitating the cost computation for

cloud and traditional as well as to help those parties who are interesting in this kind of work and be their future reference.

## **5.2. FUTURE WORK**

Future work needs to be conducted; we suggest a few studies in the future:

- 1- Using these formulas for research in any other simulation models.
- 2- Studying more parameters to compute the cost and know its effect on cost in both cloud and traditional paradigms such as database cost for platform as services.

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## Appendix

**Table 1 - Companies and its prices in cloud paradigm and traditional paradigms**

Layers	Company name	Companies edition	Prices in traditional	Prices	Companies edition	Prices in cloud	Prices
SAAS	Microsoft dynamics CRM	Workgroup server 2013 edition(limited 5 user)	Server fee maintenance 25% from total server fee	2462\$	Microsoft dynamics online SAAS	One User cost	65\$/user/month(limited) 30\$/user/month(unlimited)
		Server 2013 edition (unlimited user)	Server fee User (CAL) Maintenance 25% from total numbers of user	4922\$ 983\$	Microsoft dynamics online SAAS	One user cost Only	65\$/user/month(limited) 30\$/user/month/unlimited
	Sage CRM	Sage CRM 100 edition (limited user 30 user)	Server fee User (CAL) Maintenance 18% from total number of users	1495\$ 595\$	Sage CRM.com	One user cost Only	69\$/user/month limited 30\$/user/month(unlimited)
		Sage CRM 200 edition (unlimited)	Server fee User (CAL) Maintenance 18% from	3995\$ 795\$	Sage CRM.com	One user cost Only	69\$/user/month(limited) 30\$/user/month /unlimited

Layers	Company name	Companies provided operating system	Prices in traditional	Prices	Companies	Prices in cloud	Prices
PAAS	Microsoft	Windows 2012 Standard editions	2VM	880\$	.....	.....	.....
	Windows 2012	Datacenter editions	Cost of operating system datacenter license	6155\$	.....	.....	.....
Layers	Company name	Companies provide server	Prices in traditional	Prices	Companies provide VM	Prices in cloud	Prices
IAAS	Dell	Dell power edge R520	6,689\$		Microsoft Azure	VM(small) 1 CPU, RAM (1.75GB)	0.08\$/hour, 60\$/month, 720\$/year
		Dell server R 720 intel Xeon with 8 core	6,000\$				
	HP	HP proiant DL380	9,100		Google app engine	VM(small) 1CPU, RAM (1.75GB)	0.07\$/hour,53\$/month, 636\$/year
		Proliant DL 360p GEN 8, HP	8,500\$				
			Average	7,572\$		Average	Average VM (1 CPU)
	Company name	Companies	Prices in traditional	Prices		Prices in cloud	Price

	bandwidth			provide bandwidth		
Zain	1GB 5GB	7.09\$/per GB/month 2.834\$/per GB/month		Windows azure	10GB,40 GB, 100GB,350TB	0.12\$/GB/month .09\$/GB/month 0,07\$/GB/month, 0.05\$/GB/month
	7GB 10GB	2.834\$/per GB/month 2.551\$/per GB/month		Rackspace	10GB,40 GB, 100GB,350TB	0.12\$/GB/month, 0.10\$/GB/month 0,07\$/GB/month, 0.05\$/GB/month
	50GB 90GB	0.708\$/per GB/month 0.600\$/per GB/month		HP	10GB,40 GB, 100GB,350TB	0.12\$/GB/month, 0.09\$/GB/month 0,07\$/GB/month, 0.05\$/GB/month
	100GB	0.68\$/per GB/month		Average	10GB,40 GB, 100GB,350TB	0.12\$/GB/month, 0.09\$/GB/month 0.07\$/GB/month, 0,05\$/GB/month
Company name	Companies provide hard disk	Prices in traditional	Prices	Companies provide storage	Prices in cloud	Price
Lenovo	Lenovo 500GB internal hard disk	170\$/2 years support		Windows azure	0.12\$/per GB/hour	
				Rackspace	0.12\$/per GB/month	
				HP	1.10\$/per GB/month	
				Average	0.101\$/GB/mont h	

Table 2- Results for five cases in SAAS layer

	SAAS																			
	# U	CS(y)	CS(h)	CU(y)	CU*#U	CU(h)	CM(Y) 20%	CM(h)	T(h)	CC(h)1& CT(h)1 microsoft	#U	CU(Y)	CU(3Y)	CU(h)	CS(y)	CS(h)	CM(y) 18%	MC(h)	CC(h) & CT(h) " sage CRM"	average SAAS
CC1	5	0	0.000	65	325	0.45 1	0	0.000	720	325	5	69	345	0.479	0	0.00 0	0	0.00 0	345	335
CT1	5	2,462	0.094	0	0	0.00 0	492	0.056	720	108	5	595	2,975	0.113	1,49 5	0.05 7	536	0.06 1	166	137
CC2	10	0	0.000	30	300	0.41 7	0	0.000	720	300	10	69	690	0.958	0	0.00 0	0	0.00 0	690	495
CT2	10	4,922	0.187	983	9,830	0.37 4	1,96 6	0.224	720	566	10	595	5,950	0.226	1,49 5	0.05 7	1,071	0.12 2	292	429
CC3	30	0	0.000	30	900	1.25 0	0	0.000	720	900	30	69	2,070	2.875	0	0.00 0	0	0.00 0	2,070	1,485
CT3	30	4,922	0.187	983	29,490	1.12 2	5,89 8	0.673	720	1,428	30	595	17,850	0.679	1,49 4	0.05 7	3,213	0.36 7	794	1,111
CC4	50	0	0.000	30	1,500	2.08 3	0	0.000	720	1,500	50	30	1,500	2.083	0	0.00 0	0	0.00 0	1,500	1,500
CT4	50	4,922	0.187	983	49,150	1.87 0	9,83 0	1.122	720	2,289	50	795	39,750	1.513	3,95 5	0.15 0	7,155	0.81 7	1,785	2,037
CC5	100	0	0.000	30	3,000	4.16 7	0	0.000	720	3,000	100	30	3,000	4.167	0	0.00 0	0	0.00 0	3,000	3,000
CT5	100	4,922	0.187	983	98,300	3.74 0	19,6 60	2.244	720	4,444	100	795	79,500	3.025	3,95 5	0.15 0	14,31 0	1.63 4	3,463	3,953



**Table 3- Results for five cases in PAAS and IAAS layer**

PAAS					IAAS																	
	# VM	COST WIN	CWL	CC(h)p aas & CT(h)pa as	CVM & CSE	#VM \$ #SE	CVM*# vm	CVM(h) & CSE(h)	band width / GB/month	# GB	CBW(h)	cost storage & hard disk	#GB	CSO(h)	cost maintenance	CM(h)	cost backup server	CBS(h)	cost cooling & power	CCO (h)	PAAS +IAAS	CC(h) & CT(H) IAAS
CC1	0	0	0.000	0	0.08	8	1	0.640	0.120	10	0.002	0.101	500	0.070	0	0.000	0	0.000	0	0.000	513	513
CT1	8	440	0.134	96	7,572	1	7,572	0.173	2.551	10	0.035	425.000	1	0.010	9,526	1.087	7,572	0.173	6,000	0.137	1,259	1,163
CC2	0	0	0.000	0	0.08	16	1	1.280	0.100	50	0.007	0.101	500	0.070	0	0.000	0	0.000	0	0.000	977	977
CT2	16	440	0.268	193	7,572	2	15,144	0.346	0.708	50	0.049	425.000	1	0.010	17,098	1.952	7,572	0.173	6,000	0.137	2,113	1,920
CC3	0	0	0.000	0	0.08	32	32	2.560	0.070	100	0.010	0.101	500	0.070	0	0.000	0	0.000	0	0.000	1,901	1,901
CT3	1	6155	0.234	169	7,572	4	30,288	0.692	0.680	100	0.094	425.000	1	0.010	37,957	4.333	7,572	0.173	6,000	0.137	4,084	3,916
CC4	0	0	0.000	0	0.08	64	5	5.120	0.070	200	0.019	0.101	500	0.070	0	0.000	0	0.000	0	0.000	3,751	3,751
CT4	1	6155	0.234	169	7,572	8	60,576	1.383	0.680	200	0.189	425.000	1	0.010	68,245	7.791	7,572	0.173	6,000	0.137	7,140	6,971
CC5	0	0	0.000	0	0.08	128	10	10.240	0.120	300	0.050	0.101	500	0.070	0	0.000	0	0.000	0	0.000	7,459	7,459
CT5	1	6155	0.234	169	7,572	16	121,152	2.766	2.551	300	1.063	425.000	1	0.010	128,821	14.706	7,572	0.173	6,000	0.137	13,744	13,575

Table 4- Results for all cases in PAAS and IAAS layer

PAAS					IAAS																	
	#V M	COST WIN	CWL	CC(h) paa &C T(h) paa	CVM &CSE	#V M \$ #S E	CVM *#v m	CV M(h) &C SE(h)	band widt h/ GB/ mon th	#GB	CBW(h)	cost storage & hard disk	#GB	CSO(h)	cost mainte nance	CM(h)	cost backup server	CBS(h)	cost cooling & power	CCO (h)	PAAS+I AAS	CC(h) & CT(H)IAA S
CC1	0	0	0.000	0	0.08	8	1	0.64 0	0.12 0	10	0.002	0.101	500	0.070	0	0.000	0	0.000	0	0.000	513	513
CT1	8	440	0.134	96	7,57 2.00	1	7,57 2	0.17 3	2.55 1	10	0.035	425.00 0	1	0.010	9,526	1.087	7,572	0.173	6,000	0.137	1,259	1,163
CC2	0	0	0.000	0	0.08	16	1	1.28 0	0.10 0	50	0.007	0.101	500	0.070	0	0.000	0	0.000	0	0.000	977	977
CT2	16	440	0.268	193	7,57 2.00	2	15,1 44	0.34 6	0.70 8	50	0.049	425.00 0	1	0.010	17,098	1.952	7,572	0.173	6,000	0.137	2,113	1,920
CC3	0	0	0.000	0	0.08	32	32	2.56 0	0.07 0	100	0.010	0.101	500	0.070	0	0.000	0	0.000	0	0.000	1,901	1,901
CT3	1	6155	0.234	169	7,57 2.00	4	30,2 88	0.69 2	0.68 0	100	0.094	425.00 0	1	0.010	37,957	4.333	7,572	0.173	6,000	0.137	4,084	3,916
CC4	0	0	0.000	0	0.08	64	5	5.12 0	0.07 0	200	0.019	0.101	500	0.070	0	0.000	0	0.000	0	0.000	3,751	3,751
CT4	1	6155	0.234	169	7,57 2.00	8	60,5 76	1.38 3	0.68 0	200	0.189	425.00 0	1	0.010	68,245	7.791	7,572	0.173	6,000	0.137	7,140	6,971
CC5	0	0	0.000	0	0.08	12 8	10	10.2 40	0.12 0	300	0.050	0.101	500	0.070	0	0.000	0	0.000	0	0.000	7,459	7,459
CT5	1	6155	0.234	169	7,57 2.00	16	121, 152	2.76 6	2.55 1	300	1.063	425.00 0	1	0.010	128,82 1	14.706	7,572	0.173	6,000	0.137	13,744	13,575
CC6	0	0	0.000	0	0.08	8	1	0.64 0	0.12 0	10	0.002	0.101	500	0.070	0	0.000	0	0.000	0	0.000	513	513
CT6	8	440	0.134	96	7,57 2.00	1	7,57 2	0.17 3	2.55 1	10	0.035	425.00 0	1	0.010	9,526	1.087	7,572	0.173	6,000	0.137	1,259	1,163

CC7	0	0	0.000	0	0.08	8	1	0.64 0	0.12 0	10	0.002	0.101	500	0.070	0	0.000	0	0.000	0	0.000	513	513
CT7	8	440	0.134	96	7,57 2.00	1	7,57 2	0.17 3	2.55 1	10	0.035	425.00 0	1	0.010	9,526	1.087	7,572	0.173	6,000	0.137	1,259	1,163
CC8	0	0	0.000	0	0.08	8	1	0.64 0	0.12 0	10	0.002	0.101	500	0.070	0	0.000	0	0.000	0	0.000	513	513
CT8	8	440	0.134	96	7,57 2.00	1	7,57 2	0.17 3	2.55 1	10	0.035	425.00 0	1	0.010	9,526	1.087	7,572	0.173	6,000	0.137	1,259	1,163
CC9	0	0	0.000	0	0.08	8	1	0.64 0	0.12 0	10	0.002	0.101	500	0.070	0	0.000	0	0.000	0	0.000	513	513
CT9	8	440	0.134	96	7,57 2.00	1	7,57 2	0.17 3	2.55 1	10	0.035	425.00 0	1	0.010	9,526	1.087	7,572	0.173	6,000	0.137	1,259	1,163
CC10	0	0	0.000	0	0.08	8	1	0.64 0	0.12 0	10	0.002	0.101	500	0.070	0	0.000	0	0.000	0	0.000	513	513
CT10	8	440	0.134	96	7,57 2.00	1	7,57 2	0.17 3	2.55 1	10	0.035	425.00 0	1	0.010	9,526	1.087	7,572	0.173	6,000	0.137	1,259	1,163
CC11	0	0	0.000	0	0.08	16	1	1.28 0	0.10 0	50	0.007	0.101	500	0.070	0	0.000	0	0.000	0	0.000	977	977
CT11	16	440	0.268	193	7,57 2.00	2	15,1 44	0.34 6	0.70 8	50	0.049	425.00 0	1	0.010	17,098	1.952	7,572	0.173	6,000	0.137	2,113	1,920
CC12	0	0	0.000	0	0.08	16	1	1.28 0	0.10 0	50	0.007	0.101	500	0.070	0	0.000	0	0.000	0	0.000	977	977
CT12	16	440	0.268	193	7,57 2.00	2	15,1 44	0.34 6	0.70 8	50	0.049	425.00 0	1	0.010	17,098	1.952	7,572	0.173	6,000	0.137	2,113	1,920
CC13	0	0	0.000	0	0.08	16	1	1.28 0	0.10 0	50	0.007	0.101	500	0.070	0	0.000	0	0.000	0	0.000	977	977
CT13	16	440	0.268	193	7,57 2.00	2	15,1 44	0.34 6	0.70 8	50	0.049	425.00 0	1	0.010	17,098	1.952	7,572	0.173	6,000	0.137	2,113	1,920
CC14	0	0	0.000	0	0.08	16	1	1.28 0	0.10 0	50	0.007	0.101	500	0.070	0	0.000	0	0.000	0	0.000	977	977
CT14	16	440	0.268	193	7,57 2.00	2	15,1 44	0.34 6	0.70 8	50	0.049	425.00 0	1	0.010	17,098	1.952	7,572	0.173	6,000	0.137	2,113	1,920
CC15	0	0	0.000	0	0.08	16	1	1.28 0	0.10 0	50	0.007	0.101	500	0.070	0	0.000	0	0.000	0	0.000	977	977
CT15	16	440	0.268	193	7,57 2.00	2	15,1 44	0.34 6	0.70 8	50	0.049	425.00 0	1	0.010	17,098	1.952	7,572	0.173	6,000	0.137	2,113	1,920

CC16	0	0	0.000	0	0.08	32	3	2.56 0	0.07 0	100	0.010	0.101	500	0.070	0	0.000	0	0.000	0	0.000	1,901	1,901
CT16	1	6155	0.234	169	7,57 2.00	4	30,2 88	0.69 2	0.68 0	100	0.094	425.00 0	1	0.010	37,957	4.333	7,572	0.173	6,000	0.137	4,084	3,916
CC17	0	0	0.000	0	0.08	32	3	2.56 0	0.07 0	100	0.010	0.101	500	0.070	0	0.000	0	0.000	0	0.000	1,901	1,901
CT17	1	6155	0.234	169	7,57 2.00	4	30,2 88	0.69 2	0.68 0	100	0.094	425.00 0	1	0.010	37,957	4.333	7,572	0.173	6,000	0.137	4,084	3,916
CC18	0	0	0.000	0	0.08	32	3	2.56 0	0.07 0	100	0.010	0.101	500	0.070	0	0.000	0	0.000	0	0.000	1,901	1,901
CT18	1	6155	0.234	169	7,57 2.00	4	30,2 88	0.69 2	0.68 0	100	0.094	425.00 0	1	0.010	37,957	4.333	7,572	0.173	6,000	0.137	4,084	3,916
CC19	0	0	0.000	0	0.08	32	3	2.56 0	0.07 0	100	0.010	0.101	500	0.070	0	0.000	0	0.000	0	0.000	1,901	1,901
CT19	1	6155	0.234	169	7,57 2.00	4	30,2 88	0.69 2	0.68 0	100	0.094	425.00 0	1	0.010	37,957	4.333	7,572	0.173	6,000	0.137	4,084	3,916
CC20	0	0	0.000	0	0.08	32	3	2.56 0	0.07 0	100	0.010	0.101	500	0.070	0	0.000	0	0.000	0	0.000	1,901	1,901
CT20	1	6155	0.234	169	7,57 2.00	4	30,2 88	0.69 2	0.68 0	100	0.094	425.00 0	1	0.010	37,957	4.333	7,572	0.173	6,000	0.137	4,084	3,916
CC21	0	0	0.000	0	0.08	64	5	5.12 0	0.07 0	200	0.019	0.101	500	0.070	0	0.000	0	0.000	0	0.000	3,751	3,751
CT21	1	6155	0.234	169	7,57 2.00	8	60,5 76	1.38 3	0.68 0	200	0.189	425.00 0	1	0.010	68,245	7.791	7,572	0.173	6,000	0.137	7,140	6,971
CC22	0	0	0.000	0	0.08	64	5	5.12 0	0.07 0	200	0.019	0.101	500	0.070	0	0.000	0	0.000	0	0.000	3,751	3,751
CT22	1	6155	0.234	169	7,57 2.00	8	60,5 76	1.38 3	0.68 0	200	0.189	425.00 0	1	0.010	68,245	7.791	7,572	0.173	6,000	0.137	7,140	6,971
CC23	0	0	0.000	0	0.08	64	5	5.12 0	0.07 0	200	0.019	0.101	500	0.070	0	0.000	0	0.000	0	0.000	3,751	3,751
CT23	1	6155	0.234	169	7,57 2.00	8	60,5 76	1.38 3	0.68 0	200	0.189	425.00 0	1	0.010	68,245	7.791	7,572	0.173	6,000	0.137	7,140	6,971
CC24	0	0	0.000	0	0.08	64	5	5.12 0	0.07 0	200	0.019	0.101	500	0.070	0	0.000	0	0.000	0	0.000	3,751	3,751
CT24	1	6155	0.234	169	7,57 2.00	8	60,5 76	1.38 3	0.68 0	200	0.189	425.00 0	1	0.010	68,245	7.791	7,572	0.173	6,000	0.137	7,140	6,971

CC25	0	0	0.000	0	0.08	64	5	5.12 0	0.07 0	200	0.019	0.101	500	0.070	0	0.000	0	0.000	0	0.000	3,751	3,751
CT25	1	6155	0.234	169	7,57 2.00	8	60,5 76	1.38 3	0.68 0	200	0.189	425.00 0	1	0.010	68,245	7.791	7,572	0.173	6,000	0.137	7,140	6,971
CC26	0	0	0.000	0	0.08	12 8	10	10.2 40	0.12 0	300	0.050	0.101	500	0.070	0	0.000	0	0.000	0	0.000	7,459	7,459
CT26	1	6155	0.234	169	7,57 2.00	16	121, 152	2.76 6	2.55 1	300	1.063	425.00 0	1	0.010	128,82 1	14.706	7,572	0.173	6,000	0.137	13,744	13,575
CC27	0	0	0.000	0	0.08	12 8	10	10.2 40	0.12 0	300	0.050	0.101	500	0.070	0	0.000	0	0.000	0	0.000	7,459	7,459
CT27	1	6155	0.234	169	7,57 2.00	16	121, 152	2.76 6	2.55 1	300	1.063	425.00 0	1	0.010	128,82 1	14.706	7,572	0.173	6,000	0.137	13,744	13,575
CC28	0	0	0.000	0	0.08	12 8	10	10.2 40	0.12 0	300	0.050	0.101	500	0.070	0	0.000	0	0.000	0	0.000	7,459	7,459
CT28	1	6155	0.234	169	7,57 2.00	16	121, 152	2.76 6	2.55 1	300	1.063	425.00 0	1	0.010	128,82 1	14.706	7,572	0.173	6,000	0.137	13,744	13,575
CC29	0	0	0.000	0	0.08	12 8	10	10.2 40	0.12 0	300	0.050	0.101	500	0.070	0	0.000	0	0.000	0	0.000	7,459	7,459
CT29	1	6155	0.234	169	7,57 2.00	16	121, 152	2.76 6	2.55 1	300	1.063	425.00 0	1	0.010	128,82 1	14.706	7,572	0.173	6,000	0.137	13,744	13,575
CC30	0	0	0.000	0	0.08	12 8	10	10.2 40	0.12 0	300	0.050	0.101	500	0.070	0	0.000	0	0.000	0	0.000	7,459	7,459
CT30	1	6155	0.234	169	7,57 2.00	16	121, 152	2.76 6	2.55 1	300	1.063	425.00 0	1	0.010	128,82 1	14.706	7,572	0.173	6,000	0.137	13,744	13,575
CC31	0	0	0.00 0	0	0.08	8	1	0.6 40	0.12 0	10	0.002	0.101	500	0.070	0	0.000	0	0.000	0	0.000	513	513
CT31	8	440	0.13 4	96	7,57 2.00	1	7,57 2	0.1 73	2.55 1	10	0.035	425.00 0	1	0.010	9,526	1.087	7,572	0.173	6,000	0.137	1,259	1,163
CC32	0	0	0.00 0	0	0.08	16	1	1.2 80	0.10 0	50	0.007	0.101	500	0.070	0	0.000	0	0.000	0	0.000	977	977
CT32	16	440	0.26 8	193	7,57 2.00	2	15,1 44	0.3 46	0.70 8	50	0.049	425.00 0	1	0.010	17,09 8	1.952	7,572	0.173	6,000	0.137	2,113	1,920

CC33	0	0	0.00 0	0	0.08	32	32	2.5 60	0.07 0	100	0.010	0.101	500	0.070	0	0.000	0	0.000	0	0.000	1,901	1,901
CT33	1	615 5	0.23 4	169	7,57 2.00	4	30,2 88	0.6 92	0.68 0	100	0.094	425.00 0	1	0.010	37,95 7	4.333	7,572	0.173	6,000	0.137	4,084	3,916
CC34	0	0	0.00 0	0	0.08	64	5	5.1 20	0.07 0	200	0.019	0.101	500	0.070	0	0.000	0	0.000	0	0.000	3,751	3,751
CT34	1	615 5	0.23 4	169	7,57 2.00	8	60,5 76	1.3 83	0.68 0	200	0.189	425.00 0	1	0.010	68,24 5	7.791	7,572	0.173	6,000	0.137	7,140	6,971
CC35	0	0	0.00 0	0	0.08	12 8	10	10. 240	0.12 0	300	0.050	0.101	500	0.070	0	0.000	0	0.000	0	0.000	7,459	7,459
CT35	1	615 5	0.23 4	169	7,57 2.00	16	121, 152	2.7 66	2.55 1	300	1.063	425.00 0	1	0.010	128,8 21	14.706	7,572	0.173	6,000	0.137	13,74 4	13,575
CC36	0	0	0.00 0	0	0.08	8	1	0.6 40	0.12 0	10	0.002	0.101	500	0.070	0	0.000	0	0.000	0	0.000	513	513
CT36	8	440	0.13 4	96	7,57 2.00	1	7,57 2	0.1 73	2.55 1	10	0.035	425.00 0	1	0.010	9,526	1.087	7,572	0.173	6,000	0.137	1,259	1,163
CC37	0	0	0.00 0	0	0.08	16	1	1.2 80	0.10 0	50	0.007	0.101	500	0.070	0	0.000	0	0.000	0	0.000	977	977
CT37	16	440	0.26 8	193	7,57 2.00	2	15,1 44	0.3 46	0.70 8	50	0.049	425.00 0	1	0.010	17,09 8	1.952	7,572	0.173	6,000	0.137	2,113	1,920
CC38	0	0	0.00 0	0	0.08	32	32	2.5 60	0.07 0	100	0.010	0.101	500	0.070	0	0.000	0	0.000	0	0.000	1,901	1,901
CT38	1	615 5	0.23 4	169	7,57 2.00	4	30,2 88	0.6 92	0.68 0	100	0.094	425.00 0	1	0.010	37,95 7	4.333	7,572	0.173	6,000	0.137	4,084	3,916

CC39	0	0	0.00 0	0	0.08	64	5	5.1 20	0.07 0	200	0.019	0.101	500	0.070	0	0.000	0	0.000	0	0.000	3,751	3,751
CC39	1	615 5	0.23 4	169	7,57 2.00	8	60,5 76	1.3 83	0.68 0	200	0.189	425.00 0	1	0.010	68,24 5	7.791	7,572	0.173	6,000	0.137	7,140	6,971
CC40	0	0	0.00 0	0	0.08	12 8	10	10. 240	0.12 0	300	0.050	0.101	500	0.070	0	0.000	0	0.000	0	0.000	7,459	7,459
CT40	1	615 5	0.23 4	169	7,57 2.00	16	121, 152	2.7 66	2.55 1	300	1.063	425.00 0	1	0.010	128,8 21	14.706	7,572	0.173	6,000	0.137	13,74 4	13,575

**Table 5-Average results for cloud and traditional in all cases**

	Total					
	CC(h)SAAS & CT(h)SAAS	CC(h)PAAS & CT(h)PAAS	CC(h)IAAS& CT(h)IAAS	ACC(H)&ACT(h)	Difference	TOTAL CC&CT
CC1	335	0	513	848	549	13,048
CT1	137	96	1,163	1,397		21,850
CC2	495	0	977	1,472	1,069	
CT2	429	193	1,920	2,542		
CC3	1,485	0	1,901	3,386	1,809	
CT3	1,111	169	3,916	5,195		
CC4	1,500	0	3,751	5,251	3,926	
CT4	2,037	169	6,971	9,177		
CC5	3,000	0	7,459	10,459	7,238	
CT5	3,953	169	13,575	17,697		
CC6	335	0	513	848	549	6,568
CT6	137	96	1,163	1,397		9,795
CC7	495	0	513	1,008	681	
CT7	429	96	1,163	1,688		
CC8	1,485	0	513	1,998	373	



CT8	1,111	96	1,163	2,370		
CC9	1,500	0	513	2,013	1,284	
CT9	2,037	96	1,163	3,297		
CC10	3,000	0	513	3,513	1,700	
CT10	3,953	96	1,163	5,213		
CC11	335	0	977	1,312	938	8,519
CT11	137	193	1,920	2,250		13,378
CC12	495	0	977	1,472	1,069	
CT12	429	193	1,920	2,542		
CC13	1,485	0	977	2,462	761	
CT13	1,111	193	1,920	3,223		
CC14	1,500	0	977	2,477	1,673	
CT14	2,037	193	1,920	4,150		
CC15	3,000	0	977	3,977	2,089	
CC15	3,953	193	1,920	6,066		
CC16	335	0	1,901	2,236	1,986	12,398
CT16	137	169	3,916	4,222		21,659
CC17	495	0	1,901	2,396	2,118	

CT17	429	169	3,916	4,513		
CC18	1,485	0	1,901	3,386	1,809	
CT18	1,111	169	3,916	5,195		
CC19	1,500	0	1,901	3,401	2,721	
CT19	2,037	169	3,916	6,122		
CC20	3,000	0	1,901	4,901	3,137	
CT20	3,953	169	3,916	8,038		
CC21	335	0	3,751	4,086	3,191	20,169
CT21	137	169	6,971	7,277		
CC22	495	0	3,751	4,246	3,323	
CT22	429	169	6,971	7,569		
CC23	1,485	0	3,751	5,236	3,015	
CT23	1,111	169	6,971	8,251		
CC24	1,500	0	3,751	5,251	3,926	
CT24	2,037	169	6,971	9,177		
CC25	3,000	0	3,751	6,751	4,342	
CT25	3,953	169	6,971	11,093		
CC26	335	0	7,459	7,794	6,087	35,744

CT26	137	169	13,575	13,881		62,228
CC27	495	0	7,459	7,954	6,218	
CT27	429	169	13,575	14,172		
CC28	1,485	0	7,459	8,944	5,910	
CT28	1,111	169	13,575	14,854		
CC29	1,500	0	7,459	8,959	6,822	
CT29	2,037	169	13,575	15,781		
CC30	3,000	0	7,459	10,459	7,238	
CT30	3,953	169	13,575	17,697		
CC31	335	0	0	335	198	4,415
CT31	137	0	0	137		4,505
CC32	495	0	0	495	66	
CT32	429	0	0	429		
CC33	1,485	0	0	1,485	374	
CT33	1,111	0	0	1,111		
CC34	1,500	0	0	1,500	537	
CT34	2,037	0	0	2,037		
CC35	3,000	0	0	3,000	953	

CT35	3,953	0	0	3,953		
CC36	0	0	513	513	747	8,633
CT36	0	96	1,163	1,259		17,345
CC37	0	0	977	977	1,136	
CT37	0	193	1,920	2,113		
CC38	0	0	1,901	1,901	2,184	
CT38	0	169	3,916	4,084		
CC39	0	0	3,751	3,751	3,389	
CC39	0	169	6,971	7,140		
CC40	0	0	7,459	7,459	6,284	
CT40	0	169	13,575	13,575		