Northumbria Research Link

A Cost Modelling System for Cloud Computing

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Abstract— **An advance in technology unlocks new opportunities for organizations to increase their productivity, efficiency and process automation while reducing the cost of doing business as well. The emergence of cloud computing addresses these prospects through the provision of agile systems that are scalable, flexible and reliable as well as cost effective. Cloud computing has made hosting and deployment of computing resources cheaper and easier with no up-front charges but pay per-use flexible payment methods. However, there is lack of tools to aid decision makers in evaluating the much promised benefits of cloud computing particularly its cost benefit. To fill this gap in tools for evaluating the cost benefit of cloud services as an alternative to on premise computing, a cost modelling system for cloud computing (CCMS) is proposed. A prototype model was developed to simulate the cost incurred on maintaining an on premise IT infrastructure under various usage patterns with the purpose of determining the cost benefit of cloud alternatives. CCMS assists decision makers with insights on cost savings of adopting cloud alternatives and also demonstrate how the utilization capacity and cost of acquisition of an infrastructure can influence the cost savings from cloud alternatives.**

Keywords— **Web application, cloud computing, cloud costing, cost model, cloud analyst, cloud simulator, utilization model, cloud modelling.**

I. INTRODUCTION

The history of information technology (IT) can be thought of as a pendulum that swings between two extremes; centralized and distributed computing. The early mainframes are clear examples of centralized computing whereas the later days of PCs and workstations are a big contrast; with distributed computing [24]. The internet technology, especially with the improved performance in bandwidth and connectivity, is taking IT back to a much greater centralized computing called cloud computing. Among the hottest topics that have emerged in the field of information technology is cloud computing. It is rooted on more than a few other computing technologies such as virtualization, high-performance computing (HPC), grid computing and utility computing [11] [20] [22]. Cloud computing is not only perceived as a buzz in today's world of computing but a big and developed branch of information technology. As proposed by a research firm IDC, cloud computing was expected to hit $42 billion last year [29].

An Organization's decision to invest in Information technology (IT) may be for several reasons; some of these are demands to improve quality of product or service, to increase production without increase in cost or to cut down cost of production [17]. In recent time, cloud computing has been marketed as a technology which brings about cost savings, scalability, flexibility and reliability of services. It averts the need for underutilized IT infrastructure in anticipation of peak demands as with very short notice, services can be scaled up. Thus, lead to reduced cost of purchasing infrastructure, upgrades, and maintenance as well as energy savings [38] [22]. These promised benefits have stirred large organizations' interest in beginning to consider cloud computing options. However, there is much doubt and uncertainty in the minds of decision makers as regards the actual realization of the promised benefits, due to much hype and assumptions, particularly in the cost benefit analysis of adopting cloud computing services [15].

Also, there is growing concerns that high energy cost of running private data centres may be worsen by government led carbon taxes [33]. There are also predictions that by 2015, the initial capital cost of IT infrastructure could be exceeded by the operational cost over a lifecycle of 5-years [3] [4].This means that more organizations are likely to consider cloud options. Furthermore, many organizations' drive for change at the moment is predominantly viewed from the cost perspective as they continue to discover how underutilized their substantial capital investment into IT is on the increase. It has been noted as well that close to half the capital equipment budget goes into IT but the capacity utilization of servers is only 6% on the average [39] [38]. Therefore, the proposed cost modelling system is a tool that will provides cost benefit analysis of migrating whole or part of the organization's IT systems to the cloud and help decision makers in making more informed decisions regarding IT infrastructure procurements and maintenance and in verifying the claims of cloud service providers.

II. CLOUD COMPUTING ORIGIN

Today's Information Technology facilities are becoming more and more complex and expensive. The cost implication of maintaining data centres which includes capital and operational costs of such facilities have direct impact on the profitability of the business processes being driven by them [12]. Historically, what is today known as cloud computing evolved from utility computing and grid computing. Utility computing emerged from the materialization of virtualized systems for servers, storage and networks which provided organizations with the pay-per-use or pay-as-you-go services

like that of public utility – a key benefit of this lies in capital and operational cost savings while a computing environment where the workloads are shared or allocated to nodes which have necessary computing resources is referred to as grid computing. Usually, in grid computing, a chain of clustered servers are made available to cater for distributed workloads. It is also capable of parallel computing [9]. Cloud computing can be seen as the computing equivalent of the last century's electricity revolution- whereby everyone generated their own electricity from single units of generators. When the electrical grid became operational, everyone gradually powered down their generators and got connected to the grid for more reliability at a much lower price. Cloud computing remains a rather amorphous term but one that definitely has gained wide usage. It is a model that enables network access to a shared pool of configurable computing resources in a convenient, ubiquitous, on-demand manner. With cloud computing, client computers only serve to transmit instructions and receive results from the remote systems where the computations are carried out. The users are at liberty to use any computer provided it has connection to the internet. Prospects for improving IT efficiency and performance through centralism of resources have increased radically in the last few years with the development of technologies such as service-oriented architecture, management automation, virtualization, and grid computing. Today, what is referred to as cloud computing is a natural outcome of these developments - where a user of computational capabilities sets up or makes use of computing in the cloud over a network in a self-service manner, without direct involvement in how that computing is resourced [18] [36]. Cloud computing is a new computing paradigm which pools diverse client devices with computational and data storage capacities to the cloud. The emergence of cloud computing as one of the current topics in the field of information technology calls for a proper understanding of the domain and how individuals, private and public entities can leverage on its much promised benefits [1] [11]. Cloud computing paradigm may be traced back to the early 60s but since then there has been no commonly accepted definition for it until September, 2011 when the United States National Institute of Standards and Technology (NIST) released the 16th and final version of its definition [21].

A. What is cloud computing?

Cloud computing simply means the ability to access and utilize computing resources such as storage, applications and processing power via internet [31]. Although there have been several definitions of cloud computing, the academic definition was first given by Kenneth K. Chellappa as "a computing paradigm where the boundaries of computing will be determined by economic rationale rather than technical limits" [30]. According to NIST [21], cloud computing is defined as "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 ". This means that with cloud computing IT

capabilities such as hardware, software and services can be provided to an organization dynamically with flexibility to scale up or down as the need arises. According to Miller [24], the 24/7 reliability and universal access coupled with the ubiquitous collaboration guaranteed by cloud computing is likely to do away with today's desktop-centric computing notion. The way of the future can be seen in cloud computing [24]. Presently, cloud deployment can be broadly classified into three models, namely; public – where deployed cloud computing resources are made available for use by the general public; private – where the cloud computing infrastructures are controlled exclusively by an organization and hybrid cloud – which is a combination of private and public cloud deployment model. Private clouds have shown to be more secured than public cloud [32] [16].

B. Characteristics of cloud computing

1) *High flexibility:* Computing capabilities in the cloud is rapidly elastic which allows for resources to be quickly scaled up or released based on user demands. Cloud consumers often experience resource capacities that seem to be unlimited no matter the demand at any given moment [21].

2) *Resource Sharing:* The computing resources from the providers are pooled to service multiple clients by means of a multi-tenant model which dynamically allocates and reallocates different resources to users based on demand. For instance, computing resources such as processing and storage are often made available to consumers with no control or ability to specify the exact location of such resources [21].

3) *On-demand Self-service*: Client's request for computing resources is automated and as such requires no human interaction from the service providers. This means a user can gain access to computing capabilities unilaterally [21].

4) *Extensive network access:* The cloud resource capabilities are available to consumers via standard mechanisms which support heterogeneous client platforms such as workstations, laptops, tablets or mobile phones [21].

5) *Measured Service:* The cloud computing capabilities are provided to users through metering systems that automatically monitor, control and report resource usage to both the users and the providers. Hence, making the whole process transparent to the duo involved [21].

6) *Pay Per-usage:* Cloud resources are provided to consumers on pay per-usage. This eliminates up-front charges and allows users to release resources at the earliest time when they are not needed. In fact, cloud users see the utility based payment method of the cloud as a welcome development and considers it as a main gain of cloud computing [29].

C. The Benefits of Cloud Computing

Qaisar [31] argues that even planning well ahead does not eliminate the two likely outcomes of maintaining an on premise computing model. Maintaining an on premise computing results either on wasted capital in acquiring excess infrastructure capacity or constrained capacity due to limited infrastructure. Such resources could be better put to use for other strategic plans. Apart from the high capital cost involved, the ever changing demand and complexity of configuration

management, regular patching and required upgrades is not minor and this often stall the agility of an organization [31]. It is wise to think of how long it takes to acquire and setup a new infrastructure or system and have it ready for use; perhaps the idea of offloading part of an organization's computing needs to the cloud would be worthwhile. Cloud computing demand is driven by innovation, consumer demand and rising devices. This means that there will be a reliable infrastructure and network environment and abundance of access to network services. It lowers start-up cost, speeds up deployment and is scalable. It has been argued that it gives access to very high performance data centre space in the world. It allows locations of assets and applications in proximity to the users to improve performance. It provides easy access to the widest variety of services, platforms and applications on demand with flexibility and easy scalability. Computing in the cloud provides acceleration of application performance which improves the end users experience and return on investment. In today's digitalized world, no matter what service or product being offered, a strategic differentiator for business is performance. It impacts on business and this translates to either increase or reduction in revenue. Cloud services are designed for rapid deployments and easy adaption to changing business needs. It minimises upfront capital investments and rip benefits of more flexible operating expenses.

Computing in cloud eliminates the need for user's up-front capital commitment to computing resources, thereby allowing organizations or individuals to start small and scale up resources only when the need arises. Also the provision of pay per use which allow users to pay and utilize computing resources on short-term basis as needed and release same resources when not in use amounts to so much cost savings as computing resources are not tied down when they are not utilized. Reduces cost through elimination of expensive IT infrastructure and specialized staff to deploy, operate and upgrade systems. It swiftly accommodates business growth through scalability solutions. Researchers have argued that the power consumption of modern computer systems is not as efficient as that of cloud software service [28].

1) Pay Per-usage: Pay per usage is a very key feature of cloud computing. It permits users of cloud services to request and utilize only necessary resources needed and made available by cloud service providers for a specified period at a given cost. This eliminates up-front charges and allows users to release resources at the earliest time when they are not needed. In fact, cloud users see the utility based payment method of the cloud as a welcome development and considers it as a main gain of cloud computing [29].

2) Energy efficiency of cloud computing: There has been a growing concern about the increased rate of carbon emission from the activities of ICT due to the expansion of the information community and the introduction of new devices and services [10]. A huge part of the cost of running the traditional on premise computing can be attributed to the energy cost which does not only includes the cost of powering the IT infrastructure but also the cost of cooling the equipment. Some researchers have proposed that the traditional desktop

computing is less energy efficient than cloud computing. It has been argued that offloading of computation and storage requirements to the cloud will yield better energy efficiency. Also another research group [2] perceives that cloud computing seems an alternative to desktop computing in terms of energy consumption. At an Uptime Institute Symposium held in New York Jonathan Koomey, a data centre energy expert, recommended cloud computing as an energy saving tool [25]. In 2010, Nucleus Research in a report says that businesses running the on premise desktop computing use 91% more energy than business users utilizing cloud computing [26]. These reports from various researchers above leaves one in no doubt that the decision to partially or fully migrate an organization's computing needs to the cloud will significantly lower energy consumption which also means lower cost.

D. The hidden requirements of cloud computing

1) Cloud Implications: An implementation of cloud computing will mean a major change in the way information will be stored and how applications will be run. Unlike running programs and data from individual computer systems, everything is hosted and accessed from the cloud. This comes along with such a huge benefit of allowing access to all applications and documents from anywhere anytime around the world. This eliminates the limitation of users being confined to their desktops and provides an easy means for collaboration among team members. More so, the ubiquitous online presence so demanded by modern businesses and projects would be greatly achieved while providing opportunity for significant cost saving, internet based access, workload balancing, unlimited scalability, dynamic and granular allocation of resources with self-servicing request to users [36].

2) Consultancy: In a recent Cloud Computing event held in London [7], it was made very clear that the journey to the cloud could include some hidden cost. Such cost highlighted by one of the cloud service providers SAP, was that of consultancy. This cost is said to be varied as this depends on several factors like the size of the organization, the volume of the data to be migrated, the number of users and the volume of transactions within the organization [7].

3) Resource Usage Capacity. Performance monitoring and resource usage are critical on the journey to the cloud. The average usage capacity of the computing resources needs to be known in order to estimate the cost of acquiring same in the cloud [7]. This demands very good monitoring tools to be put in place for monitoring, recording and reporting resource utilization over a given period. Such period will include peak periods and off-peak periods. This does not only mean additional cost of acquiring such tool but enough planning time to enable a smooth and successful migration into the cloud.

4) Internet Services: The whole concept of cloud computing relies solely on the internet for connectivity between the cloud user and the provider. This fundamental requirement is usually silent during discussions on migration to the cloud. According to some of the cloud service providers

at the Cloud Computing World Forum event, readiness for migration to the cloud means that internet connectivity and bandwidth are no issues [7]. In fact, some providers say this was the reason why their services are limited to only the developed countries where persistent internet connectivity is not an issue. This then means that organizations located within developing countries where problems of reliable and persistent internet connectivity and bandwidth exist are not only likely to lose some of the benefits of cloud computing after migration but will also need to include the cost of internet connectivity in their budget when planning for migration to the cloud. Furthermore, researchers [28] have suggested that the shift from desktop computing to the cloud will mean increasing demand on the communication networks in terms of support and energy consumption.

III. COST MODELLING CONCEPTS

Cost accounting has been described as a discipline embraced by decision makers in order to plan, make decisions and control the cost of cost objects such as products or services. The chief aim of cost accounting is modelling cost objects as accurately as is economically reasonable [23]. In order to make good business decisions, accurate cost accounting is crucial because it confirms the efficient management of resources and help decision makers in making the right choice when faced with multiple alternatives of investment. Mikko et al [23] further argued that determination of advantageous prices for a particular product or service can be provided with the help of cost accounting data. This ensures wise spending since such data reveals the total cost of ownership of a particular product or service. In the case of IT infrastructures, these will include the cost of acquisition, configuration, installation, licensing and management of the given product or service. It also brings about efficient unit costing that help to justify IT resource [23]. These cost incurred may further be broken down into cost of hardware, software, space, labour, power and outsourcers [8] [14].

However, cost can be broadly classified into two types, fixed cost and variable cost. Cost that remain constant regardless of the level of production or activity are referred to as fixed costs (Cf) whereas costs that varies in proportion to the level of production or activities are referred to as variable cost (Cv) [35][20]. Relating this to acquisition and maintenance of IT infrastructures, some examples of fixed costs will include cost of hardware, software, licenses and location space while the cost power supply, cooling, and maintenance support are examples of variable cost. Hence, the cost of maintaining on premise computer systems is the accumulation of these cost components involved in purchasing and maintenance [8] [20]. According to Grisebach [13] a typical computer system can consumes up to 175 watts of power (0.18 KWh) excluding the power consumption of the monitor. The charge for every unit of power consumed is about £0.15 per KWh [34]. This has a significant effect on the overall running cost of the systems over a specified period of time. The space requirements for setup also affect the cost as the size of space will determine the amount paid for rent.

Although the rent rate differs from place to place, Officegenie [27] suggests that the space required for a system setup is about 23 square meters. This will cost about £90.00 in the UK depending on the location.

A. The Financial Model

The financial model analyses the various cost components of an infrastructure and presents the cost benefit analysis of considering available cloud options. The financial model considers basic cost components involved in acquiring and maintaining an information technology infrastructure. These include the cost of purchasing new systems (Cpc), the cost of rent on the space where the computer systems are setup for use (Cs), the cost of setup and configuration of the computer systems (Csc), the cost of power consumption (Cp), the cost of technical support and maintenance of the systems (Cm) and the cost of depreciation on the infrastructure (Cd). The following scenario is used just for the purpose of the model development.

Adoka University have several computer Labs, each dedicated to training and research studies. Students of various courses in the School of Engineering and Computing Science make use of the labs at different times during the course of their training. These Labs are equipped with the latest computer systems, powered and well maintained to ensure minimal downtime, high efficiency and availability throughout the year. The systems in each of the labs are upgraded to new ones after every five (5) years. Although the labs are available for use throughout the year, the systems are mostly utilized only within the official hours. The chief information officer is considering subscription to cloud services for one of the labs but needs to justify his proposal with cost benefit analysis before the school management board.

Considering one of the labs equipped with thirty (30) systems at the cost of £600.00 each with no salvage value after an economic life of five (5) years. Assuming the rent for the lab space is at the current market price, the maximum power consumption per system is 180w per hour (0.18 KWh) and the cost of maintenance for each system is at the rate of £100.00 per month. The cost of setup and configuration is £120.00 per system and the power utility charge is £0.15 per KWh [19][34]. Assuming the power utilization efficiency (PUE) is 1.7, the financial analytical model is shown below.

Analytical Calculation
The total number of instance (N) = 30
The cost of system acquisition (Cpc) = 1000
The cost of power = (Cp)
The cost of space = (Cs)
The cost of maintenance = (Cm)
The cost of depreciation = (Cd)
The cost of setup and configuration = (Csc)
The salvage value = (SV)
Economic Life = (EL)
Total cost of ownership of infrastructure = (TCO)
Cost of depreciation (Cd)
The annual depreciation on the systems is determined by the economic life of the system, the salvage value and the cost

of acquisition of the system. The lower the salvage value, the higher the depreciation and vice versa.

Annual cost of depreciation (Cd) = (Cpc - SV)/EL

Cd= (600 -0)/5 =£120 per system

Cost of power consumption

The total cost of power consumption by the computer systems is determined by the power consumption rate per system per hour multiplied by the utility charge and the power utilization efficiency (PUE). The power utilization efficiency is a metric used to express the relationship the ratio of the power consumed by a datacentre infrastructure to the power supplied to the datacentre. This relationship is established as a numerical value that can be used as basis for understanding the efficiency of the energy consumption of a datacentre.

Cost of power per hour (Cp) =0.18 x 0.15 x 1.7 = 0.05

Total number of hours per year = 8 x 5 x 30 = 1200

Annual cost of power per system = 0.05 x 1200 = 55.08

Cost of Maintenance

The annual cost of technical support and maintenance (Cm) on one system is given by the monthly cost of multiplied by 12 months.

Cm = 100 x 12 =£1,200.00

Cost of Setup and Configuration

The cost of setup, configuration and testing is a one off cost incurred when setting up new systems (Csc) =£120.00 per system

Cost of space

The cost of space varies according to the location of an office. The cost is usually calculated based on the square feet. According to a property management company based in the United Kingdom [27], the average space required per system is about 23 square meters which cost about £4.00 per square meter per month.

The annual cost of space (Cs) for 1 system = 4 x 12 x 23 =£1104.00

Estimated Annual Total Cost of Ownership of Infrastructure (TCO)

This is the sum of the fixed and variable cost incurred on systems for the period of one year.

TCO= {[(Cpc+ Cp+ Cm+ Csc+ Cd+ Cs) x (N)]}

$\quad$ = {[(600.00+ 55.08+ 1200.00+ 120.00+ 1104.00) x (30)]}

$\qquad$ = £95,972.40 per year

Hourly Cost of Ownership

The hourly cost of ownership = (TCO/Hours)per year (where hours represents the usage hours) = 95972.40/1200

$\qquad\qquad\qquad$ = £79.97 per hour

Hourly cost per system

The hourly cost of ownership for one system cost

$\quad$ = Hourly TCO/N

=£2.66 per hour

Actual Utilization Hours

The systems are actively used during working hours which is between 9am and 5pm for only five days a week. This amounts to a total usage hour of 40 hours per week. The number of weeks utilized by the school sessions in a year is thirty (30) weeks. This means that the actual utilization hours in a year = 40 x 30 = 1200 hours

Total number of hours per year = 8,736 hours
Total idle time in a year = 8736 - 1200 = 7,536 hours
The % utilization in hours = (1200/8736 x 100) = 13.7 %
The % idle time in hours = (7536/8736 x 100) = 86.3 %

B. The CCMS Model Architecture

The cloud computing modelling system (CCMS) is a decision support tool designed to compute, analyse and present useful analytical reports on an infrastructure cost, utilization gradient and the cost benefits of using available cloud option for same organization's Information Technology infrastructure computing needs.
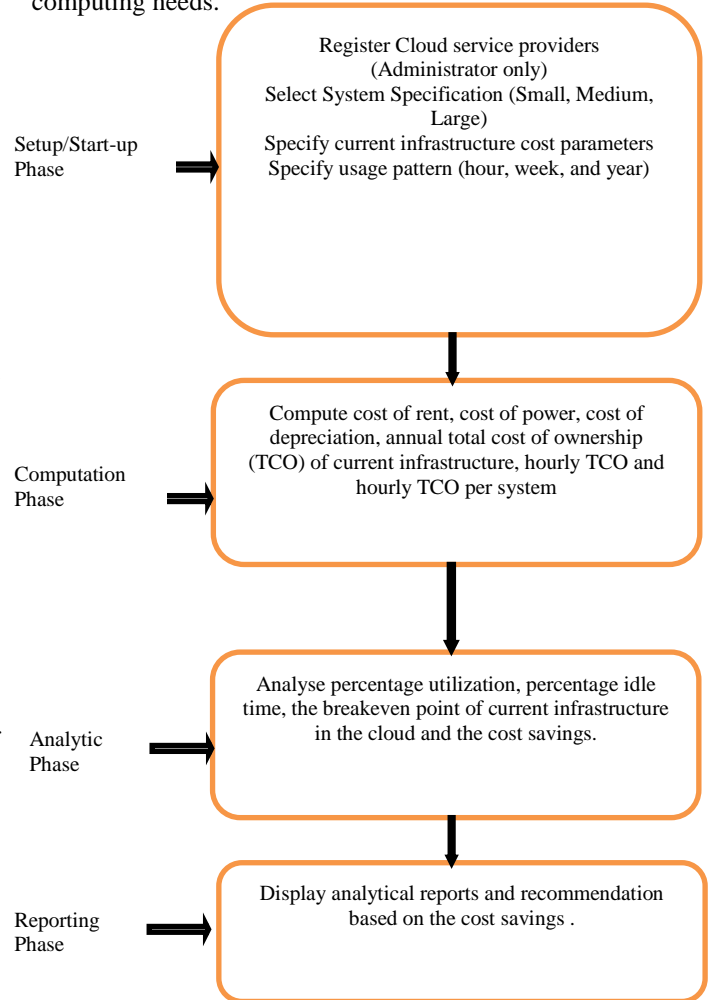

Figure 2 CCMS Architecture

The design of the CCMS model is produced considering three business scenarios. It shows how the system functions and defines the exact stages of operation of the system. The model architecture is broken down into four stages; the start-up phase, the computation phase, the analytic phase and the reporting phase. Each of these stages has unique set of functionalities performed to achieve the overall goal of the model which is to present to the user the cost benefit of considering cloud options as against their current infrastructure. In figure 1 above the CCMS model is clearly defined.
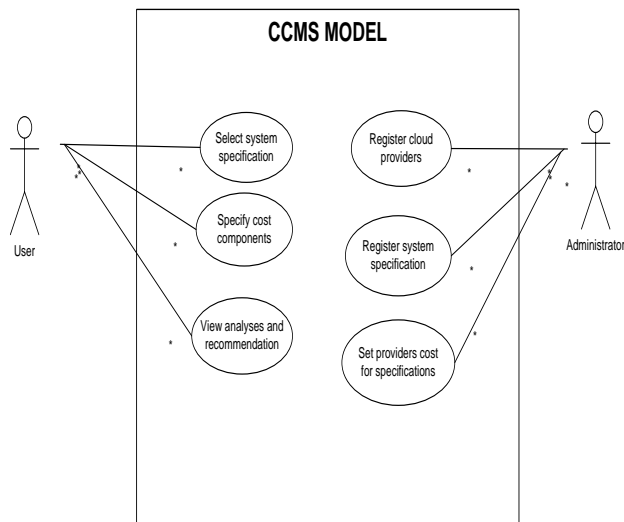
Figure 2 Use case showing the functional requirements of the CCMS Model

1) Start-up Phase

This is the stage when the CCMS set system ready to perform the required analysis. At this stage the administrator will first register the cloud service providers and the pricing of their services according to system specifications after which the user login to the system, selects a system specification and supply all the necessary parameters data according to their current infrastructure. The system proceeds to the next stage as soon as the user completes the last step of this stage.

2) Computation Phase

The computation phase is entirely handled without the user's interaction. The system compute the estimated cost of the user's current infrastructure based on the input parameter values. At this stage the estimated total cost of ownership is computed based on the usage pattern. The usage hours is also used to estimate the percentage utilization of the infrastructure and the percentage idle time. The model further establishes a breakeven point of the current infrastructure on the cloud. It also computes the cost saving for an equivalent infrastructure from any of the available cloud options.

3) Reporting Phase

This stage of the system presents the output of the whole analysis to the user on the screen. The results presented here are modular and they are displayed to the user on different screens, each allowing for easy understanding. At this stage the user is also presented with a recommendation screen showing the preferred solution based on cost savings. Additionally, the administrator can also track the various users that have successfully analysed their infrastructure on the system.

4) Analytic Phase

The analytic phase takes place after all the start-up and computation phases are completed. This phase is responsible for investigating the results of all computation derived from the input parameter specified at the star-up phase. The result of the analysis at this stage include the percentage utilization of the current infrastructure based on the active hours of the system, the percentage idle time when the systems remains powered off, the breakeven point of the current infrastructure in the cloud and the cost savings from cloud options.

IV. MODEL IMPLEMENTATION

The CCMS model is implemented as a web application using HTML, CSS, PHP, MySQL, and Javascripts. The choice of implementing the model as an online web application is because of the many advantages of web applications such as universal access to users across geographically dispersed locations, fast and easy updates to end users when new versions are released. Online application also means that there is no need of installation of the application on individual client systems as it is hosted centrally on a web server and allows users to have access to the application irrespective of their operating systems because the application is platform independent. Also, interested users can even analyse their IT infrastructure from their mobile devices provided they can browse the internet. Furthermore, there is no need of downloading and installing any software which additionally saves time and cost for the application user. The CCMS model has seven different screens beginning with the login screen and ending with the recommendation screen. The login screen is designed to allow new users to sign up and existing users to login and access the system. The system registers the analysis of the user and this can be tracked by the administrator from the admin console.

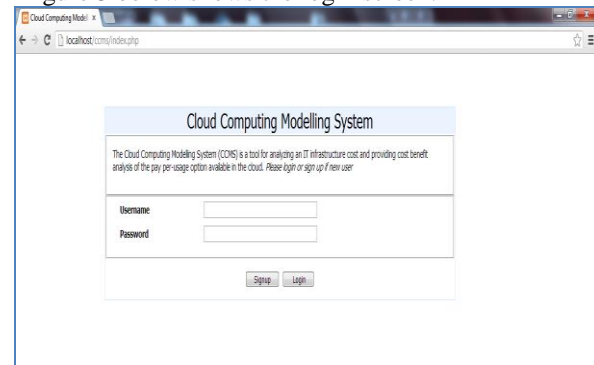Figure 3 below shows the login screen.

Figure 3 showing login screen of CCMS model

The next screen to the login is that for the system specification. It enables the user to select from the list of categories (small, medium, large) that corresponds to the intended infrastructure on the cloud. Once a selection is made, the 'proceed' button takes the user to the next screen where the user can estimate the annual costs on current infrastructure. This screen is well enhanced with sliders using Javascript language to enable easy and automatic manipulation of the values by adjusting the slider corresponding to each cost component. The next screen presents the user with the current infrastructure utilization analysis. The information shown on this screen includes the annual idle time, annual utilization time, percentage utilization and percentage idle time. The 'proceed' button from the utilization analysis screen takes the user to the breakeven screen. This screen presents the user with the view of what the cost of one system in the current infrastructure can acquire on either Amazon cloud or Microsoft cloud platform.

The cost benefit analysis screen is the next screen to the breakeven screen. This screen presents the user the cost savings from each of the cloud providers. It compares the cost for equal number of systems and usage hours and shows the cost savings for each provider. Figure 10 above shows cost benefit analysis of an infrastructure. The last screen is the recommendation screen which presents to the user the annual TCO from each provider including the current infrastructure and makes e recommendation based on the lowest cost value. In order to review previous screens, the user may click on the back button to review the previous output. The screen for the annual cost of current infrastructure can only be reviewed by setting the sliders to the position that represents the correct value for each cost component. On the recommendation screen, the user can choose to exit the application by clicking on the logout button.

V. Model Analysis and Evaluation

A. Scenario 1 – University Lab

This section considers the usage scenario of systems in a school lab to analyse their usage pattern and cost of ownership of the systems as compared to the cost of owning same in the cloud. This scenario is used to gain an understanding of the percentage utilization of an infrastructure particularly in a school lab. The test case was simulated with parameter data of thirty (30) systems setup in a lab dedicated to the learning of system forensics based on the usage pattern of 8 hours a day, 5 days a week and 30 weeks a year. This accounted for 1200 hours usage in a year out of the total of 8736 hours in a year. The cost of the systems was placed at £600.00 per system and the maintenance cost per system at £100.00 per system. The estimated cost of setting up and configuring each system was put at £120.00 and the salvage value of the systems was assumed to be zero after an economic life of 5 years. Other parameter data considered were utility rate of 0.15 pence/KWh [34] and power consumption rate of each system at 180 watts or 0.18 KWh. Taking the space requirement of 23 square meters at the cost of £4.00 per square meter, the case scenario was simulated on the model and the results are shown in Table 4 below.

Results

From the simulation result of the model, the percentage utilization of the Lab systems stands at 13.7% with an idle time of 86.3% and this is represented by the chart in figure 4 below. Also from the result of the simulation it was shown that the estimated hourly cost of owning such an infrastructure is about £80.00 per hour which means an hourly cost of one system will be £2.67 per hour. This amount can be used to acquire up to 36 systems on an Amazon cloud platform and 53 systems on a Microsoft cloud platform.

Simulation Results	
Scenario	School Lab PC
Number of systems	30
Cost of system	600
Usage hours	1200
Percentage utilization	13.74%
Percentage idle time	86.26%
Total cost of ownership of infrastructure (TCO)	95,972.40
Hourly cost of ownership of infrastructure (TCO)	79.98
Hourly cost of ownership of one system	2.67
Amazon cost	0.07
Microsoft cost	0.05
Break even for one system on Amazon	36
Break even for one system on Microsoft	53
Cost Savings on Amazon	93,240.00
Cost Savings on Microsoft	93,960.00

Table 1 showing the simulation results for a school lab infrastructure
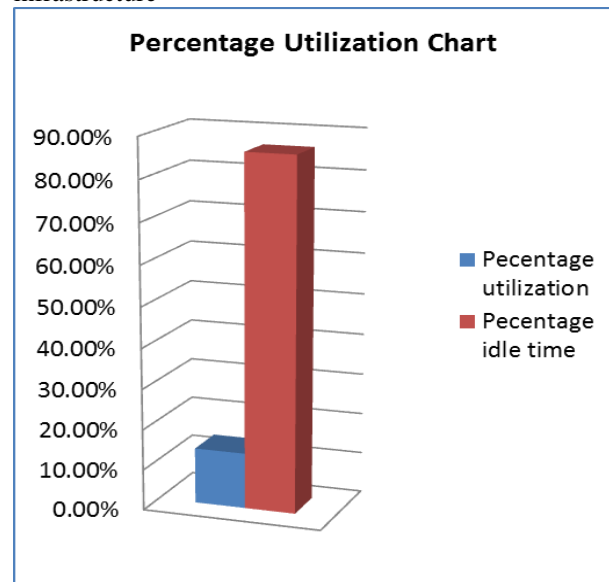

Figure 4 showing the percentage utilization of a school lab infrastructure

Analysis

These results can be useful for planning such IT infrastructure to determine from the start whether to use cloud services or on premise computing resources. It then means that by choosing the cloud computing alternative on Amazon or Microsoft, the school lab will annually save up to £93,240.00 or £93,960.00 respectively. Also going by the evaluation results obtained from the simulation, the benefits of cloud adoption in this case will not be limited to just cost saving from choosing any of the cloud alternatives but the pay per-usage feature with flexibility of usage hours, easy access to an elastic platform that can be scaled up or down at any time with the absence of upfront payments for the needed computing resource. Furthermore, a consideration of the cloud alternative will also

imply that the economic life of the current systems can be extended which means more cost saving from purchasing new systems and upgrade processes.

B. Scenario 2 – Office usage

The previous section considered systems in a school lab where the usage pattern accounts for only 30 weeks in a year. In this section the prototype model is evaluated considering 52 weeks usage pattern of desktop systems in 30 offices. The systems are powered on 8 hours a day and five days a week. The scenario here is used to provide an understanding of the percentage utilization and idle time of systems used in offices for applications processing and comparison of the cost of ownership with available cloud options. This test case is simulated with parameter data of thirty (30) systems setup in 30 different offices for standard office application usage which include word processing and internet browsing accounting for 2080 hours of use in a year. Again the cost of the systems was maintained at £600.00 per system with the maintenance cost of £100.00 per system. The estimated cost of setting up and configuring each system was put at £120.00 and the salvage value of the systems was assumed to be zero after an economic life of 5 years. Other parameter data considered were utility rate of 0.15 pence/KWh [34] and power consumption rate of each system at 180 watts or 0.18 KWh. Taking the space requirement of 23 square meters at the cost of £4.00 per square meter, the scenario was simulated on the model to yield the results shown in Table 2 below.

Results

The usage of the office systems shows that the percentage utilization of the systems stands at 23.8% with an idle time of 76.2% and this is represented in a chart in figure 5 below. Also, the results obtained from the simulation showed that the estimated hourly cost of ownership on such infrastructure is £46.72 per hour. This translates to an hourly cost £1.56 per system. The same amount can be used to procure as much as 21 systems on the Amazon cloud platform and 31 systems on Microsoft cloud platform.
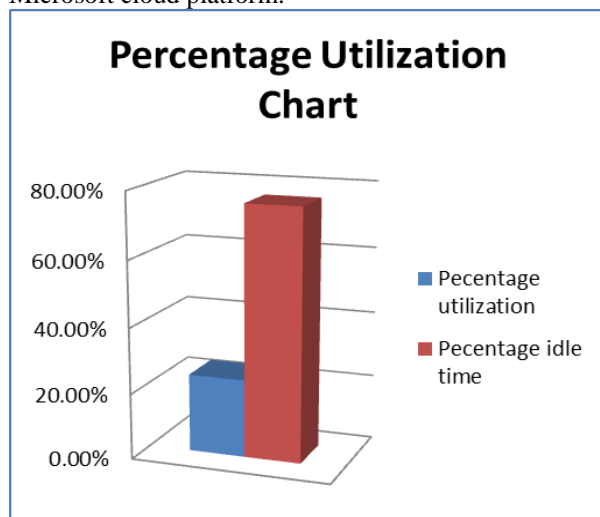

Figure 5 showing the percentage utilization of office systems

Simulation Results	
Scenario	Office PC
Number of systems	30
Cost of system	600
Usage hours	2080
Percentage utilization	23.81%
Percentage idle time	76.19%
Total cost of ownership of infrastructure (TCO)	97,184.16
Hourly cost of ownership of infrastructure (TCO)	46.72
Hourly cost of ownership of one system	1.56
Amazon cost	0.07
Microsoft cost	0.05
Break even for one system on Amazon	21
Break even for one system on Microsoft	31
Cost Savings on Amazon	92,976.00
Cost Savings on Microsoft	94,224.00

Table 2 showing the simulation results for Office PC infrastructure

Analysis

An implication of the above results is that the cost incurred on one system will be enough to provide access to 21 systems on Amazon cloud or 31 systems on Microsoft cloud. This then means that by considering migration to the cloud options provided by Amazon or Microsoft, the annual savings from running same business processes in 30 offices can be up to £92,976.00 or £94,224.00 respectively. The amount saved could be used to purchase cheaper systems with capabilities of internet connectivity and which will have longer economic life since their usage is for connectivity only. Furthermore, the results above can also be used for planning the computing budget for each employee within their organization as the system also generates the hourly cost of ownership for each system in the organization IT infrastructure.

C. Scenario 3 – Dedicated Servers

This section evaluates the usage scenario of dedicated servers to analyse their usage pattern and cost of ownership of the systems as compared to the cost of owning same in the cloud. The significance of this scenario is to gain a better understanding of the utilization percentage of such infrastructure hosted within the data centre of organizations and assert the cost benefit of its cloud alternative. The test case was simulated with parameter data of thirty (30) Servers setup in data centres across thirty (30) branch offices for dedicated online services to users throughout the year. The servers are meant to provide ubiquitous online access to different applications. This implies a usage pattern of 24 hours a day, 7 days a week and 52 weeks a year and accounting for a total of 8736 hours annually. The cost of each Server system was placed at £3000.00 with a monthly maintenance cost per system at £100.00 per system. The estimated cost incurred for setting up and configuring each server was £120.00 and at the end of an economic life of 5 years the salvage value of the systems was assumed to be zero. Some other parameter data

considered were utility rate of 0.15 pence/KWh [34] and power consumption rate of each system at 180 watts or 0.18 KWh. Also, assuming the space requirement of 23 square meters at the cost of £4.00 per square meter, the model was evaluated by simulating the above data and the results are shown in Table 3 and represented in figure 6 below.

Simulation Results	
Scenario	**Dedicated Servers**
Number of systems	30
Cost of system	3000
Usage hours	8736
Percentage utilization	100.00%
Percentage idle time	0.00%
Total cost of ownership of infrastructure (TCO)	192,749.47
Hourly cost of ownership of infrastructure (TCO)	22.06
Hourly cost of ownership of one system	0.74
Amazon cost	0.07
Microsoft cost	0.05
Break even for one system on Amazon	10
Break even for one system on Microsoft	15
Cost Savings on Amazon	175,593.60
Cost Savings on Microsoft	180,835.20

Table 3 showing the simulation results for dedicated servers' infrastructure
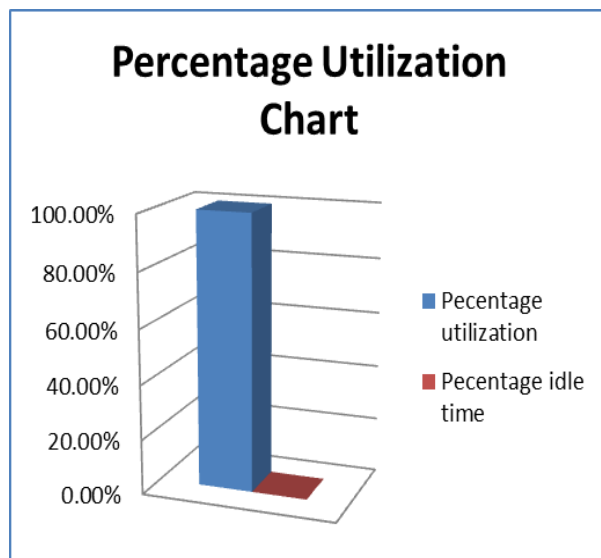

Figure 6 showing the percentage utilization of dedicated servers

Analysis

From the evaluation results above it then means that by choosing a cloud alternative on Amazon or Microsoft, an organization with such infrastructure can annually save up to £175, 593.60 or £180,835.20 respectively. Also the evaluation results obtained from the simulation shows that in an event of server breakdown the cloud can be a smart option for more cost savings with the pay per-usage feature and it also allow for easy scale up or scale down when branch offices are opened or closed down. Furthermore, a consideration of the cloud alternative will also imply that the organization can be free of frequent upgrade and complex configurations due to changing business needs and the results obtained here can also be used to estimate the losses incurred by an organization in an event of a system failure or breakdown.

D. Summary of Findings

The evaluation results above has demonstrated the capability of the model as a suitable decision support tool in analysing the cost benefit of cloud computing. The findings indicates that the usage pattern and cost of acquisition of systems when new has a high influence on the utilization capacity, the total cost of ownership and the cost savings from adopting cloud alternatives. This implies that certain usage pattern can guarantee better cost savings in the cloud. Also, an extended economic life of an infrastructure can reduce the total cost of ownership which means more cost saving.

E. Related Work

Recent academic research reveals growing interest in the challenges faced by enterprises in cloud adoption. Presently, matured toolkits or techniques are not yet available to support decision makers. Top management of enterprises such as the Chief Information Officers and Information Technology Managers face serious challenges when they need to take decisions concerning cloud adoption due to lack of decision support tools [15]. In a recent event [7] efforts are being made in this regards to bridge the gap through consultancy services provided by several companies such as Accenture, AsterCloud and AppDirect. The limitation of this kind of approach can be seen in two ways: such solutions apart from not being universally available are based on proprietary tools; and often involve high cost of consultancy periods. In contrast, given the Cloud Computing Modelling System (CCMS), enterprises can do without outside consultancy and easily analyse the economic sense of cloud computing to their organization as compared to continuing in the traditional or on premise computing. The CCMS might also be used to verify some of the claims made by cloud service providers and IT consultant about the cost benefits of the cloud.

Cloud computing have witness developments of decision support tools in recent time. The Buyya's lab recently released a toolkit called CloudSim which serves as a valuable toolkit for developers interested in modelling and simulating the cloud computing environment [5] [6]. This toolkit has been suggested as a useful tool to programmers interested in modelling the performance of their applications in the cloud and also to cloud service providers who are concerned about the properties and resource usage of data centres. Researchers [37] have also developed a CloudAnalyst, which is a virtual modelling tool for analysing cloud computing environment and applications. According to the group, the tool is meant to bridge the gap created due to lack of evaluation tools for developers who are interested in evaluating computing servers and user workloads requirements of geographically distributed large scale cloud applications. Similarly, a Cloud Adoption Toolkit have also been developed to fill the gap of existing

research in supporting decision making for deployment of complex IT systems in the cloud. Additional features of the toolkit also suggest utilization patterns as well as different pricing schemes of cloud service providers [15]. In contrast the Cloud Computing Modelling System simplifies the migration journey to the cloud by not just supporting decision maker in the cost benefit analysis of considering cloud options but goes further to break down the journey into stages of simple tasks: consideration of system specification; consideration of fixed and variable cost incurred on maintaining current IT infrastructure; specification of the usage hours of the infrastructure, analysis of the percentage utilization of the current infrastructure and comparison of the current infrastructure cost of ownership against available cloud options from renown cloud service providers.

VI. CONCLUSION

With organizations faced with several decision making challenges to meet their dynamic business environment due to changes in business processes, legacy systems, outdated IT systems, high operational cost and lack of wider data access, there is a new gap for tools to study and evaluate the benefits of technological solutions and the best time to apply them. The Cloud Computing Modelling System (CCMS) is a new tool developed to address this gap. It is not just a handy decision support tool for decision makers looking at evaluating the cost benefit of cloud computing but will also serve as a useful tool for cloud service providers who also want to verify their claims of lesser cost of computing in the cloud.

It has been demonstrated that real world scenarios can be simulated and analysed using CCMS application to determine the percentage utilization of an organization's infrastructure, the breakeven of same infrastructure in the cloud, the cost of the same infrastructure in the cloud and the cost savings from the available cloud alternative. The finding indicates that the usage pattern and cost of acquisition has a high influence on the total cost of ownership, the utilization capacity and the cost savings of adopting cloud alternatives. This implies that certain usage pattern can guarantee better savings in the cloud. Also, an extended economic life of an infrastructure can reduce the total cost of ownership which means more cost saving.

This tool can also be useful for planning an organization's IT infrastructure in order to determine from the start whether to use cloud services or on premise computing resources. Management can also use the system to plan the computing budget for each employee within their organization as the system also generates the hourly cost of ownership for each system held in the organization's IT infrastructure. The results obtained from the model can also be used to estimate the losses incurred by an organization in an event of a system failure or breakdown.

A. Recommendation

This research is a new attempt towards the development of a tool and approach for studying utilization capacity and cost of on premise computing infrastructure as compared to the cost benefit of cloud computing. Therefore, the developed prototype model of CCMS will evolve over time and result in an improved quality tool in terms of the analysis it supports. The model has the potential of being extended to generate graphical output of simulated results of analysis in the form of charts. This will aid users to identify important patterns of the output results. Also, a registered user may be granted access to view records of previous analysis without having to start afresh. Furthermore, the present model may also be extended to enable users to simulate and analyse mixed usage scenarios with mixed system specifications.

REFERENCES

[1] A. E. Youssef and M. Alageel, "A Framework for Secure Cloud Computing", *International Journal of Computer Science Issues (IJCSI)*, Vol. 9, Issue 4, No 3,pp. 478-500, July 2012.

[2] Baliga, J., Ayre, R.W. A., Hinton, K. & Tucker, R.S. "Green Cloud Computing: Balancing Energy in Processing, Storage, and Transport", *Proceedings of IEEE*, 2011, Vol. 99 (1), pp. 149 – 167.

[3] Barroso, L.A. & Hölzle, U. *The Datacenter as a Computer: An Introduction to the Design of Warehouse-Scale Machines*, California: Morgan & Claypool, 2009.

[4] Brown, D.J. & Reams, C. "Toward Energy-Efficient Computing", *Communications of the ACM*, 2010, Vol. 53 (3), pp. 50 – 58.

[5] Buyya, R., Calheiros, R.N., Ranjan, R. & De rose, C.A.F. (2009) 'CloudSim: A Novel Framework for Modeling and Simulation of Cloud Computing Infrastructures and Services' [Online]. Available: http://arxiv.org/ftp/arxiv/papers/0903/0903.2525.pdf

[6] Buyya, R., Ranjan, R. & Calheiros, R.N "Modeling and simulation of scalable Cloud computing environments and the CloudSim toolkit: Challenges and opportunities", *IEEE International Conference on High Performance Computing & Simulation*, 2009, pp. 1 – 11.

[7] CCWF (2012) 5th Annual Cloud Computing World Forum, London.

[8] D. Gmach, HP Labs., Palo Alto, CA, USA , J. Rolia , L. Cherkasova "Resource and virtualization costs up in the cloud: Models and design choices", *IEEE/IFIP International Conference on Dependable Systems & Networks (DSN)*, 2011, pp. 395 – 402.

[9] EMC (2010) Cloud Computing Security Overview

[10] Gartner (2007) 'Gartner Estimates ICT Industry Accounts for 2 Percent of Global CO2 Emissions' [Online]. Available at: http://www.gartner.com/it/page.jsp?id=503867 [Accessed February 21, 2014].

[11] Gong, C., Liu, J., Zhang, Q., Chen, H & Gong, Z, "The Characteristics of Cloud Computing", *Parallel Processing Workshops (ICPPW)*, 2010, pp. 275 – 279.

[12] Greenberg, A., Hamilton, J., Maltz, D.A. & Patel, P. (2009) 'The Cost of a Cloud: Research Problems in Data Centre Networks', [Online]. Available at: http://www.infoworld.com/d/security-central/gartner-seven-cloudcomputing-security-risks-853?page=0,1 [Accessed February 21, 2014].

[13] Grisebach, M. (2003) Information Systems and Technology: Hardware Power Consumption [Online] Available at: http://windows.uwaterloo.ca/hardware/pc_power_consumption.asp [Accessed February 21, 2014].

[14] Jun, T. & Zhongchuan, L. "Study on IT Service Cost's Calculate and Charging Strategy Based on Activity-based Costing", *IEEE International Conference on Service Systems and Service Management*, 2007, pp. 1 – 5.

[15] Khajeh-Hosseini, A., Greenwood, D., Smith, J. W. & Sommerville I. "The Cloud Adoption Toolkit: Supporting Cloud Adoption Decisions in the Enterprise", *Journal of Software: Practice and Experience*, Vol. 42 (4), pp. 447 – 465, April 2012.

[16] Krutz, R.L. & Vines R.D. *Cloud Security A Comprehensive Guide to Secure Cloud Computing*, U.S.A.: Wiley Publishing, Inc., 2010.

[17] Legris, P., Ingham, J. & Corellette, P. "Why do people use information technology? A critical review of the technology acceptance model",

Journal of Information & Management, Vol.40, Issue 3, pp. 191 – 204, Jan. 2003

[18] Liu, W. "Research on cloud computing security problem and strategy", *IEEE International Conference on Consumer Electronics, Communications and Networks (CECNet)*, 2012, pp. 1216 – 1219

[19] LondonPCGeek (2012) 'Service prices tariffs and charges' [Online]. Available: http://pcrepairs24.com/service-prices-tariffs-and-charges1

[20] Mach, W. & Schikuta, E. "A Consumer-Provider Cloud Cost Model Considering Variable Cost", *IEEE Ninth International Conference on Dependable, Autonomic and Secure Computing (DASC)*, 2011, pp. 628 – 635.

[21] Mell, P. & Grance, T. (2011) 'The NIST Definition of Cloud Computing: Recommendations of the National Institute of Standards and Technology' U.S. [Online]. Available: http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

[22] Microsoft (2010) Security in Cloud Computing Overview [Online] Available: http://www.microsoft.com/download/en/details.aspx?displaylang=en&id=327

[23] Mikko V., Marko S. & Petri S. "Detailed cost modelling: a case study in warehouse logistics", *International Journal of Physical Distribution & Logistics Management*, Vol. 37 (3), pp. 184 – 200, April 2007.

[24] Miller, M. *Cloud Computing: Web-Based Applications That Change the Way You Work and Collaborate Online*, USA: Que Publishing, 2009.

[25] Miller, R. (2010) 'Cloud Computing as an Energy Saving Tool', Data Centre Knowledge [Online]. Available: http://www.datacenterknowledge.com/archives/2010/05/17/cloud-computing-as-an-energy-saving-tool

[26] Nucleus Research (2010) "Cloud Computing: it is east to go green" [Online]. Available: http://nucleusresearch.com/research/notes-and-reports/cloud-computing-it-is-easy-being-green/

[27] Officegenie (2012) "Cost to rent office space" [Online]. Available at: http://www.officegenie.co.uk/rent [Accessed February 21, 2014]

[28] Owusu, F. & Pattinson, C. "The Current State of Understanding of the Energy Efficiency of Cloud Computing", *IEEE 11th International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom)*, 2012, pp. 1948 – 1953.

[29] Patirdar, S., Rane, D. & Jain, P. "A Survey Paper on Cloud Computing", *IEEE 2nd International Conference on Advanced Computing & Communication Technologies*, 2012, pp. 394 – 398

[30] Petri, G. (2010) "Shedding Light on Cloud Computing" [Online]. Available: http://www.ca.com/us/~/media/files/whitepapers/mpe_cloud_primer_0110_226890.pdf

[31] Qaisar, E.J "Introduction to cloud computing for developers: Key concepts, the players and their offerings", *Proceedings of IEEE Information Technology Professional Conference (TCF Pro IT) New Jessy*, 2012, pp 1-6.

[32] Ramgovind, S., Eloff, M. M. & Smith, E. "The Management of Security in Cloud Computing", *Proceedings of IEEE Information Security for South Africa (ISSA)*, 2010, pp. 1 – 7.

[33] SMART 2020: Enabling the low carbon economy in the information age, [Online]. Available: http://www.smart2020.org/_assets/files/02_Smart2020Report.pdf

[34] Utility Warehouse (2012) "View tariffs" [Online]. Available: https://www.utilitywarehouse.co.uk/energy/electricity

[35] Walker, J. *Accounting in a Nutshell: Accounting for the Non-specialist*, 3rd Ed., U.S.A: Elsevier Ltd, 2009.

[36] Wei, Y. & Blake, M.B. "Service-Oriented Computing and Cloud Computing: Challenges and Opportunities", *IEEE Journal of Internet Computing*, 14 (6), pp. 72 – 75, Nov. – Dec. 2010.

[37] Wickremasinghe, B., Calheiros, R.N. & Buyya, R. "CloudAnalyst: A CloudSim-Based Visual Modeller for Analysing Cloud Computing Environments and Applications*", IEEE 24th International Conference on Advanced Information Networking and Applications (AINA)*, 2010, pp. 446 – 452.

[38] Wu, Z. & Gan, A. "Qualitative and Quantitative Analysis the Value of Cloud Computing", *Proceedings of the International Conference on Information Management, Innovation Management and Industrial Engineering (ICIII)*, 2011, Vol. 2, pp. 518 – 521.

[39] Zhang, S., Zhang, S., Chen, X. & Huo, X. "Cloud Computing Research and Development Trend", *IEEE Second International Conference on Future Networks (ICFN)*, 2010, pp. 93 – 97.