Total Cost of Ownership Formulation Analysis for Virtualization Data Center in University

(Case Study : Universitas Gadjah Mada)

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Abstract— Aspects of information technology has influenced the business processes of all types of organizations, including the educational institutions. Educational institutions have implemented a digital campus technology trends. At present many digital campus infrastructure technology brings cloud computing. With cloud computing as part of the IT strategy, an organization can increase their capacity to concentrate on running the business process without thinking of investing in large-scale IT as IT investment before the era of cloud computing.The implementation of cloud computing, based on virtualization technology. Previous research has established that the application of virtualization technology offers ease in data center management and reduce problems may arise when technology brings physical servers in the data center. This paper will discuss the application of virtualization technology in the data center an educational institution. It will calculate and discuss about total cost of ownership through application of virtualization technology on data center.

Keywords : Cloud Computing, Digital Campus, Total Cost of Ownership, Virtualization

I. INTRODUCTION

Current information technology era, educational institutions implement a technology trend called digital campus [1] [16]. Digital campus refers to collaboration between business processes in educational institutions and utilization of information technology as a support. Digital campus is widely used today different from the previous era of digital campus. In the previous era, digital campus

using computer network infrastructure, and IT management conventionally in which is use of website for information systems academic campus. Digital campus at currently many technologies brings cloud computing to replace those conventional infrastructures [2].

Cloud computing is an evolution from computing world which unify resources from multiple computers to function as a single entity. The infrastructure cloud computing enable the development of large systems and scalable which can receive, store, process and analyze all the data from an organization [3]. Some of literatures has pointed out that application of cloud computing in an organization or business entity, can make an organization or business entity that increasing the capacity of the company or organization. The improvement can be reached because of the ease of IT management offered by cloud computing implementation, so that the company or organization can concentrate on they business. Thereby the implementation of cloud computing has become a part from strategic planning of IT within an organization [4].

In the implementation of cloud computing, virtualization technology is used. Virtualization is applied to data center infrastructure to build a private cloud infrastructure [5]. Some of previous research has discussed that application of virtualization technology offers various advantages and conveniences in data center management. Advantages and conveniences include: ease of managerial infrastructure [6], from the economical advantages in procurement of virtual server [7], efficiency of the electric power consumption [8], can create a data center technologies that are environmentally friendly [9] [18].However, from various facilities and benefits offered. There are also disadvantages of virtualization technology on cloud computing. One of the biggest disadvantages is the decrease in the performance of virtual machine caused by addition layer for data translation from a physical machine to a virtual machine. The performance degradation is supposed to reach 10% - 15% [10].

This paper will review and discuss whether the infrastructure virtualization which experience performance degradation is feasible to be applied in a data center environment. Parameters will be measured through assessment economically using the method of calculation total cost of ownership. Calculation of total cost of ownership in this research only focused on the server and operational support elements server. Calculation of the total cost of ownership will be applied to data center, Gadjah Mada University is one of university which implementing digital campus trends through virtualization technologies and cloud computing.

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II. DEFINITION OF VIRTUALIZATION

A. Concept of Virtualization

Virtualization is one of the main concepts and methods in computer science. In the broad sense, virtualization has large area coverage, but this discussion will be focused on

server virtualization. An abstract concept of dividing a physical device virtualization and operating system separately. it causes increasing utilization, and flexibility of IT resources. Virtualization allow some virtual computers on a different operating system working independently on the same physical computer. Each of virtual computer that has a set of virtual hardware also, such as RAM, CPU, NIC, etc. Operating system and application programs can be set up in it. When the computing process takes place, system will regard them as a set of standard hardware [11].

B. Characteristics of Virtualization

A virtualization layer must meet the following characteristics [11]:

- Equivalent: virtualization layer provides a condition identical to a physical machine for the software. It makes software that runs on a virtual machine can run like the original machine.
- Efficiency: software that runs in the virtual condition, no significant decrease performance. Computation can be executed directly on a physical machine without any processor intervention of the virtual machine.
- Resource Control: virtualization layer has full rights to manage the hardware resources. The resources in question are the memory and I / O.

C. Types of Virtualization [11]

- CPU Virtualization
  Processes running on the x86 architecture has a hierarchical instruction. The hierarchy determines the right to use the CPU function without causing fault. There are 4 ring hierarchy, 0, 1, 2, and 3. Ring 0 has the highest privileges, while 3 had the lowest access rights. Most operating systems use the x86 configuration 0-3. There is a ring 0 is used by the operating system. Ring 3 is used by the application program.
- Memory Virtualization
  Memory virtualization is done by dividing the physical memory of the server machine to several virtual machines dynamically. On the virtualization server, virtual memory takes 1 level again to connect the virtual memory to the guest operating system memory server machine.
- Virtualization Device I / O
  Virtualization device I / O request is done by adjusting I / O between virtual device with a physical device. Virtual hardware forwarding requests it receives to the hypervisor and then forwarded to the machine's hardware.

D. VMware ESX Infrastructure

VMWare ESX Infrastructure is one application suite which can be used to build a virtual server infrastructure. ESXi is a hypervisor or virtualization layer which is installed on the machine (baremetal), without requiring installation of host operating system first.VMware designed the ESXi to be installed with software that has been selected and required course, that reducing the kernel code for hardware drivers. It makes the kernel ESXi has a quick response and having a small overhead. Performance also higher when compared to server virtualization technology which requires installation of the operating system first [12]. VMware the ESXi has a constituent element of infrastructure virtualization, among others:

- Virtual Resource shape of Hosts and Clusters. Dynamically computing capabilities can be increased or decreased by the addition or subtraction incorporated in ESX Server cluster. Host is a representation of the hardware resources of an x86 server machine [13].
- Virtual Storage Media which is a representation of combination of several physical disk configuration that can be fiber optic SAN, NAS (Network Attached Storage), or iSCSI [13].
- Network device that connects between virtual machines or between a virtual machine with the area outside of the virtual infrastructure. Like a physical server machine, virtual server also has a network component, a virtual NIC (vNIC), vitual switch (vSwitch), and port group. Operating systems and applications to communicate with the vNIC through the drivers provided by the ESX Server. Such as NICs, vNICs also has a MAC address, one or more IP addresses, and response to standard Ethernet protocols [13].
- Virtual Machine is a virtualization of physical servers. This virtual machine consumes hardware resources dynamically, based on the workload. As the workload increases, the consumption of the CPU and memory resources has also increased. And vice versa, if the workload decreases, the resources previously used will be returned [13].

III. RELATED WORKS

Some research has been discussed implementation of cloud computing and virtualization technology in terms of profits and the performance of the platform. Research was conducted by Jingxian [1] discusses the use of server virtualization on the campus network. Jingxian has conducted an analysis of the traditional data center and virtual data center on a college campus. Jingxian has made observations to understand the workload of various system

applications on the data center, and then transmits the operating system into a virtual machine, and backup-recovery planning application. The results show virtualization can effectively reduce that server additions usually happen quickly in implementation of digital campus. In addition it also offers easy management of virtualized servers, increase server utilization, flexibility and reliability of the network.

Other research has conducted by Li [14]. Li in 2009 proposed a method for analyzing financing on cloud computing infrastructure. Li concluded that the cost reduction could be considered as one of the factors an organization switched to using cloud infrastructure. This requires a detailed analysis and documentation on the costs decline. Unavailability of tools to support the analysis, Li presents a metric formula to analyze the Total Cost of Ownership of the cloud infrastructure. The formula was developed to analyze TCO on internal cloud environments.

Research conducted by Chandra and Borah [15] that discusses the cost benefit analysis of cloud computing in education. Implementation of Cloud Computing in Education Institutions not only relieve the burden of dealing with the management of complex IT infrastructure and maintenance activities but also resulted in substantial cost savings. In the research, Chandra and Borah analyzed the cost benefit of using cloud computing services using metrics metrics TCO compared to Cost Per Use per Month.

Guowei [16] performed an analysis of applications running in virtualized environments such as servers, virtual storage and virtual network devices. The right virtualization solution for the infrastructure can be presented with considering the ease of IT infrastructure management, equipment efficiency, and maintenance costs.

Nand Kumar and Mittal [17] proposed a solution to the problem on the limitations of data storage on an university using cloud computing. The proposed solution is public cloud hybrid-service (PaaS, IaaS and Saas), with the hope of going on efficiency of the storage of the institution.

Subsequent research conducted by Yamini and selvi in 2010 [18]. The study has discussed the development of virtualization and cloud computing to the green computing which is an environmentally friendly technology with minimal consumption of power resources. Yamini and Selvi proposed star clique algorithm to determine the amount of servers that are connected to determine the maximum number of nodes. Performance of each node is obtained maximum from each server, including the consumption of power resources. The research also showed that the topology of virtualization can reduce power consumption, but still get the same performance with the non-virtual topology, but in the context of the same configuration.

Salapura from IBM research center in 2012 conducted research on the robustness and reliability from cloud computing infrastructure in data center [19]. Salapura claimed that cloud computing increases flexibility, high service availability, and ease of disaster recovery. This flexibility enables the system to be more dynamic, and optimized for more efficient for a number of metrics, for example, use of energy, capacity, reliability, availability, serviceability which are not possible with the previous infrastructure.

Some of these reviews, no one has found an analysis of cloud computing and virtualization in terms of investment and financing domain specializing discussion on data center environments only. Referring to the literatures, this paper will discusses financing and investment analysis (total cost of ownership) on the application of private cloud technology on an educational institution, where the infrastructure implemented using virtualization software VMware ESX 5 for data center management. Total cost of ownership analysis will focus on virtual data center. Results from these analyzes will be compared to financing infrastructure when not using virtualization. Parameters will be discussed include, the server cost, software cost, network cost, power and cooling costs, facilities costs and space costs.

IV. EXPERIMENTAL METHODOLOGY

In the application of virtualization technology, there are advantages or benefit expected aspect. The most common model used to measure the use of IT resources from the economic aspect is an analysis of Total Cost of Ownership (TCO)[14]. TCO was first developed in 1987 [20]. TCO is a concept that was introduced at the company level to evaluate investment efficiency in information design and architecture of the system [20]. However, TCO calculations in this research was given at the conceptual level in order to calculate monetary benefits and incremental investment when implementing virtualization technologies.

TCO metrics is used in this research is which TCO metrics used by Li [14] to made adjustments to the calculation of some metrics on data center infrastructure. This research focuses only on the TCO calculation data center infrastructure and virtual servers at PSDI UGM who have been using virtualization technology. In this study, the method to calculate the TCO is divided into 2 phases. Those steps are create a domain model which will be calculated and describe the parameters that will be used in the calculation stage.

In this research, the steps to calculate TCO was divided into 2 steps. Those steps are domain model which will be calculated and describe parameters that will be used in the calculation steps.

A. TCO calculation model calculations

TCO calculation model is divided into four major domains as shown in Figure 1. Among other domains, server number, Rack Number, Virtual Machine Number, and Virtual Machine Density . While the main parameter to be calculated is the Cost Servers , Software Cost , Cost Support, Network Cost.

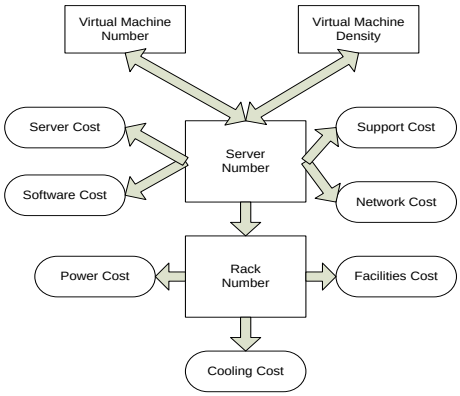

Figure 1. TCO Domain Model Calculation for Data Center

B. *Calculation Parameters*

TCO calculation model in this study will be divided into parameters , as follows:

1. *Server Cost*

TCO analysis in terms of finance / investing server . The following table analyzes the formula for the calculation of the cost server:

Table 1. TCO Formulation for *Server Cost*

Para.	Description
N_s	Number of physical servers in resource pool
VI_{ps}	Cost per physical server of same configuration

$Cost_{servers} = VI_{ps} * N_s$

2. *Software Cost*

TCO analysis in terms of financing / investment software. The following table of formulas for the calculation of the software cost analysis:

Table 2. TCO Formulation for *Software cost*

Parameter	Description
VI_s	Unit Price of Type II software
VI_o	Unit Price of Type I software
VI_m	Unit Price of Type III software
S_s, S_o, S_m	Subscription factor – percentage of unit price that yield annual fee
$N_{serverlic}$	Number of Type II software license
N_{oslic}	Number of Type I software license
$N_{monitorlic}$	Number of Type III software license

$Cost_{software} = [S_s * VI_s * N_{serverlic} + S_o * VI_o * N_{oslic} + S_m * VI_m * N_{monitorlic}]$

3. *Network Cost*

TCO analysis in terms of financing / investment on the use of network devices (switches and network cable). The following table of formulas for the calculation of the network cost analysis:

Table 3. TCO Formulation for *Network Cost*

Para.	Description
N_{switch}	Number of new network switches per year
S_{NIC}	Number of NIC per virtualized server
P_{NIC}	Number of ports per NIC
P_s	Price per switch
N_{port}	Port number of a network switch

$Cost_{networking} = P_s * N_{switch}$

4. *Power and Cooling Cost*

TCO analysis in terms of finance / infrastructure investment to the use of power and air conditioning . The following table analyzes the formula for the calculation of the power and cooling costs:

Table 4. TCO Formulation for *power and cooling Cost*

Para.	Description
S_{rp}	Sum of the power rating of working servers (it can be gotten from website of servers vendor)
E_s	Price per hour of 1kw of electricity
L_s	Steady-state constant
N_{rack}	Number of racks in working

$Cost_{power} = L_s * E_s * S_{rp} * N_{rack}$

5. *Facilities Cost*

Facility is not a server equipment, but is it necessary to run the operation on a server, such as PDUs, KVM, Cables, and others. Here is table analyzes the formula for the calculation of the cost of facilities:

Table 5. TCO Formulation for Facilities Cost

Para.	Description
N_{rack}	Number of racks
VPfp	Price of facilities per rack
time	Hours consumed

$Cost_{facilities} = N_{rack} * VPfp$

6. *Space Cost*

TCO analysis in terms of financing / investment of the place and the supporting infrastructure for data center environments such as the area of the room, rack and so on. Here is table analyzes the formula for the calculation of the space cost::

Table 6. TCO Formulation for *Server Cost*

Para.	Description
A_p	Cost per square foot to build Cloud [8]
R_{SF}	Square feet per rack
R_{SPACE}	Percent of space taken by racks in all(<1)
W_{Server}	Weight of a physical server
W_{rack}	Weight of a rack
$C_{presssure}$	Constant pressure confronted by unit floor
R_a	Annual Percentage Rate

$Cost_{space} = A_p * S_{pace}$

V. DISCUSSION

In this research, the case study is a private cloud. Not a public cloud service that is generally used by an organization. Therefore, the analysis of the security aspects will be ignored because private cloud management across the data authority and infrastructure managed independently by the organization concerned.

Stages of this analysis is to calculate Total Cost of Ownership of the virtual data center and physical data center. The next stage is compare the TCO calculation results in a comparative table parameters established metrics in a comparative table. The comparison table will be represented in the form of a comparison between virtual data center and data center physical through comparison parameters. The comparison parameters consist of: server cost, software cost, network cost, power and cooling costs, facilities costs, and space costs.

Through this comparison, we can make a hypothesis that the virtual data center has a TCO value more efficient than the physical data center. For example, the parameters for server cost in the physical environment data center would require more physical servers to establish complex applications and information systems. Whereas in the virtual data center environment, many applications and ISs can be run on each virtual servers which is instaled on one host machine as physical server. Because the virtual server has a working concept which is equivalent to a physical server at the same configuration [11], consolidating multiple virtual servers into one physical machine will not be a problem.

From cost network parameters can be retrieved hypothesis that the use of a virtual data center resource savings network devices rather than physical data center.In the physical data center, each server requires a real network device.While in the virtual data center, network device that connects each virtual server the network infrastructure has been virtualized by the virtualization software. It is one of the features of VMware ESX software that can make the hardware resources VMNIC, vNIC and vSwitch virtually [13]. Real network devices in the virtual data center is only found on a physical machine as the host that holds each virtual server. Because of virtual data center using a virtual network devices also, so can be pulled hypothesized that the virtual data center more efficient than physical data center.

From the parameters Power & Cooling Cost can also be retractable hypothesis that use of a virtual data center more efficient in power consumption and engine coolant. As comparative material, physical data center has many servers require electrical power consumption for each physical server that runs independently. Because of many physical servers are running, then the quantity needed also cooling machine that operates much more. Another case with virtual server, the power consumption only used on physical machines that accommodate multiple virtual machines in it. needs engine coolant on a virtual server is also much less because only physical machines that require cooling machine directly.

From the parameter facilities cost and space cost, Virtual data center is also expected to be more efficient than the physical data center. Physical data center consists of many physical servers are in operation will need more space and facilities to support its operations. While in the virtual data center, space and facilities needed a little more because the room and support facilities are only used for the physical machine that serves as the host of the virtual machines in it.

In terms of software cost cannot be estimated infrastructure more profitable. Context of software cost in this research is financing regarding licensing of the use of support software on the server, such as antivirus, firewall, application backup, disaster recovery, office applications and databases as the data warehouse from the data center. Use of software from the virtual data center and physical data center expected have value equivalent for software licenses can not be virtualized by the virtualization software. However, of the total cost of ownership will be analyzed from the comparison, it can be hypothesized that virtual data center infrastructure has a total cost of ownership is more efficient than the physical data center infrastructure.

Hypotheses for server costs, network costs, and facilities costs can prove in result comparison in table 9. There is the result for calculation of these 3 parameters server costs, network costs, and facilities costs. Comparative value of the calculation table converted into the IDR currency.

Table 9. Result Comparison

Infrastructure Parameters	Physical Server (IDR)	Virtual Server (IDR)
Server Cost	1.227.452.400	332.588.026
Network Cost	328.000.200	166.750.300
Facilities Cost	158.996.250	35.332.500

From comparative cost for server parameters in Table 9, it can be seen that there could be savings in terms of server funding by 73% from IDR 1,227,452,400 to arrive at a value of just IDR 332 588 026. Server cost comparison chart shown in figure 2 :

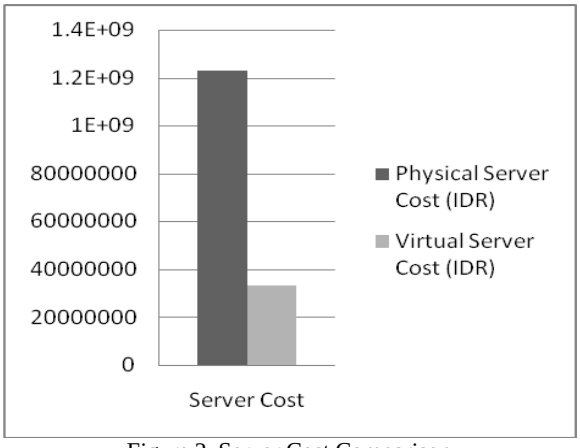

Figure 2. Server Cost Comparison

From comparative cost of network parameters in Table 9, it can be seen that there could be savings in terms of network cost, especially in network switches and NICs by 49% from IDR 328.000.200 to arrive at a value of just IDR 166.750.300. network cost comparison chart shown in figure 3:

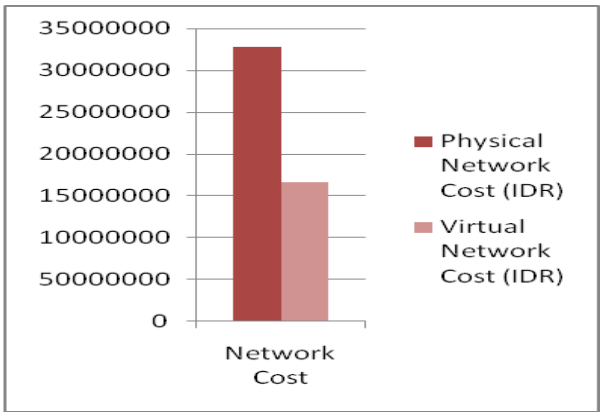

Figure 3. Network Cost Comparison

From facilities cost parameter comparison in Table 9, it can be seen that there could be savings in terms of cost facilities by 77% from IDR 158.996.250 to arrive at a value of just IDR 35.332.500. Facilities cost comparison chart shown in figure 4:

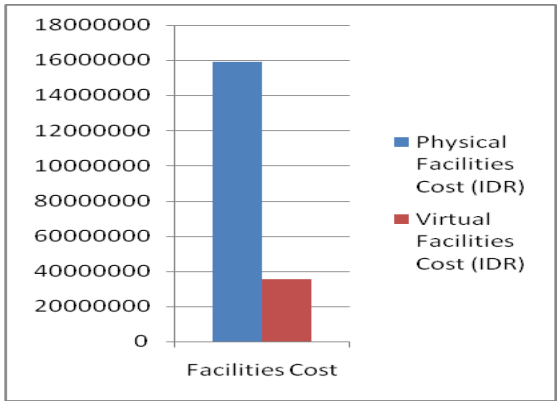

Figure 4. Facilities Cost

As for the parameters of the software cost, power and cooling costs and space costs are still in the process of calculation

VI. CONCLUSION AND FUTURE WORKS

Virtualization technology as a basic concept of cloud computing has provided benefits in terms of server management. This study will conduct a study of the economics of the application of virtualization technology in the data center in an educational institution (university). Through the analysis of the total cost of ownership will be carried out, virtualization technology is also expected to provide benefits in terms of investment and economic educational institutions. If the TCO calculations were found return on investment, it could be concluded that virtualization technology in education institutions can be an important component in the IT strategic plan.

To prove that hypothesis this research will perform calculations and analysis of the total cost of ownership for data centers use virtual infrastructure and will compare the results of these calculations with the data center that uses physical infrastructure. Case studies will be carried out on data center Universitas Gadjah Mada. The hypothesis of this study is implementation of virtualization in the data center can produce investment profits in terms of server costs, software costs, network costs, power costs, cooling costs, facilities costs, and space costs. From these result, it can be seen that the savings occur in 3 parameters, there are server cost, network cost, and facilitites cost. Meanwhile, the calculation for the software cost, power & coolling cost, and space costs, are still in the process of calculation.

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REFERENCES

[1] Z. Jingxian, "The Applied Research on Virtualization of Server in Campus Network," in 2011 International Symposium on Computer Science and Society (ISCCS), 2011, pp. 23–25.

[2] L. Guowei, "Study on digital campus IT infrastructure virtualization," in 2011 6th International Conference on Computer Science Education (ICCSE), 2011, pp. 1051–1053.

[3] N. Antonopoulos and L. Gillam, Cloud computing principles, systems and applications. London: Springer, 2010.

[4] M. H. Hugos and D. Hulitzky, Business in the cloud: what every business needs to know about cloud computing. New York: Wiley, 2011.

[5] J. W. Rittinghouse and J. F. Ransome, *Cloud computing: implementation, management, and security*. Boca Raton: CRC Press, 2010.

[6] C. Gang, "Data Center Management Plan in Cloud Computing Environment," in 2010 International Conference on Information Management, Innovation Management and Industrial Engineering (ICIII), 2010, vol. 4, pp. 393–396.

[7] J. Simão and L. Veiga, "VM Economics for Java Cloud Computing: An Adaptive and Resource-Aware Java Runtime with Quality-of-Execution," in 2012 12th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGrid), 2012, pp. 723–728.

[8] P. Graubner, M. Schmidt, and B. Freisleben, "Energy-Efficient Virtual Machine Consolidation," IT Professional, vol. 15, no. 2, pp. 28–34, 2013.

[9] L. Liu, O. Masfary, and J. Li, "Evaluation of server virtualization technologies for Green IT," in 2011 IEEE 6th International Symposium on Service Oriented System Engineering (SOSE), 2011, pp. 79–84.

[10] D. Yokoyama, V. Dias, H. Kloh, M. Bandini, F. Porto, B. Schulze, and A. Mury, "The Impact of Hypervisor Layer on Database Applications," in *2012 IEEE Fifth International Conference on Utility and Cloud Computing (UCC)*, 2012, pp. 247–254.

[11] Ruest, Danielle & Ruest, Nelson.2009. Virtualization:A Beginner's Guide.New York: McGraw Hill.

[12] Anonim. 2006, Introduction to VMware Infrastructure. Dalam http://www.vmare.com, VMware, Inc., PaloAlto.

[13] Anonim. 2010, VMware Infrastructure 3. Dalam http://www.vmare.com, VMware, Inc., PaloAlto.

[14] X. Li, Y. Li, T. Liu, J. Qiu, and F. Wang, "The Method and Tool of Cost Analysis for Cloud Computing," in IEEE International Conference on Cloud Computing, 2009. CLOUD '09, 2009, pp. 93–100.

[15] D. G. Chandra and M. D. Borah, "Cost benefit analysis of cloud computing in education," in 2012 International Conference on Computing, Communication and Applications (ICCCA), 2012, pp. 1–6.

[16] L. Guowei, "Study on digital campus IT infrastructure virtualization," in *2011 6th International Conference on Computer Science Education (ICCSE)*, 2011, pp. 1051–1053.

[17] N. Kumar and R. K. Mittal, "Cloud computing setup for a campus environment," in 2012 International Conference on Cloud Computing Technologies, Applications and Management (ICCCTAM), 2012, pp. 88–91.

[18] B. Yamini and D. V. Selvi, "Cloud virtualization: A potential way to reduce global warming," in Recent Advances in Space Technology Services and Climate Change (RSTSCC), 2010, 2010, pp. 55–57.

[19] V. Salapura, "Cloud computing: Virtualization and resiliency for data center computing," in 2012 IEEE 30th International Conference on Computer Design (ICCD), 2012, pp. 1–2.

[20] Gartner Total Cost of Ownership. . http://amt.gartner.com/TCO/index.htm