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Abstract

For many organizations it is difficult to determine the total costs caused by offering own services in the cloud as well as to compare them with the costs caused by an in-house datacenter. In practice, some models exist that support organizations in analyzing costs. However, these models are mostly static and do not consider the dynamics of cost development when using cloud computing. The purpose of this paper is to design and develop a simulation model that covers such dynamic aspects and supports decision makers in analyzing cost-benefits of cloud computing versus own datacenter. The model is based on a theoretical framework for IS and applies the method of system dynamics.

1 Introduction

As Gartner predicted, cloud computing is currently on the "peak of inflated expectations" [13]. Cloud computing is a concept where IT resources and services are provided via Internet [6], highly scalable, on demand, web accessed IT-resources, costs and flexibility benefits due to standardization, modularization, and virtualization using scaling effects [2]. Cloud computing does not only imply the applications and services delivered over the Internet, it also refers to the hardware, software and infrastructure of the database performing the demanded services [3]. Some researchers distinguish between three types of cloud computing: Software as a Service (Saas), which covers application services like Salesforce; Platform as a Service (PaaS), such as developer platforms like the Google AppEngine; and Infrastructure as a Service (IaaS), such as Amazon Web Services [28, 32].

There is a debate whether cloud computing is a cost advantage or not compared to own datacenters [18]. For instance, for service providers, one of the most frequent questions is whether it is more economical to move the existing datacenter-hosted services to the cloud, or to keep them in the datacenter [3]. This means, that one of the service provider´s primary criterion for such a decision is costs. However, for many organizations it is relative complicated to determine the costs caused by offering own services in the cloud as well as to compare them with the costs caused by an own datacenter [17]. In practice, some models exist that support organizations in analyzing and comparing costs, such as "Amazon Simple Monthly Calculator.

However, these models are mostly static and do not consider the dynamics of cost development by using cloud computing, such as additional resource request for known "peaks" for a desired time span. To close this gap, we develop a simulation model, which covers the dynamics of cost development and assists decision makers by analyzing costs-benefits associated with cloud computing and own datacenter. This simulation model is based on system dynamics approach. System dynamics is useful for identifying key decision factors and relationships between them and helps to perform decision making in a more efficient way [15]. System dynamics is a simulation methodology for modeling dynamic and complex systems, i.e. systems that change continuously over time. Cloud computing also shows continuous changes such as customer and company new demands.

The remainder of this paper is organized as follows: In section 2 we describe our research method. In section 3 we analyze the literature regarding cost, risks, advantages and disadvantages associated with cloud computing and own datacenter. In section 4 we propose our system development methodology for the simulation model. We conclude with a discussion and ideas for further research in section 5.

2 Research Method

To identify the main components of the simulation model for cloud computing costs analysis, we first conducted a literature review [7, 31]. Our scope was to account for contributions regarding costs, risks, advantages, and disadvantages in the cloud computing domain and in operating own datacenter. The proposed simulation model is based on a theoretical framework for IS development process proposed by Nunamaker et al. [29], incorporated with the method of system dynamics [30]. For an initial verification of the simulation model we conducted six structured interviews with experts in the field of cloud computing and virtualization domain.

3 Literature Review

In this section we give an overview of literature in the cloud computing and own datacenter.

3.1 Cloud Computing

3.1.1 Costs associated with cloud computing

For many organizations it is relative complicated to determine the exact total costs caused by offering own services in the cloud as well as to compare them with the costs caused by an own datacenter [17]. For instance, the average cost per year to operate a large datacenter is usually between $10 million to $25 million [23], while according to Alford and Morton [1], an organization with 1,000 file servers faces average costs in the cloud between $22.5 million and $31.1 million.

According to Durkee [17], while running into the arguments regarding cloud economics, the first controversy to solve is "*OpEx vs. CapEx*". This refers that running an application (or a service) with own resources at the own datacenter requires capital expenditure ("*CapEx*"), while using external cloud computing resources and paying just for its use means having operating expenditure ("*OpEx*") [17, 18]. In other words, the question arises whether converting capital expenses to operating expenses (CapEx to OpEx) is a cost advantage or not [3]. For instance, having an own datacenter means having costs for power, cooling, building, network, storage infrastructure, etc. [3, 17, 20]. On the other side, running the service in the cloud produces other kind of cost factors, which will be described as follows.

Expensive and slow data connection: Service providers have to develop and transfer the data of the service or application they want to offer to the cloud. Due to low bandwidth and expensive connection fees, the data transfer could be slow and cause high costs to the organization [19].

Operation costs: Using virtual machines instead of physical machines does not necessarily mean that all the costs associated with hardware and software operations are transferred to the cloud computing provider. Depending on the level of virtualization, some (or even all) of the costs related with software and hardware management may remain (i.e. upgrades, applying patches, etc.) [3].

Migration: Another issue is the costs caused by the software complexity and the migration of the data from a legacy enterprise application into the cloud. Although migration is a one-time task with a given cloud computing provider, the effort and money invested can be notable [3].

Possible failure and data loss: A temporary breakdown could cause data loss and other scenarios that may produce major damages and extra costs.

Platform costs: The application-operating environment causes generally annual maintenance costs [23].

Backup and archive costs: These costs depend on the backup strategy implemented [23].

3.1.2 Risks associated with cloud computing

Although cloud computing shows a number of benefits for many organizations, there is still a constellation of risks associated with it. According to Gartner [21], cloud computing has "*unique attributes that require risk assessment in areas such as data integrity, recovery, and privacy, and an evaluation of legal issues in areas such as e-discovery, regulatory compliance,* *and auditing*". Moreover, professionals are conscious of this situation: as ENISA shows in their study, around 45% of IT professionals believe that risks involved in cloud computing outshine any benefits [11]. ENISA [8] identifies three main risk categories associated with cloud computing: 1) Policy and organizational risks, such as lack of standards and solutions, loss of knowhow, or lack of transparency; 2) Technical risks, such as uncontrolled backup system, data deletion, or loss of governance; 3) Legal risks, such as data protection, or copyright and software licensing risks.

3.1.3 Advantages of cloud computing

There are a number of advantages and potential benefits for organizations that run their applications and services in the cloud. One of the most known advantages is the cost reduction, which according to Zeitler [35], results due to low IT infrastructure and software costs. Moreover, organizations implementing cloud computing report cost reductions of 30 percent [22]. Besides the financial factor, there are other related benefits. For instance, Erdogmus [12] describes other advantages of cloud computing as “scalability, reliability, security, ease of deployment, and ease of management for customers, traded off against worries of trust, privacy, availability, performance, ownership, and supplier persistence”. Some of these issues are discussed as follows [4, 24, 33]:

Scalability and flexible infrastructure: Cloud computing offers the possibility to scale the infrastructure with the demand for peak loads and seasonal variations, allowing greater availability for both customers and partners.

Resource management: Service providers can use more flexible and efficient resources like servers, storage and network resources by using virtualization technology in cloud computing.

Consolidation: Resources such as server, storage, databases, etc. can be used more flexible and efficient by using virtualization in cloud computing. Consequently, less physical components are needed and therefore both amount of space and costs are saved.

Energy efficiency: Cloud computing enables energy efficiency due to reduction of physical components.

Backup and Recovery: The backup and recovery options of a cloud service may be more efficient than those of an organization, since copies are maintained in different geographic locations, which makes the backup procedures more robust and faster to restore.

3.1.4 Disadvantages of cloud computing

In the last section we presented the advantages of cloud computing. Nevertheless, there are a number of drawbacks related with it. However, one of the most known and also one of the most wicked disadvantages of cloud computing is the security and privacy concern. Therefore, in this section we summarize the drawbacks and disadvantages an organization has to face while offering its services in the cloud [4, 24, 25].

System complexity: Compared to a traditional datacenter, cloud computing environments can be very complex due to the number of components and their dispersion. Moreover, the number of possible interactions between the components increases the level of complexity.

Shared environment: Service providers that offer their services in the cloud typically share the resources and components with other unknown cloud users. Consequently, the risks and threats increase producing a drawback for the offered services.

Remote administrative access: Compared to own datacenter, where the applications and data are accessed from the organization´s Intranet, organizations with services in the cloud have to face increased risk from network threats due to remote access.

Loss of control: Migrating the data in the cloud means transferring control to the cloud provider of both information and system components that were previously under the organization´s control. Consequently, by loosing control of physical as well as of logical aspects, the organization also losses the ability to set priorities, weigh alternatives and think about changes regarding security and privacy issues.

For many organizations, the advantages of cloud computing far outweigh the disadvantages, for other, the disadvantages still outshine any benefits [11].

3.2 Datacenter

3.2.1 Risks associated with own datacenter

When considering the option of offering services in the cloud, a provider should not only be aware about the risks associated with cloud computing, but also with the ones related with owning a datacenter. According to Dines [10], the primary risk associated with having an own datacenter is the capacity bottleneck. Running out of capacity means having high costs and in extreme cases, it "*requires an unexpected data center move, which is not only expensive but also potentially disruptive*". On the other side, having too much capacity could also be a risk, since IT infrastructure is most effective at peak load, making the datacenter inefficient [10]. Moreover, besides of facilities, there are also other areas of risks while running an own datacenter, such as operations, monitoring [34], natural disasters and terrorism.

3.2.2 Advantages of datacenter

Although many organizations decide to move their services to the cloud due to economical issues, there are still many reasons why organizations should keep their services running in their own datacenters [16, 24, 34]:

Visibility: Having direct access to all the infrastructure components like hardware, software and networking allows a better overview and the possibility to identify and mitigate any issues and systemic failures that crop up.

Control: Having the services running in the own datacenter enables greater control over the infrastructure and resources and therefore the access to the platforms can be restricted to direct or internal connections.

Less complexity: Datacenter are less complex since running the services in the own datacenter means having fewer components and therefore fewer interactions between them. Moreover, all physical components are located in the same place.

Optimization: Having an own datacenter gives the possibility to leverage and share existing place, i.e. having the IT department working in close proximity to the data center floor for a low cost.

Usage of knowledge: Datacenters are normally run by professionals with experience and expertise.

3.2.3 Disadvantages of datacenter

Nowadays there are many organizations that still build and maintain their own datacenters even though that is not part of the core expertise of the company [26]. As a result, there are a number of datacenters that are operated inefficiently [33]. Absence of expertise by running own datacenters also produces a number of other disadvantages that will be described as follows [3, 9, 26]:

Inefficiency: Since a service provider has to provide enough resources to deal with peak times, the average utilization rate of datacenters ranges from just five to twenty percent.

Costs: It is predicted, that the costs of datacenter facility and energy usage will become significantly larger than the actual server procurement costs.

Scalability: Running an application or service in own datacenter makes it difficult to handle a rapidly growing load.

Environment: The impact of datacenters on the environment is currently receiving negative attention.

4 Theoretical Framework

The purpose of this research is to design and develop a simulation model that supports decision makers in analyzing costs associated with cloud computing and own datacenter. The proposed simulation model is based on a theoretical framework for IS development process [29], incorporated with the method of system dynamics [30]. The theoretical framework (cf. Figure 1) consists of five stages: construction of simulation model for costs analysis, development of system architecture, analyzing and designing the system, building the prototype system, and evaluation of the system. In the following we describe each stage in more detail.

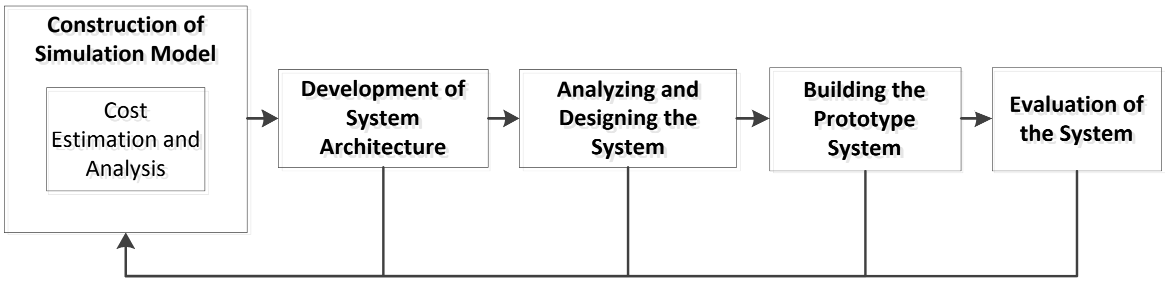

Figure 1: Theoretical framework for the simulation model

4.1 Phase 1: Construction of simulation model for costs analysis

First, a simulation model for cost-benefit analysis for cloud computing versus own datacenter is constructed as a kernel of the system.

4.1.1 Costs estimation and analysis

To analyze the costs-benefits of cloud computing and own datacenter, we apply the Total Cost of Ownership (TCO), since TCO considers not only the investment cost, but also cost over time for operation and maintenance. TCO is generally used as a means of addressing the real costs attributing to owning and managing an IT infrastructure in a business [27].

To operate an own datacenter, usually companies are confronted with significant investment in capital outlay and ongoing costs. Company must acquire the required hardware such as server, network equipment, the required software, e.g. in the form of operating system license, and the infrastructure such as uninterrupted power supply, cooling, or internet connection. Additionally, company must also account for the costs in computer room, such as costs for room square meter, fire detection and protection systems, or raised floor, as well as the ongoing costs for the administration. These costs usually depend on the average performance of server and network components in kW and the desired tier level [27].

In contrast to own datacenter, by cloud computing the company need neither own server nor own datacenter. Companies no longer require the large capital outlays in physical hardware and the administration expenses to operate and maintain it. Infrastructure as a Service (IaaS) is mostly offered by providers such as Amazon EC2, Microsoft Azure, or force.com. Since, cloud computing makes use of pay-per-use concept, the companies can get results as quickly as their programs can scale. However, the number of IaaS provider increases, thus, it is necessary to determine which cloud services meet the technical requirements a company needs. Besides cost-benefit analysis, company should also determine the security and legal aspects of offered cloud services, as they play an important role for business continuity.

4.2 Phase 2: Development of system architecture

A good system architecture is understood as a road map for the systems building process by placing components into perspective, specifying their functionalities, and defining the interrelationships between system components [29]. Our system architecture (cf. Figure 2) consists of two main fragments. The first fragment represents the simulation model, where the mathematical formulations of costs computations are implemented. It is divided into two main modules: costs module for cloud computing and cost module for own datacenter. The modularity concept enables us to use the modules in a different context for multiple customers. The second fragment represents the user interface, where the evaluators can estimate the costs. After their input, we can start the simulation and they can analyze their outputs regarding their inputs with the help of chart and graphs.

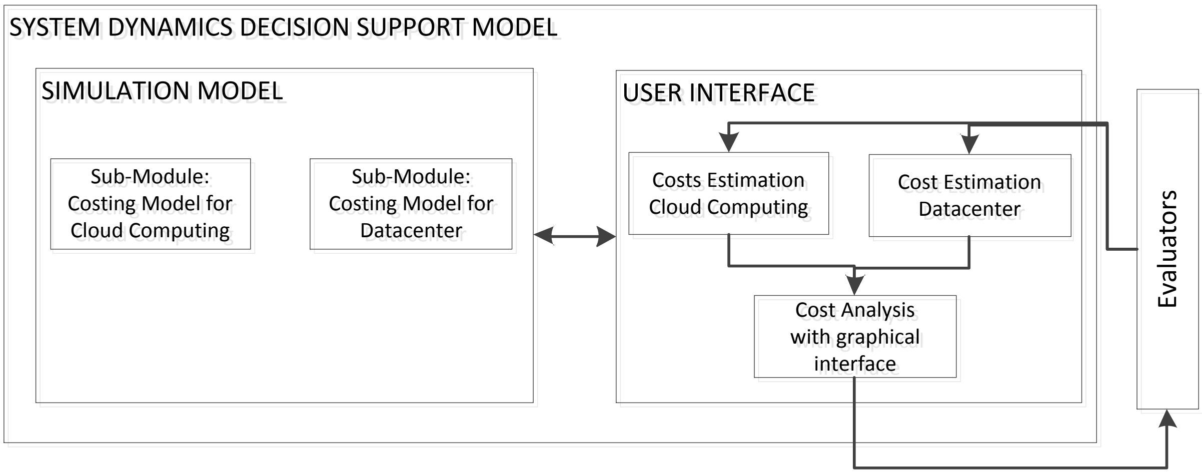

Figure 2: System architecture

4.3 Phase 3: Analyzing and designing the system

In this phase, we determine the model components and the development platform. This involves the understanding of the studied domain, the application of relevant scientific technical knowledge, and the creation and selection of various alternatives [29]. After identifying the model components, we can determine the interactions and interrelationships among them. In this phase, we also assign the mathematical formulations for costs calculations.

4.4 Phase 4: Building the prototype system

In this phase, the system architecture is transformed into a prototype model. Implementation of a prototype system is used to demonstrate the feasibility of the design and the usability of the functionalities of a system development research project [29]. Based on the mathematical formulation and identified interrelationships between the model components, we can build our simulation model. For building the simulation model, we choose the simulation approach system dynamics, since this method can be used by identifying key decision factors and their interrelationships (cf. Figure 3). In following, we explain the simulation modules.

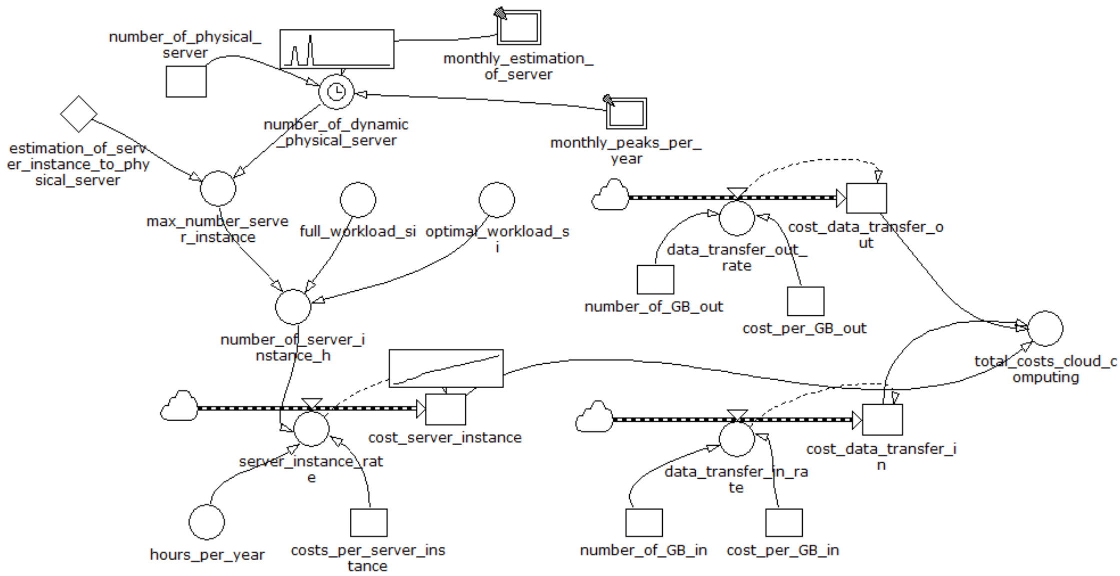

Figure 3: Cost module for cloud computing

To estimate the costs for cloud computing instance, we first need to estimate how many virtual server instances offered by the IaaS provider equal to a real server. We assume that two instances correspond approximately to the power of one physical server. Then we calculate the required number of server instances per hour. The final costs for server instances are calculated as product of “number of server instances”, “hours per years”, and “costs per server instances”. In addition to server costs, we also must take into account the costs for the data transfer, in order to obtain the final costs for cloud computing instance. Based on the real values, we calculate for the data transfer with 0.05 Euro/GB for incoming data and 0.10 Euro/GB for outgoing data. The total costs of cloud computing instance are then calculated as sum of “costs for server instance”, costs per incoming and outgoing data transfer. To cover the dynamic development of costs for required resources, we incorporate in our simulation model the *step* function. This function allows company to exactly specify the known “peaks”. Let assume, a company knows that every August and December, in the first two weeks they need additional resources. With the help of this function, company can specify the exact days, hours, or month for the increased resources demand. We also applied this function to the variable “hours per year”, i.e. company can also specify individual dynamic usage time span. The simulation model then considers these “peaks” and calculates the costs over defined time span.

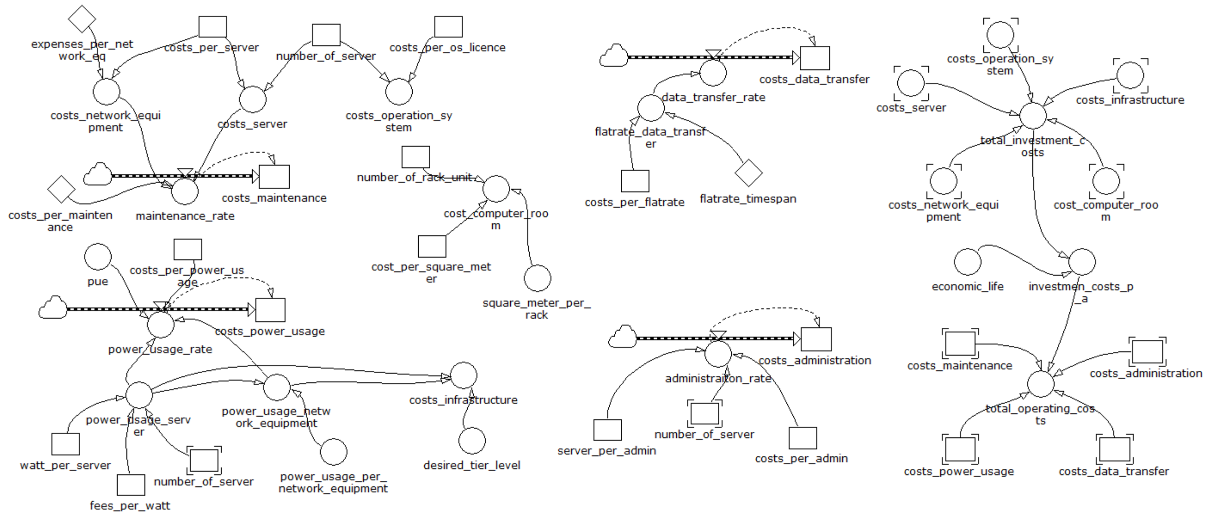

Figure 4: Cost module for in-house datacenter

To estimate the costs for server, we need to consider the initial cost of server, operating system licenses, and additional network equipment. The costs for server are calculated as product of “number of required server” and “initial costs for server”. The costs for operating system licenses consist of “number of required server” and “costs per operating system license”. The costs for additional network equipment are calculated as product of “number of server” and “the expenditures of network equipment”. The expenditures of network equipment usually consist of 10 to 30 % of the costs of server. Additionally, we need to calculate the ongoing maintenance costs for server and network equipment. We estimate the costs for infrastructure as sum of “power usage server”, “power usage network equipment” multiplied with the costs of the desired tier level [27]. Additionally, we need to consider the power usage of the infrastructure. We need first to determine the power usage effectiveness (PUE), which is given by: PUE = Total Facility Power/ IT Equipment Power [5]. The PUE can range from 1.0 to infinity, whereas 1.0 indicates 100% efficiency. The realistic PUE values are in the 1.3 to 3.0 range [5]. To calculate the costs for the administration, we need to estimate how many servers one administrator can maintain. This depends on the size of datacenter. To obtain the final administration costs, we first divide the “number of server” through “the number of estimated server maintenance per administrator” multiplied with “the costs for one administrator”. For the data transfer costs, many companies rely on the flat rates. After estimating the costs for hardware, software, infrastructure, administration and data transfer, we can sum all these costs to obtain the total costs for data center.

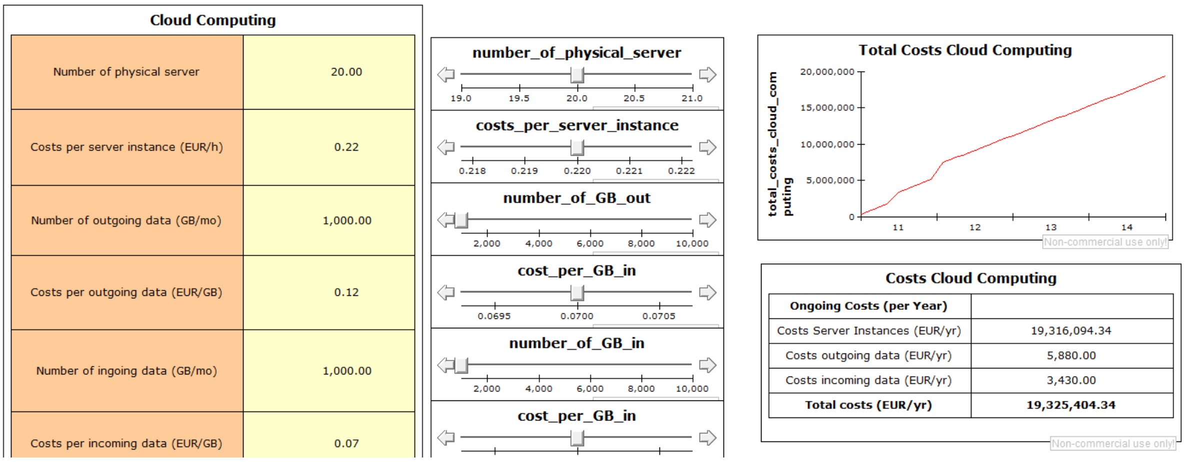

Figure 5: Overview of an user interface for cloud computing

Decision makers can change the values in the user interface, where we list the key influencing values for cloud computing and own datacenter. For example, user can modify the number of required components, such as server or licenses, or modify the costs for data transfer flat rate. In this user interface they can analyze the costs between own data center and cloud computing with the help of charts and graphs. The simulation model allows them to simulate different scenarios for different time span.

4.5 Phase 5: Evaluation of the system

To evaluate the simulation model, we performed an initial verification. For this purpose, we conducted six structured interviews with experts in the cloud computing and virtualization field. Through this verification, we capture the information whether the experts like or dislike the simulation model and whether it covers their needs or not. This verification ensure that the simulation model covers all functions that meets the users' requirements and help them to analyze the costs and risks associated with the decision whether to host services in cloud computing or whether to operate own datacenter. All evaluators are potential users of the model, and one of them has knowledge in system dynamics. According to Gasching et al. [14], evaluations by potential users help to determine the utility of a system, such as easy of interaction, its efficiency, or whether it produces useful results.

The overall results indicate that the experts found the simulation model "useful", "intuitive", and "complete" at first sight. All interviewees appreciate the modular separation of user interface. They like the separation between own datacenter and cloud computing, since this allows them to use the model only for specific domain. They also appreciate the "analysis user interface" where they found the costs comparison for both domains. Moreover, three experts stated that they like the presentation of results in "analysis user interface", as we used charts and time graph. Four interviewees agreed that they conceive of applying the model in their daily work. The remaining two experts do not agreed with the idea that cloud computing is not associated with onetime costs investments. They suggest to also to account for onetime investments such as licenses for Firewall, or costs for infrastructure setup such as internet connection. For the next version, we are going to incorporate the evaluator's feedback into the simulation model.

5 Conclusion and Outlook

We propose a simulation model for cost-benefit analysis of cloud computing versus own datacenter. This model is intended to fill the gap where a cost model that covers dynamic issues for cloud computing, is lacking. Practitioners will find the proposed simulation model useful by analyzing cost-benefits between cloud computing and own datacenter, as well as by analyzing different scenarios virtually before transferring them into the real world. Researchers can use the proposed model for testing different types of hypothesis and deriving recommendations for further actions. However, this research is not without its limitations. In this paper, we only proposed simulation model that considers costs for cloud computing and own datacenter. Thus, in the future, the simulation model might be more detailed to also be used for analyzing not only the economical impact but also organizational, as well as how is IT provisioned and used. In future work the authors will concentrate on extending the proposed simulation model to also account for other domains.

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