Integrating Cost Analysis in the Cloud: A SoS Approach

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***Abstract*—Cloud computing has succeeded in transforming the ICT industry, making software and hardware services even more accessible to businesses and establishing an environment for rapid innovation. Since cloud computing is an innovative business model, whose deployment is accompanied by huge investments, a thorough, multilevel cost analysis of provided services is vital. Such an analysis should focus, among others, on demand forecasting for computational resources and financial assessment of cloud computing investments, estimating crucial economic parameters, such as Net Present Value (NPV), Return of Investment (ROI) and Total Cost of Ownership (TCO). Into this context, a model-driven techno-economic approach is introduced in this paper targeting the estimation of economic parameters of cloud service deployment, which is able to assist decision support procedures for cloud users, cloud providers and cloud brokers. SysML is adopted as a modeling language for describing cloud architectures as system-of-systems (SoS), emphasizing cost properties. As an example, the Total Cost of Ownership (TCO) for cloud infrastructure and services is explored. TCO properties are incorporated into SysML cloud models, while cloud providers are facilitated in computing TCO.**

Keywords – Techno-economic analysis, cloud models, system-of-systems, total cost of ownership

I. Introduction

Cloud computing has experienced exponential growth over the last decade. Businesses adopt this new innovative business model in their effort to be competitive, efficient, and productive. It is an emerging business model that contributes to the growth and competition of the technology market. It has succeeded in transforming the ICT industry, making software and hardware services even more accessible to businesses, offering an environment for rapid innovation [1], [2].

Cloud computing is a fast-growing business model, while global cloud traffic is expected to be constantly increasing [3]. As a consequence, the requirements for cloud IT infrastructure are continuously growing and there is a need for a detailed techno-economic analysis, focusing on demand forecasting for cloud services and economic assessment of the investments needed to support this emerging demand.

Techno-economics engineering combines process modeling and engineering design with economic evaluation, providing with both qualitatively and quantitative understanding of the impacts technology breakthroughs have on the financial viability of an ICT infrastructure [4]. In the context of cloud computing, such an analysis extends the corresponding business model by integrating into it new entities and different types of constraints, such as economic, social and technical, regarding the development and promotion of the new cloud services [5].

Cloud users buy and manage IT resources and services and cloud vendors are responsible for providing access to servers, databases, software and other resources, ensuring that they can be flexible in their service delivery, keeping the underlying infrastructure hidden from the cloud user. The requirements for cloud IT resources provided by the cloud are continuously growing, therefore it is vital for the providers to operate their datacenters based on the requests of cloud users, but it is also important to focus on the operational requirements of a datacenter, such as Power and Cooling energy [5], [6].

As far as the demand side of the cloud market is concerned, the number of businesses that switch to the cloud seeking to improve their productivity and effieciency increases. This growth of demand will affect the supply side of the market, forcing the cloud providers to get prepared to meet this level of demand by creating and maintaining the appropriate infrastructures. However and because these infrastructures are usually accompanied by high level of investments which are also risky in nature, a detailed and thorough techno-economic analysis is needed. The analysis will study the viability of the investments and the pricing policies of cloud providers. Furthermore, it will provide details regarding forecasting of their future demands in IT infrastructure and services, which will be mainly achieved by simulating client consumption of cloud dynamics in real time. The study of aspects, such as the total cost of ownership, the cost of datacenter infrastructure expansion, the return on investment, the effective resource management and techno-economic metrics, is therefore vital.

The estimation of the Total Cost of Ownership (TCO) in particular is a procedure that provides the means for determining the total economic value of an investment, including the initial capital expenditures (CapEx) and the operational expenditures (OpEx). In the context of the cloud computing and especially from the provider's point of view, as represented by the datacenter, TCO corresponds to the estimation of the costs required to build and operate a cloud infrastructure. According to the literature, the costing entities of a cloud infrastructure can be grouped into eight categories: server, software, facilities, support and maintenance, network, power, cooling, and real estate [7].

To enable the estimation and exploration of the TCO of alternative cloud architectures, corresponding cloud models should be properly extended to describe cost-related properties. There are numerous models proposed in the literature to depict cloud architectures, mainly for design purposes or to estimate cloud performance [8], [9]. Numerous cloud simulation tools also propose alternative cloud models. As cloud infrastructure and services are complex systems, they can be also modeled as system-of-systems [10]. There already efforts adopting such an approach recorded in the literature [9]. Cloud architectures can be described as a hierarchy of autonomous systems consisting of other systems, having their own internal complexity. The System-of-Systems (SoS) approach does not advocate particular tools, methods, or practices; instead, it promotes a new way of thinking for solving grand challenges of systems whose the interactions of technology, policy, and economics are the primary drivers [10]. Cloud computing has all these features that characterize a system-of-systems.

Such model-based system approaches may also be applied in a more techno-economic context, when designing or configuring a complex system architecture. The task of exploring economic properties is really interesting, since the desired performance and availability are constrained by and combined with ownership and operating costs and investment parameters [5], [11]. The cloud is not only an Internet-based computing technology but also a new business and economic model with numerous benefits and aspects to be studied [2]. It consists of a contemporary case study of complex systems where such a techno-economic analysis is important to determine the success of forthcoming services provided in the cloud. Thus, SoS cloud models should also include cost-related properties, while cloud engineering should focus all necessary techno-economical parameters. As stated in [12], a research challenge in cloud is to take in consideration the costs, risks and benefits of running systems in the cloud. One way to achieve this is to adopt an SoS approach to model the cloud and focus on enriching cloud architecture models with cost-related properties.

Towards this direction, in the paper we propose an SoS approach to model cloud infrastructure and services, emphasizing cost-related properties. To this end, System Modeling Language (SysML) is adopted to model the cloud. SysML is a general-purpose modeling language for systems engineering targeting system-of-systems. It supports the specification, analysis, design, verification and validation of a broad range of systems and system-of-systems and is easily extendable [10]. Cost-related properties are also incorporated into cloud models, while techno-economic metrics like TCO may be computed and explored. It is vital, that all the stakeholders participating in cloud growth are accommodated by such an approach. Thus, SoS cloud model should provide alternative views of cloud users, providers and brokers.

The rest of the paper is structured as follows. Related work is briefly presented in section II. The proposed SoS approach for cloud technoeconomic analysis is described in section III, emphasing TCO exploration. A case study emphasizing cost parameter modeling and computation is discussed in section IV. Conclusions and future work reside in section V.

II. Related Work

During the recent years, cloud computing has gained enormous popularity across the business world as there is an increased demand for a new business model with various economic benefits. Its technical aspects such as security, legal and privacy issues have already been examined in many studies [2], [13], [14], while its economic side seems to have a significant scientific interest, as well [15], [1], [16].

Despite the fact that there are several proposed pricing schemes for the cloud, cloud models emphasizing techno-economical parameters has been mostly neglected. This is the reason why integrating cost analysis in the cloud using an SoS methodology is considered to be an innovative research area of interest, motivating the current study. Subsequently, this paper focuses on the following two categories of literature: (1) cloud computing from a techno-economic perspective and (2) the use of modeling approaches in the cloud.

A. Cloud computing from a techno-economic perspective

Cloud consumers buy and manage IT infrastructure and services and cloud providers offer access to their resources based on various costing models and metrics in order to bill cloud users [12]. Towards this direction there are several studies that have analyzed the developed business opportunities when moving into the cloud using a cost-benefit analysis [17], [18].

More specifically, Strebel and Stage [19] applied an economic decision model for business software application deployment, while running simulations on hybrid cloud environments. They compared operational IT costs, such as server and storage expenses and the external provisioning by means of cloud computing services (fees for CPU hour, time contingent, storage, internet service provider costs and data transfer costs). Furthermore, in [7] a method and a software tool for cost calculation and analysis was developed. The cost of building and operating a cloud, called as TCO, was divided into eight different categories that mainly represent fixed costs, such as setting-up and maintenance costs that providers need to bear during the whole lifecycle. Reference [11] presents a comprehensive TCO model for the three service models of cloud computing (IaaS, PaaS and SaaS) describing cost types and factors. They analyzed the pricing schemes of different cloud models based on data from real cloud computing services.

The results of the literature review show that the topic of technoeconomics of cloud computing has been widely studied, whereas TCO in the cloud needs to be examined more. Further information can be found from the application of the approach of TCO in case studies that use different services, such as web applications and storage from various cloud providers [11], [20].

B. Modeling approaches in the cloud

SoS Cloud modeling approaches have not been discussed widely yet, but there are some studies that made an effort to fill in this gap. [8] focuses on the need of modeling engineering methods that make easier the specification of provisioning, deployment, monitoring, and adaptation concerns of multi-cloud systems (i.e., applications on multiple clouds) at design-time and their enactment at run-time. A domain-specific modeling language, called CloudML, along with a run-time environment were presented, so that the complexity of development and administration of multi-cloud systems were tamed. In [9] a component-based availability modeling framework named Candy, was introduced to compose an availability model for cloud service semi-automatically from the system specification model expressed in SysML. Other approaches use architecture description language (ADL) to model cloud software as interactive systems [21]. In that case, an architecture-driven model-based methodology is followed for engineering cloud software and it describes mainly the logical architecture model of the cloud. The language used for this purpose introduces replication, contexts, and service interfaces as cloud-specific architectural concepts, while additional modeling languages are used as well in order to support other aspects of the system.

III. An SoS model for the Cloud incorporating cost-related properties

The increased demand from clients' side, the growing competition among cloud providers and the continually evolving services of cloud brokers raise an imperative need for the development of a model that should incorporate all the necessary techno-economic parameters of the cloud ecosystem. Such a model should provide alternative views targeting different stakeholders, helping them estimate and explore diverse techno-economic metrics. The model is described using SysML, as discussed in the following, having an SoS approach for the representation of cloud infrastructure. The model is enriched with cost-related properties, enabling the computation of techno-economic metrics. Fig. 1 represents a high-level view of this model.

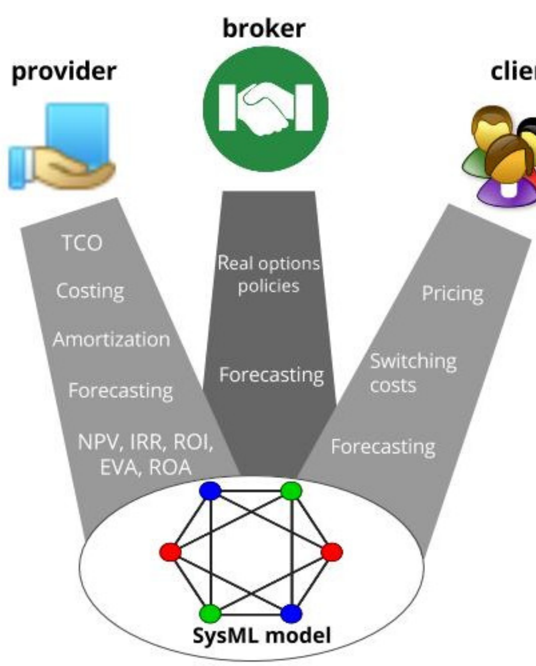

Fig. 1. A Multi-view SoS model for Cloud Techo-economic Analysis

From a client's standpoint, consumers buy and manage IT resources and services from cloud providers, or brokers, depending on the pricing policies applied, the Quality-of-Service (QoS) guarantees and the satisfaction of the advertised guarantees [22]. The work performed in this paper focuses on the construction of a model that will be able to integrate the different pricing schemes the providers use, the brokers negotiate and the clients are subjected to, so that end users, representing the demand side of the market will be able to decide the most appropriate service bundle [15], [5]. In addition, the proposed model will include forecasting information about the future need of the demanded services and resources [3] mostly using techniques that will enable incorporation of realistic, simulated cloud computing user comsumption into real applications. Finally, users intention to switch from the traditional self-owned IT infrastructure to cloud services at an individual level is always a factor that should be taken into consideration, as it can easily discourage clients to adopt the cloud computing technology [23].

On the supplier side, cloud providers offer access to their resources based on various costing and pricing models and metrics, in order to bill their users [12]. They are interested in analyzing the technoeconomic aspects of the investments needed to maintain the corresponding cloud infrastructures, deriving the values of important metrics, such as the total cost of ownership (TCO) seeking to optimize the value of their investments avoiding the high risk and uncertainty associated with them [7]. In its full version the proposed approach will include the design and development of a detailed model-driven methodology which will take into account all the appropriate economic properties, providing as output information for the assessment of an investment. The model will receive as inputs economic parameters such as initial capital expenditures (CapEx), operational expenditures (OpEx), costing schemes, amortization, forecasting details regarding the future demand of services and, in a competitive market environment, the market share of the provider. The outputs provided by the model will include the calculation of important economic indices, such as Net Present Value (NPV), Internal Rate of Return (IRR), Return On Investment (ROI), Economic Value Added (EVA) and Return On Assets (ROA), which have an important impact on the considered investment.

However, since searching for the best provider is not an easy decision for a client, the necessity of cloud broker, as a third-party business model, was born [24]. It is the middleman between users and providers, aiming to succeed in settling the best financial agreement, making a profit out of this service [25]. The brokers role is very important for reaching a point where both sides agree with the price set, reaching the equilibrium point thus maximizing the social surplus. This is the reason the broker is considered to be a significant part of the proposed model. Another goal is to incorporate brokers real options policies and forecasts regarding the future demand of cloud computing resources using simulation-based approaches, so that the model could additionally provide crucial information to the broker's decision making process.

Towards this direction, the work presented this paper can be seen as the first step in developing a model-driven techno-economic methodology which should be able to provide reliable decision support to cloud providers. An important part of this approach is the combination of the technical aspects of the cloud computing model with the economic factors and possible cost categories of cloud computing services applying the TCO methodology, one of the most important cost-oriented approaches, by means of SysML.

A. An SoS Cloud Meta-model Emphasizing Cost-Related Parameters

Emphasizing TCO exploration, a SysML profile has been defined to a) enable the description of cloud infrastructures as SoS and b) automatically compute TCO and related indices. A SysML profile constitutes of a set of SysML extensions in terms of stereotypes, used to define cloud architecture and cost related properties. The corresponding meta-model is depicted in Fig. 2.

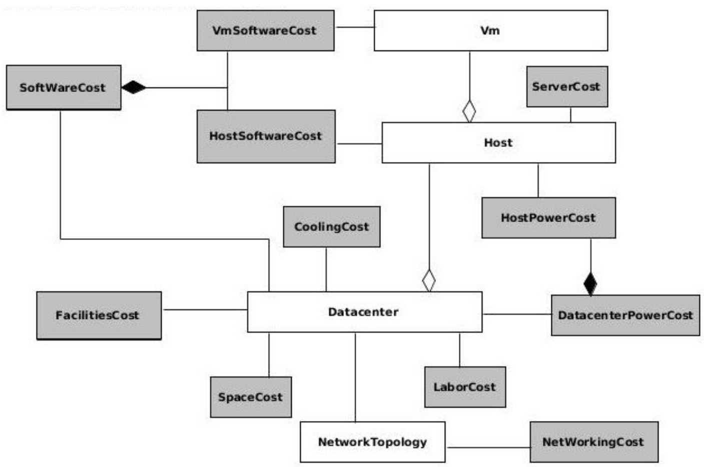

Fig. 2. The proposed metamodel for exploring TCO

The initial technical design of the cloud and its components is definitely necessary for modeling the operation and behavior of a cloud computing environment. The proposed metamodel can describe the basic system components of the cloud, such as data centers, hosts, virtual machines and network topologies, along with their functionality. This is a typical entity hierarchy representing cloud architectures, already adopted by many cloud modeling and simulation tools, as for example CloudSim. CloudSim is used in general for modeling and simulation of cloud computing infrastructures and services [26]. It exposes custom interfaces for implementing policies and provisioning techniques for allocation of VMs under internetworked Cloud computing scenarios. Several researchers from organizations are using CloudSim in their investigation on cloud resource provisioning and energy-efficient management of data center resources, making it appropriate toolkit in order to be customized for the scope of this paper.

The Datacenter entity depicts the ICT infrastructure that cloud providers offer. It encloses a set of hosts and deploys a set of policies for allocating resources, such as bandwidth, memory and storage to hosts that in turn manage VMs. Host represents a physical resource (computing or storage server) in a cloud. It allocates policies for provisioning memory, bandwidth and processing power to VMs. The Vm component models a VM instance that runs inside a host, sharing the host with other VMs. It is characterized by accessible memory, storage, processing power, configurations (software environment) and requirements (availability zone) of the provider, which are allocated by the host. Network Topology implements the network layer in the proposed model, it stores the topology information and all the details about network behavior [26].

According to [7], cloud TCO includes costs that are related with physical servers, software, facilities (wires, racks), labor, networking, power and cooling energy and real estate. Each one of these costs categories is represented as a class associated with some of the aforementioned basic classes of the cloud, composing the proposed metamodel that simulates and models the estimation of the cloud TCO. More specifically,

- ServerCost entity describes the cost of physical servers of a cloud and this is why it is associated with Host. It is assumed that all servers are of the same type, CPU, memory disk and they share the same configuration.
- SoftwareCost class represents the cost for the software licenses that run in the cloud. There are three different types of software in the cloud. Type I software includes Operating Systems licences, Type II encloses Application Software and VM Software and Type III refers to management Software. The estimation of the total software cost of the system is composed by the VMSoftwareCost and HostSoftWareCost entities. VMSoftwareCost includes the software cost of Type I and II and it is associated with the VM class because these types of software run on VMs. In addition, the cost of software Type III is calculated in the HostSoftWareCost class and is associated with Host, since management software runs on hosts.
- NetworkingCost describes the cost related to the networking, meaning to switches, cables, Network Interface Cards (NICs) and is associated with the entity of NetworkTopology.
- Power Cost is used for modeling the cost of the total power consumption and is extensively discussed in the next section of this paper.
- CoolingCost class includes the cost related with the amount of power consumed by cooling equipment.
- FacilitiesCost class refers to the necessary supplies for the operation of ICT equipment, like cables and PDU.
- SpaceCost class describes the real estate cost of a building that fulfills the specifications, in order to accommodate a cloud datacenter.
- LaborCost class represents the cost of wages paid to employees of the data center.

Most of the entities that represent the different costs categories are associated either with DataCenter and Host entities.

Based on the proposed meta-model, a SysML profile was created in the Visual Paradigm tool. An example of a SysML representation of a simple DataCenter consisting of 5 hosts is depicted in Fig. 3. DataCenter design entities are represented as a hierarchy of SysML block entities (they are depicted as gray rectangles). Cost-related properties are associated to DataCenter building blocks are depicted in the figure. DataCenter provider may automatically compute TCO using this model.

IV. Case Study: Power Cost Representation and Computation

Modern data centers that support cloud computing services, manage massive ICT equipment and various applications, providing high performance guarantees. However high service level performance is not the only concern of the provider but also power consumption maintain a vital role in the

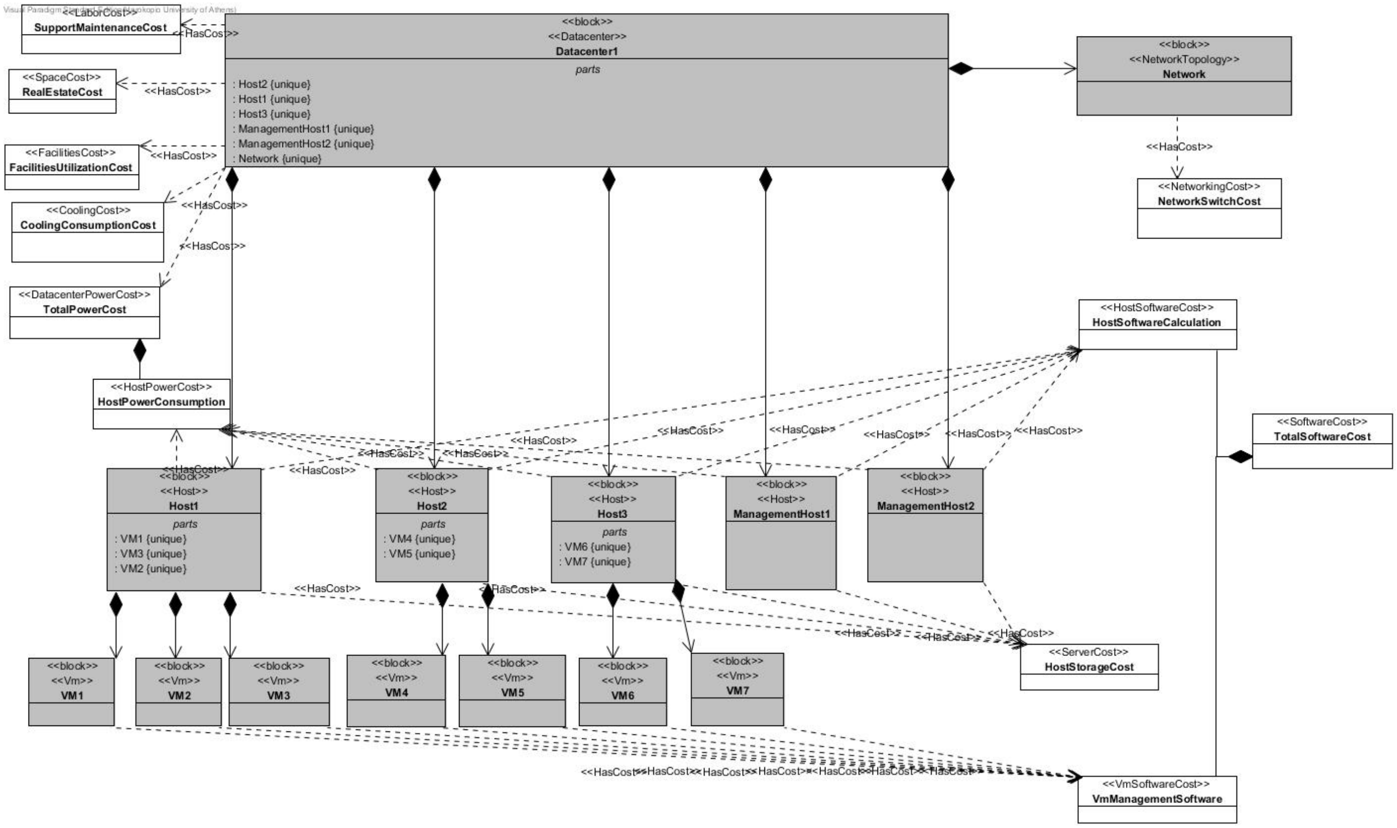

Fig. 3. SysML representation of a Datacenter, enriched with cost-related properties

management of the datacenter. Energy cost is an important factor to the calculation of the TCO [27].

In the proposed approach, the estimation of power consumption is based on the energy that is consumed by the Host and the energy cost of the facilities that are included in the Datacenter. Power Cost entity is prescribed by specific attributes as indicated in Fig. 4.

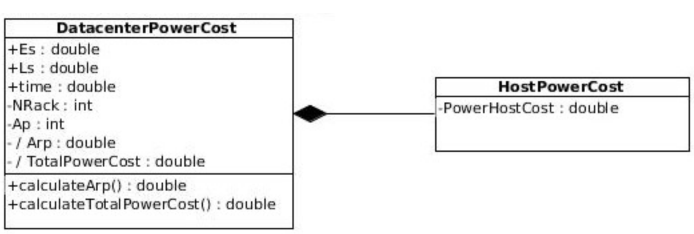

Fig. 4. Power Cost Properties

Host executes actions related to the management of virtual machines, it provides bandwidth, memory, process elements to virtual machines (VMs)[28]. The energy consumption of the hosts is presented by the attribute PowerHostCost of Host Class.

The DatacenterPowerCost class describes the total power cost of the datacenter and it is estimated by correlating the total power cost of all hosts that it is presented by HostPowerCost class and the power cost of other facilities of the datacenter, such as lighting and network devices. The power cost of each host is described by the HostPowerCost class. The attribute PowerHostCost denotes the power consumption of a host and it is a fixed value.

The attributes that are used for the energy consumption of the facilities of the datacenter are [7]:

- Es: The price per hour of 1kw of electricity
- Ls: Steady -state constant
- $Nrack$: The number of racks in working
- $Time$: Hours consumed
- Ap: Amortization period unit (year/month/hour)
- Arp: presents the cost amortizable rate parameter . It is derived from the operation *calculateArp()* that it is described by the relation:
  $Arp = (1 + 0.05) * time/(30 * 24 * Ap)$
- $TotalPowerCost$: Presents the total power cost of the datacenter. It is derived from the operation *calculateTotalCost()* and it is described by the relation:

$$\begin{aligned} TotalPowerCost =& Ls * Es * NRack * Arp(time) * \\ & * \sum_{i=1}^{i=n} PowerHostCost \end{aligned} \tag{1}$$

According to the above relation the total power cost of a datacenter is automatically calculated. Datacenter provider does not have to know the underlying mathematical functions, the only thing that needs to be done is to assign the values of the corresponding cost parameters. Similar procedure can be followed for the calculation of the other cost categories of TCO.

Eventually, the datacenter provider can design alternative cloud architectures with various basic cloud entities of different attributes running a number of scenarios. For each scenario TCO is estimated without having to know the cost functions.

V. Conclusions - Future Work

The SoS approach for analyzing the TCO of the cloud computing business model was applied in this work. The technical design of the cloud and its components were described using the main entities from the framework of CloudSim. The different cost categories of TCO represented as classes were incorporated to extend the cloud business model, so that it becomes more complete. Taking into account the high cost of investments that providers need in order to build and operate a cloud, an approach and a corresponding metamodel were proposed, to model the entities that constitute a cloud environment focusing on the necessary techno-economical parameters. Furthermore, a SysML profile to support the TCO of a cloud using the proposed metamodel was defined and implemented.

The approach of this paper is considered to be just the first step in developing a model-driven techno-economic methodology which should be able to provide reliable decision support to all cloud participants, meaning cloud providers, brokers and clients. As in most cases, there are some limitations in this work, which in turn constitute its further extension and indicate directions for future research. Among them is the transformation of SysML profile to CloudSim executable code. As a next step the framework of CloudSim may be also extended to support the created TCO SysML profile. In addition, since the SoS approach is a model-driven approach and it cannot achieve demand forecasting, the use of simulation as an alternate way for achieving this is proposed as an interesting extension of the model in the future.

The main focus of future research will lie in the modeling, identification and calculation of cost factors and indices that should be integrated to complete the techno-economic analysis and evaluation of the cloud ecosystem.

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