Winter 12-8-2014

# Benefits of Data Center Virtualization to Increase The Availability as A Central Quality of Service Aspect, Using The Example of Cloud Services

Chris Ewe

Ivayla Trifonova

Holger Schrödl

Naoum Jamous

# BENEFITS OF DATA CENTER VIRTUALIZATION TO INCREASE THE AVAILABILITY AS A CENTRAL QUALITY OF SERVICE ASPECT, USING THE EXAMPLE OF CLOUD SERVICES

Chris Ewe, Otto-von-Guericke University of Magdeburg, Germany, chris.ewe@st.ovgu.de
Ivayla Trifonova, Otto-von-Guericke University of Magdeburg, Germany, ivayla.trifonova@st.ovgu.de
Holger Schrödl, Otto-von-Guericke University of Magdeburg, Germany, holger.schroedl@ovgu.de
Naoum Jamous, Otto-von-Guericke University of Magdeburg, Germany, naoum.jamous@ovgu.de

## ABSTRACT

Like most entrepreneurs, data center operators pursue goals like profit-maximization and improvement of the company's reputation. Part of those aims is to guarantee a given quality of a service. These quality characteristics are specified in a contract, the so called service level agreement. The central part of this agreement are the non-functional characteristics of an IT service. The most important of these properties is the availability of the system. To comply with the requirements for availability, data center operators can use virtualization technologies. Regarding the performance of different virtualization solutions, there is still lack of easy prepared information about the different solutions. Therefore, the goal of this paper is to introduce a model, which represents the influence of features of different virtualization technologies on the availability of the data center's IT services. At the same time, the paper points to possible problems and sensitizes for disadvantages of virtualization. Thus, the result of the paper is to improve the transparency for opportunities and risks of data center virtualization, especially in relation to system availability.

*Keywords*: IT service, quality of service, service level agreement, availability, data center, virtualization, cloud computing

## INTRODUCTION

Companies like Amazon or Google operate comprehensive server environments in order to offer IT services to their customers. These data centers offer IT services e.g. in the form of infrastructure. Thus, they provide, for example, the processing power required for the operation of web pages [1][2]. Companies like Dropbox offer IT services themselves, but do not have their own infrastructure. Instead of that they use the infrastructure of an external provider like Amazon Web Services (AWS) with the Amazon Elastic Compute Cloud (EC2) [3]. Amazon, as a provider of data center services, has several goals like profit-maximization or improvement of the company's reputation [4][5]. In order to achieve these goals, the compliance of a given service's quality guarantee to the customer is a key factor [6]. For this purpose the so called service level agreements (SLA) determine functional- and non-functional properties, lease terms, pricing and regression rules [5]. The SLA contracts rights and obligations of both the service provider and the service customer. The central non-functional property is the availability of the system, because it is the prerequisite for all other properties of a service [1][6][7][8][9][10]. Amazon EC2, for instance, guarantees an availability of 99.95% per year [11]. If this target is not met, customers get a discount of 10% according to the SLA (Amazon Web Services 2014). Thus, the achieved service level regulates the pricing and possible damage claimed by the customer. The IT Infrastructure Library (ITIL) says that the objective of the IT service area is to provide high-quality service at the lowest possible price [12]. Therefore, IT service providers are faced with the challenge to guarantee the SLA, while realizing a cost-minimal resource consumption. To meet this requirement they can use the concept of virtualization [1]. This provides software solutions from various vendors such as VMWare or Microsoft, who try to enhance the availability of a system with the help of features like virtual machine (VM) migration (move a VM from one server to another) or disaster recovery. There is a leak of easiness to understand information, regarding the performance of different virtualization solutions from different vendors. That is the reason, why this paper will provide a model, which increases the transparency of the relation between features of virtualization and availability of data centre IT services. To illustrate this, the contribution uses the example of cloud services. According to Portnoy virtualization is the engine, which moves cloud computing [1]. That is why, users of the cloud obtain virtualized IT services from their provider [5]. Regarding this point of view, data centers for cloud services like AWS are not able to operate without using virtualization technologies [5]. Therefore, those services represent a vivid example of the potential of virtualization.

## OBJECTIVES AND RESEARCH METHOD

Aim of this paper is to provide a bridge between the data center virtualization and the system's availability. On the one hand, the benefits of virtualization are presented in the form of different functions and their positive impact on the system's availability. On the other hand, potential problems are pointed out too. This is the reason why, the research approach of design science, according to the principles established by Hevner, is used [13]. The research aims to solve a problem by using pre-existing knowledge through the construction of an artifact. The newly generated knowledge expands in turn the basic knowledge and enables future research. This context is represented in figure 1.

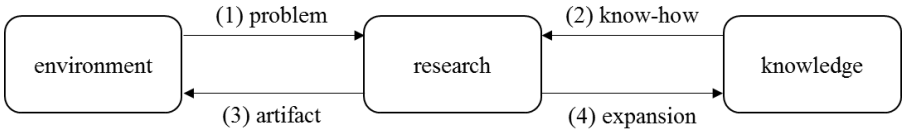


**Figure 2. Design Science Research principal referring to [13]**

The treated problem is that many data center operators ignore the potentials of virtualization technologies for increasing the availability of their IT services, due to the lack of simple processed information on this topic [1]. By using the pre-existing knowledge [2] we create an artifact in the form of a model to solve this problem (3]. The findings of the contribution in turn enhance the knowledge base and provide the basis for further research [4].

For this purpose is the four stage process of analysis, design, evaluation and communication, imposed by Peffers [14], used. The analysis is based on a literature review and a case study. It concludes by describing and isolates the problem. In the course of the literature research in scientific databases, such as ACM Digital Library, IEEE Xplore, or Lecture Notes in Computer Science, it was searched for keywords such as, 'virtualization', 'service level' or 'availability'. Chapter 3 presents the research background to IT services, quality of service and virtualized data centers. The step of the design in Chapter 4 forms the core of the work and describes the creation of the artifact in the form of the model. The evaluation of the work is shown in Chapter 5. It was conducted an interview with an IT professional as well as the case study is used. In Chapter 6 is drawn a conclusion and further research needs are identified.

## RESEARCH BACKGROUND

### IT Services and Cloud Service Solutions

Through the development to outsourcing and outtasking, for example of computing power in the course of cloud computing, there is currently a shift from the far more technically oriented IT world into the direction of services orientation [6][15]. Olbricht says that business arise in which the focus shifts to services as an interaction between customer and service provider [6]. Stych and Zeppenfeld define an IT service as a service of information technology, which includes consulting, planning and provision of services, such as the provision of hardware and software [16]. ITIL defines an IT service as one or more IT systems, which enables a business process or supports it and which is perceived by the customer as a coherent whole [9]. Cannon et al. added the human factor, which works with the systems, to those definitions [7].

Vaquero et al. says that these IT services are provided by IT service provider [17]. They distinguish various types, which specify the exact field of the provider. One of those types is provider of cloud services [17]. Because of that, the three service models: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) are distinguished [5][18]. What those include, in detail can be read in the descriptions of the National Institute of Standards and Technology (NIST) [15]. Central message of the definitions of the NIST, in the context of this work, is that cloud computing offers virtualized resources that can be used by customers as needed [15]. A representative of those is the already mentioned AWS. For example, customers use under this Amazon EC2 as „a web service that provides resizable compute capacity in the cloud." [11]. The infrastructure, required for this purpose, is presented in the form of the Amazon data centers. This includes resources in the form of hardware, e.g. central processing units (CPU), storage and networking, and also in the form of software. According to Portnoy, the cloud provides an easy way to access data and applications and is an example for IT services of a data center [1].

### Quality of Service as a Part of the Service Level Agreement

The ISO 20000 defines a service level agreement (SLA) as a „written agreement between a service provider and a customer that documents services and agreed service levels" [19]. Thus, SLA creates clear business requirements in terms of quality and quantity of IT services for both the service customer and the service provider [6][10][12]. This relationship is illustrated in a simplified form in Figure 2.

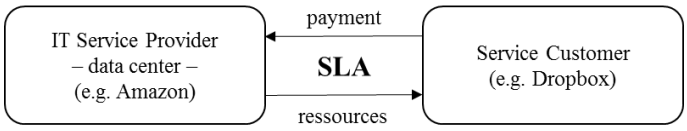


**Figure 3. SLA between a provider and its customer based on [6]**

The basic consensus of the agreement is that the provider, in this case Amazon, provides its customers, here Dropbox, infrastructure in a certain quality and that Dropbox pays for these services in return. The central idea of the SLA is to ensure the agreed quality of service (QoS) [10]. Inter alia, the document includes conditions for services such as prices, contract terms and rules that determine the customer's claims in case of a breach of the agreement [5].

In addition to these conditions, the document includes functional and non-functional properties, which affects the quality of a service [5]. Lamanna says: SLA "capture the mutual responsibilities of the provider of a service and its clients with respect to non-functional properties." [20]. Turowski et al. also say that functionality is complemented by quality[21]. Besides the availability of the system, which is described more detailed in the following chapters, response time, throughout and ease of use are among the most important non-functional properties which decide if a high QoS is given [1][6][7][8][9][10][12].

**Classification of Virtualization**

According to the dictionary, the term virtual can be translated with "'thought" or "apparently" [22]. In one of the first works on this topic Popek and Goldberg defined: „A virtual machine is taken to be an efficient, isolated duplicate of the real machine.“[23]. Jehle at el. note that a VM is no longer necessarily a duplicate of the real machine, but that this definition in its basic features still has its validity [24]. Jehle et. al. expand in their paper the original definition of Popek and Goldberg. They define virtualization as a tool for decoupling the services from physical hardware resources [24]. As this view captures the core of virtualization in the sense of this paper, we proceed with this definition. To illustrate the concept of virtualization solutions the layered structure is shown in Figure 3.

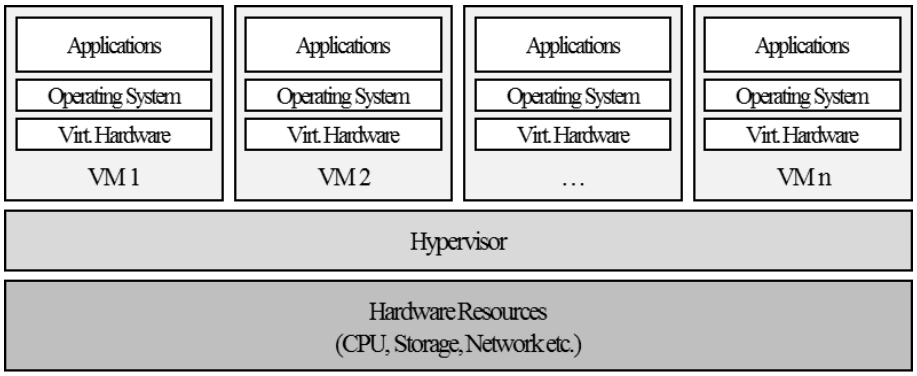


**Figure 3. Level model of virtualization based on [1]**

The figure is divided into three levels. On the bottom are the hardware resources such as CPU, storage and network. Between the individual VMs at the top level and the hardware is the so-called hypervisor. This is the software that provides the virtual environment in which a VM operates. The VMs on the main level include their respective operating system and the applications. Furthermore, the 'virtual hardware' is shown in the figure. That is why, we can again refer to the translation of virtual with "thought" or "seemingly". Each VM has apparent possibility to access all resources in the cluster. However, in reality they only get dynamically allocated the needed resources by the hypervisor. Referring to the example of cloud services, virtualization allows the dynamic resource accesses that make up the cloud computing and without which it would not be possible [1].

## VIRTUALIZATION TO IMPROVE THE QUALITY SERVICE

**Particular Case Consideration – Use Case of Zumtobel-Arango**

To illustrate the basic potential of virtualization, this section presents an example of two companies [25]. These have achieved an increase in their quality of service by using virtualized data centers for cloud services. In focus of this case study are the Zumtobel Group, a company in the lighting industry, and Arango, an IT service company for data management. The Zumtobel Group provides its customers a range of online services, and portal applications to plan a room lighting or to view the latest products. Tom Brady, CIO of the Zumtobel Group, says that the various user groups expect at any time online services at the highest level. If Zumtobel cannot offer this, the company loses sales and even worst customers [25].

In 2010, the Company completed a restructuring of its data center landscape. The aim was to create a more flexible and efficient environment. The problem was that the existing infrastructure was not able to scale flexibly and to respond effectively to increased inquiries. An increased workload could lead to failures and thus to customer complaints. In addition, a total of 62 servers caused high costs for power, cooling and space requirements. Brady said that in about 60 servers and dozens of applications there just have to be a potential for improvement.

The solution was to implement a fully virtualized hybrid cloud. This has only nine physical servers locally at Zumtobel and if necessary add resources of the data center operator Arango. This means that both Arango and Zumtobel act as an operator of a data center, since both have infrastructure. The NIST defines a hybrid cloud as „[…] a composition of two or more distinct cloud infrastructures […] that remain unique entities, but are bound together by standardized or proprietary technology […]”[15]. Both Zumtobel and Arango benefit of the virtualized infrastructure. On the one hand, it helps Arango to comply SLAs with Zumtobel. On the other hand Zumtobel can meet a high quality of service to its customers.

Outcome of the project was a significantly increased availability and performance of the system. In addition, as a result of server consolidation, hardware and energy costs could be significantly reduced. Brady says that in fast moving markets the IT should react just as dynamic as the business. The virtualized infrastructure enables exactly that [25]. Thus, the example shows the potentials that virtualization offers and the positive effects a virtualization project may have to the system availability.

**Central Benefits of Data Center Virtualization**

To achieve the objectives mentioned above, data center operators have to fulfil a number of sub-tasks, such as to comply with the minimization of costs or maximization of sales [4]. In many of these tasks, virtualization can help them. As one of the main reasons to use virtualization Baun et al. calls the consolidation of data center resources and the resulting effects [26]. In conventional data centers often arises the problem that a plurality of server is not used, while others are congested [5]. By the hypervisor of a virtualization solution, the resources of all servers are summarized and allocated dynamically as needed to VMs (load balancing) [1]. As mention in the case study, beyond the consolidation of servers, virtualization leads to other advantages like cost reductions in the purchase of hardware, lower consumption costs (e.g. power, cooling) and to less space costs [27]. According to Hantelmann, virtualization can decrease the investment in new hardware and software, up to 70% [28]. He also says that data center costs can decrease up to 50% [28].

Baun et al. describes that a reduction of the physical machine and the use of sophisticated management tools allows a simplified administration and that routine tasks can be easily automated, too [26]. Furthermore, the simplified maintainability is to be mentioned [26]. Since VMs consist of individual files, they can simply be moved to another server without downtime, e.g. for maintenance purposes [26]. This may also counteract human errors, one of the most common source of errors for system failures [1]. Hence, reduce the personnel costs because fewer employees are needed for administrative tasks [26]. Both Baun et al. and Portnoy confirm that all efforts ultimately aim the agreed SLA targets. Their compliance can not only save costs but also generate revenue through customer satisfaction [1][5][6][26]. One of these targets relates to the system availability, which is considered below.

**Availability as the Central Quality of Service Aspect**

In a series of publications, ITIL describes best practices for the implementation of IT service management [29]. For this purpose ITIL shows how services should be provided to have a accepted high quality for the customer. Be considered, inter alia, incident management, availability management or capacity management [6]. In the course of research in ITIL and other literature, in connection with the survey of a group of experts, the availability of the system was identified as the most important non-functional property [1][6][7][8][9][10]. To this, the availability management section is the focus in ITIL [6]. However, other sections, such as incident management are critical, too. They ensure for their part of the system readiness and define in turn availability parameters [6]. Portnoy says that when companies examine the benefits of virtualization, a high availability is under their highest priorities [1]. This is justified by the fact that the availability is a prerequisite for all subsequent properties. ITIL defines the availability as the „Ability of a configuration item or IT service to perform its agreed function when required.” [6]. According to ITIL, it results from the following four components [6]:

- Reliability: Prevention of failures and maintaining the operability of components and services.
- Maintainability: Enable access to components and services in a normal working condition.
- Serviceability: Agreed internal and external support services.
- Security: Security measures to ensure normal operation.

Stych and Zeppenfeld describe that SLAs allow an assessment of IT, if they include the necessary information and objectives [16]. To determine the availability there have to be defined meaningful metrics and measurement procedures [6]. Therefore, it is crucial what to measure, how to measure and how to interpret and communicate the results [6]. To demonstrate the availability, there are various metrics, which serve as a basis for measurement. The measurement can be based on the Mean Time Between Failure (MTBF), the Mean Time Between System Incidents (MTBSI) or generally on the Time to Repair (TTR) [6]. These measures serve as proof of compliance with the target values of the SLA and are also part of them [6]. To increase individual parameters virtualization can be used as described in the following chapter.

**Influencing Factors of Virtualization to Increase the Availability**

The focus of the system availability is the prevention of downtimes [6]. A distinction is made between planned and unplanned outages [1]. Planned outages are made for maintenance purposes or hardware or software updates. Unplanned outages occur suddenly, by a natural disaster or an incorrect entry of an administrator. In both cases, virtualization has features to resolve and to keep the system standby upright. According to Portnoy, virtualization combines existing availability solutions of the physical world with new functions that are only possible with virtual machines [1].

To illustrate these features we describe following, the model for imaging the relationship between virtualization and availability. Differences will select three levels to which different functions are used [1]: Individual virtual machines, group of virtual machines on a cluster of hosts (servers) and the entire data center.

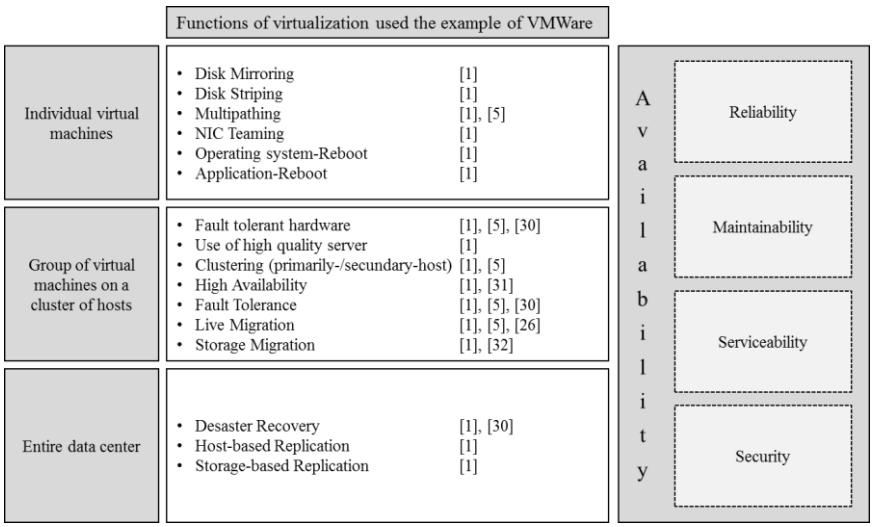


**Figure 4. Model of virtualization features to increase the system availability**

The figure shows some features on the example of VMWare. The provider was chosen due to its current leadership in the market. On the one hand, the levels are interrelated into the form that problems on the upper level (entire data center) always cause problems on the lower levels (individual VMs). On the other hand problems, with individual VMs can also influence the entire data center. All functions acting on the right side of the model and affect the parameters of the availability. As an example, one function of each level will be detailed described below [1][5][30]:

- Level 1 - Individual VM – Multipathing: Multiple redundant access paths from the host to the storage array are set up. So the access path from the hard disk space to the host system is protected against failures. If e.g. two path are set up and one fails the other can be used. To realize load balancing both paths can be transmitted simultaneously. This results in further performance benefits.
- Level 2 - Group of virtual machines on a cluster of hosts – Fault Tolerance: Fault tolerant VMs can survive the failure of a virtualization host without them even precipitate or that their applications are affected. In addition to the primary VM a secondary VM is installed on a different server that permanently duplicates the state of the primary. If the primary fails, the secondary takes over seamlessly. However, the disadvantage of this method is the duplicate resource requirement.
- Level 3 - Entire data center – Disaster Recovery: In the event of a natural disaster, the entire data center can be destroyed. With disaster recovery, there is a second data center, either at another location of the company or like in the case study at an external provider (hybrid cloud). In the case of failure of the primary data center, the backup takes over, which has the identical infrastructure (replication).

The statements show an example how individual functions can positively affect the availability. How the other functions can be found in the references shown in the figure. The model can, therefore, be used as a template so that vendors such as Microsoft and Citrix make adjustments for their products and thus may provide a more transparent overview of their software on the three level model.

**Critical Examination of the Influence of Virtualization**

Besides all positive voices from software vendors and the literature on the topic, this contribution should also raise awareness that virtualization does not always lead to success and can also bring disadvantages. In a study presented by Lampe, a thousand companies were interviewed for problems of virtualization [33]. Main points were the partially increased complexity, the required expert know-how and an initial performance loss. Hardt also mentioned that through the implementation of access by the hypervisor, VMs have less power than real hardware [1][34]. The additional software layer can explain this. The hypervisor in turn consumes resources [5]. However, because of the very mature technology this disadvantages lie only between 5-10% [34].

Another possible disadvantage can be found at the live migration of virtual machines [5]. In addition to increasing the availability, it also promises to improve the system performance, e.g. by using load balancing. This is not shown in every case, but strongly depends on which algorithm is used. Frequent migration operations can overload the network and negatively affect with an increased input-output traffic the response time and availability of the system. It is thus possible that in a completely homogeneous data center virtualization has no positive effect and influence factors such as the availability even negative. Therefore, virtualization is the core technology in cloud computing, since in this case there is a heterogeneous infrastructure in which virtualization can play to their strengths [5].

The points above are only some of the disadvantages that may arise. Other points that can be called are organizational barriers

or the general problem of such a comprehensive IT project. For virtualization still speaks that this offers many opportunities that can't be offered by any other technology [1][5]. It can be clearly noted that as long as providers are aware of the possible disadvantages due to side effects, such as lack of migration processes, virtualization can have the desired effect, inter alia, on minimize downtime.

## INTERVIEW WITH AN EXPERT ON THE RELEVANCE OF THE CONTRIBUTION

The evaluation of the work is to once again question the established hypotheses in the article. Furthermore, it clarifies how the generated model can be used to solve the problem initially described. For this purpose, an interview with an IT expert of the Magdeburg Research and Competence Cluster (MRCC) was performed. The expert applies his skills from his years of work in the field of virtualization. Furthermore, he has in turn published a variety of recognized publications on the subject. The interview was conducted as a twenty minute conversation. No audio recording was made. The evaluation was carried out on the basis of the discussion notes in comparison with the previous findings of the contribution. Following the key messages from the interviews are analogously reproduced:

1. How important is for a data center to ensure a recognized service quality in terms of adherence to the service level agreements?

The expert highlighted the importance of service quality once again. The quality of the company is associated with the quality of the delivered product. Infringements will result in sanctions and in addition to this direct measurable costs to reputation loss. Thus in turn lost revenue incurred in the form of migrated customers. Furthermore, the expert pointed to a trade-off for each service provider. On one side, the service quality should be kept as high as possible and on the other side, the costs should be kept as low as possible. Each provider has to face this challenge.

2. What do you think are the most important non-functional properties, which influence the quality of service?

The expert identified the availability, response time, overall system performance and throughout as the decisive non-functional properties. For him, the availability is the key criterion, since it is a prerequisite for all other properties. Thus, the expert could confirm the due to the literature review and the survey of the expert group [1][6][7][8][9][10] established hypothesis of outstanding relevance of availability.

3. How important is virtualization to the availability of IT services of a data center and how do you assess the model?

On this issue, the expert especially highlighted the live migration and the possibilities for disaster recovery. He stressed again that virtualization offers everything what a physical server environment offers, extended by new features and improvements to existing features. Based on the new model, these functions can now be more easily understood. So the model provides a good overview and an added value for IT service providers and their customers. Moreover, he mentioned the potential of the artifact, since due to the extension of the model to an additional dimension would create an even better overview.

4. Can virtualization achieve an improvement in service quality, particularly in terms of availability in each case?

This question was critical for the expert. From his perspective, virtualization is not always as partially promised a solution to every problem. He stressed that in certain cases, no benefits at all arise. Thus, each data center operator has to weigh the pros and cons of virtualization in its specific situation. The expert said that to answer this question a model as presented in this contribution is very helpful.

Thus, the expert interview can confirm the key assumptions of the work. Furthermore, it was demonstrated that the established model has an added value for IT providers. These providers can gain a better understanding of the impact of individual functions of virtualization on the availability. Moreover, the future work that can be done on the basis of this paper was also highlighted once again.

## CONCLUSION AND FUTURE RESEARCH

System failures at Amazon, Microsoft or Google prove, that the industry is still in the learning stage and that virtualization has to come up with further innovations to generally improve the quality of service, especially availability of data centers. To this, the paper was able to show that the system availability is a crucial factor for business operations and customer satisfaction [1]. In addition to other non-functional properties, the functions of the system itself and frameworks such as contract terms, the system-availability forms the core of the SLA. The Compliance with this agreement contributes itself to the goals of the data center company. To foster progress in this area, the transparency of the solutions must be increased so that data center operators can better assess the extent to which a virtualization technology is relevant to them. Based on the described model, the basic relationships between business processes, IT services, service level and the design of the IT infrastructure using virtualization can be represented in relation to the system availability. The model provides a first step to improve the transparency of the capabilities of different software vendors. Customers can use this overview and decide more easily.

The model provides the basis for future research. For example, it would be possible to develop a prediction model that helps companies in their specific situation to make a decision in order to virtualize their data center resources. This construct could provide statements to help companies decide on a specific virtualization type based on an actual and the desired situation in connection with an expected trend. The first step in this direction would be to extend the model to include additional dimensions. Thus, the availability might initially be separated into its components (reliability, maintainability, serviceability, IT security) in order to calculate its exact effects [33]. Moreover, various types of failures could take a dimension. For example, this first model extension could allow statements which virtualization function acts on what part of the availability, for a given

type of failure, at the level of individual VMs. In addition, the other properties mentioned in the SLA means of the model could be made transparent. The continuous development of this idea would then lead to the aforementioned prediction model. A decision support in this form could help companies to go the right way in deciding on the future of their infrastructure. Thus, the data center can save costs, generate revenue and increase the company's reputation further.

## REFERENCES


[1] Portnoy, M., & Engel R. (2012) 'Virtualisierung für Einsteiger',. Wiley-VCH, Weinheim

[2] Teuffel, M., (1981) 'Service-Qualität im Rechenzentrum. In: Das Rechenzentrum 4', pp.119–126

[3] Narendula, R. (2012) *Amazon Web Services: a Case Study*, No. l.

[4] Haric, P., Gewinnmaximierung. Url: http://wirtschaftslexikon.gabler.de/Archiv/54767/gewinnmaximierung-v5.html. Letzter Zugriff: 10.06.2014

[5] Turowski, K., Bosse, S., & Splieth, M., (2013/2014) 'Very Large Business Applications - System Landscape Engineering', Otto-von-Guericke Universität Magdeburg

[6] Olbrich, A., (2008) *ITIL kompakt und verständlich. Effizientes IT Service Management*, Den Standard für IT-Prozesse kennenlernen, verstehen und erfolgreich in der Praxis umsetzen. Wieweg + Teubner, Wiesbaden

[7] Cannon, D., Wheeldon, D., Lacy, S., & Hanna, A., (2011) *ITIL service strategy*. TSO

[8] Border, C.B., (2013) 'Cloud computing in the curriculum: fundamental and enabling technologies', *In: Proceeding of the 44th ACM technical*

[9] van Bon, J., &Wilkinson, J., (2008), *Foundations in IT Service Management. Basierend auf ITIL V3*, Van Haren Publishing, Zaltbommel

[10] Elsässer, W., (2006) *ITIL Einführen und Umsetzen. Leitfaden für effizientes IT-Management durch Prozessorientierung*, Hanser, München [u.a.]

[11] Amazon Web Services: Amazon Elastic Compute Cloud (EC2) - Service Level Agreements, available at http://aws.amazon.com/ec2/sla/. Letzter Zugriff: 09.06.2014

[12] Buchsein, R, Victor, F., Günther, H., & Machmeier, V.., (2007) 'IT-Management mit ITIL V3', Strategien, Kennzahlen, Umsetzung. Friedr. Vieweg & Sohn, Wiesbaden

[13] Hevner, A.R., March, S.T., Park, J., & Ram, S., (2004) 'Design Science in Information Systems Research', *MIS Quarterly*, Vol. 28, pp.75-106.

[14] Peffers, K., Tuunanen, T., Rothenberger, M.A., & Chatterjee, S., (2007) 'A Design Science Research Methodology for Information Systems Research', *Journal of Management Information Systems*, Vol. 24, pp. 45–77.

[15] Mell, P., & Grance, T., (2011) 'The NIST definition of cloud computing Computer Security Division', *Information Technology Laboratory*, National Institute of Standards and Technology, Gaithersburg, MD.

[16] Stych, C., & Zeppenfeld, K., (2008), *ITIL (Informatik im Fokus)*. Springer, Berlin, Heidelberg

[17] Vaquero, L.M., Rodero-Merino, L., Caceres, J., & Lindner, M., (2008) 'A break in the clouds', *SIGCOMM Comput. Commun. Rev.*, Vol. 39, No. 50.

[18] Dukaric, R., & Juric, M.B., (2013) 'Towards a unified taxonomy and architecture of cloud frameworks', *In: Future Generation Computer Systems*, Vol. 29, pp. 1196–1210

[19] Disterer, G., (2009) 'Zertifizierung der IT nach ISO 20000', *In: Wirtsch. Inform.*, Vol. 51, pp. 530–534.

[20] Lamanna, D.D., Skene, J., & Emmerich, W. (2003). 'SLAng: a language for service level agreements', pp. 100-106

[21] Turowski, K., (2014) *Very Large Business Applications - System Architecture*. Otto-von-Guericke Universität Magdeburg

[22] *Duden: virtuell*, available at http://www.duden.de/suchen/dudenonline/virtuell. Letzter Zugriff: 02.06.2014

[23] Popek, G.J., &Goldberg, R.P., (1974) 'Formal requirements for virtualizable third generation architectures', *In: Commun. ACM 17*, pp. 412–421.

[24] Jehle, H., Wittges, H., Bögelsack, A., & Krcmar, H., (2008) 'Virtualisierungsarchitekturen für den Betrieb von Very Large Business Applications', *In: Multikonferenz Wirtschaftsinformatik (MKWI)*, pp. 1901-1912.

[25] Arango Institut für komplexes Datenmanagement AG: Fallstudie Zumtobel Group / Arango, available at https://www.arago.de/wp-content/uploads/2012/02/Fallstudie_Zumtobel_Maerz11_DE-130212.pdf. Letzter Zugriff: 28.05.2014

[26] Baun, C., Kunze, M., & Ludwig, T., (2009) 'Servervirtualisierung', *In: Informatik Spektrum*, Vol. 32, pp. 197–205

[27] Singh, A., 'An Introduction to Virtualization', available at http://www.kernelthread.com/publications/virtualization. Letzter Zugriff: 01.06.2014

[28] Hantelmann, F., (2008) 'Mit Virtualisierung', *RZ-Kosten halbieren*, Vol. 12, pp. 88.

[29] Arraj, V. ITIL® : the basics, available athttp://www.firesafetyguides.co.uk/gempdf/ITIL_The_Basics.pdf. Letzter Zugriff: 02.06.2014

[30] Langes, M., (2012) 'Das Managementmodell zur Datenverfügbarkeit und Datensicherheit', *Von der Anwendung bis zum Rechenzentrum. Books On Demand*, [S.l.]

[31] Kircher, H. (Hg.): (2006) *IT: Technologie, Lösungen, Innovationen*. Springer, Berlin, Heidelberg

[32] Zimmer, D., Wöhrmann, B., Schäfer, C., Baumgart, G., Kügow, O., & Wischer, S., (2012) *VMware vSphere 5. 'Das umfassende Handbuch*. Galileo Press, Bonn.

[33] Lampe, F., (2010) Green-IT, 'Virtualisierung und thin clients', *Mit neuen IT-Technologien Energieeffizienz erreichen*, die Umwelt schonen und Kosten sparen.
Hardt, M., 'Virtualisation for Grid-Computing', *In: n. i. n v.* (n.y.).