Developing a Cloud Provider Selection Model

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Abstract. Recently, a growing development and use of Cloud computing services has been observed. Especially modeling cross-organizational cooperation and the respective provider comparison are gaining importance. Despite initial positive results, it is challenging in theory and practice to find an appropriate provider matching the individual requirements. Moreover, the comparison process is complicated by a number of new entrants as well as offers of non-transparent services, which sometimes differ significantly.
Due to the lack of adequate possibilities to compare and classify Cloud providers we are presenting in this paper a provider independent classification model for Infrastructure as a Service (IaaS). For this purpose, the target dimensions for Cloud Computing from a customer perspective were defined, based on expert interviews, an international literature review and a Cloud provider market (IaaS and hosting) analysis.

1 Motivation

For several years Cloud Computing has been influencing the IT landscape and has been an important economic factor. *Gartner* predicts a strong growth of Cloud services with a worldwide revenue of 146.8 billion US dollars in 2014 [Pr09]. In this context, Cloud Computing has become a fast growing and non-transparent market with many small and large providers, each of them having their specific service model [RZ11a], [HK10], [VJ10]. That makes it difficult to compare the providers as such and their service offerings. In the majority of cases the service portfolios are heterogeneous and combined with complex pricing models and service features. Furthermore, the fact that interoperability between providers hasn't been achieved makes a provider selection often irreversible or requires much effort [HK10], [RZ11b]. This difficulty, known as "provider lock-in", is discussed extensively and is an important topic in many companies and international research activity e.g. Open Grid Forum (OGF) [CH09], [Ar09]. Consequently, the customer is confronted with the situation to select an appropriate provider to realize his specific requirements

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mostly based on diffuse classification criteria. Due to the lack of adequate possibilities of comparing a Cloud provider, especially on the infrastructure level, this paper focuses on developing a classification model for IaaS providers. In this context the following research question need to be answered:

What are appropriate classification characteristics for Cloud providers and what should an Infrastructure as a Service (IaaS) classification model look like?

To reduce entry barriers and support the migration into the Cloud this paper starts with examining Cloud Computing characteristics and the IaaS provider's market. Based on a literature review and interviews conducted with experts we have derived six customer target dimensions valid for Cloud Computing (see chapter 4). These target dimensions serve as strategic objectives regarding Cloud Computing and provide a structure for Cloud characteristics in the first place. Next we gathered all requirements available and appropriate classification criteria for Cloud providers and reviewed them in cooperation with the experts. On this basis we have developed a classification model by assigning relevant provider and service requirements to the target dimensions using a four level hierarchy (see chapter 5). We defined 17 classification criteria on the 2nd level and 51 criteria on the 3rd level.

2 Cloud Computing introduction

With Cloud Computing a paradigm shift to standardization and service orientation in the information and communication industry emerges and marks the industrialization of IT [Le10]. Cloud Computing allows companies to rent IT services on demand to support their business processes. As a new part of IT sourcing, the effort of operation and maintenance is completely managed by the provider. The customer only rents the service in a pay-per-use manner like a commodity similar to the energy or water market.

Considering the extensive usage of on demand services, mobile applications and interactive elements, transactions and workloads will rise significantly and require scalable IT structures [La10]. This growing acceptance will result in an increasing demand for IT resources. At this point the Cloud Computing model is essential. It makes *on demand network access* to a *shared pool of configurable computing resources* possible, that can be *rapidly provisioned* and released with minimal management effort or service provider interaction [GM09]. The resources (e.g. networks, servers, storage, applications and services) are offered in a *scalable* way via the Internet without the need for any long-term capital expenditures and specific IT knowledge on the customer side. It is possible to obtain complete software applications or the underlying IT infrastructure in the form of virtual machine images. Basically Cloud Computing is composed of the characteristics above described and consists of three levels, *software as a service (SaaS), platform as a service (PaaS)* and *infrastructure as a service (IaaS)* [GM09].

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On the infrastructure level customers have the possibility to obtain on demand resources from a Cloud provider with no need to operate the required IT infrastructure. On the one hand, the customer can extend his existing IT infrastructure by renting additional capacity from the Cloud to compensate load peaks, preventing the customer from having much capacity available. On the other hand, the complete infrastructure and respective services can be obtained from the Cloud. This decreases the IT maintenance effort and creates value especially for small businesses with fluctuating demand, e.g. due to seasonal activities. Alongside the benefits of Cloud Computing, several challenges emerge on the management level regarding different technological components and modules, integration of heterogeneous interfaces, usage dependent provisioning and billing of resources as well as ensuring data privacy and data security [IH10], [Bi10], [Cl09].

3 Research Methodology

Cloud Computing is characterized by various factors and a common definition of this term doesn't exist [We09], [Wa08], [Va09]. Thus Cloud Computing was examined from different perspectives (technological, business issues, applications and general aspects) [YT09]. According to this, we attempted to develop an IaaS classification model which would be valid for all research fields without limitation.
Prior to the literature review five experts were interviewed on common objectives in Cloud Computing. As a result four target dimensions for the Cloud could be derived. The expert interviews were conducted with five experts from four companies, all holding different positions within their companies. Care was taken that those respondents were representative of all perspectives (provider, customer and mediator/consultant) being important for the selection process (see Table 1). The interviews with the experts were structured and conducted referring to *Glaeser and Laudel* [GL10].

Table 1. Type of experts interviewed

(Expert from) Company type	Company data	Position within company	Cloud experience
IT service provider	170.000 employees Global IT service offerings 10-15% revenue based on Cloud Computing Innovative solutions in IaaS	Director of IaaS division	Deep understanding of IaaS services and infrastructure
Software provider	SME software company 11 employees Development of standardized components for web-based services	CIO	Expert know-how in SaaS and general Cloud approaches
Software provider	SME software company 11 employees Development of standardized components for web-based services	Software architect	Expert knowledge in IaaS and PaaS especially in the implementation
Consulting company	International consulting company 500 consultants worldwide Cloud Computing as one consultancy topic	Partner	Current consulting focus; Cloud market appreciation
Customer / Client	Automotive sector ca. 95.000 employees	Divisional director IT	Experience in selecting, implementing and operating IaaS

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Next, in order to describe, synthesize, evaluate and integrate the results of existing scientific work in comparison of Cloud providers and distinguishing criteria of Cloud offerings, we conducted a systematic literature review following the approach of *Webster and Watson* [WW02]. This research method ensures that an extensive number of relevant papers considered. During the literature review we attempted to match each criterion gathered to a representative target dimension. The necessity emerged to define two more target dimensions in order to allocate all relevant criteria. Afterwards the additional dimensions were discussed and evaluated with the experts as well. The outcomes were six target dimensions, each including a group of relevant classification criteria.

The first step in the literature selection process was conducted to identify a comprehensive list of literature sources. We started off by taking the top journals based on the *VHB-JOURQUAL2* [SH09] and *Saunders's journal ranking* [Sa11b]. To complete the analysis, publications of renowned national and international organizations and associations (e.g. *Bitkom*) were included. Table 2 lists all literature sources that were examined to identify relevant papers.

Table 2. Journals and conferences investigated for the literature review

Publication type	Publisher
Journals	ACMSIG, CACM, CAIS, CompDcsn, DATABASE, DSI, DSS, EJIS, I&M, I&O, IBMSJ, IEEEComp, IEEESw, IEEEIC, IEEETC, IEEETKDE, IEEETrans, IEEETSE, IEEETSMC, IJEC, IJHCS, InfoSys, ISF, ISJ, ISM, ISR, IT&M, IT&P, JACM, JAIS, JCIS, JComp, JCSS, JIM, JITTA, JMIS, JSIS, KBS, MISQ, MS, SMR, WIRT
Conferences	AMCIS, ECIS, ICIS, HICSS, IEEE Conferences, LNI, LNCS, MKWI, PACIS, WI
Associations, Organizations, Companies	Cloud Security Alliance (CSA), EuroCloud, Bitkom, Bundesamt für Sicherheit in der Informationstechnik (BSI), Securing Europe's Information Society (ENISA), Center for Experimental Researchin Computer Systems (CERCS), Fraunhofer SIT, Distributed Management Task Force (DMTF), The European Telecommunications Standards Institute (ETSI), National Institute of Standards and Technology (NIST), Open Grid Forum (OGF), Object Management Group (OMG), Open Cloud Consortium (OCC), Organization for the Advancement of Structured Information Standards (OASIS), Storage Networking Industry Association (SNIA), The Open Group, TM Forum, SaaS EcoSystem, OpenCloudManifesto, Experton Group, T-Systems

In a subsequent step, we chose topic related papers from the selected literature sources. An initial list of papers was generated by using key words such as "*Cloud Provider*", "*Cloud Vendor*", "*Cloud Characteristics*", "*Cloud Classification*", "*Cloud Selection*", "*Cloud Taxonomy*", "*IaaS*", "*Infrastructure as a Service*", "*Platform as a Service*", "*Software as a Service*", "*PaaS*" and "*SaaS*" to search for titles, abstracts and keywords. We only scanned the directories of the journals and conference proceedings manually if no electronic search was possible. Furthermore, we expanded our scientific foundation by reviewing the citations in the papers identified in the first cycle of literature exploration to determine previous papers that should be considered for an analysis in a subsequent cycle of literature exploration.

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We identified 55 papers all dealing with the comparison of Cloud providers or at least containing related keywords. In order to identify the final set of publications we subjected these papers to a detailed (content-related) review. Therefore, we manually reviewed the papers of the initial list and selected only those papers which primarily dealt with the comparison of Cloud providers. Thus, 38 articles were selected which dealt primarily with the classification or selection of Cloud providers and distinguishing criteria of Cloud offerings. It is surprising that almost the entire set of finally selected papers consists of conference papers and there is just a small amount of high-quality journal papers available. This probably shows that there is a lack of research regarding the classification of Cloud services and distinguishing criteria of Cloud offerings.
Complementary to the literature review the provider market of IaaS and hosting were investigated. This analysis was based on an extensive internet research where the websites of relevant companies were examined regarding their pricing model, IaaS service offering, company data and customer segment. By means of market studies and business publications on the Cloud market we detected over 60 relevant providers in the IaaS and hosting business [VJ10], [LC10], [HF09]. Based on this analysis we compiled a feature catalog for IaaS providers.
In order to develop a detailed proposal for an IaaS classification model the target dimensions including the related criteria from the literature review were matched with the features of the provider catalog supported by the experts. Thereby, a design-oriented approach was used.

4 Target Dimensions in Cloud Computing

In this contribution we define six target dimensions - such as cost savings or increasing flexibility - to group and structure the Cloud characteristics. Each target dimension represents a general objective which the customer pursues and which characterizes his Cloud or IT strategy. Four target dimensions (costs, IT security & privacy, scope & performance, reliability & trustworthiness) were defined together with the experts prior to our analysis. Through our literature review and market research, we validated these four dimensions and simultaneously discovered two additional dimensions (flexibility and service & Cloud management), which were evaluated subsequently by the experts as well. Table 3 shows the relevant sources assigned to the six target dimensions. In this context we discovered that practitioners mainly deal with questions about security, reliability and manageability of Cloud Computing. Largely unnoticed, however, remain so far the performance as well as the cost / price models. Science is exploring the topic covering all target dimensions and attaches significantly more importance to the performance dimension.

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Table 3. Results of the literature review

Target Dimension / Source	Flexibility	Costs	Scope & Performance	Reliability & Trustworthiness	IT Security & Compliance	Service & Cloud Management
Academic Publications						
Günther et al. (2001)		■■■	■■		■■	
Hilley (2009)	■■■	■■	■	■■	■■	
Hoefer and Karagiannis (2010)	■■	■■	■■	■■	■■	
Li et al. (2010)	■■■	■■■	■■■			
Prodan and Ostermann (2009)	■■■	■■	■■■	■■	■	■
Annecy (2010)				■	■	
Vaquero et al. (2009)	■	■	■■	■	■	■
Peng et al. (2009)	■■		■■■	■		■
Weinhardt et al. (2009)	■■	■■■	■■			■
Hay et al. (2011)	■				■■■	
Martens et al. (2010) (2011)	■	■■■	■	■■■	■	■
Christmann et al. (2010)				■■■	■■■	
Tsvihun et al. (2010)	■	■■	■■		■■■	
Armbrust et al. (2010)	■■■	■■■	■■■	■	■	
Iyer und Henderson (2010)	■■■					■■■
Anandasivam and Premm (2009)		■■■				
Lehmann et al. (2009)		■■■				
Rimal et al. (2009)	■■■		■■■	■	■	■■
Schwarz et al. (2009)		■■	■■	■■	■■	
Talukder et al. (2010)	■■■	■■■	■■■	■■■	■■■	■
Koehler et al. (2010) (2010)	■■	■■■		■■		■■
Saya et al. (2010)	■■	■■	■■	■■	■■	
Narasimhan et al. (2011)	■	■	■	■	■	■
Russell et al. (2010)				■■■		
Popularity	**36**	**41**	**35**	**30**	**29**	**14**
Industry Publications						
BITKOM (2010)	■■	■■		■■■	■■■	■■
BSI (2010)	■			■■■	■■■	■■
EuroCloud (2010)	■			■■■	■■■	■
ENISA (2009)	■			■■■	■■■	■
CSA (2009)	■■■			■■■	■■■	■■■
SaaS EcoSystem (2011)	■			■■■	■■■	■■
DMTF (2009) (2010)	■■■				■	■■■
OpenCloudManifesto (2009)	■■■					■
T-Systems (2008)	■■	■	■		■	
Experton Group (2010)	■■	■				■■
The Open Group (2009)	■■	■■			■	■
Popularity	**21**	**6**	**1**	**24**	**27**	**18**

■ **Low priority** ■■ **Average priority** ■■■ **High priority**

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4.1 Target Dimension: Flexibility

An associated advantage of Cloud Computing, identified in science and industrial practice, is the gain in flexibility compared to traditional solutions [We09]. Resources, for example, can be allocated and de-allocated as required, whereas requirements can sometimes vary greatly. The provisioning time is shorter compared to traditional outsourcing such as Application System Provider (ASP) and with a very small overall commitment period to the vendor [RZ11a]. Also other aspects such as standardization (e.g. APIs), the traceability of data, the short-term contracts or a demand-driven and scalable resource recovery have to be considered regarding an appropriate supplier selection.

4.2 Target Dimension: Costs

The decision to choose Cloud Computing and a particular provider is often guided by monetary considerations [Hi09] and linked with the slogan "pay-as-you-use". Customers who decide to use Cloud services benefit mostly from small capital commitment, low acquisition costs for required servers, licenses or necessary hardware space and the reduced complexity of IT operations. Despite similar services on the IaaS level the pricing and billing models often differentiate between each provider [RZ11a].

4.3 Target Dimension: Scope & Performance

With this target dimension the scope of services and the performance of a Cloud provider are described. To select the Cloud provider which best meets the requirements, knowledge about their service and performance is of crucial importance [Ar09]. Here it is essential to consider features regarding performance (latency, or transaction speed), capacity limits (e.g. maximum number of accounts or storage space), service complexity (how many functions are available) and degree of customization (how far the service can be adapted).

4.4 Target Dimension: IT Security & Privacy

The decision on selecting a provider in the Cloud is very often influenced by company requirements in the areas of security, compliance and privacy [CH09], [Ts10], [Ja08], [Cl09]. Companies have to be sure that their data and applications, even operated in the Cloud, meet the required compliance guidelines of both and are adequately protected against unauthorized access. Here, the decision criteria are rather referring to the infrastructure of the provider itself than to the provided service.

4.5 Target Dimension: Reliability and Trustworthiness

This target dimension describes how certain the customer can be that the service from the Cloud has the guaranteed availability [Ja08]. It is important to know what commitment the provider makes, mostly in form of Service Level Agreements (SLAs). Moreover, the reliability with which these commitments are kept is of great importance. In contrast to the commitment, the trustworthiness describes the provider's infrastructural features, which may be evidence of a high reliability. These include disaster recovery, redundant sites or certifications.

4.6 Target Dimension: Service & Cloud Management

The Service & Cloud Management includes features of the provider that are substantial for convenient Cloud service operations. These include the offered support and functions for controlling and monitoring as well as the individualization of the web interface [YT09]. The manageability (usability) of services, especially in a distributed IT architecture, and the Cloud governance, dealing with requirements and responsibilities by the customer, are essential features of this target dimension.

5 Classification Model for Infrastructure as a Service (IaaS)

The aim of this paper is to develop a classification model for supporting a Cloud service selection on the infrastructure level. The model may help companies in their selection process and creates greater transparency in the Cloud market. For that purpose, different target dimensions were elaborated (chapter 4). These dimensions cover the Cloud Computing in its entirety and aren't limited to one level (SaaS, PaaS, IaaS). Next, these dimensions have to be broken down into selection criteria that are measureable and comparable. Based on the fact that all three Cloud levels are targeting different customer needs, it wasn't possible to define selection criteria valid for all levels at once. At this point, we limited our examination to the infrastructure level (IaaS) because in our opinion the services are particularly convenient due to a certain degree of consistency. With the purpose of developing a classification model we summarized and mapped similar characteristics and requirements regarding their target dimension into three hierarchical levels (see Figure 1). Thereby abstract and operational selection criteria were identified. The abstract selection criteria are used for further structuring and differentiation purposes. On the third level of the classification scheme, criteria have been operationalized, so that they can be weighted and compared (e.g. pricing options, delivery time). The level below finally defines figures and measurable requirements (key performance indicator, KPI). Each operative criterion (3. level) consists of various level 4 requirements. Furthermore, requirements can be divided into provider requirements and service requirements (see Figure 1). Provider requirements describe the features of the Cloud provider independently from any service, e.g. existing certifications, IT infrastructure characteristics or key figures of the company. Service requirements in contrast deal

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with characteristics directly referring to the usage of a service, e.g. service availability, scalability or interface features.
Classification scheme example: The target dimension "Flexibility" (1st level) consists of "service dynamics" among other things, an abstract classification criterion (2nd level) which is characterized through the provisioning time (3rd level). The "provisioning time" is measured among other things by the required time to start up an instance (4th level; KPI). For instance, if the deployment time is less than five minutes, the provisioning time is rated as low, assuming the other requirements will be rated similarly.

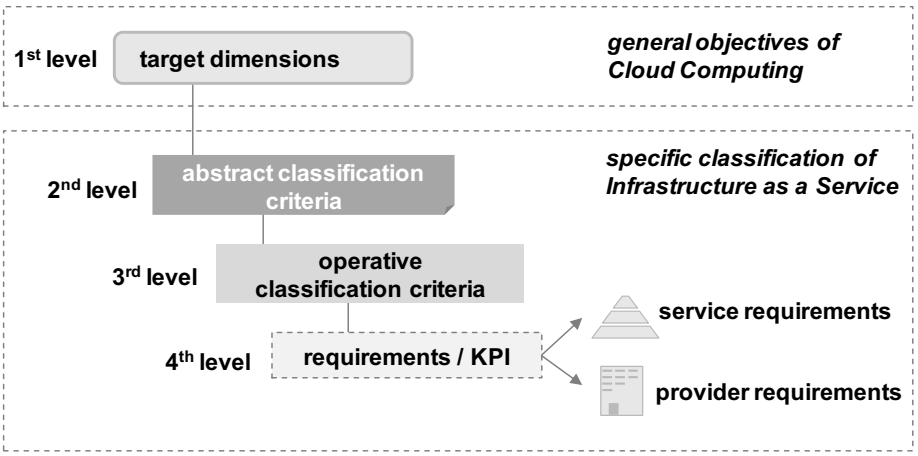

Fig. 1: Classification scheme

The result of this paper is a classification model with six target dimensions, 17 abstract selection criteria (2. level) and 51 operative selection criteria (3. level). This model is illustrated in Figure 2. For reasons of clarity the requirements on level four are not shown.

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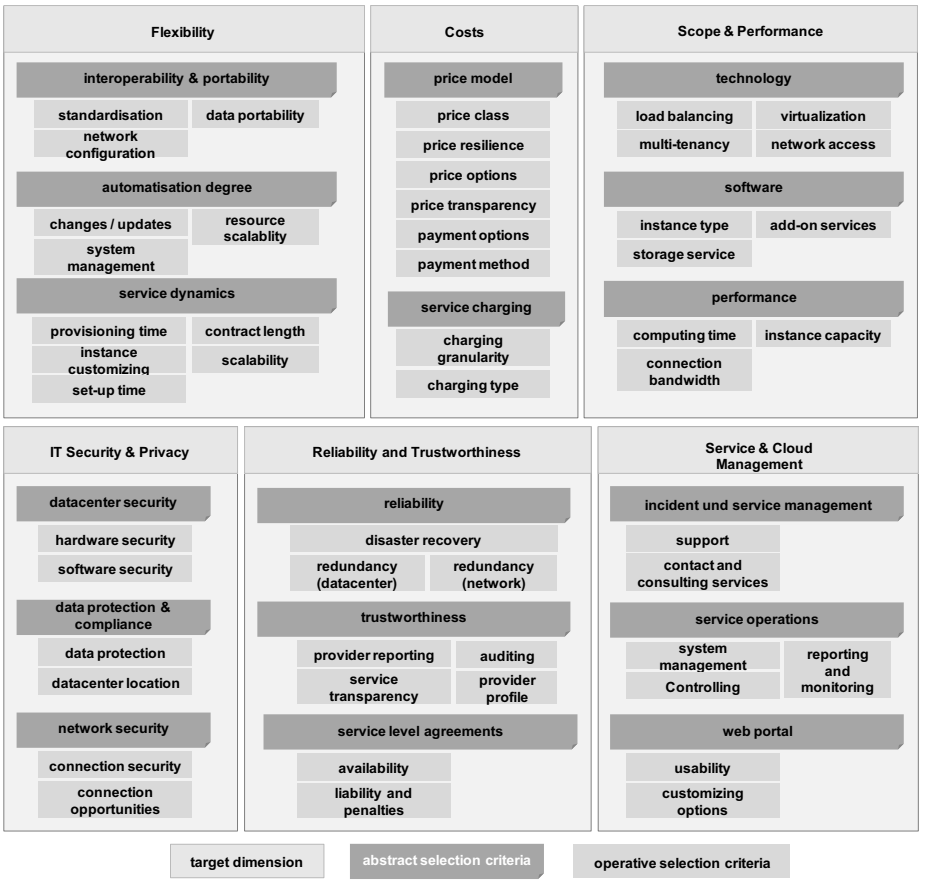

Fig 2: Classification model for IaaS (without KPIs)

Next, the selection criteria and target dimensions will be briefly explained. The classical target dimension is the flexibility, which describes the ability to respond quickly to changing capacity requirements. Here, the topics interoperability & portability, automation and service dynamics are particularly noteworthy. But there are far more important aspects in supplier selection. These include, for example, price stability (duration of the agreed price) and the granularity of allocation (e.g. 1 MB, 100 MB or 1 GB steps). Between IaaS providers in particular, the pricing (price range, pricing options, price transparency, payment options etc.) and billing model differentiate clearly. The performance is regarded as a relevant criterion for selection by the experts, although it was marginally discussed so far in practice (see Table 3). The efficiency and the scope of services can be divided into performance, technology and software. Criteria like the max. CPU, RAM, hard drive, transfer volumes and transfer speed belong to the topic of performance. Features such as the type of virtualization, the load balancing and so on will be subsumed under the term

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technology. This target dimension is completed by software characteristics, such as the selection of different operating systems. The target dimension of IT security is attracting particular attention in practice and refers to the data center or network. There are requirements for privacy (encryption of data) and compliance (e.g. location of data center) as well. Using external services from the Cloud, trustworthiness and reliability are very important. In this field they can be grouped into commitment (which efforts are guaranteed by the provider, service SLAs), reliability (the probability that service pledges can be met) and trustworthiness (e.g. performance transparency, market experience). The target dimension Cloud & Service Management can be differentiated according to incident and service management (support and customer service), service operation (e.g. monitoring of services and volume control via APIs) and web portal (usability and adaptability of the surface).

6 Conclusion & Future Work

Based on our literature and provider review, complemented by interviews with specialists in the respective field, we introduced in this contribution a classification model enabling a provider selection on the IaaS level. Our view is that via the model, companies are able to support their decision process and simplify the provider comparison. In this way, heterogeneous IaaS offerings in the Cloud can be compared a lot easier and the time of the selection process can be accelerated as well. It is conceivable that via middleware or standardized interfaces different IaaS offerings can be automatically selected and offered based on the customer preferences (target dimensions). Cloud actors like mediators or aggregators are becoming more important. The consequence is a shift from a subjective provider assessment to a mostly fact -based performance selection where the realization of service requirements is gaining importance. There is no need for customers to know from which provider they obtain the service as long as the requirements are met.
As further research approach, the classification model will be evaluated and refined. Therefore IT managers will be surveyed and various case studies will be conducted to ensure applicability of the presented classification model.

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