RECOMMENDING CLOUD VENDORS/SERVICE PROVIDERS (CSP)

Thesis Design

Renee Vaessen, VU Amsterdam, June/August 2014

1. Abstract

For the selection of a CSP (Cloud Service Provider) the criteria that are generally taken into account are functional requirements (configuration), quality (Quality of Service, QoS) and cost of the services. In order to improve the decision-making process, the organizational factors influencing the CSP selection must be identified and validated. A set of organizational factors will be retrieved from literature and validated by content experts. The organizational factors are then validated, in a case study, for a specific IaaS selection.
The subject is limited to (European) public IaaS cloud services and, as a customer base, IT-companies, with software development projects as use cases. The focus of this study is on the tactical level (preferred supplier selection). The outcome will be a set of organizational factors, validated for CSP selection in use cases for Small & Medium Enterprises/IT-companies, and evaluated in an IaaS case study.

2. Introduction

2.1. Problem description

2.1.1. Cloud Computing

The essence of Cloud computing is that variable computational power (servers), data storage facilities and a collaboration infrastructure is made available, on demand, over a network (in general via the Internet). In addition, multiple software applications or services are available to the end user (Hill, Hirsch, Lake, & Moshiri, 2013, p. 3).
In cloud computing, three service models were initially defined: SaaS (Software as a Service), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). In addition, four deployment models (Public, Community, Private and Hybrid) are distinguished. These are further clarified in the next section. For this study, the focus is on IaaS in the Public cloud.
Cloud Infrastructure as a Service (IaaS) is a standardized offering of compute resources, in combination with storage and networking capabilities, which is on demand offered to the end user. The resources, owned by a Cloud Service Provider (CSP), are scalable and elastic in near real time, and metered by use (Gartner b, 2013). For Public IaaS, the services are available to any end user.

2.1.2. End user requirements for IaaS

End users develop and/or deploy applications, often with variable computing needs, which are more or less predictable in capacity and schedule. To fulfill this dynamic computational need within a private datacenter, the in-house compute volume has to be large enough to fulfill the maximum requirements. This provisioning for maximum capacity is very costly, compared to external acquiring of the flexibly needed computational resources. Public IaaS enables investment and maintenance cost savings as well as agile provisioning of the compute need.
Depending on the characteristics and use cases of the end users the requirements for the IaaS differ.

2.1.3. Selection criteria for IaaS

The research concerning decision support on IaaS selection mainly focuses on functional requirements (configuration), quality (Quality of Service, QoS) and cost aspects and operational service composition.

This also holds for commercial comparison programs. However, organizational and social factors like certification requirements, vendor lock-in and sustainability influences the end users choice for a CSP and its services. Some of these factors are yet to be included in the selection process.

In order to improve the decision-making process, the organizational factors influencing the CSP selection must be identified and validated. Depending on which factor, measuring its (aggregate) value will be possible. Alternatively, only a qualitative description can be given. Moreover, the end user characteristics and the use case impacts the relative importance of the organizational factors. Subsequently, these weighted organizational requirements for a specific end user and use case are then matched with offerings from CSPs

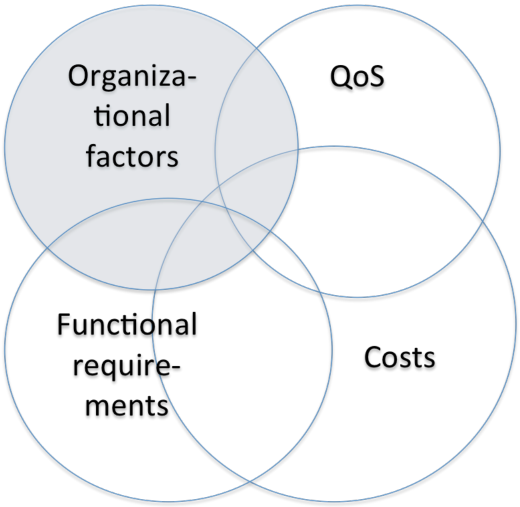

Figure 1 selection criteria

2.2. Research Question

The main research question (RQ) is:

RQ: How to evaluate organizational factors in the selection of a CSP

This RQ is divided into two sub questions:

- *RQ-A: What organizational factors are important when selecting a CSP?*
- *RQ-B: How does integration of these factors influence the outcome of a specific IaaS use case selection process?*

The outcome should be a recognizable and validated set of organizational factors, with an evaluation of the integration of these factors for a specific case.

2.3. Research Relevance

In general, CSP recommendation methods or systems focus on the cost, the functional requirements and the QoS of the required configuration/service. However, in order to select a CSP and face the cloud computing challenges, organizational factors must be taken into account. A recognized and validated set of organizational factors is of great value in the selection process for CSPs.

As many research organizations (both non profit and business) study the cloud computing opportunities and challenges, the topic has an important social, business and academic relevance. The specific research subject of this thesis can be a small addition in this field.

3. Background

3.1. Definition of Cloud Computing

The definition that is often cited is the NIST definition (NIST, 2011). In a concise form:

> Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services). These resources can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of

- five essential characteristics (On-demand self-service, Broad network access, Resource pooling, Rapid elasticity, Measured Service);
- three service models (Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS); and,
- four deployment models (Private cloud, Community cloud, Public cloud, Hybrid cloud).

The SaaS service model means that the end user deploys the provider's application, which runs on a cloud infrastructure. Following this, the application is accessed from a variety of client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface.

For PaaS, the CSP provides programming languages, libraries, services, and tools.

This is in contrast with IaaS, which implies that the end user provisions processing, storage, networks, and other fundamental computing resources, and is able to deploy and run arbitrary software, e.g. operating systems and applications in the cloud.

In addition, services like XaaS (anything/everything as a service) and Virtual Desktops or Data Storage are mentioned as future or distinct services.

The key element of a public cloud is that the owner of the resources (the CSP) offers services to anyone who wants to make use of that service. This implicates additional security issues because of the multi-tenancy of the resources. For a private cloud, however, the resource owner is the end user of the service, and the services are hidden behind a firewall. A hybrid cloud is a mix of public and private cloud, in a non-specified configuration (Hill, Hirsch, Lake, & Moshiri, 2013, pp. 22, 27, 29). A community cloud is shared by and supports a specific group of organizations or individuals (a community) that have a mutual concern (e.g. compliance consideration for governmental use, (NIST, 2011) .

3.2. Essence of Cloud computing

Two of the underlying technologies for cloud computing are grid-computing, which emerged in the 1990's, and hardware virtualization. For grid computing, a combination, or a grid, of computers from multiple sources is configured to execute a specific compute task. Middleware is used to divide and allocate workloads to the constituent computers. Nowadays with cloud computing, the 'grid' is accessed over the Internet. In virtualization, a so-called hypervisor intermediates between the physical hardware ('bare metal') and the virtual machines (VMs, servers) that deliver the actual computational power/storage/memory capability

Cloud computing offers the opportunity to adjust the supply to the variable demand for computing resources (elasticity). Often, the comparison is made with the power grid, in that computing resources become a utility, for which the customers only pay for the amount of power they use (Databarracks, 2013)

From the point of view of the end user, two business characteristic are very different for cloud computing (Hill, Hirsch, Lake, & Moshiri, 2013, p. 13): business agility and transition from capital expenditure costs (CAPEX) to operational expenditure costs (OPEX). The added value of cloud computing depends on the nature of the end users business process; e.g. use cases with a volatile pattern of compute requirements will benefit more.

3.3. Cloud Service Providers (CSPs)

Cloud computing capabilities are offered by Cloud Service Providers (CSPs), thus providing the requested services to the end users and exploiting this business opportunity.

For SaaS, examples of large CSPs or Application Service Providers are Salesforce (CRM-system), SAP (ERP-system) and Google with its Google Apps (e.g. Google Mail, Google Docs and Google Drive).

For IaaS, the best-known worldwide operating CSPs originate from the United States: Amazon Web Services (AWS), Google Compute Engine, Microsoft Azure, Softlayer (with IBM) and HPCloud. They all have European datacenters, often in the UK.

Other large US IaaS providers with European data centers are GoGrid and Joyent (both have their EMEA HQs in Amsterdam). Rackspace, that differentiates with its 'fanatical support', even has a Dutch support office and website.
In Europe as well as in the USA, many local providers are offering their IaaS services, often on a small and local scale.

3.4. Cloud Brokers

Consultancy and system support for CSP selection is the specialty of cloud brokers. 'Cloud Broker' has two meanings: first, a person or organization that acts as an intermediary, and second, a software application that facilitates the distribution of work between different clouds service providers. This second type of cloud broker is called a cloud agent.
The business model for cloud brokers (as human intermediaries) is still evolving. At its simplest, the end user hires a broker at the beginning of a project, to research the opportunities of cloud computing to support business goals and to analyze the services from different CSPs. A further role is that the cloud broker negotiates contracts with cloud providers on behalf of the customer.
A broker system acts as a cloud aggregator when the end user is provided with application program interfaces (API) and user interfaces (UI), thus hiding complexity. This 'cloud portfolio management' presents the end user a variety of cloud services seemingly purchased from a single CSP, which leads to the reduction of complexity for the end user (TechTarget, 2013).

3.5. IaaS use cases

The main use cases for IaaS are: (Gartner b, 2013) and (Hill, Hirsch, Lake, & Moshiri, 2013) and (Amazon, 2014)

- Application development and testing, both for internal and external (commercial) use (e.g. IT-companies that offer their products as SaaS). The development projects can be locally organized or global collaborations.
- Production environments, both internal (backend) and customer-facing (front end) applications.
- Batch computing (e.g. big data, high-performance computing (HPC) or specific research functions
- Disaster recovery
- Start ups or short running projects: no up front investment required, easily scalable in case of success (and failure), e.g. campaigns and events.
- Web applications, with worldwide coverage.

The IaaS use cases include single-application workloads as well as combinations and varieties of workloads, even those supporting mission-critical workloads. IaaS is suitable for a wide range of application design patterns, including both "cloud-native" application architectures and enterprise application architectures. All use cases can have a local/regional character or can be on a global scale.

4. Current state of research and implementations

4.1. General limitations to optimal decision making

Selecting the best CSP for a given end user-organization and use case is sometimes not feasible. This is because several difficulties constrain the selection of the best option.
First, the (environment of the) end user organization is a Complex Adaptive System (CAS), with three characteristics of its behavior: evolution, aggregate behavior and anticipation (Holland, 1992, p. 18). Because of the dynamic nature of the environment and the anticipative behavior of the end user, the resulting selection may not be optimal (Holland, 1992, p. 20).
Second, there may be a gap between the competency (C) of the decision maker/agent and the difficulty (D) of the selection process, creating uncertainty (Heiner, 1983, p. 563). He states

> …. that when genuine uncertainty exists, allowing greater flexibility to react to more information or administer a more complex repertoire of actions will not necessarily enhance an agent's performance.

Heiner's research implicates that an optimal, rational solution for a CSP selection problem may not be feasible, as both exhaustingly analyzing the alternatives as well as making the selection process more complex might have counterproductive effects.
However, it is important to consider organizational and social factors when selecting a CSP. In the 1980's, IBM was often mentioned in a quote, in the selection process of buying hardware: "Nobody ever got fired for buying IBM". This is sometimes paraphrased as "Nobody ever got fired for buying AWS", implicating an additional social factor in the CSP selection process, that is the position of the decision maker.

4.2. Academic research and (governmental) research organizations

In general, the focus of academic research on Decision Support Methods is not on the organizational factors. Several studies on QoS attributes for the individual services have been executed, including a systematic literature review (Jula, Sundararajan, & Othman, 2014). Of these studies, the research on MCDM (multi criteria decision making) as described in (Rehman, Hussain, & Hussain, 2011), and the agent based Cloudle research (Sim, 2012) also focuses on QoS in selecting individual services. The research of (Omerovic, Muntes-Mulero, Matthews, & Gunka, 2013) into risk assessment, quality and cost prediction is closer to the topic at hand.
The IEEE (Institute of Electrical and Electronics Engineers) has a Community for Cloud Computing and Big Data and organizes international conferences on Cloud computing. (IEEE, 2014). The research presented at these conferences is generally on technical topics.
The EU initiates many research programs, in collaboration with academic and business partners. Examples with regard to this research are:

- The European Cloud Computing Strategy (part of the Digital Agenda, (EC Digital Agenda for Europe, 2014)) is of great importance, but has a different focus (i.e. technical standardization and governance/privacy)
- The MODAClouds project, on decision support systems for cloud services selection (MODAClouds, 2014)
- ETSI, the European Telecommunications Standards Institute is officially recognized by the European Union as a European Standards Organization. One of its projects is the ETSI Cloud Standards Coordination initiative, which describes the Acquisition of Cloud Service phase in its report (ETSI, 2013, p. 14).

The Cloud Services Measurement Initiative Consortium (CSMIC), an international private public partnership, is developing a Service Measurement Index. This is a set of business-relevant Key Performance Indicators (KPIs) that provide a standardized method for measuring and comparing a business services (CSMIC, 2014).
The US National Institute of Standards and Technology (NIST) develops security recommendations and guidelines for cloud computing, for use by USA's Federal agencies. They can be used by nongovernmental organizations on a voluntary basis (NIST, 2014).

4.3. Business (profit) research organizations

The main business research organization with a European focus is Gartner. Its Magic Quadrant publications for IaaS and European managed hosting are often quoted and are significant for the organizational factors and evaluation of the CSPs (Gartner b, 2013; Gartner a, 2013)
The broker company RightScale (RightScale , 2014, pp. 11, 13) supports Cloud Portfolio Management for their customers, to accelerate their delivery of applications while optimizing the customers cloud usage to reduce risk and costs. In their annual survey, several organizational factors are mentioned, e.g. cloud maturity of the end user organization.

4.4. CSP selection applications

In the UK, the Government provides a website, Cloudstore (G-Cloud a, no year) that gives an overview of cloud providers that are 'approved by HM government'. This online marketplace

allows end users in public sector organizations to buy off the shelf cloud-based services on a pay as you go basis, via the G-Cloud framework. It covers infrastructure, platform, software and support services, e.g. a 'Buyers Guide' ((G-Cloud b, 2014).
Furthermore, the PlanForCloud application (RightScale PlanForCloud, 2014) from RightScale enables modeling of the cloud deployment configuration, including usage scenarios that incorporate growth, seasonality and other variability in the consumption of cloud resources. A simulation of deployments can be run; resulting in a detailed 3-year forecast cost report.
Two others systems are Cloudyn and Cloudability. Cloudyn is a support system for AWS and Google cloud, improving and customizing cloud use (Cloudyn, 2014); Cloudability supports cost management for end users, at the operational level, by providing billing data from multiple CSPs (e.g. AWS, HPCloud and Rackspace) (Cloudability, 2014).

5. Research Design

5.1. Focus and limitation of RQ

5.1.1. Strategic and tactical selection of a CSP

The selection of a CSP takes place on three business decision levels (strategic, tactic and operational). On the strategic level, the overall direction for the future of the client's organization is decided on, internally and especially with regard to its competitive environment (Wikipedia, 2014). For the tactical level decisions are made to meet the strategic objectives with the available resources (Gorry & Scott Morton, 1971, pp. 50-51). Operational decisions concern the execution of tasks and deployments; they are based on set rules, within fixed, measurable boundaries.
In the strategic and tactical selection of a CSP, the objectives and policies of the end user-organizations are taken into account, including the plans and allocated resources to achieve the objectives. On these levels, the emphasis will lie on selecting the Service Provider, as an organization. For the operational level (both design/build and run time choices for deployment), the focus is on selecting specific services from a CSP.
The delineation of this study is on the tactical level (preferred supplier selection). The underlying assumption is that the operational decision-making is based on the functional requirements, the QoS and the costs, within a set of suppliers that meet the organizational requirements. Differences in organizational characteristics of a CSP are therefore more important at the strategic and tactical decision level.

5.1.2. Limitation to public IaaS, software development and SMEs

The study is limited to (European) public IaaS cloud services and, as a customer base, IT-companies, with software development projects as use cases. The focus will be on small and medium-sized enterprises (SMEs, with a limited number of employees and turnover/balance sheet total (EU European Commission, 2014)).
This limitation to Public IaaS and SME IT companies has three advantages to reduce complexity: the use cases are relatively simple and isolated, the IT companies have an understanding of the matter, and the business functionality match that is part of PaaS and SaaS is omitted.

5.1.3. Research approach and limitation

In order to support the decision-making process on the tactical level, a set of factors is identified that influence the decision to select a (shortlist of) IaaS Cloud Service Provider(s) and their services. The first step is to derive the factors, from literature study and initial interviews. A second step is to aggregate these factors into a limited number of classes. Interviewing stakeholders from both academic and business background then validates this model.
The third step is to apply these factors to a specific IaaS use case and their added value for the CSP selection is evaluated.

In order to support a Decision Support Method (DSM) or Decision Support System (DSS), additional research is necessary. Three essential requirements are that (1) an individual end user should be able to indicate the relative importance of a factor for the use case(s) at hand, and (2) a measurement method for scoring on the factors is needed, and (3) the CSPs scoring on these factors is available.
Developing a scoring/measuring method for the organizational factors is out of the scope of this research, as well as evaluating the CSPs and their offerings along these factors.
For future research, the integration of the organizational factors could be extended to the selection of other cloud services (e.g. Software as a Service, SaaS) and a different customer base.

5.2. Research design

The research method is a combination of structured literature research (SLR) and interviews with experts in the field and stakeholders from academic and business background. This approach follows the general guidelines of the grounded theory study (Robson, 2011, pp. 79, 146-151). The resulting model is then validated and improved.
Research activities (partly parallel executed):

- Exploration of cloud computing: background, challenges and opportunities, focused on IaaS and SME
- Analysis of available CSP selection methods and implementations: investigate currently available cloud-recommendation models on use of organizational and social factors;
- Inventory of organizational factors**:** The factors influencing CSP selection are derived from structured literature research (SLR) and initial interviews with the thesis supervisors and one or two content experts.
    1. Reduce the long list of factors into a shortlist, by selecting the most important/most mentioned factors and aggregate the organizational factors into a draft set, with descriptions
    2. Evaluate (includes feedback) and improve the framework:
        a. Evaluation of the set is executed by means of semi-structured interviews. The interviews will in general be one to one, partly face-to-face, partly via on line connection due to the place of residences of the interviewees. Part of the questions will be of a quantitative nature (scoring on a Likert scale).
        b. Improvement of the set, in collaboration with the thesis supervisors.
    3. Finalize aggregate and description
- Apply these factors in a case study of a specific IaaS use case
  Analysis of one IaaS selection process, as to how organizational factors are taken into account
- Write thesis: general parts of the thesis will be written in parallel to the other activities. After evaluation of these parts, they can be improved to the final version.

As a last step, the thesis must be evaluated and graded.
The planning is depicted in table 1.

5.3. Sources

The field of cloud computing is evolving very quickly, business and technology driven. This calls for the use of other than academic sources (e.g. IEEE), such as profit research organizations (e.g. Gartner), public private partnership research organizations (EU-projects), standardization organizations (NIST, ETSI) and commercial sources, such as YouTube presentations from Google and a cost calculator from RightScale (RightScale PlanForCloud, 2014). For the structured literature review (SLR), Google Scholar, the search function of VU University Library and Google search (non academic sources) are used. In general, the time frame for the search inquiries is from 2010 to this date. In addition, if possible, some Dutch seminars or conferences are visited.

The thesis supervisor acts as an intermediary for the content experts and interviewees; in turn, these contacts can propose additional contacts and interviewees. These contacts are from the Netherlands, Italy and Spain and work in business or international research.

5.4. Planning

Activity	Start date	End date	Involved actors	Remarks
THESIS DESIGN				
Thesis design	January 2014	June 15, 2014	D. Tamburri (VU) H. Fernandez (VU/ElasticBox Inc)	
Presentation of thesis design		July 11th	D. Tamburri,	Alternatives?
Evaluation and grading of thesis design	July 1	August 8	2nd reader D. Tamburri, Supervisor P. Lago	ASAP after writing
THESIS				
Cloud computing theoretical basis	January 2014	June 15, 2014	Supervisor / 2nd reader D. Tamburri, H. Fernandez	
Analysis of CSP selection methods (SLR)	April 2014	June 15, 2014		
Inventory of organizational factors (SLR)	May 2014	June 29, 2014		
Model org. factors into aggregate set, draft	June 16, 2014	July 4th 2014	D. Tamburri, H. Fernandez Content experts	
Prepare interviews (content and selection of interviewees)	June 30, 2014	July 13	D. Tamburri H. Fernandez Content experts?	
Evaluation of draft aggregate set in interviews	July 7	July 20	Interviewees	
Finalize organizational factors and clusters	July 21	August 1	D. Tamburri H. Fernandez Content experts	
Select case to apply organizational factors and clusters	July 1	July 13	D. Tamburri? H. Fernandez? Albert Mahler, Convenience ICT	
Analyze and evaluate case		August 1	Albert Mahler, Case owner	
Finalize results of research questions		August 15	D. Tamburri P. Lago Albert Mahler	
Write thesis	June 15, 2014	August 17		
Evaluate concept parts of thesis	August 1	August 18	D. Tamburri P. Lago? Content expert?	
Presentation of thesis results		August 1	2nd reader P. Lago	
Evaluation and grading of thesis	August 18 SEPTEMBER	August 22 (→ August 29) SEPTEMBER	Supervisor P. Lago H. Fernandez 2nd reader D. Tamburri	Final grade has to be at FEW OWB at end of August, latest Monday August 25

Concerns: Availability of supervisor (partially not in Amsterdam) and 2nd reader
Holidays of supervisor, 2nd reader and some content experts and interviewees

Table 1: planning of thesis

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