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Tools and requirements to consider when migrating to cloud

A case study

Bachelor of Science Thesis in Software Engineering and Management

David Larsson



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A case study on cloud adoption tools in industry

A study evaluating the usability of Technology Suitability Analysis in practice performed at a company providing a platform as a service, including cloud requirements prioritization at said company.

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Supervisor: Jan-Philipp Steghöfer
Examiner: Richard Berntsson Svensson

University of Gothenburg
Chalmers University of Technology
Department of Computer Science and Engineering
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

Abstract—In today’s software development environment, more and more enterprises are interested in using cloud computing to provide them with everything from data storage to processing power, features which previously could only be achieved through building their own data centers, something deemed not feasible for many companies. The adoption of cloud computing does however require a sizable effort, since it includes changes both to the architecture of the enterprises system and their work flow. This study aims to evaluate one proposed tool to help enterprises adopt cloud computing, the Technology Suitability Analysis (TSA), as well as provide empirical data on how a company providing a platform as a service prioritize architectural requirements connected to cloud computing. Semi-structured interviews were conducted following the questions of TSA with added evaluation of its usefulness, and data was gathered on requirement prioritization in the form of distributed questionnaires and analysis of an architectural document. The findings of this study showcase TSA to be a helpful tool in building a catalog of basic needs, but further questioning connected to the user specific use case is needed to provide a full understanding of what is needed.

I. INTRODUCTION

Cloud computing is a growing phenomenon that has gained popularity as a result of its ability to provide enterprises extensive IT infrastructure for a reasonably low cost compared to traditional data centers [1]. For any enterprise looking to provide their customers with a software platform as a service [2], but lack the extensive infrastructure demanded for this type of venture, cloud services provide a solution. However, when it comes to migrating an existing service to the cloud, there is no general design guideline for developers and architects to follow [3], and the effort of cloud adoption can seem daunting. Issues such as *Scalability* [4] and *Security* [5] are only two of many to consider when approaching cloud computing.

The effort of migrating an existing service to the cloud should not be taken lightly, seeing how adopting cloud computing isn’t just an improvement of an enterprises data center, but a re-imagining of how its infrastructure is provisioned and used [6]. This leads not only to a change of infrastructure, but also to changes in budgeting and the development process. Defining which requirements to prioritize and what solution to choose is highly dependent on the enterprise’s solution and needs, but researchers have made efforts to help clarify these questions. Khajeh-Hosseini et al. have tried to make the adoption of cloud simpler with their Cloud Adoption Toolkit (CAT) [7]. In CAT they provide five tools to help decision making in what approach to take, including their Technology Suitability Analysis (TSA). Regarding which requirements to take into account Rimal et al. define 22 architectural requirements to consider when approaching cloud [3]. While TSA provides a promising helping hand for cloud adoption, it has not been studied empirically, and the 22 architectural requirements would be differently prioritized between different projects.

In this case study the goal is to evaluate one proposed method of simplifying cloud adoption, in this case TSA, by applying it in a real world scenario within a company currently undergoing an effort to migrate an existing service to the

cloud, as well as gather empirical data on what requirements a company providing a platform as a service prioritize in its cloud solution. This study aims to help further mature the TSA tool, by evaluating its usefulness and possible improvements, as well as contribute to the ongoing research into cloud adoption, by providing empirical data on which requirements enterprises providing a platform as a service prioritize.

In section II the selected case company will be detailed and section III will provide background to the study, including a brief description of cloud computing. Section IV will provide details on the selected tools as well as other related work. A detailed description of the case study’s methodology, including the research questions, can be found in section V. The results of the case study will be reported in section VI, with discussion and finally conclusion following in section VII and VIII.

II. CASE COMPANY DESCRIPTION

Novacura is a medium-sized, international enterprise specializing in providing a platform as a service. Their product is a low-code business-process platform that enables the end users to make their own apps and business flows in a visual editor, to deploy as they see fit. Examples of areas of use are in production, delivery, maintenance, sales, service and logistics. Novacura has many different customers with varying needs regarding e.g. security and availability, and multiple customers have existing infrastructures in place that needs to be integrated with the new platform. This case study took place at one of their offices, located in Gothenburg, Sweden.

III. BACKGROUND

Cloud computing can provide enterprises with extensive infrastructure, remove the increasing complexity of managing said infrastructure, while also lowering their costs [1]. There are many types of service models within cloud computing, ranging from software, to development platforms, to entire hardware infrastructures. The National Institute of Standards and Technology (NIST) defines three major types of service models in cloud computing [2].

Software as a Service (SaaS) – The consumer uses the software through an interface from the provider, but the underlying infrastructure is run in the cloud, out of the consumers control.

Platform as a Service (PaaS) – The consumer has the ability to deploy, configure and run apps supported by the platform on the cloud infrastructure, but does not have access to the underlying cloud infrastructure.

Infrastructure as a Service (IaaS) – The consumer has full control over the cloud infrastructure provided by the cloud provider, on which they can deploy operating systems, manage storage and other fundamental computing resources.

NIST also defines four different deployment models for cloud computing.

Private cloud – The cloud infrastructure is used exclusively by a single organization, which might contain multiple units. It can be owned, managed and operated by either the organization, a third party, or a combination of them, and it may be located both on and off premises.

Community cloud — The cloud infrastructure is used exclusively by a community of users from organizations with shared concerns. These concerns may range from mission and security requirements, to policies. It can be owned, managed and operated by either of the organizations, a third party, or a combination of them, and it may be located both on and off premises.

Public cloud — In a public cloud the cloud infrastructure can be used by the general public. It can be owned, managed and operated by a business, government or academic organization, or any combination of the three. The public cloud is always located at the premises of the cloud provider. Some examples of public clouds are Amazon Web Services, Microsoft Azure, and the Google Cloud Platform.

Hybrid cloud — The last infrastructure defined by NIST is a composition of two or more cloud infrastructures that remain as single units, but share standardized technology to enable application and data portability.

Depending on which type of service model used, and what type of deployment model the enterprise will support, the choice of approach, the cloud provider most suitable, and the architectural requirements prioritization would be different. A company specializing in the production of military equipment would likely prioritize *Security* higher than an enterprise providing a social media platform.

IV. RELATED WORK

Although the proposed lowered cost of adopting cloud computing, in relation to traditional infrastructure, can seem like a easy choice to make, there are more things to consider before taking the leap. In a case study by Khajeh–Hosseini et. al. on cloud migration of an oil and gas enterprises IT solution, they found that the calculated cost benefits of 37% over 5 years would come at a price [8]. In their study they did a stakeholder impact analysis which showed significant disadvantages such as heightened risks to customer dissatisfaction as well as decreased job satisfaction, connected to the proposed change in work and the loss of control to a third party. Consequences like these are further aspects to take into account when considering migrating to cloud, in the choice of approach and solution. The importance of making the right choice early on can be seen in Boehm’s estimations where he states that the cost to fix a requirements error later in development is 200 times higher compared to correcting it during the requirements engineering phase [9].

In an effort to help enterprises choose a cloud solution or evaluate a chosen solution, researchers have created frameworks and tools. Khajeh-Hosseini et. al. provide a Technology suitability analysis (TSA) as part of their cloud adoption toolkit [7]. TSA consists of a checklist of questions used to determine if the enterprise would benefit from adopting cloud, and if the chosen solution is suitable for their effort. TSA covers the main issues to focus on during decision-making, and provides the user with 8 characteristics with paired questions to determine the suitability. For instance, negative answers to questions 1-3 about technical properties, showcases that

the enterprise would have difficulties taking full advantage of cloud computing [10] Negative answers to questions 5-7 would increase the risks of using cloud computing [11], and negative answers to questions 4 and 8 could hinder the use of cloud computing altogether [7]. The full list of questions used in TSA can be found in *Table I*.

Desired technology characteristics	Questions
1. Elasticity	Does your software architecture support scaling out? If not, will scaling up to a bigger server suffice?
2. Communications	Is the bandwidth within the cloud and between the cloud and other systems sufficient for your application? Is latency of data transfer to the cloud acceptable?
3. Processing	Is the CPU power of instances appropriate for your application at the expected operating load? Do instances have enough memory for the application?
4. Access to hardware / bespoke hardware	Does your cloud provider provide the required access to hardware components or bespoke hardware?
5. Availability / dependability	Does your cloud provider provide an appropriate SLA? Are you able to create the appropriate availability by mixing geographical locations or service providers?
6. Security requirements	Does your cloud service provider meet your security requirements? (e.g. do they support multi-factor authentication or encrypted data transfer)
7. Data confidentiality and privacy	Does your cloud provider provide sufficient data confidentiality and privacy guarantees?
8. Regulatory requirements	Does your cloud provider comply with the required regulatory requirements of your organization?

TABLE I: Technology Suitability Analysis [7]

Another approach to cloud adoption with regards to requirements engineering can be found in Goal Oriented Requirements Engineering (GORE) [12]. With GORE, authors Zardari and Bahsoon propose using goals to elicit and specify the requirements of stakeholders, dividing the goals into three categories: *Strategic/Business Goals*, *High Level/Core Goals* and *Low Level/Operational Goals*, and prioritizing the goals importance. By doing this the user would be able to define an acceptance level of each goal, seeing as satisfying each goal perfectly with one solution would be close to impossible [12]. Once goals have been generated the user of GORE would perform a matching of the goals against the stated performance and features of different cloud providers, calculating a satisfaction score. The satisfaction scores of each provider would give the user an estimate of its suitability for their effort. Once matching is done the next phase of GORE is to analyze mismatches and manage risks. In this phase the inevitable drawbacks of each solution would be compared, calculating the risk with each unfulfilled goal, while

examining ways to mitigate said risk. Mitigation could include: changing a stated goal, choosing other alternative or negotiate features. Once this analysis is complete, the choice of optimal provider would be the one solution satisfying the specified goals, with surmountable risks, at an acceptable cost. While GORE could prove to be an effective method of evaluating goals and choosing cloud provider, TSA is the main focus of this case study, since Novacura has already taken its first steps into migration.

Regarding which requirements to consider in a cloud migration effort, Rimal et al. defines 22 architectural requirements [3] connected to cloud computing. In their report they provide a classification of architectural requirements, grouping them in to three layers consisting of the different requirements of cloud providers, such as Google and Amazon, the enterprises using them, and the end-users. The three layers are used to differentiate between the different needs of the different users, as well as highlight which requirements are shared between users. In this case, *Interoperability* and *Scalability* are shared requirements between the cloud providers and the enterprises, while *Quality of Service* is the only requirement shared by all three types of users. The complete list of requirements and which layer they belong to can be found in Fig. 1.

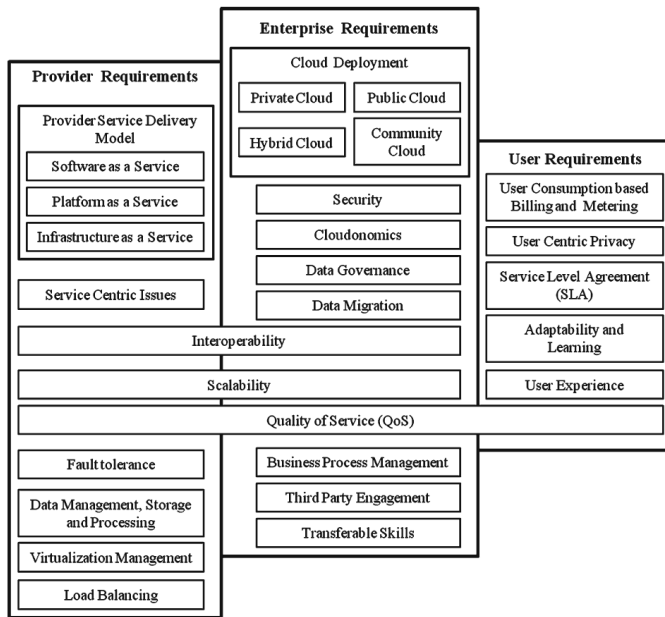


Fig. 1: Three layered architectural requirements [3]

V. RESEARCH METHOD

A. Research Objectives

The objectives of this study is to do a concrete case study on the relevance and usability of TSA when applied in practice on a company currently undergoing a migration to cloud, as well as get a better understanding on how cloud requirements are prioritized within a company providing a platform as a service. By examining the TSA tool in practice, future efforts to adopt cloud computing could have a better starting point, knowing

the usefulness of it. The prioritization of requirements would be of use to any company with a similar business model to the case company, and to future researchers.

The following research questions will act as a basis for this study.

- RQ1) *How useful is TSA in practice?*
 - RQ1.1) *How does it help clarify the needs?*
 - RQ1.2) *How well does it cover the needs?*
- RQ2) *How does a company providing a platform as a service prioritize cloud requirements?*

B. Case study design

The design of the case study is based in the objective to evaluate Novacuras solution for migrating their service to the cloud, and follows the steps proposed by Runesson and Höst in their case study guidelines [13]. By examining literature, a lack of clear guidelines or solutions to migrate an existing service to the cloud was found, rather suggestions and tools, some never been used in practice, resulting in the choice of using TSA as a basis for research. Research questions were defined, and methods and procedures were decided around them. To answer RQ1, semi-structured interviews were selected as the data collection method, focusing on asking the questions stated in TSA, with added questions on the usability of TSA. To answer RQ2 the choice of using a questionnaire was deemed appropriate, where the participants get to rank the priority of the stated requirement on a scale of 1-5. Another method chosen to answer RQ2, as well as to ensure *Data Triangulation* [14], was to analyze architectural documents to find requirements specifications, which would indicate that requirement being prioritized by the company.

C. Case study subjects

The subjects of this case study are employees working at a medium sized software company specializing in delivering a platform as a service. The sample for the face-to-face interviews was drawn from developers, architects and managers working at Novacura, based on their involvement with the cloud solution and knowledge of the system. The selected interviewees included an architect, a senior developer, and a product manager. The selected subject sample for the questionnaire was the workforce in Novacuras research and development department, residing in their office in Gothenburg, Sweden.

D. Preparation for data collection

In preparation for data collection the semi-structured interview outline was defined, following the TSA checklist, with added questions in the end of the interview to evaluate the tools coverage of criteria. The added questions asked the interviewee if they thought the interview gave them an overview of what was needed of their solution, as well as if the interview provided them with an insight on if their current choice was suitable, or if they felt anything was missing. Interview slots were scheduled with the selected interviewees beforehand to

be conducted at their convenience, to help them plan around the time slot.

The questionnaire was produced to evaluate stakeholders prioritization of the requirements defined by Rimal et al. [3], by letting the participants answer questions regarding how they would prioritize the stated requirements on a scale of 1-5, where 1 is of the lowest priority and 5 is of the highest priority. Each question included a short description of the requirement, to help participants understand its correlation to their product. The questionnaires were printed and distributed among the sample in the Gothenburg office. With the questionnaire came a defined time span, for which the participants were requested to complete them at their own discretion within. The full questionnaire can be found in the *Appendix*.

To make it possible for data collection regarding architectural documents, key employees handling architectural documents were identified.

E. Data collection

Data collection was done in face to face interviews, following the schedule with the chosen interviewees, using the previously defined interview outline. The interviewee was given a brief introduction to the subject and purpose of the interview, as well as encouragement to answer each question in as much detail as possible. Seeing how some of the TSA questions are simple Yes/No questions, rendering them unsuitable for a qualitative interview [15], the interviewer made sure to follow up these questions with further questions about the answer, if they deemed the first answer to be non-descriptive, or needing clarification. After the interviews had been conducted the audio recording was transcribed to text documents.

After the given time frame for the printed questionnaire was over, the questionnaires were to be collected. During collection it was noted that many were left unanswered due to time constraints on the participants side, which lead to an extension of the initial time given to answer. At the second collection attempt the same result was found. This led to a change of strategy where the participants who previously received a printed version from the researcher, received an online version of the questionnaire, with added encouragement from management to complete it.

During identification of architectural documents it was found that the company was lacking updated, detailed documents about their cloud solution, but was able to share a solution overview, containing some information on their implementation and usage.

F. Data Analysis

The transcripts of the interviews were used in a directed content analysis [16] where the answers were coded and categorized with regards to which desired technology characteristic in TSA they are referring to, and whether the referral is positive or negative, meaning if the answer to the TSA question is highlighting if the chosen solution is suitable according to TSA or not suitable. The answers to the added

questions were categorized according to if they are positive or negative towards the TSA and their chosen solution, as well as if they are requests or comments on the usefulness of TSA. Regarding the results of the questionnaire, the requirements were ranked depending on their score from the collected answers, where the requirement with the highest number would be considered the highest prioritized by the participants. The collected architectural document's elements were analyzed and coded depending on their relevance to a certain requirement. The element would contribute to a requirement's score where e.g. a development document element specifying the systems use of a specific encryption, would add 1 additional point to the priority score of the requirement *Security*.

G. Threats to validity

In Yin's research on case studies he specifies the importance of *internal validity* and *external validity* of any given study [17]. The internal validity of a study is based on how well the study is structured and implemented, in terms of the used research methodology as well as data collection methods. One threat to the internal validity to this study is the lack of investigator triangulation [14]. In any research effort the confirmation of data from multiple investigators, without previous discussion, gives a greater credibility to the findings. This was not possible in this study since there was only one researcher conducting the interviews, analysis, coding etc. Another threat to the internal validity of this study can be found in the lack of pre-testing being conducted on the questionnaire before being distributed to the target population. Pre-testing can prove a powerful tool to identify faults in the design of the questionnaire, both regarding individual questions and overall design, and gives the opportunity to fix said faults which otherwise could hinder the data collection of the study and negatively impact the results [18]. A final threat to the internal validity identified in this study is the use of a pre generated list of requirements to prioritize. This could potentially lead to confusion among the participants as to how the requirements relate to their effort, since they have not been involved in the process of selecting the requirements.

The external validity of the study is based on how well the findings correlate to the real world, in terms of applicability and generalization. One identified threat to the external validity of this study is the limited sample for the interviews, as well as the questionnaire, and the limited architectural documents available. All data from the interviews, questionnaire and artifact analysis comes from one company providing a platform as a service, and might not be representative of other enterprises going through the same effort. Since the analyzed document only includes implementation details for their current solution, it could lead to some architectural requirements such as *R7 Security* and *R13 Data governance* scoring higher in the final evaluation, since they are directly related to implementation.

VI. RESULTS

A. Interview results

1) *Interview A:* During questioning about *Elasticity*, the interviewee answered that their currently chosen cloud provider does support scaling out, but when asked to clarify regarding their own architecture, it was made clear that it does not have support for this currently. In regards to if scaling up would suffice, the interviewee stated that in their opinion it would, seeing how Novacuras product in itself is very light weight. The interviewee also stated that if anything would be taxing on their system it would be a transactional database, something they found very simple to scale within their currently chosen cloud providers tools. In the discussion following the questions regarding *Communications*, it was made apparent that they so far hadn't encountered any major problems regarding bandwidth and latency, but that they had however taken precautions on where they placed their servers, to minimize latency. The interviewee stated that they always try to place the server close to the physical location of their customers, something that is possible with their currently chosen provider. When *Processing* was discussed, the interviewee stated that they so far hadn't ran into any issues regarding CPU power of instances or having enough memory. It was clarified though that while everything was working well now, there could be issues with scaling in the future. The interviewee also expressed dissatisfaction with their current providers ability to provide detailed cost estimations connected to scaling. When discussing *Access to hardware/bespoke hardware*, it was made clear that the interviewee was dissatisfied with one aspect of customization within their chosen provider. There is an issue with a regular automatic change connected to licenses which requires a manual effort from the team to fix, for which the interviewee believes they should have the ability to toggle on or off at will. Regarding *Availability/dependability*, the interviewee stated that for their purposes the provided SLA from their provider was appropriate, but that they have had customers that do not approve of it, resulting in these customer simply not using cloud. When it came to the question about mixing geographical locations to create the appropriate availability the interviewee stated they didn't have experience in the matter and therefore could not provide an answer. When asked about the *Security requirements* it became clear that the interviewee felt that their chosen provider met their security requirements, commenting on how the security provided is better than what they could produce in house, given the providers scale. When discussing *Data confidentiality and privacy* the interviewee shared that for their purpose the provider could provide sufficient data confidentiality and privacy guarantees, but clarified that some customers demand their servers to be located physically in Sweden, something they are able to provide. A similar answer was given in regards to *Regulatory requirements*, where the provider complies with Novacuras required regulatory requirements, but customization is sometimes needed depending on the customer.

In the discussion following the added questions the interviewee stated that they found the TSA questions to cover the architectural features they would consider during an effort to adopt cloud or migrate an existing service to cloud. The interviewee stated that in a discussion about which provider to choose, the questions would be helpful to determine differences and benefits among different providers. A missing feature of the TSA according to the interviewee, was a way to compare scalability and pricing of different providers, and they thought the question of cost overall was underrepresented in the questioning.

During the interview the interviewee gave 11 positive answers regarding the suitability of the chosen solution, spanning all technical properties of the TSA, with an exception to *Access to hardware/bespoke hardware* where the interviewee felt their current provider fell short in regards to customization.

2) *Interview B:* When asked about *Elasticity* the interviewee stated that their currently chosen provider supports scaling out, but their current software architecture does not fully support it at the moment of the interview. The interviewee clarified that while some parts of their system support scaling out, it is not fully implemented and specifically they had some issues with scaling some of their data layers. This is something the interviewee perceived as an issue moving forward, and something they would have to solve before trying to fully implement cloud support. At the moment they manage by scaling up to a bigger server, but it is viewed as a temporary solution to the issue. During the discussion on *Communications* the interviewee stated that for their purposes, the bandwidth from their provider isn't usually an issue, but for some customers it can be a critical point between the cloud and their on premise systems. For customers whose entire systems are on the cloud is has never been an issue however. Regarding data transfer speed the provider fulfills their needs, and the only point where latency could be considered as a potential issue is between their mobile client and the cloud. The interviewee clarifies that since this isn't critical to their solution, it is not viewed as a concern. In the questions about *Processing* the interviewee answered that the CPU power of instances provided was sufficient for their systems, especially since they now use scaling up instead of scaling out. Regarding memory they had so far not encountered any issues, but the interviewee expressed concerns about their internal architecture in regards to this, viewing it as something that needs further evaluation moving forward. In the discussion about *Access to hardware/bespoke hardware* the interviewee stated that this is not their area of expertise, but they had not encountered any issues related to it. When questioned about *Availability/dependability* the interviewee was under the impression that their providers SLA was appropriate for their effort. On the question on availability in regards to geographical locations their current system allows for each customer to have their own hosted environment locally, but in the future they could run into issues with customers requesting solutions for systems spanning multiple sites, as their current internal architecture doesn't support this. With regards to *Security requirements*

the interviewee stated that their current provider fully meets their demands, and that they handle security issues such as authentication with their own software. In questioning about *Data confidentiality and privacy* the interviewee answered that their current provider does provide them with sufficient data confidentiality and privacy guarantees, and that they are able to further isolate the customers data by having the locally hosted environments completely separated from each other. Finally regarding *Regulatory requirements*, the interviewee shared that their current provider complies with the required regulatory requirements of their organization, but clarified that they might encounter issues in the future if customers demand their data to be stored at certain geographical locations that they cannot provide.

In the follow up discussion about TSA the interviewee stated that they felt the TSA covered most of the architectural features they would consider during an effort to adopt cloud or migrate an existing service to cloud. The one thing the interviewee would find beneficial to be added to the TSA was more questions surrounding location based data storage. The interviewee felt the TSA was a helpful tool to open up the discussion about architectural features, and further evaluate some of their "known unknowns".

During the interview the interviewee gave 12 positive answers regarding the suitability of the chosen solution, spanning all technical properties of the TSA.

3) *Interview C*: In the discussion following the questions regarding *Elasticity*, the interviewee shared that their software architecture does not support scaling out, but that this is a goal they have, as well as something they view as critical moving forward. The interviewee stated that for now, their solution of scaling up to a bigger server does suffice and work well. They do however plan on not using scaling up to the same degree once they've successfully implemented scaling out, since it is also an issue of cost. Regarding *Communications* the interviewee answered that the bandwidth had been sufficient so far, but that they had noticed some latency issues related to the connection between customers on premise systems and the cloud, which could prove critical in the future. The latency of data transfer is acceptable, and the interviewee clarified that the minor issues they had encountered so far stem from their internal architecture, rather than the provider. While discussing *Processing*, it was made clear by the interviewee that neither CPU power or memory had been an issue for them so far, attributing it to their software being very lightweight in its nature. Regarding *Access to hardware/bespoke hardware* the interviewee found the question difficult to understand, but answered that if the question was related to customizability they felt their current provider have everything they need and more. During the discussion on *Availability/dependability* the interviewee stated that they felt their currently chosen provider provides an appropriate SLA, sharing that they have to make sure to match their SLAs towards their customers with the one provided by their provider. They also shared that they were able to provide the appropriate availability with using a combination of the providers abilities, as well as offering on premise

systems to customers with further needs. Regarding *Security requirements* the interviewee stated that their currently chosen provider meet their security requirements. They also shared that they are currently working on updating their security, and that they have not found anything that would point to their current provider failing to meet their requirements, even after this update. In the discussion about *Data confidentiality and privacy* the interviewee answered that they weren't sure if their currently chosen cloud provider could provide sufficient data confidentiality and privacy guarantees, since they had not looked into this matter themselves. To the question about *Regulatory requirements* the interviewee answered that they had so far not encountered any problems, and that they were happy with the setup from their current provider.

In the discussion following the added questions about TSA, the interviewee felt that TSA covered the basics, but could use more concrete questions about the technology used, bringing up a need in their organization to know more about the connectivity options between cloud and on premise systems.

During the interview the interviewee gave 10 positive answers regarding the suitability of the chosen solution, spanning all technical properties of the TSA, with an exception to *Data confidentiality and privacy* where the interviewee felt they did not possess the knowledge to give an answer to the question.

B. Architectural Requirements results

1) *Questionnaire results*: Out of the 14 employees handed the questionnaire, there were 3 recorded answers, resulting in a response rate of 21.4%. Out of the 22 architectural requirements included in the survey, only 2 had a perfect priority score, where each participant had rated it to be of the highest priority. The requirements with the perfect score were *R1 Service delivery model* and *R8 Quality of service*. The requirement with the lowest score was *R16 Third party engagement*. The complete answers to the questionnaire with their combined priority score, sorted by highest score, can be found in *Table II*, where *P* indicates a participants individual rating of the requirement.

2) *Architectural document analysis results*: The provided solution overview contained information about Novacuras deployment environment, software deployment and upgrades, data storage and backup, operational data storage and access to on premise resources, administrative access controls and end user access control. The analysis of the document generated further priority points for the architectural requirements *R2 Service-centric*, *R3 Data management and storage*, *R7 Security*, *R8 Quality of service*, *R10 Load balancing*, *R12 Scalability*, *R13 Data governance*, *R14 Data migration*, *R18 User consumption-based billing and metering* and *R19 User-centric privacy*. The complete added points to their respective architectural requirement can be found in *Table III*, sorted by the amount of points generated.

Finally, in *Table IV*, the combined priority score of the architectural requirements from the gathered answers to the questionnaire as well as the added points from the document

Architectural requirement	P1	P2	P3	Score
R1 Service delivery model	5	5	5	15
R8 Quality of service	5	5	5	15
R2 Service-centric	5	5	4	14
R6 Fault tolerance	4	5	5	14
R7 Security	5	5	4	14
R14 Data migration	4	5	5	14
R15 Business process management	5	4	5	14
R19 User-centric privacy	4	5	5	14
R22 User experience	5	4	4	13
R11 Interoperability	5	4	3	12
R12 Scalability	3	5	4	12
R13 Data governance	3	4	5	12
R18 User consumption-based billing and metering	5	3	4	12
R5 Cloud deployment	3	4	4	11
R3 Data management and storage	3	4	3	10
R4 Virtualization management	5	3	2	10
R9 Cloudonomics	3	3	4	10
R10 Load balancing	3	4	3	10
R17 Transferable skills	3	3	3	9
R20 Service level agreements	4	3	2	9
R21 Adaptability and learning	3	3	3	9
R16 Third party engagement	3	3	2	8

TABLE II: Priority Score from Questionnaires

Architectural requirement	P1	P2	P3	AP	Score
R2 Service-centric	5	5	4	5	19
R7 Security	5	5	4	5	19
R8 Quality of service	5	5	5	2	17
R13 Data governance	3	4	5	4	16
R19 User-centric privacy	4	5	5	2	16
R1 Service delivery model	5	5	5	-	15
R14 Data migration	4	5	5	1	15
R6 Fault tolerance	4	5	5	-	14
R15 Business process management	5	4	5	-	14
R12 Scalability	3	5	4	1	13
R18 User consumption-based billing and metering	5	3	4	1	13
R22 User experience	5	4	4	-	13
R3 Data management	3	4	3	2	12
R11 Interoperability	5	4	3	-	12
R5 Cloud deployment	3	4	4	-	11
R10 Load balancing	3	4	3	1	11
R4 Virtualization management	5	3	2	-	10
R9 Cloudonomics	3	3	4	-	10
R17 Transferable skills	3	3	3	-	9
R20 Service level agreements	4	3	2	-	9
R21 Adaptability and learning	3	3	3	-	9
R16 Third party engagement	3	3	2	-	8

TABLE IV: Final priority score

Architectural requirement	Points
R2 Service-centric	5
R7 Security	5
R13 Data governance	4
R3 Data management and storage	2
R8 Quality of service	2
R19 User-centric privacy	2
R10 Load balancing	1
R12 Scalability	1
R14 Data migration	1
R18 User consumption based billing and metering	1

TABLE III: Added priority points from analyzed document

analysis can be found, sorted by final score, where *AP* stands for *Added points*.

VII. DISCUSSION

To answer RQ1: *How useful is TSA in practice?* we must first look at RQ1.1: *How does it help clarify the needs?* and RQ1.2: *How well does it cover the needs?*.

Regarding RQ1.1 the TSA questions proved to be a useful tool in clarifying Novacuras needs from a potential provider, as well as clarifying what needs to be improved or altered in their internal architecture to be able to make full use of the benefits cloud computing has to offer. During the TSA interviews the questions were found to be beneficial in providing a base for discussion, and provide new viewpoints on issues and possible solutions already considered in their effort.

With regards to RQ1.2 all interviewees felt that TSA covered the basic architectural features to consider, but each interviewee felt that some further questions would be beneficial to their effort. Interviewee *A* found TSA to be lacking in evaluating potential costs, and thought added questions to compare scalability vs pricing among different providers would make a good addition. Interviewee *B* felt that TSA lacked questions on location based storage, and interviewee *C* wanted more evaluation on different providers abilities in terms of connections between the cloud and the solutions on the premise of the end customer.

In light of RQ1.1 and RQ1.2 the study shows that TSA can be considered a useful tool in practice, in evaluating needs and opening up discussion. TSA covers most basic features to consider, but further evaluation regarding user specific needs are to be used in tandem to the questions to provide a full coverage. If the user however wishes to compare different cloud providers up for consideration, TSA could be used to build a report on each provider and create their own method of weighing them against each other based on the features and potential drawbacks highlighted by TSA, as opposed to Goal Oriented Requirements Engineering [12] where the providers are compared using their satisfaction scores.

In regards to RQ2: *How does a company providing a platform as a service prioritize cloud requirements?* the study does not have the sufficient amount of data to give a definitive answer to the question. The data gathered however points towards *R2 Service-centric*, *R7 Security*, *R8 Quality of service*, *R13 Data governance* and *R19 User-centric privacy* being the

5 highest prioritized requirements. The data gathered from the questionnaires suggested that *RI Service delivery model* would be one of the highest prioritized requirement, but fell below the top 5 rating after the architectural document was analyzed. The reason for this in this specific case could be caused by the fact that the architectural document analyzed only includes an overview of the implementation details with regards to the already selected provider. Therefore the requirement *RI Service delivery model* had already been fulfilled at the time of producing the document and has no impact on their chosen implementation, resulting in this specific requirement not being mentioned in the document.

In contrast to the numerical method of prioritizing the requirements used in this study, another method of grading the priority can be found in Karlsson's case study at Ericsson [19]. In their study they used a comparative technique, by pairing requirements and evaluating their relative priority to each other, and propose this as a more efficient and accurate way of prioritizing requirements than a numerical method.

VIII. CONCLUSION

This case study aimed to evaluate the practical use of Technical Suitability Analysis in a company undergoing an effort to migrate their system to the cloud, as well as provide empirical data on how a company providing a platform as a service prioritize architectural requirements. By using qualitative interviews with the questions stated in TSA, with further evaluation of TSA itself, TSA was found to be a helpful starting point to build a basic understanding of Novacuras needs, albeit not a complete one. The findings of this study could prove beneficial to help further mature TSA as a tool, as well as provide enterprises with an evaluation of its usefulness in their own efforts to adopt cloud computing. Recommendations for future research would include additional case studies on the usefulness of TSA in practice, used in both similar and contrasting environments, and additional data collection on how enterprises prioritize requirements, as well as research on how stated requirement priority correlate to the architecture in use.

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Architectural Requirements Prioritization

In this questionnaire we measure how you prioritize the architectural requirements regarding your choice of cloud provider and your cloud solution. It is completely anonymous. The answers are graded 1-5, and translates as follows:
1 = *Lowest priority* 2 = *Low priority* 3 = *Standard priority* 4 = *High priority* 5 = *Highest priority*

R1 Service delivery model (SaaS, PaaS, IaaS)

The service providers ability to deliver the correct service delivery model. Such as *Software as a service, Platform as a service* and *Infrastructure as a service*.

1 2 3 4 5

R2 Service-centric

The architectures ability to be autonomic, and include processes related to provisioning and deployment, service decommissioning and service planning.

1 2 3 4 5

R3 Data management and storage

The solutions ability to manage data, in terms of storage space, accessibility and flexibility.

1 2 3 4 5

R4 Virtualization management

The abstraction of logical resources from their underlying physical resources.

1 2 3 4 5

R5 Cloud deployment

The solutions ability to provide the adequate deployment model. E.g. *Public Cloud, Private Cloud, Hybrid cloud*.

1 2 3 4 5

R6 Fault tolerance

The systems ability to continue operating in the event of a failure of some sort.

1 2 3 4 5

R7 Security

Overall security of the system, including data integrity and user privacy.

1 2 3 4 5

R8 Quality of service

The guarantee of performance and availability among other aspects. Both from the provider to the enterprise (you), and from the enterprise to the end user (your customers).

1 2 3 4 5

R9 Cloudonomics

The economics of cloud computing. Pricing, *pay-per-use* models, and overall cost benefits/drawbacks.

1 2 3 4 5

R10 Load balancing

The mechanism to self-regulate the workload within the clouds entities.

1 2 3 4 5

R11 Interoperability

Enabling migration and integration of applications and data between different platforms.

1 2 3 4 5

R12 Scalability

The systems ability to manage increased traffic or complexity when given additional resources.

1 2 3 4 5

R13 Data governance

The enterprises control over data being stored in the cloud.

1 2 3 4 5

R14 Data migration

The systems ability to distribute information to its' users, with high availability, high performance and without data loss.

1 2 3 4 5

R15 Business process management

Providing business structure, security and consistency.

1 2 3 4 5

R16 Third party engagement

The involvement of a third-party in the cloud solution, providing support in questions of legalities such as intellectual property.

1 2 3 4 5

R17 Transferable skills

Evaluating the skill-set of the workforce prior to cloud adoption, to identify transferable skills in the new environment.

1 2 3 4 5

R18 User consumption-based billing and metering

The systems ability to bill end-users according to their usage.

1 2 3 4 5

R19 User-centric privacy

Safely storing end-users sensitive data.

1 2 3 4 5

R20 Service level agreements

A mutual contract between cloud provider and user stating the agreed upon service expectation.

1 2 3 4 5

R21 Adaptability and learning

The cloud providers ability to adapt to the enterprises needs, as well as provide adequate learning materials.

1 2 3 4 5

R22 User experience

The overall user experience, both regarding enterprise users and end users.

1 2 3 4 5