Design and Evaluation of an Impact Analysis Methodology for the Adoption of Cloud-based Services (IAMCIS)

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***Abstract*—An impact analysis of adopting any new technology for fulfilling IT requirements of an organization is a very crucial task. It enables the identification of effects such a technology change will have on the organization from the technical, economical, and organization perspective. In the context of cloud-based solutions these facets are typically more complicated and the impact analysis of such large IT architectures cannot be completed with much accuracy at a high level. Therefore, each major single component of such an architecture has to be evaluated with respect to relevant factors, which appropriately denote the success or failure of the newly adopted solution. This paper develops and evaluates in this context a new impact analysis methodology, termed Impact Analysis Methodology for Cloud-based Services (IAMClS), which estimates the impact for cloud-based solutions in quantifiable terms. IAMCIS is illustrated in conjunction with a representative use case obtained from a survey conducted with 10 organizations, who plan to adopt or have adopted cloud-based solutions for fulfilling their IT requirements.**

***Index Terms*—Cloud Computing, Cloud Services, Impact Analysis**

I. Introduction

The National Institute of Standards and Technologies (NIST) defines Cloud Computing as ubiquitous, on-demand network access to shared pool of configurable computing resources (*e.g.,* networks, servers, services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [11]. Any organization, which decides to fulfill its IT requirements with a cloud-based solution, requires to have an insight into benefits and risks of Cloud Computing, *i.e.,* the potential impact of such a decision [17]. However, defining the impact an adoption of a cloud-based solution will have on the organization is crucial in order to determine Cloud Computing advantages. This impact is driven by technical, economical, and organizational factors [16]. The impact of Cloud Computing is due to the changes, an adoption of cloud-based services will bring to the organization as a whole. Clouds have distinct advantages in terms of (1) pay-as-you-use instead of install and own, (2) flexibility, or (3) business agility in terms of scalability and maintenance [1], [2], [7]. However, there are disadvantages in terms of security, privacy risk, or vendor-lock in effects [7], [8]. Cloud Computing is associated with vulnerabilities, risk, and uncertainties [1]. Cloud-based services also decrease the uncertainty caused by the initial cash investment (in case of traditional technologies), due to its inherent model of expenditure only in terms of operating costs. All of these factors combined with others, such as cost vs. utilization of resources, reliability, or operational changes in organization, denote to the economical change, technical capability, and organizational changes of the organization once a cloud-based solution is adopted.

The challenge for any potential cloud customer is to predict with as much accuracy as possible the impact, any of these scenarios will have on its organization. If the impact is accurately predicted it will result in minimization of operating cost, identification of uncertainties in terms of relevant technical factors (such as security, privacy, reliability), and counter-measures in terms of any structural changes in organization (such as number of personnel required and their qualifications). This paper acknowledges the need of a general impact analysis methodology and explicitly addresses a formal evaluation approach for assessing the potential impact of cloud-based solutions on an organization.

The new methodology proposed in this paper — termed Impact Analysis Methodology for Cloud-based Services (IAMClS) — is driven by the notion that it is difficult for large IT architectures to estimate the impact at a high level. Since the complexity for cloud-based architectures is too high, it is modularized into components, so that each can be evaluated individually, for enabling the estimation of the overall impact of the solution to be adopted.

The remainder of this paper is organized as follows. Section. II outlines the background and related work, which is followed by the definition of the IAMCIS methodology to calculate the impact of cloud-based solutions on organizations in Section. III. IAMCIS is illustrated in Section. IV, based on those results obtained from a survey. Finally Section. V summarizes the work and draws conclusions.

II. Background and Related Work

An impact analysis has to account for factors at all of those following 3 categories in order to estimate accurately the impact of cloud adoption in an organization:

1) The technical impact of cloud consists out of changes in terms of functionality and capabilities a new cloud-based solution brings to the organization [13].

2) The economical impact consists out of changes in terms of cost structure and value flow within the organization [18].

3) The impact at the organizational level comprises of changes in processes, business policies, infrastructure management, and application deployment and maintenance [18].

In order to compare and list related work addressing a methodology to identify and analyze the impact of a cloud adoption, current and existing research literature can be categorized into 2 categories. Category A consists of frameworks, which (1) analyze various risks, vulnerability, and threats associated with Cloud Computing [1], [4], [3], and (2) calculate the loss associated with any of these scenarios. Risks, threats, and vulnerabilities adversely effect (because of associated uncertainties, loss of value, and breach of security), expectations that organizations have from of cloud-based services. Category B consists out of analysis approaches, which address (1) economic aspects, specially from the return of investment perspective [5], [12], and (2) technical aspects, specifically from the implementation and maintenance point of view [6], [9], [15]. For example, any changes in terms of cost efficiency, return of investment, technical capabilities and functionality, effect the IT capacity of an organization. As shown in Table I the comparison of related work to impact the analysis methodology developed in this paper is based on five key features, "Yes" describing the presence and "No" denoting the lack of that feature.

TABLE I: COMPARISON OF RELATED WORK TO THE NEW METHODOLOGY

Features	Category A: Frameworks	Category B: Analysis Approaches	Impact Analysis Methodology
Risk Analysis	Yes	No	Yes
Economic Consideration	No	Yes	Yes
Technical Consideration	No	Yes	Yes
Component-based Impact Analysis for each Relevant Factor	No	No	Yes
Severity of Impact on Organization	No	No	Yes

Each category of related work, as investigated, has a narrow approach and concentrates on specific topics and, therefore, cannot estimate the potential impact such a decision of adopting cloud-based services has on the organization from all relevant perspectives. Therefore, the new method IAMClS fills the gap to analyze a potential impact and its severity on the organization in order to successfully evaluate any cloud-based solution before its adoption.

III. IMPACT ANALYSIS METHODOLOGY FOR CLOUD-BASED SERVICES (IAMClS)

Cloud Computing can be explained as a package of on-demand computing resources, which fulfill IT requirements of an organization and is delivered as a service over the network [14]. Depending on the specification of these requirements, the complexity of the service delivered (cloud-based solution) can be high. Thus, in order to evaluate the performance of a service delivered, measurable factors must be identified. These factors must be able to define and quantify the impact of such a service on an organization. To identify these factors accurately, the complex architecture of the cloud-based service, is decomposed into smaller and manageable components. Consequently, the impact analysis process is carried out for each of the component, thereby making the overall process accurate and efficient.,

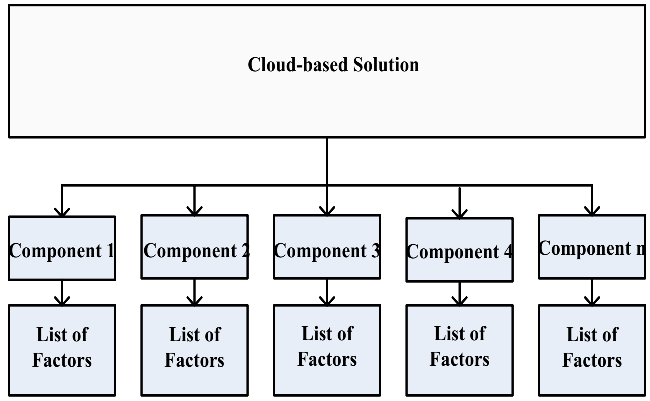

Fig. 1. Impact Analysis Methodology of IAMCIS.

As shown in Fig. 1, IAMClS consists of five steps:

Identification of Components of Cloud-based Service: This step identifies components of the cloud-based service by decomposing the entire service into independent units, e.g., servers, operating system, database. IAMClS supports the quantification of impact by efficiently aggregating the individual impact of the decomposed components back to the overall impact distribution (shown in Step 4). For example, when a certain infrastructure requirement is fulfilled by a cloud-based solution, it can have components in terms of virtual machines, servers, and storage space.

4) **Identification of Relevant Factors**: Based on requirements and objectives of the organization, for each of these components, factors are identified, which can measure the performance of these components. In order to completely and accurately identify these factors, the components must be analyzed in terms of economical, technical, and organization requirements. For example, from the technical perspective servers can be evaluated in terms of availability, throughput, reliability, flexibility, power, and security.

5) **Evaluating Expected Value for Identified Factors:** Once relevant factors are identified, for each of those factors, expected performance levels have to be determined. For example, servers can have an expected value for the availability equivalent to 99.5%, reliability of storage space can be evaluated in terms of memory having the capability of error detection and correction, and the presence of redundant disk and power supply may be needed.

6) **Calculating Impact:** Finally, each of these expectations is associated with a probability of failure and its consequent loss. These values are based on the experience of the decision maker and the market analysis of the service provider. The final impact for *m* components, each having *n* factors to be evaluated is denoted by Eqn. 1 , where l_{ij} and p_{ij} define the loss and probability of factor *j* of component *i* not being fulfilled:

$$I = \sum_{i=1}^{n} \sum_{j=1}^{m} l_{ij} \cdot p_{ij} \qquad \text{(Eqn. 1)}$$

The range of probability is as follows: $0 \le p_{ij} \le 1$. Loss denoted by, l_{ij} , can have value of high, medium, low level of loses. Both of these values are associated with failure of each component with respect to an individual factor. These three level of losses can be replaced with any three positive integers in the equation while calculating the quantitative impact, where high loss is replaced by the highest integer and low level takes the lowest integer. For example, high, medium, and low level of loss can be denoted by integers 3, 2, 1, respectively. The higher the value of *I*, the more adverse is the effect of this solution on the organization. Based on the experience of decision makers of organizations and their use of this methodology over the time, the decision makers can attach relative meaning to this value of *I* based on services adopted in the past.

TABLE II: COMPONENTS AND LIST OF FACTORS FOR CLOUD-BASED SOLUTION

Component	List of Factors
Server	Availability Reliability Security
Storage Space	Interoperability Consistency Access Control Resumable Uploads
Virtual Machine	Response Time Workload vs. Utilization Ratio

IAMClS assumes that the decision maker provides values of probability of failure and associated loss. To utilize the methodology to its complete potential these values must be carefully identified.

IV. ILLUSTRATION OF IAMCLS BASED ON SURVEY RESULTS

The methodology developed above was applied to the use-case obtained from organizations during a survey conducted. These surveys were semi-structured interviews so that it could be adapted according to individual circumstances, such as focusing on specific areas or discarding questions, which did not apply. Organization that participated in the survey varied in size, the scope of their expertise, and their geographical scope. Therefore, there IT requirements also varied in terms of expectations of they had from cloud-based service, and the factors with which impact of cloud-based service was measured. However, each of the organization had no concrete methodology in place to identify the impact that adoption of cloud-based services will have on an organization.

All organizations, who were part of the survey, currently evaluate the impact based only on the economical returns of this investment. For example, by using factors like return-of-investment (RoI), total cost of ownership, cost vs. utilization of resources. The survey was conducted with 10 organizations who plan to adopt or have adopted cloud-based solution. Here only a single use-case is illustrated due to the fact that in principle the data obtained are similar (only different in terms of service to be adopted and factors used to measure the impact of cloud-based service), and explanation of this use-case suffices the requirement posed by illustration of IAMCIS. Organizations were asked to evaluate a current scenario of IT requirement of the organization, for which cloud-based services are considered as a potential solution. In order to aid the decision of adopting this solution and to evaluate the impact of such a decision, IAMClS was used. The use-case illustrated here is that of an organization that provides networking solutions and planned to adopt cloud-based services in order to fulfill its infrastructure requirements.

Following step-wise results were obtained when IAMClS was applied for this use-case:

1) **Identification of Components of Cloud-based Service**: Components that were identified included server, storage space for file storage, and virtual machines.

2) **Identification of Relevant Factors**: As shown in Table II for each of these components a list of factors was determined, which were used to evaluate and measure the performance of this component with respect to the identified objective of the component by the organization.

3) **Evaluating Expected Value for the Identified Factors:** As shown in Table III for each of the factor an expected value was identified, which cumulatively marks the expected performance of that component.

4) **Calculating Impact:** The methodology requires to identify probability that the expected value will not be fulfilled along with its consequent associated loss. These values were obtained during the survey discussion with the organization and are shown in Table IV.

TABLE III: FACTORS AND THEIR EXPECTED VALUE

List of Factors	Expected Value
Availability	99.5%
Reliability	Error correction and detection
Security	Encryption
Interoperability	Support to existing standards
Consistency	Read after write consistency for all delete and write operations
Access Control	Internal staff should have access to data as per need
Resumable Uploads	For large files, if network error occurs, upload should start where it stopped. Bandwidth should be saved.
Response Time	6-8 ms (even at peak times)
Workload vs. Utilization Ratio	Indicator of cost effectiveness. Should range between 95-97%

Loss is calculated by estimating cost of failure, *i.e.*, when an expected value of a factor is not achieved. Cost then is mapped to three levels of loss. Probability of failure is identified by the decision maker based on the evaluation of the performance of a cloud-service for a factor in the past. **.**

TABLE IV: PROBABILITY OF FAILURE FOR FACTORS AND ITS ASSOCIATED LOSS

Component	Factor	Probability of Failure	Associated Loss
Server	Availability	0.2	High
Server	Reliability	0.4	Medium
Server	Security	0.5	High
Storage Space	Interoperability	0.6	Medium
Storage Space	Consistency	0.2	Low
Storage Space	Access Control	0.2	High
Storage Space	Resumable Upload	0.2	Low
Virtual Machine	Response Time	0.1	High

TABLE IV: PROBABILITY OF FAILURE FOR FACTORS AND ITS ASSOCIATED LOSS

Component	Factor	Probability of Failure	Associated Loss
Virtual Machine	Cost vs. Utilization Ratio	0.2	High

Applying Eqn. 1 for estimating the potential impact of adopting this cloud-based solution leads to the value of *I* equaling 6.7, which was obtained as follows:

$$I = (0.2 \cdot 3) + (0.4 \cdot 2) \cdot (0.5 \cdot 3) + (0.6 \cdot 2) + (0.2 \cdot 1) + (0.2 \cdot 3) + (0.2 \cdot 1) + (0.1 \cdot 3) + (0.2 \cdot 3)$$

Higher the value of *I*, more adverse is the impact of cloud-based service on the organization. After applying IAMCIS on the survey based data, it can be seen that impact can be quantified using this methodology. Also, if the methodology is used several times in an organization, value of I for various scenarios of adopting different cloud-based service, can lead to relative comparison of values of *I* for all the scenarios. The adversity of impact can be calculated by first calculating the worst value of *I*. This is done by substituting for each factor maximum value of probability and high level of losses. The degree of adversity is denoted by calculating ratio of actual value *I* to the worst value of *I*.

V. SUMMARY AND CONCLUSIONS

This paper has determined and discussed the existing gap of analyzing and quantifying the impact of cloud-based solutions adopted formally in order to fulfill IT requirements of an organization. To fill this gap the methodology IAMClS was developed. IAMClS estimates the potential impact by analyzing each of the component of the cloud-based service on the basis of factors, which denote the measurement of successful performance of the respective component. The impact is calculated as the cumulative product of probability of failure for each of the factor in terms of expected level of performance and its consequent loss. The higher the value of this calculated impact, the more adverse is the impact of the solution adopted.

IAMClS was also illustrated by applying it to an use-case obtained from the survey with one of the potential cloud customer. It can be concluded that the current ad-hoc process of calculating the impact of cloud adoption in organizations can be replaced with the quantitative methodology of impact analysis as explained in this paper. This is because of it breaks down the complexity of such an analysis and provides quantitative result. The impact is calculated based on factors from technical, economical as well as organizational perspective. The result of applying IAMClS is the indication of how severe the impact of decision of adopting a particular cloud-based service will be on the organization, if any of the expected value is not fulfilled for the relevant factors. This also helps the organization to prepare for possible countermeasures, in order to handle any adverse impact (when an expected value for a factor is not achieved) due to the adoption of new cloud-based solution.

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