# Evaluation of Influencing Factors in an Impact Analysis Methodology for the Adoption of Cloud-based Services

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***Abstract*—Technical advancements in virtualization and Service-oriented Architectures, the technology backbone of Cloud Computing (CC), along with the availability of high speed Internet has escalated the performance of CC in terms of elasticity, throughput, agility, or response time. However, according to the Gartner's Hype cycle of 2014, CC is at the "Trough of Disillusionment", which hints at "waning of interest as the implementations fail to deliver" [7]. The reason for this situation is the lack of a methodological impact analysis for adopting cloud-based services in an organization. In the context of CC an impact analysis is complicated due to the complex architecture of services and presence of influencing factors from multiple dimensions (technical, economical, and organizational). This paper, therefore, extends and evaluates the methodology "Impact Analysis Methodology for Cloud-based Services (IAMCIS)" that quantifies the impact of cloud-based services before they are adopted in an organization [6]. The methodology is illustrated in combination with a use-case obtained from a survey conducted with 17 organizations (with varied domain of expertise, size, and geographical scope), who plan to adopt or have adopted cloud-based services for fulfilling their IT requirements.**

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

## I. Introduction

Cloud Computing can be defined as a delivery model of IT services over the Internet with dynamically scalable resources [11]. Organizations aiming at the adoption of cloud-based services for fulfilling their IT requirements do it mainly due the benefits, such as cost reduction, business agility, or elasticity. However, there are also disadvantages of moving to the cloud, like that of security, privacy, vendor-lock in, or lack of standards. In order to make a decision for adopting a cloud-based service, an impact analysis is required. The impact analysis establishes the relationship of "cause and effect" of any change the new technology will bring in an organization. This analysis is driven by numerous interdependent technical (*e.g.,* reliability or availability), economical (*e.g.,* marginal cost or total cost of ownership), and organizational factors (*e.g.,* control of data or size of organization). These factors will have different priorities for an organization, depending on its IT requirements, not only because of the presence of various types of IT components but also because these factors are based on virtualized resources. Thus, making the cloud architecture complex to be evaluated. Therefore, the challenge for any organization, which plans to adopt cloud-based services for fulfilling their IT requirements, is to accurately predict the impact cloud services will have on that organization.

The methodology of "Impact Analysis Methodology for Cloud-based Services" (IAMClS) has two major aspects. First, the complexity for cloud-based architectures is too high, therefore, it needs to be modularized into components, so that each can be evaluated individually, for enabling estimation of the overall impact of the solution to be adopted. Second, factors measuring performance of component are interrelated and can have different priorities. If the impact is accurately quantified and predicted it will support the specification of potential areas of risk and the direction of required changes. Also, impact analysis helps in the decision of identifying what part of current infrastructure should be moved to the cloud. In addition, a countermeasure schema, specifying how to manage or mitigate potential risk or vulnerability, can be prepared in advance.

While the new methodology IAMClS of this work was published in [6], the new extensions in this paper here cover the impact analysis method's addition of (a) priority and (b) explicit inter-relation of relevant factors. Therefore, 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

According to the NIST reference architecture of CC [11], various actors (cloud provider, cloud broker, cloud consumer, cloud auditor, and cloud auditor) are involved in deploying and maintaining cloud-based services. All these actors are bound by Service Level Agreements (SLA) to deliver the expected and promised performance. Inferring from the performance expected of cloud-based service, it can impact the organization, who migrates to cloud-based services, with respect to technical, economical, and organizational factors. These factors are mutually interdependent. For example, the expected quality level of a service influences the cost of such a service, which in turn affects the business plan in terms of expenditure per business process.

The related work in this area is divided into three categories (c.f. Table I). Category A consists of frameworks, which analyze and calculate loss of various risks, vulnerability, and threats associated with CC [1], [2], [3]. Category B consists out of analysis approaches, from economical view and technical implementation, and maintenance view [4], [12], [5], [9], [14]. While these categories were already identified in the

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previous work [6], additions here include the determination of related work with respect to the identification of relevant factors, their interrelations, and priorities. There was no related work identified, which enlists how to account for relevant factors and their interrelations. However, few surveys and research efforts exist, which assist in identifying the relevant factors, from either technical or economical perspective [4], [8], [10], [13], thus forming Category C. However, a holistic approach has never been studied before, that explicitly specifies a combined understanding from the technical, economical, and organizational perspective at the same time. As shown in Table I, the comparison of related work to an impact 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 | Category B | Category C | IAMCIS |
|---|---|---|---|---|
| Risk Analysis | Yes | No | No | Yes |
| Economic Consideration | No | Yes | Yes | Yes |
| Technical Consideration | No | Yes | Yes | Yes |
| Component-based Impact Analysis for each Relevant Factor | No | No | No | Yes |
| Inter-relation of Relevant Factors | No | No | Partially | Yes |
| Priorities of Relevant Factors | No | No | No | Yes |
| Severity of Impact on Organization | No | No | No | Yes |

None of the above mentioned related work studies and quantifies the impact that adoption of any cloud-based service will have on an organization. Also, those approaches do not account for on how influencing factors from multiple domains can be included in such an analysis. Therefore, this paper here fills that gap by extending the IAMCIS methodology to include such factors and their interrelations into the analysis.

## III. INCLUDING INFLUENCING FACTORS IN IAMCIS

IAMCIS was driven by modularizing the complex architecture of cloud-based services into components [6]. Based on requirements and business objectives of the organization, factors were identified to evaluate the performance of each component. In turn, the impact was calculated, based on the probability of failure and its consequent loss, if the expected level of performance is not achieved for each factor.

The final impact ($I$) 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 $i$ of component $j$ 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 a value of high, medium, low level of losses. These three levels 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 a low level takes the lowest integer [6].

To accurately predict impact, IAMCIS must be extended to include the following information:

1) **Priorities of Factors per Component**: As per requirements and business goals of the organization, factors per component can have different priorities or relevance. For example, for business critical applications, availability is more important than its associated cost.

2) **Inter-relations of Factors per Component**: Factors from technical, economical, and organizational are interdependent. For example, cost of a virtual machine is dependent on the CPU unit, storage, bandwidth, and RAM. Based on the expected level of values for each of these factor, organizations will decide the cost they are willing to bear. The interrelations of these factors are translated as conditional values of $l_{ij}$ and $p_{ij}$. Therefore, Eqn. 1 is extended as follows to include the priorities of factors:

$$I = \sum_{i=1}^{n} \sum_{j=1}^{m} w_{ij} \cdot l_{ij} \cdot p_{ij} \qquad \text{(Eqn. 2)}$$

where, $w_{ij}$ determines the priority of the factor $i$ of component $j$. $I_{sev}$ indicates the relative impact to the worst case value and is calculated as follows:

$$I_{sev} = \left( I \div \left( \sum_{i=1}^{n} \sum_{j=1}^{m} w_{ij} \cdot (l_{ij})_{max} \cdot (p_{ij})_{max} \right) \right) \qquad \text{(Eqn. 3)}$$

## IV. APPLICATION OF IAMCIS TO SURVEY RESULTS

In order to validate the applicability of this extended methodology developed above, surveys were conducted with organizations who have either adopted cloud-based solutions in the past or are potential customers. These organizations were selected based on their domain of expertise, size of organization, and the geographical area served. This was done to avoid any bias in the data collected and the conclusions drawn. This paper illustrates the application of the extended IAMCIS on one of the use-cases from the total of 17 surveys conducted. In summary, the general key findings obtained from these surveys read as follows:

1) All organizations surveyed currently do not have any quantitative impact analysis methodology in place.

2) Organizations fail to evaluate the influence of factors from technical, economical, and organizational domain. Majority of the surveyed organizations evaluate the impact based on the economical returns of investment only.

3) Also, due to the lack of an impact analysis methodology, organizations failed to evaluate consequences of failure of cloud services and, therefore, can not prepare for a countermeasure schema.

In surveys, 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. The use-case illustrated here is that of an organization, which provides telecommunication solutions and plans to adopt cloud-based services in order to fulfill its infrastructure requirements. The following four results were obtained when IAMClS was applied for this use-case:

1) **Identification of Components and Relevant Factors of Cloud-based Service**: Components that were identified included storage space and virtual machines. As shown in Fig. 1, for each of these components a list of factors was deter-

mined by the organization, which was used to evaluate and measure the performance of these components.

2) **Interrelations and Priorities between Factors:** As shown in Fig. 1 factors of a component can have interrelations. Also, relative priorities between factors per component are shown in Table III. Based on those requirements of the organization following interrelations were identified:

**Storage Space**: Throughput is the number of transmitted data per time unit. This depends on the network performance. Also response time depends on the network performance. If the response time is too high, it will be more costly to the organization. In addition, the location where data is stored, and the level of security provided by the cloud-service provider are important factors to ensure legal and regulative compliance.

**Virtual Machines**: Number of VMs needed depends on the workload and guaranteed level of availability of cloud-based service. This in turn influences the cost of the organization. Also, the time taken to migrate data and applications to cloud-based infrastructure (leading to down-time of the application) influences the cost, that the organization has to bear.

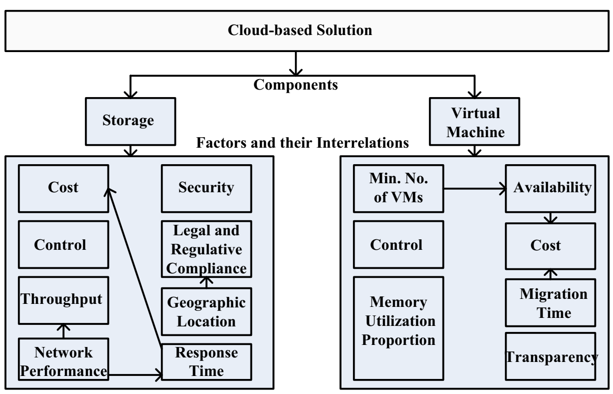


Fig. 1. Impact Analysis Methodology of IAMCIS.

3) **Evaluating Expected Value for the Identified Factors:** As shown in Table II for each of those factors an expected value was identified. These values cumulatively mark the expected performance level of components.

4) **Calculating Impact:** In the next step, values of probability of failure per factor and its consequent associated loss are identified. These values were obtained during the survey in a personal discussions with the organization and are shown in Table III. Loss is calculated by estimating the cost of failure, *i.e.*, when an expected value of a factor is not achieved. Cost is mapped to three levels of loss (High, Medium, or Low). 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 [6]. For interdependent factors the values of probability of failure and its associated loss are calculated cumulatively as shown in Table III.

TABLE II: FACTORS AND THEIR EXPECTED VALUE

| List of Factors | Expected Value |
|---|---|
| Throughput | Sustained Read throughput for vol. size of 1 GB is 0.15 MB/s<br>Sustained Write throughput for vol. size of 1 GB is 0.30 MB/s |
| Security | Encryption, authentication |
| Network Performance | Same region approximately 800 Mbit/s. 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) |
| Control for Storage | Internal staff should have access to data as per the need |
| Legal and Regulative Compliance | Data residency: storing data in the same geographical region as that of organization. Certificates like ISO 27001, SSAE-16, SOC 1 needed |
| Geographic Location | Data is to be stored within the same region |
| Cost for Storage | 0.02 GB/month |
| Minimum # of VMs | 2 instances in the same availability set |
| Availability | 99.5% |
| Migration Time | For around 1000 concurrent users down-time should not be greater than 4 seconds for one migration. |
| Cost for VMs | Approx 550 US$ per month, with 8 cores, 15 GB RAM, disk size 600 GB |
| Transparency | Load balancing to handle additional load, to be integrated via a management API |
| Control for VMs | Internal staff should have access to data as needed |
| Memory Utilization Proportion (mem) | 40% < mem < 80% |

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

| Component | Factor, Priority | Probability of Failure | Associated Loss |
|---|---|---|---|
| Storage Space | Throughput and Network Performance, 3 | 0.2 | Medium |
| Storage Space | Security with Compliance, 5 | 0.4 | Medium |
| Storage Space | Network Performance and Response Time, 4 | 0.3 | High |
| Storage Space | Additional Cost due to Response Time, 2 | 0.2 | Low |
| Storage Space | Legal and Regulative Compliance and Geographic Location, 4 | 0.5 | High |
| Storage Space | Storage Cost, 4 | 0.2 | High |
| Virtual Machine | Minimum Number of VMs and Availability, 7 | 0.2 | High |
| Virtual Machine | Cost for VMs, 4 | 0.2 | Medium |
| Virtual Machine | Migration TIme, 6 | 0.3 | High |
| Virtual Machine | Additional Cost due to Migration Time, 3 | 0.5 | Low |

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

| Component | Factor, Priority | Probability of Failure | Associated Loss |
|---|---|---|---|
| Virtual Machine | Transparency, 4 | 0.5 | Medium |
| Virtual Machine | Control for VM, 5 | 0.4 | High |
| Virtual Machine | Memory Utilization Proportion, 5 | 0.4 | High |

Based on the value of priority, probability of failure, and its associated loss, for each factor, the impact of cloud-based service on an organization is quantified. Applying Eqn. 2 for estimating the potential impact of adopting this cloud-based solution leads to the value of $I$ equaling 40.9, which is obtained as follows:

$$I = (3 \cdot 0{,}2 \cdot 2) + (5 \cdot 0{,}4 \cdot 2) \cdot (4 \cdot 0{,}3 \cdot 3) + (2 \cdot 0{,}2 \cdot 1) + (4 \cdot 0{,}5 \cdot 3) + (4 \cdot 0{,}2 \cdot 3) + (7 \cdot 0{,}2 \cdot 3) + (4 \cdot 0{,}2 \cdot 2) + (6 \cdot 0{,}3 \cdot 3) + (3 \cdot 0{,}5 \cdot 1) + (4 \cdot 0{,}5 \cdot 1) + (5 \cdot 0{,}5 \cdot 2) + (5 \cdot 0{,}4 \cdot 3)$$

The higher the value of $I$, the more adverse is the impact of a cloud-based service on the organization. Here, the value of $I_{sev}$ is approximately at 25%, as calculated with Eqn. 3. Therefore, the considered cloud-based service does not have severe negative impact, even if all of these factor, are not fulfilled (worst case scenario). Hence, based on this illustration it can be seen that the impact of a cloud-based service and its severity can be quantified using the extended IAMCIS methodology. This approach takes into account factors that are from multiple domains that can have qualitative or quantitative expected level of performance.

## V. Summary and Conclusions

The successful adoption of CC depends on the selection of an alternative that suits the requirements of the organization in the best way. Therefore, it is crucial to analyze the impact of cloud-based service on an organization, which is influenced by technical, economical, and organizational factors. Impact, is calculated as a cumulative product of priority of factors, probability of not achieving expected performance level per factor and its consequent loss. Also, conditional values for interdependent factors are considered to include interrelations of these factors. At last IAMCIS methodology was illustrated with a selected representative, use-case obtained from the survey conducted with 17 organizations who are potential customers of cloud-based services. The other use-cases vary in terms of number of components, number of factors and their inter-relations. However, the applicability and relevance of IAMCIS is equivalent. Hence, proving that IAMCIS can be applied to alternative cloud-based service, irrespective of cloud deployment or service models.

It can be concluded, that adopting any cloud-based service is not just about technology, but also about business transformation in terms of new processes, services, and organization structure and model. This is achieved in IAMCIS, by bringing various influencing aspects of such a transformation under one umbrella, in quantified terms. IAMCIS, helps organization: (1) To focus on value of adopting cloud-based services, which depends not only on technical benefits such as agility or scalability but also on numerous economical and organizational benefits and challenges. 2) To decide whether or not to adopt a cloud-based solution, based on the severity of impact. As numerous deployment models and service providers (offering several alternatives) exist, an organization must evaluate the impact of all alternatives in order to select the best suited solution. 3) To prepare for any counter-measures schema, specifically with respect to those factors that have high probability of failure and high associated loss.

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