Assessing Cloud Computing SaaS adoption for Enterprise Applications using a Petri net MCDM framework

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Abstract
Cloud computing has become a very popular technology for IT infrastructure (infrastructure as a service - IaaS), with big players offering attractive pricing schemes. Software vendors are interested in offering products in the cloud as services. However, in order to evaluate software as an offer of service (SaaS) for a given enterprise application, we need to assess some qualitative factors other than just price-security and trust being the most relevant factors. In this work, we propose a Petri net multi-criteria decision making (MCDM) framework to evaluate SaaS as opposed to an on-premises alternative. The proposed framework can help IT managers in deciding between the two options, as well as being able to help software vendors in their efforts to establish SaaS pricing.

Keywords—*Cloud computing, SaaS, BDIM, AHP, Decision-making, Petri nets.*

I. INTRODUCTION

Cloud computing is a new paradigm defined by the *National Institute of Standard and Technology* (NIST) as a "model for enabling on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction"[1]. Cloud services may be classified as IaaS (Infrastructure as a Service), PaaS (Platform as a Service) or SaaS (Software as a Service).

In SaaS, the software is delivered as a service to the client who has no control over the underlying cloud infrastructure, including network, servers, operating systems, storage, or even individual application capabilities. On the other hand, the vendor provides the software on a pay-per-use basis, with no requirement for upfront investments, turning capital expenses into operational expenses that may be attractive for many types of business. Moreover, the overall cost of the cloud solution is often lower than a similar on-premises deployment.

SaaS is a term that encompasses a very broad type of application. It can be applied to general use software, such as Google Apps, but also for specific enterprise applications, such as *Sales Force* CRM. With the growing success of these applications, many software vendors are planning on offering their packages following a SaaS model. However, "licensing web apps is a fiercely competitive market with rampant risks. Software, as a service, must overcome several challenges in order to prove itself as a successful business model" [3].

One of the many difficult decisions for IT manager´s today is: to adopt a software package in the cloud SaaS model or to have the software installed in the conventional, on-premises model? The manager has to account for a great number of different criteria with cost being possibly the most important one. SaaS option is appealing for the low initial investment; however, the IT department will no longer have any control over the infrastructure, and will completely rely upon the fulfillment of the SLA contract clauses to provide the service. This paper aims to shed some light upon the business problem of identifying factors and parameters to evaluate advantages and disadvantages of opting for SaaS instead of on-premises solutions for enterprise business applications. The objective here is two-fold: i) to help customers to decide whether or not to use SaaS; and, ii) assist vendors in identifying whether or not their SaaS offer will in fact be attractive to potential customers.

Here we propose a novel framework that combines several of the most relevant factors (according to the current literature) to assist in the evaluation of both SaaS and on-premises options. The framework has been designed around *Petri nets* in order to benefit from its formal description and to provide a simple visual interface, yet powerful enough to perform simulations with different purposes for model validation. The main contribution of this work resides in the framework proposal.

II. LITERATURE REVIEW AND RELATEDWORK

This work relates to *SaaS Decision Support* using *Petri Nets* and *Analytic Hierarchy Process* in a *Business-Driven IT Management* (BDIM) setting.

Petri net theory was developed from the early work of Carl Adam Petri, and has evolved into a useful tool for modeling systems. Analysis of the Petri net can, hopefully, reveal important information concerning the structure and dynamic behavior of the modeled system [24].

Formally, a Petri net structure, C, is a four-tuple, C = (P, T, I,O). $P = \{p_1, p_2, . . . ,p_n\}$ is a finite set of places, n >= 0. $T = \{t_1, t_2, ..., t_m\}$ is a finite set of transitions, m >= 0. The set of places and the set of transitions are disjoint, $P \cap T = \emptyset$. $I : T \rightarrow P^{\infty}$ is the input function, a mapping from transitions to bags of places. $O : T \rightarrow P^{\infty}$ is the output function, a mapping from transitions to bags of places. A graphical representation of a Petri net structure is very useful for illustrating the concepts of the Petri net theory. A Petri net graph G is a bi-

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partite directed multi-graph, G = (V,A), where $V = \{v_1, v_2, . . . , v_s\}$ is a set of vertices and $A = \{a_1, a_2, . . . , a_r\}$ is a bag of directed arcs, $a_i = (v_j, v_k)$, with $v_j, v_k \in V$. The set V can be partitioned into two disjoint sets, P and T, such that $V = P \cup T$, $P \cap T = \emptyset$, and for each directed arc, $a_i \in A$, if $a_i = (v_j, v_k)$, then either $v_j \in P$ and $v_k \in T$ or $v_j \in T$ and $v_k \in P$. A marking μ of a Petri net C = (P, T, I,O) is a function $\mu : P \rightarrow N$ from the set of places P to the non-negative integers N. [24].

CPN Tools [2] is a tool for editing, simulating, and analyzing colored Petri nets. A colored Petri net is a Petri net where more complex types (e.g. text and colors) can be used for marking instead of just non-negative integers. CPN tools offer statistical functions that can be used to design stochastic Petri nets.

The AHP (Analytic Hierarchy Process) is a multi-criteria decision making process developed by Thomas I. Saaty [9]. It decomposes the decision problem in a hierarchy of criteria and alternatives, and uses pair-wise comparisons to express the relative importance of one criterion over another. Using these comparisons, it is possible to build pairwise matrices and compute the eigenvector to compute the criteria ranking. AHP can combine qualitative and quantitative criteria [23].

The literature on SaaS evaluation and adoption is growing as the SaaS model is becoming more popular. We conducted a systematic literature review, searching for the terms 'SaaS' and 'evaluation or evaluating or evaluate' in IEEE explore, ACM digital library and Science Direct (Elsevier), published after 2011. From the initial 228 items found, we selected 32 papers that seemed more relevant to our study. Many articles relate to the SaaS evaluation from the strict technical performance point of view, however, our work follows the BDIM research line [8]. There are few studies in this line of research for evaluation of cloud solutions. The framework presented in [6] is useful for comparing costs of Infrastructure as a Service (IaaS) versus on-premises datacenters, and it presents examples where IaaS is not so competitive. The *Primitive Cognitive Network Process Approach* [10] presents a modified version of AHP and is useful for selecting an offer of service (SaaS) from a list of providers of equivalent software. The survey in [4] reveals that cost advantages are the strongest and most consistent opportunity factor significantly affecting perceived opportunities in SaaS adoption, whereas security risks are the dominant risk factors, followed by performance and economic risks. The study in [11] presents the results of a survey conducted in Korea, in order to evaluate the adoption of SaaS and its related benefits to business, via four measures - learning and growth, internal business processes, and customer performance, following BSC [12]. The results show that these four key elements for SaaS success are interrelated, thus confirming the core premise of BSC [11]. The work in [13] proposes a process based upon *Goal Oriented Requirements Engineering* (GORE) to provide a systematic approach to evaluate a cloud provider. In [14], the authors identified the strengths, weaknesses, opportunities and threats for the cloud computing industry, as well as the various issues that affect the different stakeholders of cloud computing.

The study in [7] attempts to develop an explorative model that examines important factors affecting SaaS adoption, integrating *Technology Acceptance Model* (TAM) [5] related theories with additional imperative constructs such as marketing effort, security and trust. Security is the major risk affecting SaaS adoption for most of the authors [4, 5, 7, 16, 19], whereas cost reduction is the major expected benefit [4, 5, 18, 19].

Other interesting studies of cloud evaluation and adoption are related to pricing schemes [17], facets of security in the Cloud [20], selection of cloud providers based upon security, and privacy requirements [21]. The cost analysis of on-premises versus SaaS solutions is extensively studied in [22]. In this study, unlike in our framework, the authors do not include qualitative benefits and risks to obtain a final score. The work in [23] used AHP to combine QoS attributes in order to address the problem of selecting a cloud provider, which differs from our problem of comparing on-premises to SaaS solutions. To the best of our knowledge, there has been no study that provides a final ranking of SaaS versus on-premises solutions considering both cost and qualitative attributes, including security, which is a major concern.

III. The Proposed Framework

Studies in the literature tend to evaluate SaaS costs compared to that of a traditional on-premises model [6, 22] or to consider major qualitative factors that can affect a SaaS adoption decision [4, 5, 7, 16]. Our proposal intends to create a novel framework that combines cost and qualitative issues to produce a final score. The usage of the framework is carried out in three steps:

1. Estimate the cost advantage (or disadvantage) of a SaaS solution compared to on-premises alternatives;
2. Evaluate the benefits and risks in a qualitative way using AHP.
3. Compute the benefits/cost ratio. The option with the highest ratio should be preferred.

Step 2 of our proposed frameworkis based upon an opportunity-risk framework [4] and it also uses elements extracted from TAM [5]. AHP is used as a MCDM classical technique. We used CPN Tools [2] to design the hierarchical Petri nets to compose our framework.

Step 1: Estimating costs

Cost estimates for SaaS can vary greatly, depending upon the application, the size of the enterprise, and the complexity of the enterprise´s business processes [15]. Following the work in [22], the model addresses the initial costs, which are one-time costs, as well as the expected annual divestment and operational costs. As for our on-premises cost model, please refer to Figure 1.

"*Users*" represent the number of users of the software, which is the basic information for someone to size up the necessary hardware and to acquire the necessary software licenses, as well as being able to estimate annual utilities expenses, such as energy and internet access. The "*estimates*" transition will estimate costs using step functions based upon the number of users, and store values in places as described in Table 1.

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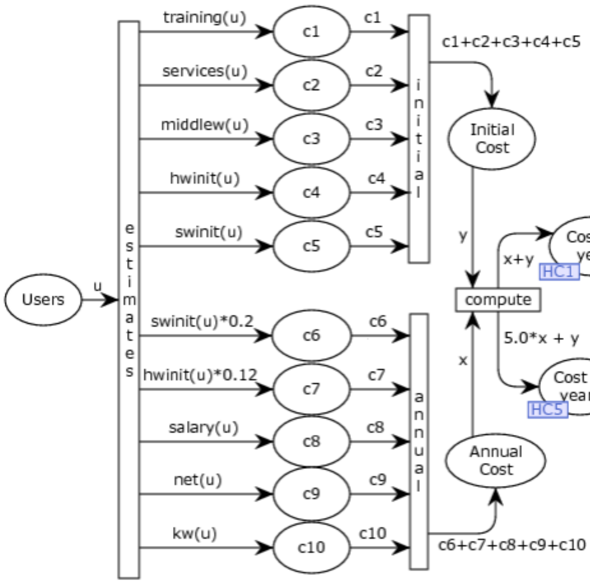

Figure 1. On-premises cost model

Table 1. Step functions used in On-premises cost models

Function	Description	Output
training(u)	Costs for initial training effort necessary for application users and IT personnel	c1
services(u)	Costs for customization and integration	c2
middlew(u)	Licensing cost for middleware required to run the application, such as operating system and database servers	c3
hwinit(u)	Up-front expenses for hardware acquisition	c4
	Percentage of hardware acquisition up-front expenses estimated for annual maintenance	c6
swinit(u)	Software licensing costs for the application	c5
	Percentage of software licensing costs estimated for annual maintenance	c7
salary(u)	Annual costs of salaries of IT personnel required to run the application and its corresponding infrastructure	c8
net(u)	Annual costs of network connectivity required to run the application	c9
kw(u)	Annual costs of energy for the infrastructure required to run the application	c10

The "*initial*" transition will add together all initial costs stored in places c1, c2, c3, c4 and c5, in order to compute the initial on-premises cost, and will store the computed value in the '*Initial cost*' place. Similarly, the "*annual*" transition will add all annual costs stored in places c6, c7, c8, c9 and c10 and store the computed value in the '*Annual cost*' place. Note that costs in places c6 and c7 are a percentage of initial costs for acquiring hardware and software. Finally, the "*compute*" transition will add initial costs stored in the '*Initial cost*' place and annual costs stored in the '*Annual cost*' place for the first year and for 5 years, and will store the values in the '*Cost 1 year*' and '*Cost 5 years*' places, respectively. Note that these are fusion places labeled '*HC1*' and '*HC5*' that will be used in step 3 of the framework.

The SaaS cost model is slightly different, as one can see in Figure 2. A similar '*Users*' place represents the number of users of the software, and "*Estimates*", "*initial*", "*annual*" and "*compute*" transitions to compute costs. However, these use different step functions, because the values may be different. There are no functions for initial hardware, software and middleware acquisition. Instead, there is a "*subscription*" function that computes the annual fee charged for the SaaS cloud service, which provides access to the application software through the internet. The computed value is then stored in place c3. The "*initial'* transition adds the initial costs stored in places c1 and c2 to compute the initial SaaS costs, and stores the computed value in the '*Initial cost*' place. The "*annual*" transition adds all annual costs stored in places c3, c4 and c5 to compute the annual SaaS cost, and stores the computed value in the '*Annual cost*' place. The "*compute*" transition adds initial costs stored in the '*Initial cost*' place and monthly costs stored in the '*Annual cost*' for the first year and for 5 years, and stores the value in the '*Cost 1 year*' and '*Cost 5 year*' place. Note that these are fusion places labeled '*SC1*' and '*SC5*' that are used in step 3 of the framework.

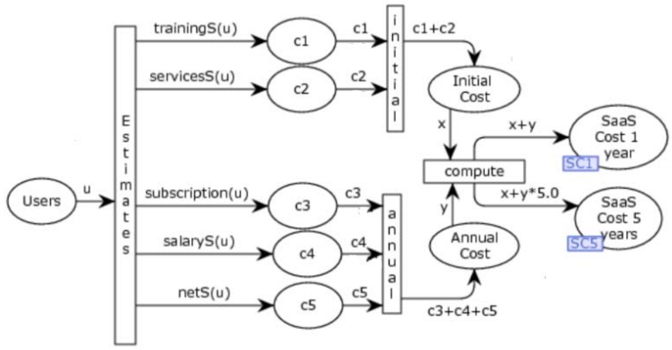

Figure 2. SaaS cost model

Step 2: Evaluating benefits and risks

For evaluation of benefits and risks, the framework uses AHP [9], since qualitative factors are to be analyzed. We have two alternatives to rank: SaaS and on-premises. We refer to previous studies [4, 5 and 7] to select the most important criteria for evaluation:

- **Strategy**: refers to strategic issues such as: 1) flexibility to switch IT provider, 2) scalability, 3) quicker implementation of applications, 4) reduction of vendor lock-in due to lower initial costs and 5) concentrating efforts on enterprise´s specific core competencies
- **Quality**: refers to the efficiency and effectiveness of the processes that the application services support.
- **Performance Risks**: refers to the possibility that the alternative might not deliver the expected level of service.
- **Security Risks:** refers to the possibility of data corruption, data leakage, errors in authentication, among other threats to security. This is by far the most important inhibitor of SaaS adoption [25].
- **Economic risks:** refers to the possibility that a client may have to pay more to reach the expected level of service than initially anticipated — the so called "hidden costs" [4].

We deliberately left cost out of this part, because "discussing costs together with benefits can sometimes bring forth many political and emotional responses" [9]. For simplicity, we also did not include some criteria that were considered non-significant in previous studies, such as: access to specialized resources (human and technological) that are not available

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internally, and managerial risks, which are the possibility that the personal reputation and career of the manager responsible for the application will be harmed if the software is sourced to an external service provider [4]. Figure 3 shows the colored Petri net designed to compute the AHP final ranking.

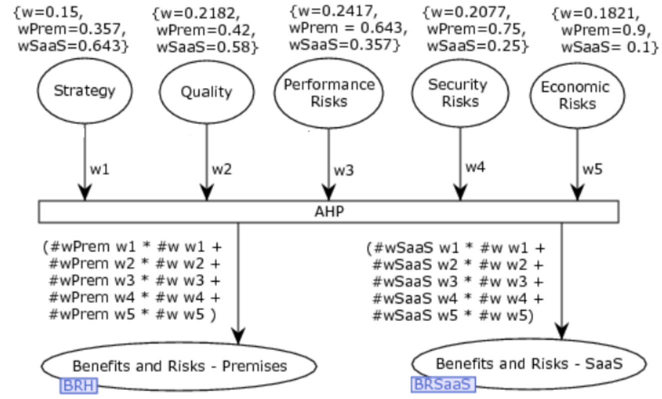

Figure 3. Benefits and risks evaluation model

It is assumed that the pairwise comparison was made previously, whereby this net will compute the final ranking based on the weights for each criterion. We create a composite type (color) for the net named Criteria, a record of three real numbers: Criteria = {*w, wPrem, wSaaS*}, where *w* represents the weight computed (through eigenvector of pairwise comparisons matrix of criteria); *wPrem* represents the weight for this criterion for the on-premises option and *wSaaS* represents the weight for this criterion for the SaaS option. Places represent the selected qualitative criteria. The transition '*AHP*' ranks the alternatives using the previously computed weights (according to AHP), and stores them in places '*Benefits and Risks – Premises*' and '*Benefits and Risks – SaaS*'. Note that these are fusion places labeled '*BRH*' and '*BRSaaS*' that are used in step 3 of the framework.

Step 3: Compute cost/benefit ratio

The last step of the framework normalizes costs computed on step 1 and computes a benefit/cost ratio, which will rank the alternatives. Figure 4 shows the corresponding Petri net.

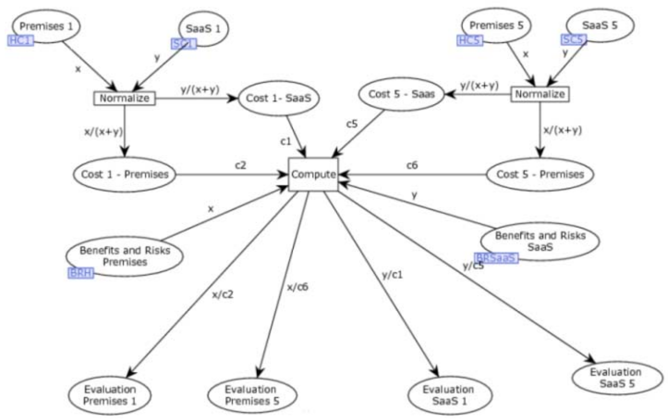

Figure 4. Benefits/cost ratio model

Places '*Premises 1*', '*SaaS 1*', '*Premises 5*', '*SaaS 5*' are the fusion places that represent the costs computed in step 1. They are normalized to produce values between 0 and 1 which are computed by transitions '*Normalize*' and stored in places '*Cost 1 - Premises*', '*Cost 1 - SaaS*', '*Cost 5 - Premises*', '*Cost 5 –SaaS*'. The places '*Benefits and Risks – Premises*' and '*Benefits and Risks – SaaS*' are the fusion places that represent the benefits and risks computed in step 2. The '*compute*' transition computes the benefit/cost ratio and stores the value in places '*Evaluation Premises 1', 'Evaluation Premises 5', 'Evaluation SaaS 1'* and *'Evaluation SaaS 5'*, which hold the scores for on-premises and SaaS evaluations for the first year and after 5 years. These scores are the final result of the framework.

IV. AN ILLUSTRATIVE EXAMPLE

As an illustration of an SaaS decision scenario, consider a private school with 2,000 students that needs to upgrade its academic management software.

The current software was purchased when the school was much smaller. However, with new mobile technologies, it has become obsolete. The current software operates in the school´s IT department, using two servers, one for the web and another for the database. These two servers also need to be replaced, since they are already presenting technical problems. The IT manager, after careful research, decides to buy new software, SCHOOL1, which has two deployment options:

1) On-premises option: Perpetual license, where the school will have to pay an initial licensing fee of $145,000 (value for up to 2,500 students). There is also an optional annual maintenance fee of $29,000 for technical support and software upgrades. An IT infrastructure is needed to install and run the software.

2) SaaS option: Annual subscription of $99,000 (value for up to 2,500 students, which includes technical support and software upgrades), whereby the school will access the software using a web browser over the internet. In addition, the vendor will sign a SLA contract, to ensure a given level of service for availability, performance, and security.

In any of the two above options, the vendor recommends a training package to enable IT personnel or power users to customize the software to meet the school´s requirements, and to make sure users can operate the software in the most adequate and efficient way.

For the on-premises option, suppose the software vendor provides an estimate for costs as in Table 2.

Table 2.On-premises application costs

Users	Licensing	Maintenance	Training	Services
1000	$72,000	$14,400	$19,200	$38,400
2500	$145,000	$29,000	$19,200	$38,400
5000	$247,000	$49,400	$38,400	$72,000
>=10000	$421,000	$84,200	$38,400	$92,000

In the on-premises option, it will be necessary to buy two physical hosts (or a corresponding virtual solution), for database and web servers. Software licenses for a Windows Server and Microsoft SQL Server will be required as well. We estimate annual salary costs for two IT people at $60,000 each. Internet costs will be estimated at $24,000 and energy at $3600 per year. For the SaaS option, training prices will be the same, but service will be 10% lower, because there is no installation effort. Internet costs will be higher at $36,000.

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Salary will be reduced, because only one IT person will be required. Application prices can be estimated as illustrated in Table 3.

Table 3.SaaS application costs

Users	Subscription	Training	Services
1000	$60,000	$19,200	$34,560
2500	$99,000	$19,200	$34,560
5000	$168,000	$38,400	$64,800
>=10000	$288,000	$38,400	$82,800

Using these parameters, one can build the step functions required for the cost models as shown in Table 4.

Table 4. Step functions used in cost models (prices in thousands)

Function	Description
training(u)	If u<5000 then $19.2 else $38.4
services(u)	If u<5000 then $38.4 else if u<10000 then $72 else $92
middlew(u)	$11
hwinitial(u)	If u<5000 then $8 else $15
swinitial(u)	If u<1000 then $72 else if u<2500 then $145 else if u<5000 $247 else $421
salary(u)	If u<5000 then $120 else $180
net(u)	If u<5000 then $24 else $36
kw(u)	If u<5000 then $3.6 else $5
trainingS(u)	If u<5000 then $19.2 else $38.4
servicesS(u)	If u<5000 then $34.56 else if u<10000 then $64.8 else $82.8
subscription(u)	If u<1000 then $60 else if u<2500 then $99 else if u<5000 $168 else $288
salaryS(u)	If u<5000 then $60 else $120
netS(u)	If u<5000 then $36 else $48

Simulation of the Petri nets for on-premises and SaaS cost model (see Figures 1 and 2) will produce results as shown on Table 5.

Table 5. Cost estimation example

OnPremise				SaaS			
c1	19.2	Initial = c1+c2+ c3+c4+ c5 = 221.60	Cost 1 year = initial+ annual = 399.16	**c1**	19.2	Initial = c1+c2 = 53.76	Cost 1 year = initial+ annual = 248.76
c2	38.4			**c2**	34.56		
c3	11						
c4	8						
c5	145						
c6	29	Annual = c6+c7+ c8+c9+ c10 = 177.56	Cost 5 years = initial + 5*annual = 1109.4	**c3**	99	Annual = c3+c4+ c5 = 195	Cost 5 years = initial + 5*annual = 1028.76
c7	0.96						
c8	120			**c4**	60		
c9	24			**c5**	36		
c10	3.6						

Figure 5 shows evolution of costs for both models. We can see that costs are lower for the SaaS option in the beginning (lower than 60% of on-prem, perpetual license), but after 5 years, they become very close (SaaS relative costs become almost 93% of those of the on-prem, perpetual license). Since the cost function is linear, it is expected that SaaS costs will be higher than on-premises in the long term. In the short and medium-terms, however, SaaS should be clearly preferable, if one considers costs only.

The next step will be to perform the pairwise comparisons, in order to obtain weights to be used in step 2 for evaluating benefits and risks. We asked experienced practitioners to assign values for our example, whereby the consistency indexes CI and Ratios CR were checked, giving a value of < 0.1. Table 6 and Table 7 show values obtained in the comparisons. Using these pairwise comparisons, one can compute eigenvectors, and finally, weights as shown in Figure 3. We can then use CPN tools to simulate AHP results.

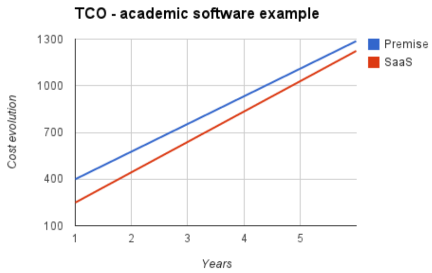

Figure 5. Costs evolution for the example

The on-premises option is evaluated as 0.62 and the SaaS option as 0.38. The on-premises option was expected to have a higher evaluation, as the evaluator ranked on-premises higher in three of the five qualitative criteria.

Table 6. Criteria pairwise comparison

	Strategy	Quality	Performance	Security	Econ
Strategy	1	5/9	5/9	5/6	5/5
Quality	9/5	1	8/9	8/9	6/5
Performance	5/9	8/9	1	6/5	6/5
Security	6/5	9/8	5/6	1	5/6
Economic	5/5	5/6	5/6	6/5	1

Table 7.Alternative pairwise comparison

	On Premise	SaaS
Strategy	5	9
Quality	5	7
Performance	9	5
Security	9	3
Economic	9	1

Table 8. Final ranking

	On Premise	SaaS
1st year	1.00	0.99
5 years	1.19	0.78

Finally, step 3 will evaluate the benefit/cost ratio. Table 8 shows the results. The on-premises option has the best ratio in the first year and also in the 5 years analysis. This is basically due to the poor evaluation given to SaaS in step 2. The SaaS option, even with lower costs, does not convince our decision makers.

The SaaS evaluation is closer to that of the on-premises in the first year because of the on-premises' higher initial costs. However, in the 5 years analysis, the on-premises option is much better. These conclusions are valid only for our example, which is based upon our *Brazilian scenario*, where we have *high internet costs*, *medium salary ranges*, and a *strong perception of security and economic risks*. In fact, the qualitative analysis was the major SaaS evaluation enemy, and the advantage in costs was not powerful enough to reverse this situation. In our example, to be more attractive to customers, SaaS costs would have to be less than 61% of on-premises costs –i.e., it should maintain its year one cost advantage throughout the period of analysis.

V. A WORK IN PROGRESS FACE VALIDITY

Framework initial face validity. Can we believe in the outputs provided by the framework - Is the framework useful? Is there performance improvement in the decision making process? Answering such questions and validating a complex framework, such as we have presented here, is a multi-year effort.

We have work in progress at a Brazilian IT company, whereby we executed a preliminary evaluation and used a fast-lane approach, establishing our theory face validity. In other

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words, does the framework appear reasonable on its face to people who are knowledgeable about the real system? We applied a face validity questionnaire to eleven managers of companies in the industrial, bank (finances) and IT sectors. The questionnaire included five questions, each of which leads to a hypothesis to be tested. Since the population of managers is much larger than eleven, statistical inference was used to test the hypotheses. The complete framework theory was presented to the managers before the evaluation. A binomial statistical test with a 5% significance level was used to produce the results as shown in Table 8.

Table 8. Hypotheses to test theory face validity

Hypothesis	% who agree	Is there statistically significant evidence to accept hypothesis?
Preference: Manager prefers the framework to the current process	100	yes
Utility: Manager considers the framework useful	100	yes
Effectiveness: In modeling a business scenario, manager can identify value elements in decision-making	82	yes
Reliability: Manager considers that the framework improves the decision-making in terms of reliability	91	yes
Trustworthiness: Manager consider that the framework improves the decision-making in terms of trustworthiness	100	yes

Face validity appears to be established in all dimensions analyzed. Managers considered the framework to be "useful" and "preferable" to their current way of decision making. We gathered additional insights through talks with the managers. The face validity test is being expanded and repeated.

VI. Final considerations and future work

This paper outlined a framework to evaluate SaaS adoption relatively to the on-premises equivalent solution, using a BDIM approach.

What have we achieved? We proposed a framework in order to capture quantitative and qualitative factors, and combined them in an organized way, producing a final ranking of both evaluated solutions. The evaluation can also help software vendors in their pricing strategies to make a SaaS offer really attractive to the final customers.

What are the main conclusions? Preliminary studies indicate that security threats, performance uncertainty and economic risks play an important role in the overall ranking of the solutions. Cost advantages need to be high enough to overcome these obstacles, or SaaS probably will not be adopted.

What is ahead in term of future work? Complete face validity of the framework will be the next effort of our research. Evaluating *SaaS* solutions in other scenarios and addressing evaluation of other cloud services like *PaaS* and *IaaS,* using a stochastic PN to run different simulation types will also be of interest.

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