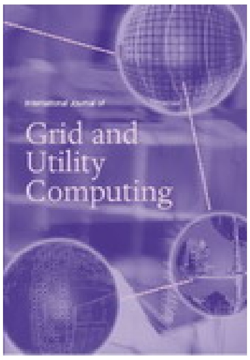

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Towards a cloud model choice evaluation: comparison between cost/features and ontology-based analysis

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Towards a cloud model choice evaluation: comparison between cost/features and ontology-based analysis

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Abstract: In academic institutions, there is frequently the need to provide new services, in a cloud model, to be used either in teaching or in research activities. One of the main decisions to be addressed is related to the cloud model to adopt (private, public or hybrid), and what mixing of functionalities to use for the hybrid one. In this paper two different methodologies (cost/features and semantic-based) are been experimented in order to identify the best suited cloud model to adopt for a specific problem. The long-term perspective is to build a methodology to serve as a tool to be used as decision support for the ICT manager in order to help him in this decision. The comparison between the two different methodologies shows the strengths and weaknesses of both approaches.

Keywords: cloud model; decision support system; SWRL; OWL; cloud evaluation; cloud cost analysis.

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1 Introduction and objectives

The main purpose of this paper is to explore new approaches in evaluation methodology in order to help in the choice of the cloud model (private, public, hybrid) to adopt when there is the need of provisioning ICT services for teaching and research activities in the academia.

In this paper, the problem of Cloud Model evaluation is faced up experimenting two different methodologies, a *traditional* methodology based on Cost/Features analysis, and a more innovative one using Semantic approach. Both approaches have been designed to be used as a decision support tool for an ICT manager of a University where there is the need to provision a new service for research or teaching activities and the question is related to what cloud model to adopt.

Both methodologies start with a survey that is divided into two parts: the first to be answered by the person who needs the service, and the second part to be answered by the ICT manager.

By representing the the results of the survey as value parameters in a graph, some starting analysis can be done in order to give design directions.

This work continues and extends what has already been done in Cantiello et al. (2020), by adding costs' analysis as a further decision support for the manager in order to help him to choose among private, public and hybrid cloud approaches.

In our first methodology, as we can see later, cost analysis comes into play by giving prices of private and public approaches for each one of the series of parameters. These prices identify ranges of costs that, after a proper normalisation phase, can expand or collapse every values under investigation. In our study we are more interested in cost differentials rather than their absolute values. The resulting graph, by taking into account both functional requirements and costs, can give more hints in order to do the final choice.

Later is described the second methodology, which aims to solve the same problem using AI techniques. A Cloud Ontology is used to semantically represent the cloud system, in which are included the costs and the survey, apart from a defined budget assigned by the management in order to implement the system.

In this way, two different solutions may be compared in order to assess strengths and weaknesses of both approaches.

After this introduction, the paper continues in Section 2 with a related works analysis. In Section 3 the first part of the methodology is introduced: the services are classified with some parameters and a representation is shown, and the analysis continues by taking into account costs. A case study on a real academia need is presented in Section 4. In Section 5 is an alternative approach, using a specialised ontology to implement the methodology proposed; in particular an original system of inferential rules OWL based is presented. In the Section 6 are faced off the main issues related to both methodologies. The paper ends with Section 7 with conclusions and future works directions.

2 Related works

From the analysis of recent work on the topic made by the authors, no papers have been found that are related to decision support methodologies on private vs. public cloud system choice.

In Attardi et al. (2018) has been exploited the services offered in a federated way to support service provisioning in the Italian Academia. These can be used as component to realise more complex services provisioned in a hybrid cloud model.

As reported in Vikas et al. (2013), Kumar and Murthy (2013) and Singh and Jangwal (2012) the cost factor is not always in favour of the public solution. The authors of that works have shown that, in a long time terms, the private solution is cheaper than the public one.

Konstantinou et al. (2012) in the analysis operated for their project “StratusLab”, show that, even for a small scale private cloud installation, the economic benefits of the adoption of a private cloud can be experienced in a relatively small period of 2–3 years.

Dantas et al. (2015) have compared the cost related to cloud implementation using both public cloud providers and private cloud based on Eucalyptus platform. This paper shows that the cost of the public cloud becomes higher than the private cloud architectures from a moment between 12 and 24 months. The authors also highlight that the larger is the architecture the sooner is the moment when the private cloud begins to cost less than the public one. This work shows that private cloud solutions are valuable options and must be taken into account in order to implement a cloud-based solution.

The adoption of cloud computing in e-learning systems as a strategy to improve agility and reduce costs has been studied in Pocatilu et al. (2009). The authors have dealt with the problem of the choice between a public or private cloud with a suggestion to use the experience of the manager to do the final choice. In this sense our work can also be thought as a way to expand the research started with this work.

Subramanian and Savarimuthu (2015) studied the benefits of using services from federated clouds with various coupling levels and different optimisation methods.

A comprehensive study on cloud for research computing has been done in Bottum et al. (2017). This report summarises the results from a workshop on topics and challenges for academic research cloud computing in applications, support, data movement, administrative, legal, and financial issues.

Ercan (2010) has reviewed what the cloud computing infrastructure will provide in the universities and what can be done to increase the benefits of common applications for students and teachers.

Several papers dealt with cost analysis in Cloud Computing context.

Nanath and Pillai (2013) proposed a model to analyse the cost-benefits to decide upon adoptability of cloud computing. The model uses a three layer approach purely based on costs. That work goes very deep into technical aspects of cloud solution but does not take into account any requirement constraints. Further on, it focuses only on a single cloud provider to derive costs for technical features.

Nayar and Kumar (2018) presented an approach to identify benefits and limitations of cloud computing in a specific lab setup for education. The approach is interesting as the authors focus on evaluating the ROI factors that are involved in cloud computing for education. They correctly include costs for adoption, for maintaining and terminating the service, but no analysis is done on what leads to the adoption of a cloud solution.

Maresova et al. (2017) conducted and described the evaluation model for cloud computing to be used as a business practice for evaluating the investment’s effectiveness. Their approach is also based on several aspects as the parameters of this work, but they differentiated among costs aspects and organisational aspects and uses a multi-criteria decision making to select and evaluate the effectiveness of the solution that is on adoption. They also explore, for each criteria, the alternatives and assess the impact of each of them, determining the proper evaluation.

In Weinman (2016), the author adds several key factors to the classical technical and performance aspects. In fact he adds qualitative factors as the focus of management attention, core competencies, human motivational and cognitive biases. With these in minds, the author states that it is not so easy to do proper calculation of costs to compare different approaches. He introduces the *Fundamental Equation of Cloud Economics* that shows the costs variability starting from a pure private model toward a pure public, to demonstrate that hybrid cloud approach gives always lower costs.

The *Hedonic Pricing* approach for Cloud Computing services has been proposed in Wu et al. (2018) where the point of view is that of the Service Provider. The authors not only consider how much does the service cost (intrinsic value) to a CSP, but also how much the customer is willing to pay for that service (extrinsic value), in order to determine the selling price of a service. They demonstrate that the extrinsic values are more important and that it can be the key to CSP to gain market and increase profit margin.

A survey on economic and pricing models used to do resource management in cloud computing can be found in Luong et al. (2017). In that paper are also highlighted important challenges, open issues and research directions of applying that models to cloud networking.

Rosati et al. (2017) authored a systematic literature review about financial value of cloud investments. In this work, are identified 53 articles, which were coded in an analytical framework across six themes (measurement type, costs, benefits, adoption type, actor and service model), and some future research directions are presented for each theme.

A significant description about knowledge elicitation is reported in O’Hagan (2019), in which is set out a number of practices through which elicitation can be made as rigorous and scientific to perform statistical inference and decision-making in numerous ways.

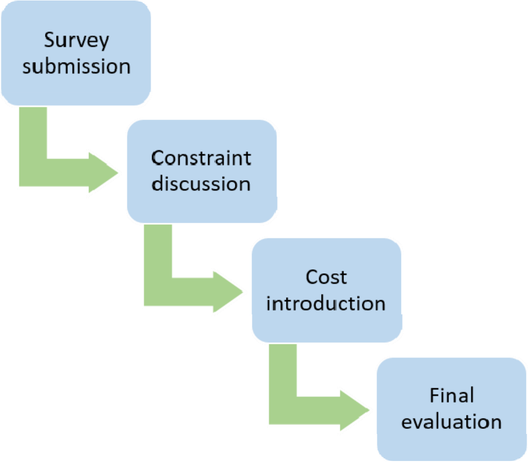
Another significant work about knowledge elicitation is reported in Chrysafi et al. (2019), in which is described a method to elicit expert knowledge to inform stock status and a novel, user-friendly on-line application for expert elicitation.

In Mishra et al. (2018), the application of situational method engineering in requirements elicitation phase is investigated, and a novel, simple and dynamic web-based tool, Situational Requirement Method System (SRMS), is developed which can aid in conception/formulation, repository, and elicitation/derivation of methods related with this stage.

3 Methodology 1: cost vs. features

This methodology is based on a *traditional* Cost and Features evaluation. Using a survey, the requirements and the constraints are acquired by the management and the technician, and a first graph helps to identify the prominent aspects that will shape the choice between public and private cloud implementation. The second round consists in a discussion on constraints, with the aim of locate the constraints that may be released. The third round introduces costs associated with the implementation. At this point, is possible to proceed with cloud model evaluation. A diagram of this procedure is shown in Figure 1.

Figure 1 Structure of the cost/features evaluation



3.1 Services classification

The starting point of the methodology is represented by a brief survey to be answered by the person who needs the service be implemented (e.g. the University manager). This survey is focused not on ICT aspects, but mainly on domain requirements and this permits to obtain a first parameterisation of the requirements.

Now these informations are enriched with other ICT related parameters. They are also given by a brief survey answered by the ICT manager.

Both set of parameters become variables measured in both domains and represented with a scale of values in $0 \ldots N$ range. The choice of this scale is dictated by the need to express qualitative parameters with numbers. In our case, the meaning of the numerical values is this: they grow according to the necessity of having specific features not publicly available. A value of 0 means that the feature could be obtained by a full-public solution, while a value of N denotes the need of that feature only in a private model.

The first group of parameters under analysis for this starting point of the research are those related to the application domain ($P1$ to $P5$) and shown in Table 1.

Table 1 Domain parameters

Par.	*Name*	*Description*
P1	H/W customisation	Does the application require custom devices?
P2	Privacy	Is there the need of specific privacy constraints (e.g. for health or government data)?
P3	Mission critical	Is the service to be considered mission critical for the university (or research centre)?
P4	Inter-operation	Does the service need to interoperate with other on-premise services?
P5	Rights	The service and its related data involve specific copyrights or patents requirements?

The second group of parameters deals with pure ICT aspects of the problem. They are labelled from $P6$ to $P10$ and shown in Table 2. They come from the answers to the survey as given by the ICT specialist.

Table 2 ICT parameters

Par.	*Name*	*Description*
P6	Customised H/W	Is there already customised on-premise hardware?
P7	Security	Are there specific policies to ensure data security (e.g.: redundancy, availability)?
P8	Throughput	Are there specific needs in term of bandwidth or throughput?
P9	Authentication	Are there specific authentication and accounting that must be ensured?
P10	Resources	Has the university enough hardware and human resources?

3.2 Parameters representation

In order to represent and later analyse parameter values, the Kiviat graph has been used. This choice has been derived by the graph's easiness and the immediacy of understanding and also by the types of analysis that are in the objective of the work. This graph also allows to easily identify total or partial overlapping zones, and also regions with small deviations.

In our case, the graph will have as many rays as the number of parameters to represent. Each parameter's value, as extracted by the answers to the survey, is represented with a point on the ray of the corresponding parameter with a $0 \ldots N$ scale. A value of 0 means that there is no need for the corresponding parameter feature to be provided as private.

Values grow with the importance of the parameter till the N value which represent the not substitutability of the requirement and the mandatory private model for it.

3.3 Model analysis

After the representation of the parameters on the diagram, they are connected as usual with segments in order to form the polygon representing the model. Now the process continues by adding regular polygons with growing rays. Each growing ray represents the greater necessity to have the service provisioned in a private model.

Among these regular polygons, some of them must be highlighted:

- The smallest one containing all the problem polygon, called *external polygon* with a ray R_e . This gives the guarantee that all requirements are met.
- The one with an immediately lower radius called *peak polygon* ($R_p = R_e - 1$). This indicates the possibility to operate the service with some relaxed requirements.
- The *internal polygon* that is the biggest one (ray R_i) entirely contained in the problem polygon. This represents the maximum of the minimum requirements.

The analysis of the requirements that fall in the polygonal crown (rays R_e and R_p) permits to extract information on the constraints that could be relaxed if one want to contains all the problem diagram in the R_p polygon. The number of values in the crown is indicated with N_p (*number of peaks*). The distance between internal and external rays $D = R_e - R_i$ gives an indication of the regularity of shape of the problem polygon.

So, at the end of the representation, we have obtained the values R_e, R_p, R_i, N_p and D, and we can obtain several suggestions from them.

- First of all, if $R_e = N$, there is the impossibility to provide the service with an entirely public model.
- If $R_i = 0$, there is no need to provide the service in a completely private model.
- Low values of D are useful design directions that drive to proceed toward non hybrid solutions.
- High values of D denote strong fluctuations in the values of the parameters and drive to adopt hybrid models. In this case the N_p value has more importance, since it represents the functionalities that must be realised in the private part of the hybrid model.

At this point it would be appropriate to operate a new round of refinement of the values obtained by the survey. This time it will be directed only to deepen with the stakeholder the actual need of the requirements that corresponds to the peeks. Maybe some of them could be relaxed in order to regularise the shape of the problem polygon with a design simplification.

The peak parameters investigation requires now more effort, not a simple survey as in the first round. There is the need of a deep discussion on the peak parameters. In this round the actors involved are all together and this can help to verify the effective need of a private approach for the related features.

If some of these peeks are lowered, a new graph with a new representation of the parameters can be done and used as the final one. This is shown in the case study.

3.4 Cost analysis

Starting with the parameters identified in the previous phases, we move on to a purely economic evaluation.

For each of the parameters, both the cost of the private solution and the cost of the public solution are taken into account. In that sense each indicator is related to two costs, one for the private realisation and the other for the public one.

A simplistic approach would only consider these costs, but in our case we do not want to make a choice purely dictated by the economic value alone, instead we want the choice to be bound by the satisfaction of technological constraints or non-monetisable constraints.

For the parameter P_i, we will have two costs: PRC_i and PUC_i *(private and public costs)*. They can be represented in a table along with their variability ranges $VR_i = PRC_i - PUC_i$

By finding the minimum and maximum or variability ranges:

$$VR_{min} = min(VR_i) \tag{1}$$

$$VR_{max} = max(VR_i) \tag{2}$$

and given $VR = VR_{max} - VR_{min}$ as the global variability range, we can calculate for each parameter the cost factor as:

$$CF_i = \frac{VR_i - VR_{min}}{VR} \cdot G \tag{3}$$

Where G can be seen as a *gain factor* used to express the maximum values of the all factors. These factors will be used to multiply the parameter values obtained from the first phase.

In our methodology we have chosen $G = 2$ in order to amplify ($CF_i > 1$) or to attenuate ($CF_i < 1$) the corresponding parameter depending on the relative cost against the total costs.

Also from a graphical point of view, the evaluation is improved by that value. In that way the values in $1-5$ range from the first phase will be scaled in $1-10$ range. The parameters will be now represented in a new Kivyat diagram, with the same number of radius, but with a $1-10$ scale. In this way parameters' dynamic will be amplified and *values per costs* products will be more evident. This diagram will permit the manager to visualise the whole evaluation picture.

Note that on the new diagram some parameters could have a near zero value. This leads to the consideration that that parameter does not affect the overall assessment.

The final diagram area provides an indication of the cost reduction using the internal solution.

The analysis of the peaks of the final diagram also provides important indications for the manager, in fact these peaks represent strong constraints that weigh on the adoption of a purely public solution.

If the peaks are high, the possible approaches can be of two types:

- Purely private implementation
- Hybrid model adoption, with only the functionality related to peaks to be implemented in a private model.

4 Methodology 1: a case study

As a case study the model has been tested with the real need to provide a new e-learning service to the students of the University of the authors.

In this context the main features requested by the system are summarised as follows:

- Special-purpose board to interface scientific instruments in labs (e.g. data acquisition board, mass spectrometer, etc.)
- Student authentication with SPID (Italian Public Authentication Service) or Digital Signature
- High importance of provisioning of remote teaching due to the current Covid-19 pandemic state
- Need for interfacing with existing University software (e.g. career, administration)
- Copyrights and intellectual property of lectures, coursewar and study materials.
- Security constraints in order to guarantee access only to authorised people (students and teachers).
- Bandwidth and throughput to guarantee that each student can attend lectures both remotely and in campus premises.

4.1 Survey submission

The stakeholder and also the domain expert is the teacher delegated by the rector as responsible of innovations in teaching. The first part of the survey has been submitted to him.

The second part of the survey has been submitted to the ICT manager of the University.

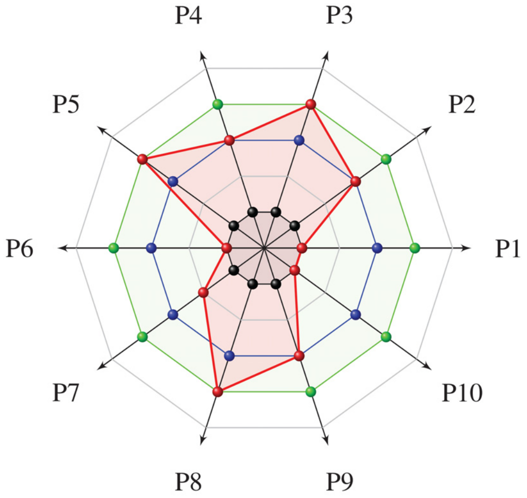
For this study, the answers of the survey as weighted in a $0...5$ scale ($N = 5$). The corresponding values are shown in Table 3.

Table 3 Survey result

Parameter	*Name*	*Value*
P1	H/W customisation	1
P2	Privacy	3
P3	Mission critical	4
P4	Interoperation	3
P5	Rights	4
P6	Customised H/W	1
P7	Security	2
P8	Throughput	4
P9	Authentication	3
P10	Resources	1

These values have been subsequently graphically represented in the Kiviat graph of Figure 2. The parameter values are represented in red and the same is for the problem polygon and for the corresponding shape.

Figure 2 Kiviat graph for e-learning service



On the same graph can be seen (in grey) the regular polygons with increasing values of parameters.

The *external polygon* is represented in green and has $R_e = 4$. All the problem polygon is inside this one and since $R_e < N$, the full-private solution is not mandatory.

The *internal polygon* is represented in black and has $R_i = 1$. Also in this case since $R_i > 0$ there is no need to adopt a full-public solution.

The *peak polygon* is represented in blue and has $R_p = 3$.

The *number of peaks* is $N_p = 3$. They corresponds to the requirement of P3, P5 and P8 and are the constraints that must be investigated if we want to lower the R_e by one unity.

4.2 Second round

In order to verify if the peak parameters can be lowered, a second trip with the stakeholder and the ICT manager has done. Now there is not a simple survey as in the first round, but a discussion with all the actors together.

The first peak parameter (P3) is related to the mission critical aspects of the service for the academia. A deepen discussion with the stakeholder has revealed that this critical issue has been understood more as value added of the service for the students rather than its effectiveness with the whole academia system. So, it has been agreed that P3 can be surely lowered from 4 to a value of 2.

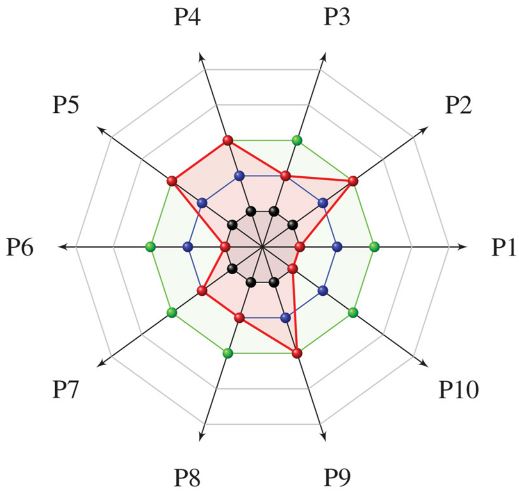
The second peak parameter (P5) is related to the copyrights or patents affecting the data managed by the service. It is certainly true that the lessons with related audio, video and teaching materials and their authors must be protected, but there are no specific needs to do this on on-premise systems, since cloud providers can easily assure the protection needed. So, a middle value answer seems more appropriate. So P5 has been lowered from 4 to 3.

Last parameter (P8) concerns throughput and bandwidth parameters of the service. It is obviously that audio/video streaming requires proper connections with high bandwidth, and it is undoubtedly that a private cloud can provide better performance than a public cloud, but this is true only on the local contexts.

The answer given at first by the ICT manager with a value of 4, was right, but the stakeholder shows that most users want to use the e-learning service, not in the campus, but rather away from it (e.g. at home, or during trips). In this case the best results can be given by a public system that, if required, can also be spread over other regions. The new value of P8 is 2.

After the second trip the new Kiviat graph is shown in Figure 3.

Figure 3 Kiviat graph after 2nd round



As we can see on the new graph, the shape of the polygon problem is more regular.

The *external polygon* in green now has $R_e = 3$.

The *peak polygon* in blue has now $R_p = 2$.

It is worth noting that the number of peaks N_p has grown from 3 to 4 and relate to parameters P2, P4, P5 and P9. This must not be considered a worsening of the model.

There is no need to do further rounds of investigation on peak parameters since one of them, P5, was also a peak parameter at the beginning and has already been discussed.

Since $R_e = 3$ and $R_i = 1$, the suggestion we can derive from the analysis, with no cost factors involved, is to adopt an hybrid solution, where the components related to the peak parameters are more candidate to be given by a public provider.

4.3 Cost impact

At this point we begin to consider the importance of costs on the choice of the model to be adopted. As described before, for each parameter we consider two costs: one for the private solution and the other for the public approach.

In Table 4 we can see these costs. For our work we have estimated these values, for each parameter, from an internal evaluation (by involving IT manager, administrative ...) and by analysing public providers' price lists. All costs are calculated on a three years' basis and expressed in thousands of euros.

Table 4 Cost values

Parameter	*Name*	PRC_i	PUC_i
P1	H/W customisation	100	200
P2	Privacy	10	30
P3	Mission critical	100	30
P4	Inter-operation	10	50
P5	Rights	70	20
P6	Customised H/W	20	20
P7	Security	100	30
P8	Throughput	20	100
P9	Authentication	10	10
P10	Resources	100	30

By applying our methodology we can calculate variability ranges, their minimum and maximum values along with the global variability range. For each parameter the corresponding amplification factor is then computed and the final values are also derived.

In Table 5 we can see values and factors computed for each parameter.

In our case $VR_{min} = -100$, $VR_{max} = 70$, $VR = 170$, and as already explained we have chosen $G = 2$.

Table 5 Cost values

Parameter	PRC_i	PUC_i	VR_i	CF_i	*value*	*final*
P1	100	200	–100	0.000	1	0.000
P2	10	30	–20	0,941	3	2.824
P3	100	30	70	2.000	4	8.000
P4	10	50	–40	0.706	3	2.118
P5	70	20	50	1.765	4	7.059
P6	20	20	0	1.176	1	1.176
P7	100	30	70	2.000	2	4.000
P8	20	100	–80	0.235	4	0.941
P9	10	10	0	1.176	3	3.529
P10	100	30	70	2.000	1	2.000

With these values we can construct the final graph shown in Figure 4.

4.4 Final results

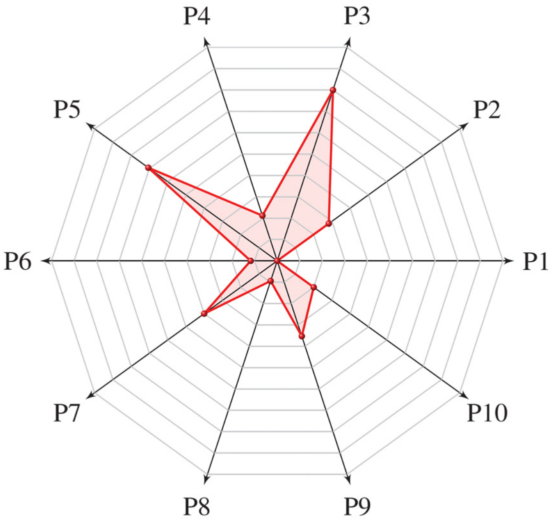
As we can see in Tables 5 and in Figure 4, we can make some considerations:

- Some parameters express now with high values and peaks in graph. This represents that the related aspect has a high importance that could lead to a private solution, but also an high cost that drive in the opposite direction.
- The null, or very low values are related to aspects for which there is no need to use a pure private solution and at the same time, their costs are low in relation to the other.

- The area of the graph gives an idea of what are the costs to implement the service in a pure private approach.

The most important aspects to focus on are those related to peaks.

Figure 4 Final Kiviat graph with cost amplification



5 Methodology 2: semantic approach

Our research group has been working for years in the field of ontology-based methods in order to face off management issues in several application domains (Cretella and Di Martino, 2015; Martino et al., 2015; Di Martino and Esposito, 2016; Martino et al., 2017; Di Martino et al., 2017a; Di Martino et al., 2017b; Di Martino and Esposito, 2018; Di Martino et al., 2018; Di Martino et al., 2019).

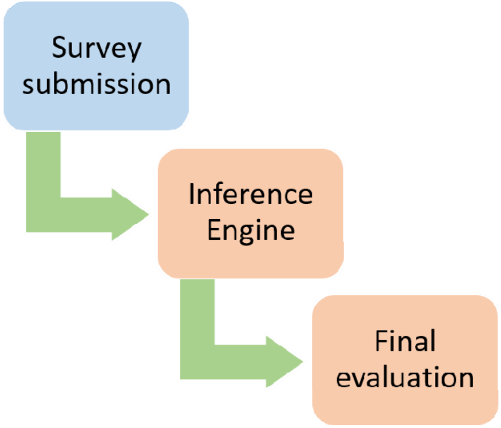
That said, the methodology proposed in the Section 3 is also analysed from a semantic point of view. In particular, this section illustrates a semantic approach that investigates a possible OWL semantic representation. This is used as a knowledge base to build a decision support system able to suggest the cloud model that best suits the needs of the stakeholder.

In this case, the steps of the procedure are the following (Figure 5):

- Submission of a Survey (this step is the same used in Section 3)
- The survey is processed using AI techniques using a Cloud Ontology and with regard also to costs
- Final evaluation

To build this decision support system the SWRL language has been used. More specifically in Sections 5.1 and 5.2 are reported some overviews on the OWL and SWRL language, that are used to implement it. Then in the Section 5.3 is reported the OWL ontology that describes semantically all most important methodology's concepts. Finally in the Section 5.4 is illustrated the logical inference rule-based system to support decisions built in SWRL.

Figure 5 Structure of the cost/features evaluation



5.1 OWL overview

The Web Ontology Language (OWL) is a family of knowledge representation languages to build ontologies, that are a formal way to describe complex application domains. The W3C has supported the development of OWL as language for defining Web-based ontologies. In Figure 6 the OWL elements are shown. In OWL we identify concepts with some classes, then we identify their individual and define properties that characterise them (McGuinness et al., 2004). There are the kinds of properties between individuals:

- *Object Property*: link an individual with another individual.
- *Data Property*: link an individual with a literal. In other words it assigns a data value to individual.

5.2 SWRL overview

The Semantic Web Rule Language (O'Connor, 2009), acronym of SWRL, is a proposed language for the Semantic Web that can be used to express rules as well as logic, combining OWL DL or OWL Lite with a subset of the Rule Markup Language. The specification was submitted in May 2004 to the W3C by the National Research Council of Canada, Network Inference (since acquired by webMethods), and Stanford University in association with the Joint US/EU ad hoc Agent Markup Language Committee. The specification was based on an earlier proposal for an OWL rules language. In the latest versions of Protegè a SWRLTab has been introduced to write SWRL rules and apply them directly to the ontology. It provides a set of libraries that can be used in rules, including libraries to interoperate with XML documents, and spreadsheets, and libraries with mathematical, string, RDFS, and temporal operators. The SWRLTab has several software components, like, SWRL Editor which supports editing and saving of SWRL rules in an OWL ontology, SWRL Built-in Libraries which includes the core SWRL builtins defined in the SWRL Submission and built-ins for querying OWL ontology (Mohan and Arumugam, 2011). Protegè users can write SWRL rules in a Human-Readable format, but the SWRLtab saves them in a more machine readable format. In Figure 7 is shown an example of SWRL rules editing using the SWRLtab.

Figure 6 OWL elements

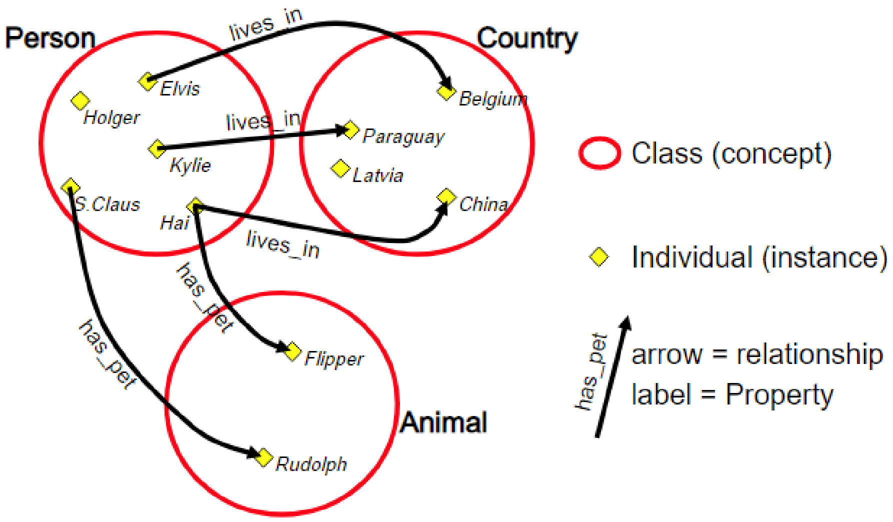
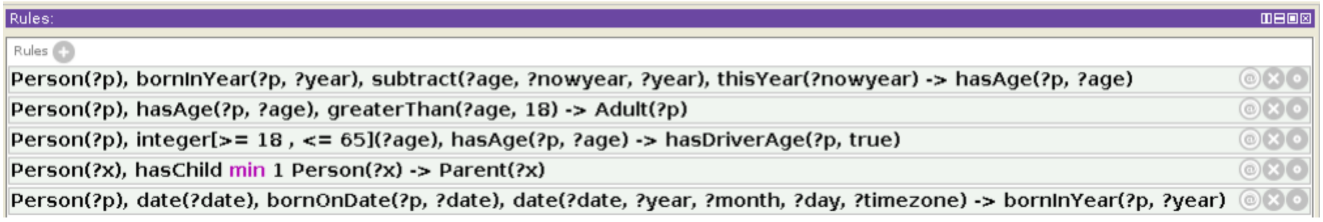


Figure 7 SWRLtab view



```
Person(?p), bornInYear(?p, ?year), subtract(?age, ?nowyear, ?year), thisYear(?nowyear) -> hasAge(?p, ?age)
Person(?p), hasAge(?p, ?age), greaterThan(?age, 18) -> Adult(?p)
Person(?p), integer[>= 18 , <= 65](?age), hasAge(?p, ?age) -> hasDriverAge(?p, true)
Person(?x), hasChild min 1 Person(?x) -> Parent(?x)
Person(?p), date(?date), bornOnDate(?p, ?date), date(?date, ?year, ?month, ?day, ?timezone) -> bornInYear(?p, ?year)
```

Writing a SWRL rule is very simple: at the end of each rule there is the implication, which is preceded by all the properties that must be verified for the implication to be true. All terms that have a question mark in front of them are variables, for example with clause “Person(?p)” is possible to indicate any instance of the Person class. With the symbol “∧” is possible to define a new rule as a conjunction of two clauses (AND). Since SWRL rules are Horn clauses, isn’t possible to use NOT and OR clauses.

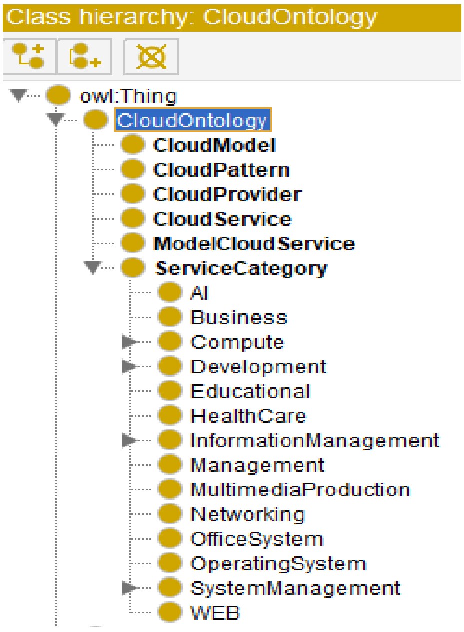
5.3 Semantic representation

In order to realise a logical inferential rule-based system, it is necessary to start from a semantic representation of all the concepts involved in the evaluation process. For this semantic approach is was considered the university use case reported in the Section 4. It is necessary to start from a semantic representation of all the concepts involved in the evaluation process and to do this we built an ontology obtained by incorporating and extending with specific concepts of the evaluation process. This ontology includes concepts belonging to two different knowledge domains: i) an ontology of Requirements. ii) an ontology of the Cloud. All other generic concepts used in the evaluation are included in a general ontology.

5.3.1 Cloud ontology

The Cloud ontology defines concepts related to Cloud’s world. In Figure 8 is illustrated this ontology.

Figure 8 Cloud ontology



Class hierarchy: CloudOntology

- owl:Thing
  - CloudOntology
    - **CloudModel**
    - **CloudPattern**
    - **CloudProvider**
    - **CloudService**
    - **ModelCloudService**
    - **ServiceCategory**
      - AI
      - Business
      - Compute
      - Development
      - Educational
      - HealthCare
      - InformationManagement
      - Management
      - MultimediaProduction
      - Networking
      - OfficeSystem
      - OperatingSystem
      - SystemManagement
      - WEB

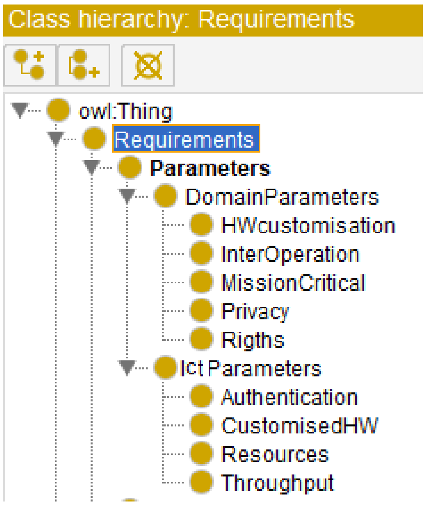
All the classes that have been included in the Cloud Ontology are described below:

- **CloudProvider**: defines all cloud services provider (i.e. Amazon, IBM, Azure).
- **Cloud Model**: defines all main Cloud model present in marketplace (i.e. Public Cloud, Private Cloud and Hybrid Cloud).
- **CloudPattern**: defines all pattern that cloud providers use to build reliable, scalable and secure applications.
- **CloudService**: defines all main services provided by cloud providers (i.e. DynamoDB, MapReduce and AutoScaling).
- **ModelCloudService**: defines all main model of cloud services (i.e. IaaS, PaaS and SaaS).
- **ServiceCategory**: defines all main cloud services category (i.e. Networking, Development and Compute).

5.3.2 *Requirement ontology*

The Requirement Ontology defines the requirements model knowledge, which is extended mapping the requirements reported with the specific requirements such as Domain Parameters and IctParameters of the methodology proposed (see Section 3). In Figure 9 is showed the main view of requirement ontology that contains the semantic description of all requirements involved in methodology explained in the Section 3.

Figure 9 Requirement ontology

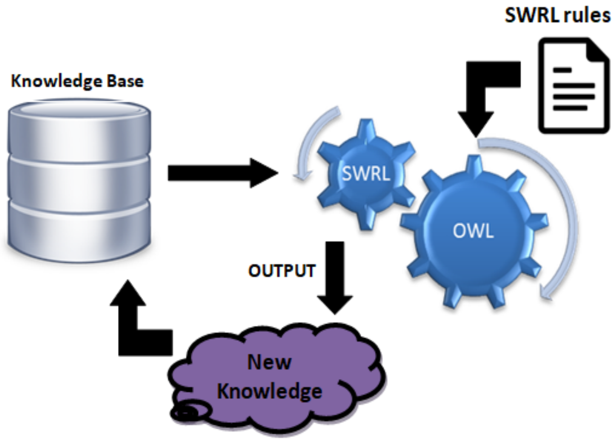

Class hierarchy: Requirements

- owl:Thing
  - Requirements
    - Parameters
      - DomainParameters
        - HWcustomisation
        - InterOperation
        - MissionCritical
        - Privacy
        - Rigths
      - IctParameters
        - Authentication
        - CustomisedHW
        - Resources
        - Throughput

5.4 *Rule-based decision system to suggest cloud model*

In order to create a system of logical inference rules able to simulate the decision-making system proposed in this work, the SWRL language was used. In Figure 10 the workflow of the *Inferential Engine* is shown.

Figure 10 Inferential engine



The inferential engine takes in input the OWL ontology proposed in the Section 5.3 and a set of inferential rules that have been defined and expressed in *SWRL* (see Section 5.2). The OWL ontology constitutes the knowledge base of inferential engine. The new inferred knowledge finally populates and enrich the knowledge base with a set of OWL assertions inferred by the inferential engine. The SWRL rules that compose the inferential engine are reported below:

- **Rule 1 - BudgetAssociatedToUniversity**: given a survey compiled by the IctSpecialist, which in our application case of the university world is the professor that the Rector delegates to deal with technological innovation, is able to infer what is the maximum budget not to be exceeded, i.e. the budget that the Rector has allocated for investments in that area.
- **Rule 2 - FinalScoreDomainRequirements**: for each survey gives the final score of the Domain Requirements (sum of the scores from 1 to 5 assigned by the IctSpecialist to all the Domain Requirements).
- **Rule 3 - FinalScoreIctRequirements**: for each survey gives the final score of the Ict Requirements (sum of scores from 1 to 5 assigned by the IctSpecialist to all Ict Requirements).
- **Rule 4 - SuggestPrivateCloudMode**l: given the total score (FinalScoreDomainRequirements + FinalScoreIctRequirements) this rule inferred if, with such a score, it suggests a private cloud model.
- **Rule 5 - SuggestPublicCloudModel**: given the total score (FinalScoreDomainRequirements + FinalScoreIctRequirements) this rule inferred if, with such a score, it suggests a public cloud model.
- **Rule 6 - SuggestionAccordingToBudget**: check given the suggestion (public or private) given by the two previous rules, if this suggestion can be applied according to the budget available.

- **Rule 7 - SuggestionHybridCloudModel**: if the cost of implementing the cloud model suggested exceeds the available budget, this rule recommends the adoption of an hybrid cloud model.
- **Rule 8 - HybridCloudModelImplementation**: if the suggested cloud model is a hybrid solution with this rule, then it is necessary to determine which requirements must be implemented with a public cloud solution and which with a private cloud solution.

As example is reported one of these inferential SWRL rule, that is *hasCloudModelSuggest*:

```
        Survey(?surv) ^
        hasFinalScoreDomainParam(?surv,
?var1) ^
        hasFinalScoreIctParam(?surv, ?var2) ^
        swrlb:add(?sum, ?var1, ?var2) ^
        swrlb:greaterThan(?sum, 25) ->
        hasCloudModelSuggest(?surv,
PrivateCloud)
```

The structure of all SWRL rules can be graphically represented with a SWRL call graph as suggested in Mei and Boley (2006), and it is reported in Appendix A.

The inferential rule system described above has been applied on two example surveys reported in Table 6. For the survey1 the support decision system has suggested a public cloud solution, while for the survey2 the support decision system has suggested a private cloud solution, but the costs to implement this solution exceed the available budget. So, in this case, the system also suggests a cloud hybrid solution, in which the requirements with greater weights are implemented with a cloud private solution, and that with lowers weight are implemented with a cloud public solution. Table 7 shows how is implemented the hybrid solution suggest for the survey 1. In order to make the reading more understandable, the output obtained by inferential rule system is reported in more detail in Appendix A (see Figures A2 and A3).

Table 6 Parameters used in the evaluation surveys

Requirement	*Survey1*	*Survey2*
H/Wcustomisation	3	1
Privacy	1	1
MissionCritical	5	1
Inter-operation	4	1
Rights	2	1
CustomisedH/W	2	1
Security	4	2
Throughput	5	1
Authentication	3	1
Resources	3	1

Table 7 Hybrid solution implementation for survey 1

Requirement	*Cloud Model*
H/Wcustomisation	public
Privacy	public
MissionCritical	private
Inter-operation	private
Rights	public
CustomisedH/W	public
Security	private
Throughput	private
Authentication	public
Resources	public

6 Drawbacks of the methodologies analysed

The methodologies analysed in this work suffer from various issues, due to the specific techniques used to acquire the needed information.

The Cost/Features methodology is based on the knowledge of several experts (domain experts, ICT experts). One of the main issues of this approach is the difficulty of persuading experts with differing opinions to reach "consensus". A strong personality may dominate the group discussion and consensus judgments even without merit, or the judgments of a quieter and less extrovert expert may be ignored or overlooked. Another feature of expert groups, which might be called a group heuristic, is a tendency for discussion to be restricted to ideas that will be broadly acceptable to all the group members (O'Hagan, 2019).

Moreover, the Cost/Features analysis is affected by problems related to the trustworthy cost evaluation. In fact, even if the costs have been well evaluated in the design phase, the lowering of ICT costs during the implementation phase, or the fast obsolescence of ICT solutions might affect the analysis (Maresova et al., 2017). This is a problem also for the Ontology-based approach, although in this case the new costs may be taken into account by changing cost parameters in the Ontology structure.

Another issue in both methodologies is the bias related to the answers to the questionnaire. The scientific literature on economics and psychology, as well as IS, argued that individuals' decision-making is influenced by perceived value, which is a combination of costs and benefits. More recent studies on users resistance in adopting new systems; this particular kind of bias was called *status quo bias* (Lee and Joshi, 2017).

7 Conclusion and future work

In this work we have proposed two different approaches to help in the choice of the most appropriate cloud model to be used when there is the need to provide a new service in the academic world.

The experiments conducted lead us to a comparison between the two approaches in terms of strengths and weaknesses, summarised in Table 8.

In the Cost/Features approach, the most obvious strength point is the easiness of implementation, while the weakness is that the results need experts to assess definitely.

On the other side, in the Semantic approach, may be needed many interactions to get to an acceptable solution. For example, in many cases, the budget is not really set to a specific value, and may be negotiable in case of achieving certain goals; in other terms, using Semantic approach in what-if analysis leads to multiple runs of the implemented tool. The Semantic approach has also another advantage: since it uses a Cloud Ontology, it may be expanded to add other constraints and both functional and non-functional requirements in the analysis.

Table 8 Comparison between the proposed approaches

Approaches	*Strengths*	*Weaknesses*
Cost/Features	Simple to implement	Needs experts to evaluate results
Semantic	Needs only a single step survey Immediate results	May need many iterations to get to the solution (in the case of budget change)

The future work on this topic will take place in two different directions. One issue to address is the bias reduction in the questionnaires, hence we will study the most suited technique for this topic. On the other hand, an ensemble approach will be investigated, in order to exploit the advantages of both methodologies.

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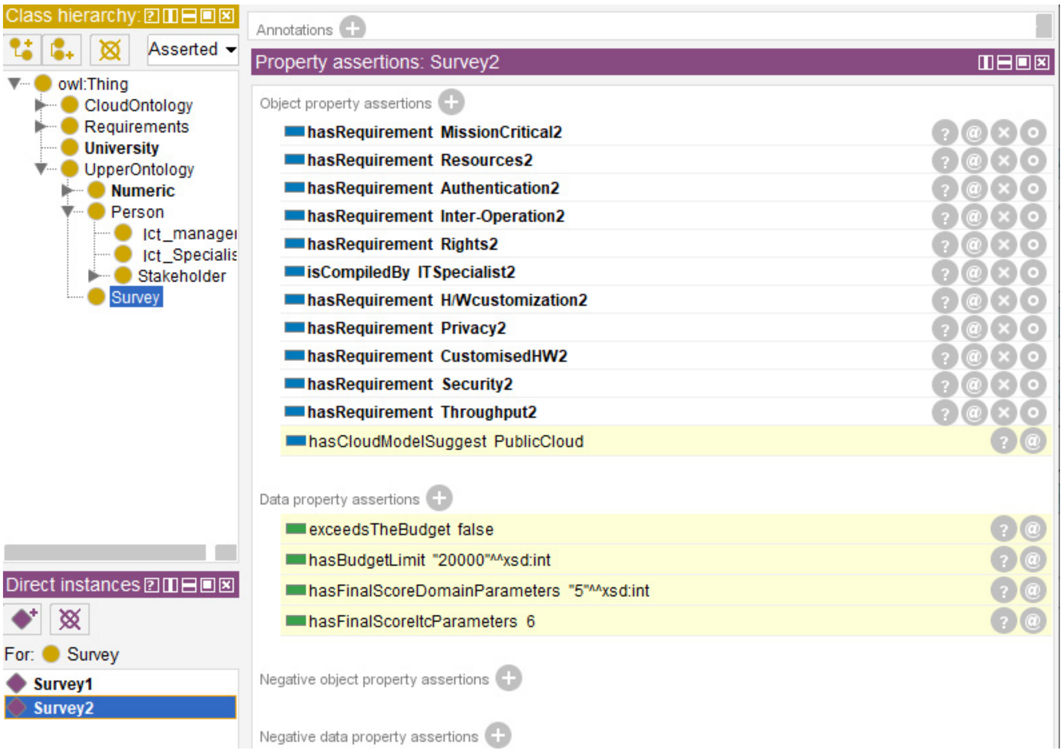
Appendix A

The SWRL Call Graph that graphically describes the structure of inferential engine mentioned in 5.4 is reported in Figure A1. The output obtained by inferential rule system mentioned in 5.4 is reported in Figures A2 and A3.

Figure A1 SWRL call graph

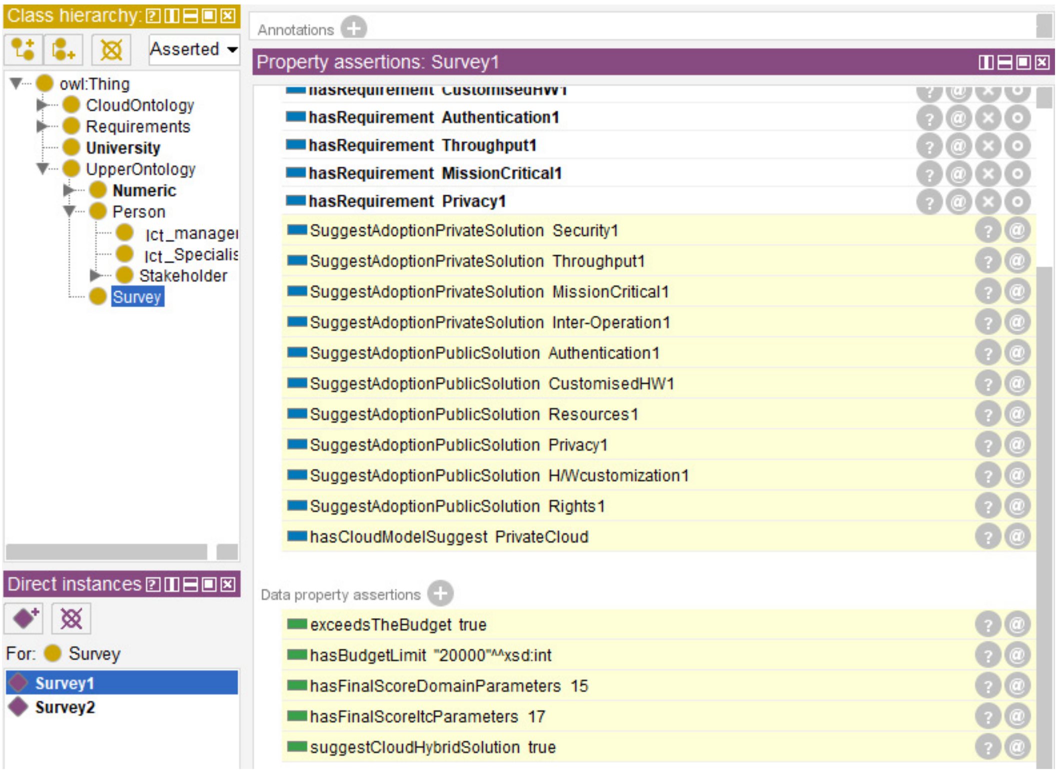
Figure A2 Inferential rule system's output for Survey 1



hasRequirement MissionCritical2
hasRequirement Resources2
hasRequirement Authentication2
hasRequirement Inter-Operation2
hasRequirement Rights2
isCompiledBy ITSpecialist2
hasRequirement H/Wcustomization2
hasRequirement Privacy2
hasRequirement CustomisedHW2
hasRequirement Security2
hasRequirement Throughput2
hasCloudModelSuggest PublicCloud

exceedsTheBudget false
hasBudgetLimit "20000"^^xsd:int
hasFinalScoreDomainParameters "5"^^xsd:int
hasFinalScoreItcParameters 6

Figure A3 Inferential rule system's output for Survey 2



hasRequirement CustomisedHW1
hasRequirement Authentication1
hasRequirement Throughput1
hasRequirement MissionCritical1
hasRequirement Privacy1
SuggestAdoptionPrivateSolution Security1
SuggestAdoptionPrivateSolution Throughput1
SuggestAdoptionPrivateSolution MissionCritical1
SuggestAdoptionPrivateSolution Inter-Operation1
SuggestAdoptionPublicSolution Authentication1
SuggestAdoptionPublicSolution CustomisedHW1
SuggestAdoptionPublicSolution Resources1
SuggestAdoptionPublicSolution Privacy1
SuggestAdoptionPublicSolution H/Wcustomization1
SuggestAdoptionPublicSolution Rights1
hasCloudModelSuggest PrivateCloud

exceedsTheBudget true
hasBudgetLimit "20000"^^xsd:int
hasFinalScoreDomainParameters 15
hasFinalScoreItcParameters 17
suggestCloudHybridSolution true