Using Ontologies in the Measurement of IT Service Management Processes

Abstract

Most IT service providers do not know what and how should be actually measured for each IT Service Management (ITSM) process in order to demonstrate the service value or to operate in a cycle of continuous service improvement. This paper analyzes the use of ontologies for the purpose of measuring ITSM processes. Ontologies may capture the required knowledge in form of a metrics model which provides a basis for its analysis and for business decision making in a well-defined manner. To do so, ITSM processes from the Information Technology Infrastructure Library (ITIL) V3 and the corresponding ITIL process-related metrics will be modeled using the Web Ontology Language (OWL) and enriched with a set of rules defined using the Semantic Web Rule Language (SWRL) to provide semantic constraints and knowledge inference. The definition of a set of queries based on the Semantic Query-Enhanced Web Rule Language (SQWRL) enables the retrieval of knowledge from OWL and inferred by the SWRL rules.

1. Introduction

To enhance their competitiveness and performance in this new Internet- and technology-driven business logic, organizations must assess the efficiency and quality of their services [1]. Nowadays, business people have increased their expectations related to the *Information Technology* (IT) department, and now they need IT to support their business processes in a strategic way. That is, companies are aware of the closer relationship and convergence between business and IT. However, it is important to notice that, in many cases, IT services do not meet business requirements, and business people see IT as a limitation on their business growth. It is as if business and IT were not sharing their challenge and goals, but they must do so as one of the resources required for *Sustained Competitive Advantage* (SCA) [2].

Responding to this problem, *IT Service Management* (ITSM) provides a set of specialized organizational capabilities and a professional practice, supported by an extensive body of knowledge, experience and skills for providing value to customers in the form of services [3]. The main objective of ITSM is to improve the quality of IT services (within ITSM, and in this paper, service is understood as an IT service). Services are recognized as crucial, strategic, organizational assets that must be managed for business success [4]. Thus, the need of reliable and flexible services becomes apparent.

Metrics are an important part of ITSM. ITSM metrics can be used to measure and monitor the health and state of each ITSM process in order to demonstrate the impacts and effects of ITSM practices [5]. Following the guiding principles of *"If you do not measure it, you cannot manage it"* [6] and *"If you do not measure it, you cannot improve it"*, without ITSM metrics, organizations cannot monitor the IT services they are trying to manage, and this should be unacceptable in any business organization [7]: *"any business unit, even IT, cannot operate without learning how to effectively govern itself."*

However, the complexity of service management measurement is still a challenging problem in the industry. Even adopting best practice guidance for ITSM measurement, the task of connecting ITSM metrics models with formal semantics and machine-processable modeling languages is too complex to tackle. That is, a human comprehensible text form is not directly processable by computers, and the semantics associated to natural language can lead to different representations and interpretations of the terms included in a metric specification [8].

In this paper, we address this problem by means of the integration between ontologies and an ITSM metrics model associated with ITSM processes from the *Information Technology Infrastructure Library* (ITIL[1]) V3. We aim at translating ITSM metrics expressed in natural language to an ontology which is a formal representation of the ITSM processes measurement domain. The proposed ontology provides support for the formal specification of an ITSM metrics model. It is worth noting that the ITIL/ITSM terminology used throughout these work is aligned with the one adopted by the *Spanish Association for Standardization and Certification*, AENOR[2].

The aim of the proposed ontology is to support: (i) business and IT integration managed in terms of an ITSM metrics model, (ii) knowledge representation, (iii) formal taxonomy development, and (iv) reasoning capabilities. The contributions of this work are therefore: (i) an ontology that can be used as a basis for the analysis of *"metrics that matter"* for an organization, in order to validate the quality and effectiveness of IT services in a cycle of continuous improvement, and (ii) an ontology that enables business decision making in a well-defined manner.

The rest of this paper is structured as follows. Section 2 covers the background. Section 3 summarizes the

[1] http://www.itil-officialsite.com/
[2] http://www.aenor.es/

process of creating an ontology from an ITSM metrics model, followed by how metrics and required constraints can be modeled and executed in Section 4 using a practical example. Finally, Section 5 concludes the paper and outlines future work.

2. Background

2.1. Ontologies

Ontologies [9] [10] are explicit representations of a shared conceptualization, i.e. an abstract, simplified view of a shared domain of discourse. More formally, an ontology defines the vocabulary of a problem domain, and a set of constraints (axioms or rules) on how terms can be combined to model specific domains. An ontology is typically structured as a set of definitions of concepts and relations between these concepts.

Ontologies are machine-processable, and they also provide the semantic context, by adding semantic information to the models, that enables natural language processing, reasoning capabilities, domain enrichment, domain validation, etc. A domain always continues to evolve, and ontologies are a good alternative to manage the evolution of the associated knowledge.

Since the inception of the Semantic Web, in which ontologies are the principal resource to integrate and deal with online information, a new set of standards have been proposed. The *Web Ontology Language* (OWL) [11] is one of such standards that belongs to a family of knowledge representation languages prepared for the Semantic Web (although this standard can be adopted in other domains). OWL has reached status of the *World Wide Web Consortium* (W3C) recommendation. From a technical point of view, OWL extends the *Resource Description Framework* (RDF) and the RDF Schema (RDF-S). Therefore, due to its RDF basis, OWL ontologies can be associated to any other form of information expressed on the Semantic Web.

A related specification, the *Semantic Web Rule Language* (SWRL) [12], is based on RuleML[3]. The SWRL extends the OWL, providing logic-based rules and, in consequence, providing more expressiveness. Rules together with stored facts (knowledge base) are executed as inputs by the rule engine, which infers new facts as an output.

Finally, the Semantic *Query-Enhanced Web Rule Language* (SQWRL) is a query language that enables to extract information from OWL ontologies [13]. SQWRL is based on the SWRL and it uses the SWRL's semantic foundations as its formal support. SQWRL includes a set of operators that allow the definition of negation as failure, disjunction, counting, and aggregation functionality in the construction of retrieval specification.

2.2. IT Service Management

There are several well established good practice frameworks to create an effective ITSMS such as ITIL, which is designed to integrate IT with business needs. Nowadays, ITIL is the best known and most widely accepted guidance and it has become the de facto standard for ITSM [14], providing *"a detailed description of a number of important IT practices, with comprehensive checklists, tasks, procedures and responsibilities which can be tailored to any IT organization"* [3].

ITIL version 3, also known as ITIL V3, is an enhanced and consolidated framework that proposes a new approach to ITSM by considering the lifecycle of a service. Provided that ITIL V3 is the most complete and up-to-date version of this ITSM framework, and since the *Office of Government Commerce* (OGC) has announced its plans for the withdrawal of publications and qualifications of ITIL version 2 (complete in the middle of 2011)[4], we selected ITIL V3 for our ontology approach.

As mentioned earlier, ITSM metrics represent an important issue in the validation of IT services for quality improvement. Metrics must be designed in line with customer requirements and they should act as a basis for a continuous *Service Improvement Plan* (SIP) [15]. Without metrics that really matter, *"it is impossible for any ITIL effort to ever demonstrate its value or operate in a cycle of continuous improvement"* [7]. However, most IT service providers really do not know what should actually be measured in order to determine the maturity of their ITIL processes. Many metrics could be measured, but only the most important of these are defined as *Key Performance Indicators* (KPIs) and used to actively manage and report on an ITIL process [16].

The benefits of using an ITSM metrics model have been reported by Steinberg in [7]:

1) Accurate and timely business decisions
2) Visibility into how IT services are operating in terms of efficiency and effectiveness.
3) A basis for identifying and prioritizing IT service improvement enhancements.
4) Analytical information to identify IT service deficiencies and problems before they result in serious impacts.

[3] http://ruleml.org/

[4] http://www.ogc.gov.uk/itil_ogc_withdrawal_of_itil_version2.asp

5) A process-based focus for getting at root cause of deficiencies in IT services.
6) Confidence in how IT is being managed.
7) Foundation for modeling the impacts of business and IT decisions.

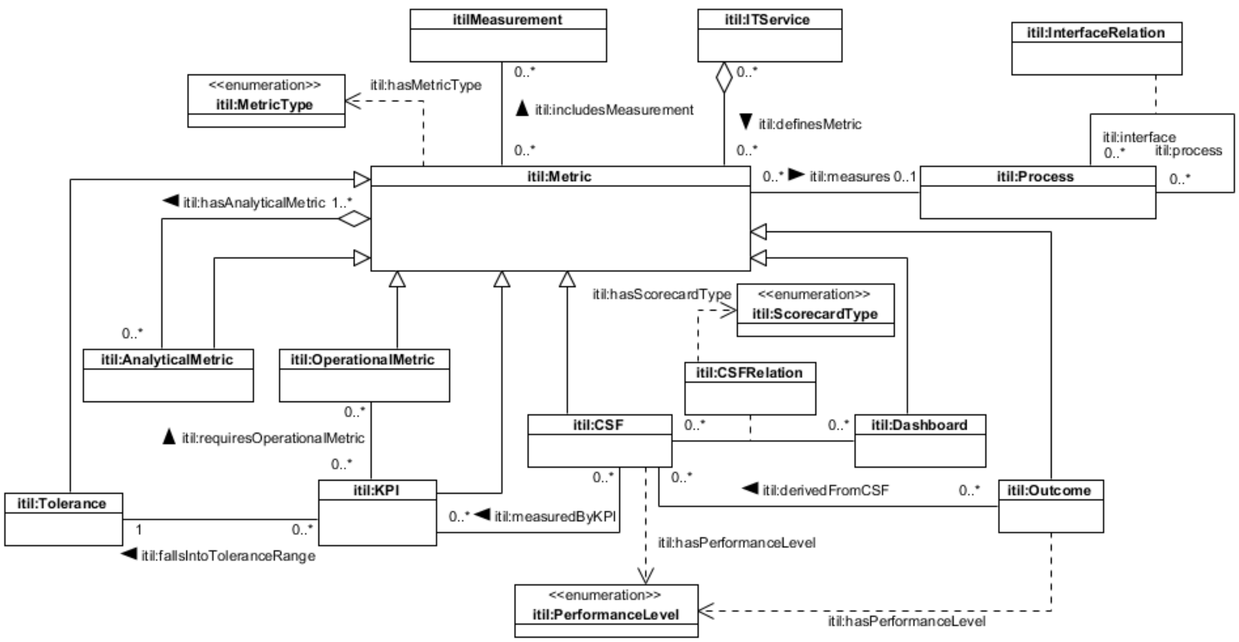

Figure 1. UML class diagram representing the ITSM metrics knowledge

3. Ontology-based ITSM metrics model

In this section, we discuss an approach to build an ontology for the ITSM metrics model. Our approach integrates the ITSM metrics model presented in [7] with the proposed modeling approach for ITSM, presented in [17]. In our ontological approach, *IT services* are managed by *Processes* which are measured using appropriate *Metrics*. In the proposed model, a Metric $m_i = \{r_1, r_2,...,r_n\} \in M_i$ represents a set of measurements designed to manage an IT service s_i. A metric is a scale of measurement r_i defined in terms of a standard, for example, in terms of a well-defined unit. The quantification of an event through the process of measurement relies on the existence of explicit or implicit metrics, which are the standard to which measurements are referenced.

The proposed ontology, as shown in Figure 1, collects all the information related to suggested metrics for each *itil:Process*[5] whose purpose is to measure the quality and effectiveness of *itil:ITService*s in order to take timely actions that make sure service are delivered in line with business needs.

The ontology concepts of *itil:OperationalMetric*, *itil:KPI*, *itil:Tolerance*, *itil:CSF*, *itil:Dashboard*, *itil:Outcome* and *itil:AnalyticalMetric* are the subclasses of *itil:Metric*, where according to [7], *itil:KPI* and the related *itil:Tolerance*, *itil:CSF*, *itil:Dashboard* and *itil:Outcome* are the metrics that really matter. That is, the metrics that provide a basis for making business decisions in the delivery of the *itil:ITService*.

An *itil:OperationalMetric* is a basic observation of operational events that provides live data from ITSM process (i.e., *itil:Process*) reporting and other infrastructure measurements and observations. For example, *itil:Percentage_of_incidents_handled_within_agreed_response_time* and *itil:Total_number_incidents* are examples of instances of *itil:OperationalMetric* that help determine the efficiency and effectiveness of the *itil:ICTD_IM_Process* instance.

An *itil:Metric* is considered as an *itil:KPI* when it measures the success with the *Service Level Agreements* (SLAs) defined with a customer. That is, only the *itil:Metric*s that provide a basis for making business decisions are defined as *itil:KPI*s and they are used to actively manage and report on the *itil:Process*. Each

[5] From here on, we use the prefix ‘itil’ to refer to the namespace of the ITIL metrics model

itil:KPI is trying to answer a question. While *itil:OperationalMetric*s are generally historical in nature, *itil:KPI*s are, as mentioned earlier, the metrics that really matter in order to demonstrate the value of a service and for the operation in a cycle of continuous improvement. These *itil:KPI*s become the data inputs to analyze and identify improvement opportunities. For example, *itil:Incident_resolution_rate* and *itil:Customer_satisfaction_level* are instances of *itil:KPI* for the *itil:ICTD_IM_Process* instance. In our approach, according to Steinberg [7], the *itil:KPI*s are calculated or derived from one or more *itil:OperationalMetric*s. For example, the *itil:KPI* of *itil:Incident_resolution_rate* is the result of dividing *itil:Number_incidents_resolved_within_agreed_service_levels* by *itil:Total_number_incidents* (instances of *itil:OperationalMetric*). The results of these calculations are then compared to an *itil:Tolerance* range to identify whether those results fall within acceptable levels.

In order to get decisions, we need another type of metric that indicates when to take actions. The *itil:Tolerance* is an indicator that identifies, in advance, the boundary in which the IT service provider expects a KPI to operate and behave. That is, the *itil:Tolerance* class represents the boundaries for acceptable and non-acceptable *itil:KPI* values (i.e., service target and warning level). For example, if the service target of the *itil:Tolerance* boundary for the *itil:KPI* of *itil:Average_Incident_Resolution_Hours* is 2.0 it means that the service target for this *itil:KPI* would be 2.0 hours. On the other hand, if the warning level of the *itil:Tolerance* boundary for the *itil:KPI* of *itil:Average_Incident_Resolution_Hours* is 3.5, it means that the performance of this *itil:KPI* would be considered acceptable as long as it is not higher than 3.5 hours. If it is higher, management actions may need to take place to raise the performance back to acceptable levels.

A *Critical Success Factor* (CSF) is something that must happen if an *itil:Process* is to succeed. The *itil:KPI*s are used to measure the achievement of each *itil:CSF*. For example, *itil:Quickly_resolve_incidents* is a instance of *itil:CSF* measured by the *itil:KPI*s of *itil:Incident_reopen_rate*, *itil:Average_time_to_resolve_severity1_and_severity2_incidents_hours* and *itil:Incident_management_tooling_support_level*. In another example, the *itil:KPI* of *itil:KPI_10_percent_increase_in_customer_satisfaction_rating_for_handling_incidents_over_the_next_6_months* would measure an *itil:CSF* of *itil:Improving_IT_service_quality*, and the *itil:KPI* of *itil:KPI_10_percent_reduction_in_the_costs_of_handling_printer_incidents would measure an itil:CSF of itil:Reducing_IT_cos*ts. Also, an *itil:CSF* can be associated with an performance indicator (modeled using the *itil:PerformanceLevel* enumeration class). In an *itil:CSF*, to receive the performance level of 'High', all the associated *itil:KPI*s must have met or exceeded their *itil:Tolerance* acceptable values. When one of the associated *itil:KPI*s falls into an *itil:Tolerance* non-acceptable value, the *itil:CSF* performance level might be 'Medium' or 'Low' depending on how the associated *itil:KPI* value fell within the specified *itil:Tolerance* range for it.

An *itil:Dashboard* is a graphical representation of overall IT service performance and availability. The *itil:Dashboard* images may be updated in real-time, and can also be included in management reports and web pages. Therefore, *itil:Dashboard*s can be considered as key *itil:Metric*s that are represented on a report or graphical interface that indicates the success, at risk or failure of a business activity. The *itil:Dashboard* results are derived from *itil:CSF* results (modeled using the *itil:CSFRelation* class). The *itil:CSF*s can contribute to one or more *itil:Dashboard*s and each *itil:Dashboard* may have one or more multiple *itil:CSF*s. For the purpose of our approach, just like the approach of Steinberg [7], we use the *Balanced Scorecard* originally developed by Kaplan and Norton [18]. The *Balanced Scorecard* was originally developed around the concept that financial measures alone are not critical for business success. The *Balanced Scorecard* has been generally recognized as an acceptable approach for senior management levels where the scorecard categories recommended for ITSM are (modeled using the *itil:ScorecardType* enumeration class): *Customer*, *Capabilities*, *Operational*, *Financial* and *Regulatory*.

The *itil:Outcome*s are key indicators of general business risk areas, that is, they are the kind of things that IT is trying to protect against. These are associated with performance indicators that identify the success, at risk or failure of *itil:KPI*s or *itil:CSF*s. The *itil:CSF*s are used to determine *itil:Outcome*s (operational risks). *itil:Legal_exposure*, *itil:Service_outages*, *itil:Rework*, *itil:Waste*, *itil:Security_breaches*, *itil:Unexpected_costs*, *itil:Slow_response_to_business_needs_and_changes*, *itil:Fines_and_penalties*, *itil:Loss_of_market_share_and_dissatisfied_customers* are examples of instances of *itil:Outcome*s. The *itil:Outcome*s can be associated with a performance indicator: *High*, *Medium* or *Low* (modeled using the *itil:hasPerformanceLevel* property) that might reflect the likelihood of risk that the *itil:Outcome* will occur. In our approach, the risk level is derived from the mean average of the *itil:CSF* performance levels. Scoring for an *itil:Outcome* runs opposite to how the *itil:CSF*s are calculated. If an *itil:CSF* scores 'Low', meaning the likelihood of achieving that *itil:CSF* is low, then the *itil:Outcome* would score 'High'. This means that the risk of the *itil:Outcome* occurring is high because the *itil:CSF* achievement was low.

An *itil:AnalyticalMetric* is used to separate out certain *itil:Metric*s that are really more helpful for supporting research into an issue, incident or service problem. The *itil:AnalyticalMetric*s are metrics that IT service providers may report on only on a one-time basis or as part of a drill-down (such as for an *itil:Dashboard*). An *itil:AnalyticalMetric* is a subset of subdivision of an *itil:Metric* (modeled using the *itil:hasAnalyticalMetric* property). For example, the *itil:OperationalMetric* of *itil:Total_number_incidents_for_analytical_purposes* has been broken out by the next *itil:AnalyticalMetric*s: *itil:Department_of_business_unit*, *itil:Physical_Intervention*, *itil:Expert*, *itil:IT_service_delivered* and *itil:Time_of_day*.

Table 1. Operational metrics for the Incident Management process

ID	Metric
A	Total number of incidents
B	Average time to resolve severity 1 and severity 2 incidents (hours)
C	Number of incidents resolved within agreed service levels
D	Number of high severity / major incidents
E	Number of incidents with customer impact
F	Number of incidents reopened
G	Total available labor hours to work on incidents (non-Service Desk)
H	Total labor hours spent resolving incidents (non-Service Desk)
I	Incident Management Tooling Support Level
J	Incident Management Process Maturity

Table 2. KPIs for the Incident Management process

ID	KPI	Calculation
1	Number of incident occurrences	A
2	Number of high severity / major incidents	D
3	Incident resolution rate	C/A
4	Customer incident impact rate	E/A
5	Incident reopen rate	F/A
6	Average time to resolve severity 1 and severity 2 incidents (hours)	B
7	Incident labor utilization rate	H/G
8	Incident management tooling support level	I
9	Incident management process maturity	J

4. Proof of concept: The Incident Management metrics model

The objective of the metrics illustrated in Table 1 and Table 2, which have been included from [7] in our ITSM metrics model as instances of *itil:Metric*, is to determine the efficiency and effectiveness of our *Incident Management* process (the *itil:ICTD_IM_Process* instance), and its operation. The next SWRL rule is an example of rule that is used to assign the value to a specific KPI derived from two operational metrics. SWRL rules can be executed on our ontology using Protégé[6] and the Jess[7] rule engine, allowing us to both verify constraints and inconsistencies in the ITSM metrics model, and to incorporate new inferred knowledge into the ontology.

```
itil:OperationalMetric(itil:Total_number_incidents) ∧
itil:OperationalMetric(itil:Number_incidents_resolved_w
ithin_agreed_serv_levels) ∧
itil:metricValue(itil:Total_number_incidents,?v1) ∧
itil:metricValue(itil:Number_incidents_resolved_within_
agreed_serv_levels,?v2) ∧
itil:KPI(itil:Incident_resolution_rate) ∧
swrlb:divide(?ratio, ?v2, ?v1) ∧
swrlb:multiply(?r, ?ratio, 100)
→
itil:metricValue(itil:Incident_resolution_rate,?r)
```

(1)

[6] http://protege.stanford.edu/
[7] http://www.jessrules.com/

Rule **(1)** shows how it is possible to force the computation of a specific metric in order to document it and test its results following the metrics model proposed by Steinberg [7], where, the KPI of the incident resolution rate, is defined as the ratio between the number of incidents resolved within the agreed service levels and total number of incidents.

We also can define rules that enable IT service providers to analyze the impact of a business decision increasing or decreasing the values of *itil:OperationalMetric*s that are related to it. For example, if an IT service provider plans to include a new application in a specific service, the incident manager can model the impact of such decision increasing the number of incidents which are supposed to occur. Then, the IT service provider can examine the impact on KPI and CSF results if they fall within tolerance levels:

```
itil:OperationalMetric(itil:Total_number_incidents)
→
itil:metricValue(itil:Total_number_incidents, 300)
```

(2)

```
itil:OperationalMetric(itil:Total_number_incidents)
itil:KPI(itil:Number_incident_ocurrences) ∧
itil:metricValue(?v)
→
itil:metricValue(itil:Number_incident_ocurrences,?v)
```

(3)

```
itil:OperationalMetric(itil:Total_number_incidents) ∧
itil:OperationalMetric(itil:Number_incidents_with_custo
mer_impact) ∧
itil:metricValue(itil:Total_number_incidents,?v1) ∧
itil:metricValue(itil:Number_incidents_with_customer_im
pact,?v2) ∧
itil:KPI(itil:Customer_incident_impact_rate) ∧
swrlb:divide(?ratio, ?v2, ?v1) ∧
swrlb:multiply(?r, ?ratio, 100)
→
itil:metricValue(itil:Customer_incident_impact_rate,?r)
```

(4)

```
itil:OperationalMetric(itil:Total_number_incidents) ∧
itil:OperationalMetric(itil:Number_incidents_reopened)
∧
itil:metricValue(itil:Total_number_incidents,?v1) ∧
itil:metricValue(itil:Number_incidents_reopened,?v2) ∧
itil:KPI(itil:Incident_reopen_rate) ∧
swrlb:divide(?ratio, ?v2, ?v1) ∧
swrlb:multiply(?r, ?ratio, 100)
→
itil:metricValue(itil:Incident_reopen_rate,?r)
```

(5)

```
itil:OperationalMetric(itil:Total_number_incidents)
∧ itil:KPI(?kpi) ∧
itil:requiresOperationalMetric(?kpi,
itil:Total_number_incidents) ∧
itil:metricName(?kpi, ?name) ∧
itil:metricValue(?kpi, ?value) ∧
itil:Tolerance(?tolerance) ∧
itil:fallsIntoToleranceRange(?kpi, ?tolerance) ∧
itil:toleranceServiceTarget(?tolerance, ?r1) ∧
itil:toleranceWarningLevel(?tolerance, ?r2)
→
sqwrl:select(?name, ?value, ?r1, ?r2) ∧
sqwrl:columnNames("KPI Name", "KPI Value", "Service
Target", "Warning Level")
```

(6)

This would be an example of rule chaining, where rule **(2)** assigns a value to the *itil:Total_number_incidents* operational metric. Then, rule **(1)**, rule **(3)**, rule **(4)** and rule **(5)** calculates the incident resolution rate (%), the number of incident occurrences, the customer incident impact rate (%), and the incident reopen rate (%), respectively. That is, we execute all the SWRL rules that calculate the KPIs which are affected by this operational metric in our *Incident Management* process. Finally, the SQWRL query **(6)** extracts the tolerance values from the instances of the *itil:Tolerance* class associated with each selected *itil:KPI* (*itil:toleranceServiceTarget* and *itil:toleranceWarningLevel*) in order to determine the CSF performance level.

5. Conclusions and future work

The Ontology-based ITSM metrics model presented in this paper measures the quality and effectiveness of each ITSM process, providing a basis for its analysis and for business decision making in a well-defined manner. Poor IT decision making has been taking place, and the proposed ITSM metrics model can help IT service providers support the business.

Our ITSM metrics model enables IT service providers to know and understand the KPIs that should be used to measure IT services in order to operate in a cycle of continuous service improvement. In addition, our ontological approach can be used to test the impact of those decisions on KPIs and CSFs (i.e., how KPIs change according to new scenarios). Furthermore, this model can act as a basis for identifying and prioritizing IT service improvements, such as acquisition of new resources and computer tools to support the ITSM processes

Future work of this proposal includes completing the definition of the proposed ITSM metrics model for all

ITIL process and the underlying constraints for ITIL-based ITSM measurement.

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