A Process Oriented Assessment of the IT Infrastructure Value: A Proposal of an Ontology Based Approach

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Abstract. The impact of IT infrastructure on organizations' activities and performance is hard to evaluate since complex IT infrastructures affect multiple business processes. An integrated perspective on IT and business processes is required. Previous research dealing with process-based IT impact evaluations lacks practical applications of proposed methods. Adopting a value-based perspective, this paper focuses on the organizational impact of IT and introduces first results from an ongoing research. This paper introduces an ontology based approach to represent the relationships among business processes and IT infrastructure components.

Keywords: Ontology, Business Value, IT costs evaluation, Process Based IT Value assessment.

1 Introduction

The impact of IT infrastructure on processes and the reflexes of processes changes on IT infrastructure are hard to evaluate in a landscape where, complex IT infrastructures are linked to business processes in a network of relationships. Each IT Component can affect more than one business process [1, 2]. For example, a few years ago, the purchase department of an international manufacturing company decided to increase the frequency of the orders registration process (from weekly to daily), estimating an annual savings cost of € 400.000. However the new frequency caused an increase in the workload of the server supporting this procedure and the company had to buy a new one (cost € 450.000). The net financial performance of this operation was therefore € -50.000 for the first year. When the decision was taken, none of the two parts involved (IT and Purchase Department) were able to tell the exact effect that the modifications would have had on the IT Infrastructure.

To face problems like this, an integrative perspective of IT and business processes is required. Available research on process-based IT impact evaluations are in lack of practical applications from proposed methods [3]. The practitioners' side offers more practical approaches, providing collections of best practices adopted by organizations: both ITIL

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v3 and CoBIT v4.1 give guidance to companies so as to manage their IT infrastructures. Even if these frameworks provide help, they fail to establish an integrated view of IT infrastructure and business processes (as described subsequently in this paper).

Another aspect that emerges in contexts like the one previously described is related to the fact that, matching IT infrastructural needs with business needs usually brings into play problems connected to shared and mutual understanding [4, 5].

This paper focuses on the organizational impact of IT management, adopting a value perspective, and introduces the first results of an ongoing research. The research question this paper is concerned with is: "By which means can IT Management be linked with the business process level?". The proposed approach uses an ontology to represent the relationships among business processes and IT infrastructure components.

The structure of this paper is as follows: after the introduction, the research methodology is described. Subsequently, the related work section serves to orientate our work within the body of available research. We then describe the proposed ontology and show its application by means of a test case. Some final remarks and considerations on further research conclude the paper.

2 Research Methodology

The research methodology of this paper follows the design science paradigm [6], aiming at the development of an ontology (the "IT artefact") that is useful to solve a problem stemming from the "business environment". The underlying design process of the ontology is displayed in Fig. 1, and is primarily based on the work of SURE et al. [7], and FOX et al. [8].

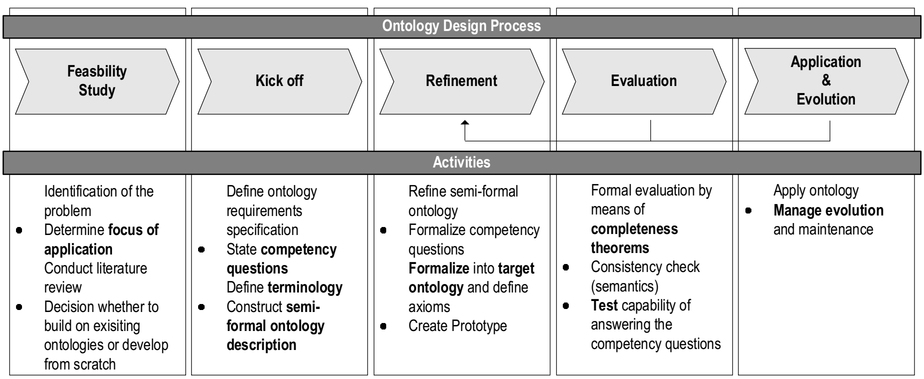

Fig. 1. Ontology Engineering Process (c.f. [7, 8])

As this paper describes a research in progress, we have not covered all phases of the design process with equal intensity. In particular, the phases of "Refinement" and "Evaluation" have been only iterated twice at the time of writing. The phase "Application and Evolution" is currently iterated the first time, so we can hardly provide resilient results from this phase for now.

Within the feasibility phase we identified the business need (practical relevance, described in the introduction), as well as the problem which was unveiled by the IT management of the company. The structure of the problem allows for a formal modeling approach and at the same time requires the models to exhibit a clear semantics. The semantic aspect is important as the modeled concepts have to be clearly understood and interpreted by all parties involved (including non-human actors). According to the design science guidelines stated by HEVNER et al. [6] we seek to apply existing foundations and methodologies from literature and practice (knowledge base) for the design of our ontology. Therefore, the concepts presented in the ontology have been strongly inspired by previous efforts of the ITIL v3 and CoBIT v4.1 frameworks as well as from preliminary work in the field of enterprise ontology.

Competency questions
Which services does IT has to offer to fulfill Business needs?
What is IT offering to the business side (service catalogue)?
What are the most infrastructure critical services?
What happens if a piece of hardware fails?
What are potential single points of failure in a given situation?
When is the IT infrastructure running into a bottleneck?
Which investments are required to solve bottlenecks?
To what extent are individual services underemployed / overburdened?
Is our IT infrastructure capable of fulfilling business requests?

Fig. 2. Sample competency questions

During the kick off phase we specified the requirements of the ontology, defining the ontology's competencies [8]. Sample competency questions are listed in Fig. 2. Within the remaining sections, we present the outcomes of the first iterations of the "Refinement" (ontology description) and the "Evaluation" (application example) phase. Prior to this, we give coordinates to position our work in the literature.

3 Related Work

Bearing in mind the proposition of this paper, the area of research which we consider to be of relevance is the one that investigates the impact of IT inside organizations under a value perspective. On this topic there is sufficient acknowledgement of the assumption that IT investments generate value inside organizations [9, 10], anyhow, the debate on how to assess or measure it is still ongoing. According to SCHEEPERS and SCHEEPERS [1] literature relevant to this topic has focused on the problem by adopting two interrelated perspectives: the IT Value and the IS Alignment perspective.

In the genesis of IT Value research the work of BRYNJOLFSSON [11] contributed to the identification of the so called “IT Paradox”, intended as the absence of productivity improvements as a consequence of IT investments. Since then, IT Value has been analyzed using a wide range of different approaches [9] and theoretical perspectives [12]. The number of research papers published on this topic is high. For example, OH and PINSONNEAULT [12] and MELVILLE et al. [9], who provide extensive literature reviews on IT Value, cite (respectively) 109 and 202 papers.

Past research on IT Value was until now unable to build a consensus among researchers on the role of organizational impacts of IT investments. Even if the need to evaluate profitability and effectiveness of IT investments in organizations is a relevant priority [13], results on IT Value are not always unambiguous [14] and, moreover, they lack practical applications of proposed methodologies [3].

In a recent paper, KOHLI and GROVER [15] summarize findings about value generated by IT investments in literature with the following assumptions: IT does create value; IT creates value under certain conditions; IT-based Value manifests itself in many ways; IT-based value could be latent; there are numerous factors mediating IT and value. MELVILLE et. al [9] identified that IT investments could produce value at three different loci: the focal firm (referring to the organization investing in IT), the competitive environment and the macro environment. The difficulties connected to the identification of a proper link between IT spending and productivity induced many researchers to focus more on the focal firm. Many recent studies adopt the process perspective to analyze the value impact of IT investments [4, 2]. In particular, RAY et al. [4] highlight how IT applications tend to be process specific (effects produced at a specific process may not transfer to others), emphasizing the need for a process based IT impact evaluation.

TILLQUIST and ROGERS [16] notice that separating IT value in a process is equally difficult because it mixes with other values delivered by other resources in the process. Moreover, due to their complexity, modern IT infrastructures, may easily impact more than one process [1], creating difficulties in identifying which specific component affects a specific process or activity.

SCHEEPERS and SCHEEPERS [1], citing TALLON et al. [17] and WEILL and BROADBENT [18] identify the existence of a “dilution effect” that affects the traceability of the impact of IT investments. On the basis of this consideration they highlight the role of literature in addressing the problem of organizational value impact of IT investments under a strategic alignment and competitive environment perspective. Under this perspective the value impact of IT investments is seen as a pre-requisite for a better organizational performance that on a strategic level, can be acquired by means of a strategic fit between IT and business. According to BYRD et al. [19] literature on the strategic alignment of IS and business strategy suggests the existence of a positive effect on performance.

Perspectives adopted by research papers on IS Alignment literature are divided by SILVA et al. [20] into three main branches: managerial, emergent and critical. These approaches identify the need to adopt a managerial model so as to achieve alignment, but at the same time highlights the necessity to deal with the uncertainty of strategy formulation and the drift effect of technology [21]. The complexity of the aspects that come into play when studying the IS Alignment phenomenon makes it an ongoing or a moving target [22].

To mitigate the difficulties connected to the alignment of Strategy and IT, the business process level perspective is suggested as a vital dimension of analysis by the most cited IS Alignment framework [23] when they identify a suitable contact point between these two opposites [24, 3].

3.1 Common Contact Points and Open Issues: Enterprise Models

With the aim of identifying common traits between major trends in the areas of interest for the present work, we point out the following three elements. First of all, the process dimension of analysis can be seen as a contact point between the two perspectives adopted to investigate organizational impact of IT investments, since IT infrastructure impacts the profitability via business processes.

Consequently there is the need for a common and shared understanding between the business side and the IT side, which are involved in this context [4, 5]. Therefore, an organization might strive to adopt communication tools and mechanisms to create a shared understanding. In particular, modeling methods capable of describing the relationships between the IT Infrastructure and the business process is necessary.

Generally, Enterprise Architectures (EAs) provide the means to foster a common (model-based) understanding of an enterprise. EAs address the problem of IT and business perspective integration, i.e. IT-Business Alignment [25, 26]. In addition to IT related artifacts EAs consider business related artifacts like organizational goals, business units, products and services [26].

An enterprise model is a fundamental constituent of any EA. An enterprise model captures the entities and their relationships from multiple perspectives. Usually a hierarchical approach for modeling an "enterprise" is applied by distinguishing several architectural layers starting with a strategy or organizational layer and then establishing a hierarchy of subordinate layers (e. g. application layer, infrastructure layer). Depending on the modeling concept applied, the models may differ in their degree of formality. In particular, three generic modeling concepts can be distinguished: glossary, meta-models and ontological theories [27]. Among these modeling concepts, ontological theories exhibit the highest degree of formalization. In addition to the model concepts and their relationships (meta-model approach), ontological theories are used to comprehensively specify rules and constraints from the domain of interest [27, 28]. An ontology is commonly referred to as an explicit specification of a shared conceptualization [29, 28] and hence, can be seen as a suitable tool to create a mutual understanding among related actors. In particular, ontological theories allow for a formal analysis, execution and validation of enterprise models as well as for drawing inferences on them. Ontological theories are best suited to describe the most generic enterprise-related concepts and to define the semantics of modeling languages to be employed [27]. Due to their high degree of formalization and their capability to define semantics, ontological theories serve as an ideal means to ensure consistency of enterprise models and to reduce the number of facts to be modeled (due to the formulation of axioms and rules). Enterprise models based on an ontological theory are capable of not only answering queries of what is explicitly represented in the enterprise model (as in the traditional meta-model-based approach) but also answering queries of what is implied by the model [8], therefore allowing for a comprehensive model-based performance analysis.

Despite a considerable variety of different ontologies for individual enterprise-related phenomena, only two ontologies – the Edinburgh Enterprise Ontology (EEO, see [30]) and the TOronto Virtual Enterprise (TOVE, [31]) have been explicitly constructed for the purpose of enterprise modeling [28]. Both approaches considerably overlap in their set of concepts as they both define classes related to organizational aspects, strategy, activities and time. As opposed to EEO, TOVE has been fully translated into a target language and applied within a supply chain management scenario and thus might serve as a core ontology to be extended [28]. Both ontologies conceptualize processes, resource usage and costs. However, they do not introduce IT related concepts. Therefore we aim at conceptualizing IT artifacts and their relation to the business domain. Future research will focus on integrating the existing ontologies with our conceptualization. At the present stage, we only concentrate on conceptualizing the IT part, with the first results of this effort presented in the subsequent sections.

4 The Proposed Ontology

Fig. 3 depicts the structure of the Ontology for Linking Processes and IT infrastructure (OLPIT) indicating its classes (the grey boxes) and their relationships (the arrows). Each box contains the name of the class and its attributes. Sub-classes inherit attributes from super-classes. Inherited attributes are indicated by the (…) notation. This Ontology has been modeled using Protégé and the OWL v. 2.0 language. Due to space limitations we introduce the ontology by only using a graphical representation that aids the understanding of its constructs and their relationships, and describe its semantics in the following text.

The OLPIT builds on the ITIL v3 and COBiT v4.1 frameworks in order to consider best practices in IT management. These frameworks have been used to gain an initial understanding of the key concepts that are relevant in the problem domain and to define a first taxonomy. The taxonomy helped in the identification of a set of classes that was subsequently extended, reviewed and modified on the basis of further insights emerging from evaluation efforts.

In the proposed ontology, the Business Process is the focal point. Business processes can be understood as value interfaces as organizations deliver value to their (internal/external) customers through their business processes. Following the implications of the thought of IS Alignment, the IT infrastructure delivers value to the Business Processes via IT Services. In order to be able to reason the structural relationships between IT components and business processes as well as to reason the course of value consumption (IT cost), our ontology proposes classes and relationships of relevance in the application domain. Starting the description of the ontology from the bottom level, the IT Infrastructure is formed by IT components divided among hardware that can be Physical, Virtual or classified in Groups. A Group can be used to represent a set of hardware entities that are commonly interrelated (like for example a cluster of servers or the total ensemble of network components). In order to make the ontology schema general and not case dependant, IT Components can have extended properties associated to them (e. g. the amount of RAM, the amount of disk space, the amount of cache). IT Components, together with Human Resources, constitute the Resources that are necessary to deliver IT Services.

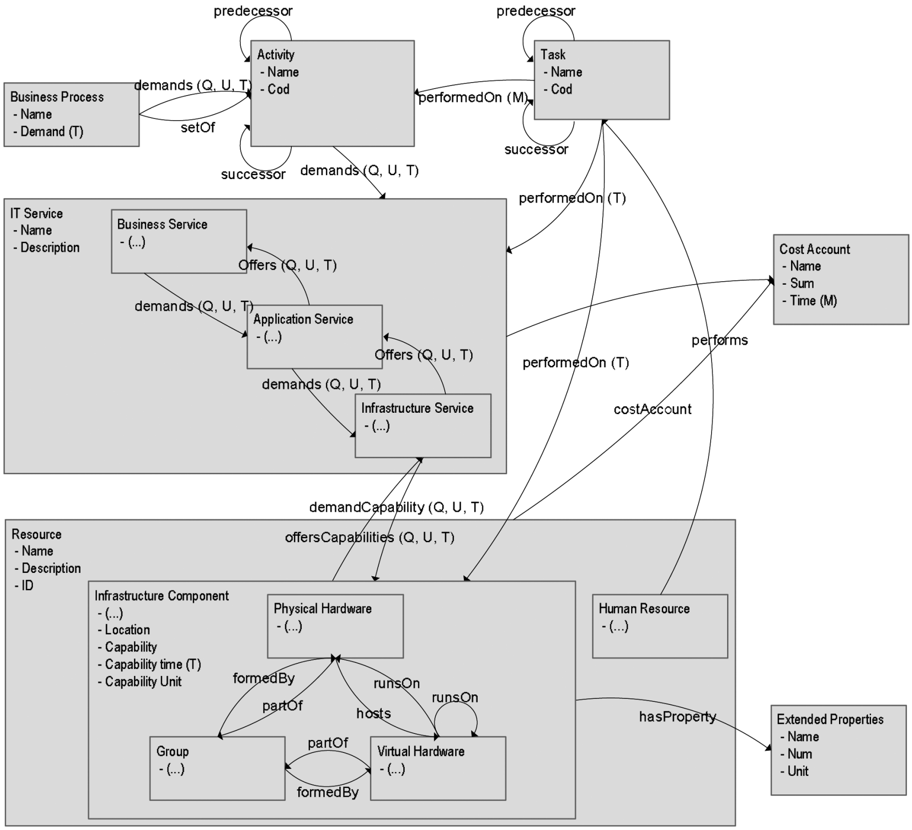

Fig. 3. The OLPIT Ontology schema

IT Services are divided into three categories: IT Infrastructure Service(s), IT Application Service(s) and IT Business Service(s). An IT Infrastructure Service delivers the capabilities of the IT Infrastructure Components to Application Services. Examples of such services could be a network service or a storage service.

An IT Application Service is a service delivered by the functions of specific software. This class is not intended to include all software (e.g. operating systems) in an IT Infrastructure, but only those which are used to deliver services to the business side. Examples of IT Application Services could be e-commerce software, content management software, ERP software and so on.

Finally, an IT Business Service, is a service that delivers value to the customer side (via Activities and Business Processes). Under this perspective, an IT Business Service contributes to the execution of one or more activities in a process. An example of IT Business Services could be a credit card verification service.

A Business Process is defined as a collection of Activities that takes inputs from other resources, manipulates them and produces outputs. Input and outputs may come from, or be directed to, other Business Process(es). An Activity may demand the execution of one (or more) IT Service(s) to deliver value or may require some Task(s) performed by Human Resource(s). Activities and tasks are linked in a chain and can have a predecessor and a successor.

The capabilities of the IT Infrastructure and the demand of the business side are represented in the ontology by means of the quantity (Q), unit (U) and time (T) constructs associated to each demand/offer relationship.

Finally, the proposed ontology models the cost information by means of the Cost Account class. A Cost Account represents a specific cost identified by its name (i.e.: depreciation), an amount (i.e.: € 1.500) and a time (i.e. year). Cost Accounts can be associated with IT Infrastructure Components, IT Services and Human Resources.

5 Test Case

In this paragraph we will introduce an example of the application of the proposed ontology in order to solve three practical problems: the measurement of the IT infrastructure capability on the base of the actual (and future) business demand, the identification of possible points of failures of the IT infrastructure and the cost calculation of a single service. The figures and the process depicted in Fig. 4 (which shows an instance of the OLPIT ontology) are not real, but act as an example.

The process indicated in Fig. 4 is a generic order entry process from an e-commerce website. In this process the customer browses the catalogue (Activity 1),

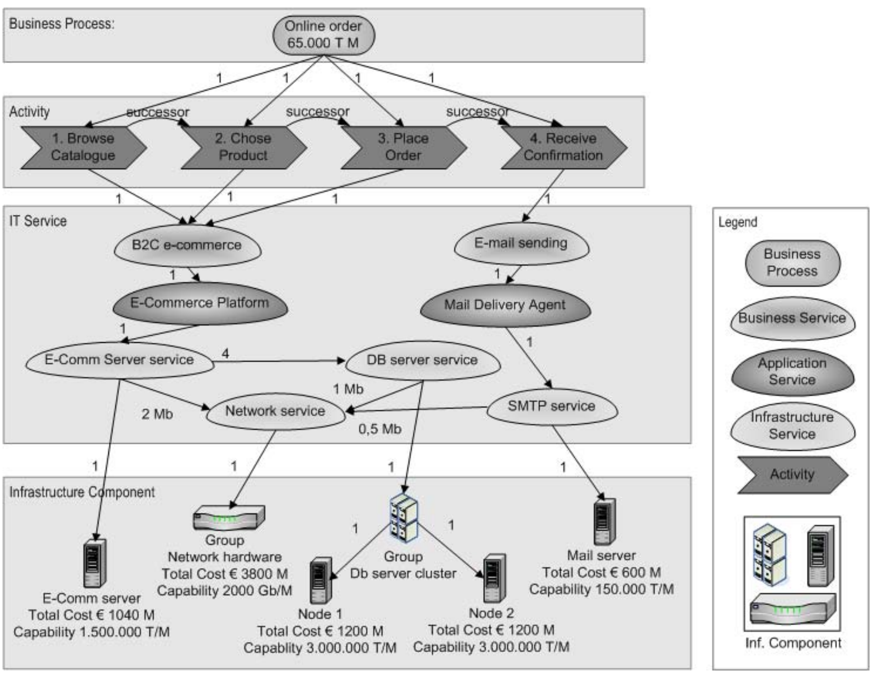

Fig. 4. A Sample Business Process modeled with OLPIT

chooses a product (Activity 2), places an order (Activity 3) and finally receives a confirmation of the order via mail (Activity 3). The business process is executed 65.000 times per month (M). To simplify costs and capability calculations, the time frame is always the month (M). Due to lack of space, costs are directly indicated as total per month per component. Each component has its own capability associated to it: the capability is indicated by a number, a unit and a time frame. For example, the capability of the e commerce server is indicated as 1.500.000 T/M, indicating that this server can offer 1,5 millions Transactions (T) per Month[1].

The numbers that are indicated in the relationships among components specify the demand: the time frame is always the month and, whenever not indicated, the unit is always “Transaction”.

Fig. 4 indicates the network of relationships among all IT Components, IT Services and Activities. This network can highlight which IT Infrastructure Component affects which phase in a business process. The OLPIT ontology can be used to represent the relationship among IT infrastructure with different levels of granularity. In the test case, for example, the network has been modeled as a Group, without going too much into the details.

On the basis of the Capability and the Demand numbers presented in Fig. 4, it is possible to evaluate the balance between IT Infrastructure Capability and IT Business demand. The actual used capability of the IT infrastructure is estimated by multiplying the demand of the business side with all the factors of the relationships among the classes of the ontology and, afterwards, summing up all the demands that belong to the same Infrastructure Component. The maximum capacity of the IT Infrastructure can therefore be evaluated maximizing the function composed by the sum of all the capacity of each component multiplied by each factor: for this test case the maximum capacity of the infrastructure is close to 83.000 executions of the “Online order” process per month.

Fig. 5 (left side) shows the actual capability (C) of the infrastructure, as well as the actual request from the business side (D). If we move from a static scenario (Fig. 5 left side) to a dynamic scenario (Fig. 5 right side), and hypothesize that the total demand increases at a constant rate (0,5% each month in this example) from the point in time t_0 time it is possible to notice that the IT Infrastructure will no longer be able, ceteris paribus, to fulfill business needs at the time t_1 (49 months later).

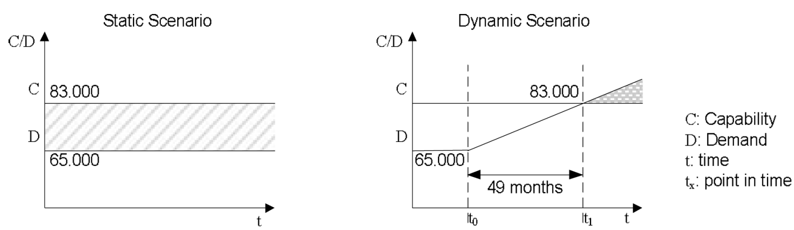

Fig. 5. IT Infrastructure capability evaluation: static and dynamic scenario

[1] In this context we use the word “Transaction” to indicate a generic request made by a service to a component: as a matter of example, a transaction for the DB server could be a query, and a transaction for the mail server could be a mail message to be sent.

Furthermore, using the capability and the demand values modeled in the ontology, possible bottlenecks can be identified. The "Usage %" column in Fig. 6 shows the actual percentage of used capacity of each IT infrastructure component. Looking at the percentages it is possible to identify the components that are about to run out of capacity (in our example, the network, with a usage percentage of 78,29%).

IT Services Cost Calculation – Service: B2C e-commerce							
Item	**Class**	**Request M**	**Capability M**	**Unit**	**Usage %**	**Total Cost M**	**Unitary Cost**
B2C e-commerce	IT Business Service	195.000		T/M		€ 7.137,30	€ 0,0355
E-Commerce Platform	IT Application Service	195.000		T/M		€ 7.137,30	€ 0,0355
E-Commerce Server Service	IT Infrastructure Service	195.000		T/M		€ 1.040,00	€ 0,0045
Database Server Service	IT Infrastructure Service	780.000		T/M		€ 2.400,00	€ 0,0020
Network Service	IT Infrastructure Service	1174,32		Gb/M		€ 3.697,30	€ 0,0038
E-Commerce Server	IT Infrastructure Component	195.000	1.500.000	T/M	13,00%	€ 1.040,00	€ 0,0045
Db Cluster	IT Infrastructure Component						
- Node 1	IT Infrastructure Component	780.000	3.000.000	T/M	26,00%	€ 1.200,00	€ 0,0010
- Node 2	IT Infrastructure Component	780.000	3.000.000	T/M	26,00%	€ 1.200,00	€ 0,0010
Network Hardware	IT Infrastructure Component	114,32	1.500	Gb/M	78,29%	€ 3.800,00	€ 0,0227
Total demand (M)	65.000						

Fig. 6. IT Service total cost calculation

Finally, the cost information modeled with the ontology enables the reconstruction of the total cost of each service. By means of an example Fig. 6 shows costs associated with each component. The total cost of the services is the total sum of all the costs of the components that belong to it. For shared services (like the network in our case), the cost is divided on the base of the total usage. In the example, the total cost of the Network Hardware is equal to € 3.800 but the actual cost of the Network Service (which will be part of the total cost of the B2C e-commerce service) is only € 3.697,30 (a quota calculated on the basis of the amount of network traffic generated by this service). The other quota forms the total cost of the "E-Mail sending" business service, not covered in this example.

6 Conclusion

In this paper we focused on the organizational impact of IT management adopting a value perspective. As a first result of an ongoing research we introduce an ontology that links IT management to the business process level. The proposed ontology is based on a lean set of classes and, according to our opinion, forms a good base for future extensions. The testing section of this paper demonstrates practical problems that can be solved by means of our ontology.

A current limitation of our approach is the limited number of test iterations our ontology has undergone. Since this is the first result of an ongoing research, our ontology has been tested with experimental data only, and only a small part of them is currently used in the real context.

A further limitation deals with the value perspective adopted, because we are only addressing the passive side of the financial cycle (only costs). Nevertheless, since we decided to adopt an ontology based approach due to the possibility of integration of different ontologies, we can now think about integrating our ontology with others available and in doing so address the positive side of the financial cycle. For these reasons, future research will be addressed to fully test the proposed ontology in a real context and to evaluate its possible integrations with existing (and related) ontologies for enterprise modeling.

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