Modeling Enterprise System Adoption: An Ontology-based Approach

Completed Research Paper

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Abstract

This paper seeks to model enterprise system (ES) adoption using an ontology-based approach. The main contribution of the research is the elaborated comprehensive ontology which encompasses key stakeholders, adoption considerations, and relationships between the components. The ontology was designed on the basis of literature review, hands-on experience, and empirical data gathered among more than a hundred enterprise system implementation projects in Poland. Possible applications of the ontology include comparison of different ES implementation projects, discovering critical areas of ES projects, and ES implementation evaluation.

Keywords

Enterprise systems, ontology, adoption, modeling.

Introduction

An enterprise system (ES) adoption issues have been under investigation for more than two decades (e.g. Billing et al. 2007; Olson & Staley 2012). Researchers focused on various aspects of this process such as business modeling, motivations, critical success factors, barriers, problems, and evaluation of success and benefits (Ehrig et al. 2005; Esteves & Pastor 2001). Nonetheless, extant research suggests that researchers tend to deal with various considerations of ES adoption separately and do not employ a holistic, integrative approach (Esteves & Bohorquez 2007; Soja 2011).

In consequence, since prior works lack comprehensive approach to ES adoption investigation, it is difficult to gain a deep, multifaceted insight into ES implementation considerations. Therefore, this study seeks to fill this research gap and to provide the readers with a rich picture of ES adoption (Skok & Legge 2002). This could be achieved by using ontology-based approach since ontologies are built mainly "to make domain assumptions explicit, to separate domain knowledge from the operational knowledge, to analyze domain knowledge" (Noy & McGuinness, 2001, p.1). To this end, the authors propose an ontology that captures key stakeholders of enterprise system adoption process, the main aspects of ES adoption evaluation, and relationships between them. The general research question addressed in this paper might be formulated as follows:

- How ontology-related approach can benefit enterprise system adoption modeling?

This paper starts with research background that presents the previous attempts to modeling enterprise, the concept of ontologies, and their applications in enterprise system modeling. Then, the methodology of developing the ontology and the preliminary ontology are described. Next, the discussion of potential applications is presented. Finally, limitations and paths for future research are outlined.

Research Background

Enterprise Modeling

Enterprise modeling (EM) is a central activity in enterprise engineering and enterprise integration (Berio & Vernadat 2001) and sometimes is even perceived as the most important element in the design of next-generation enterprise systems (Dalal et al. 2004). EM is concerned with representing the structure, organization and behavior of a business entity or of a group of enterprises to evaluate its performances or reengineer its material, information or control flows in order to make it more efficient (Berio & Vernadat 2001).

Dalal, Kamath, Kolarik and Sivaraman (2004) emphasize a number of challenges connected with enterprise modeling. These challenges are related to building holistic process models that link business and technical parameters, integrating—semantically, logically, and physically— process submodels created by distributed users; linking descriptive models to underlying formal analytic models; and linking process models with the overall logic of enterprise systems. Further, Esteves and Bohorquez (2007) emphasize the need for holistic and interdisciplinary research in ES-related field.

In general, it is advised that companies reengineer their processes to fit the ERP (Enterprise Resource Planning) system characteristics and keep customization of the system to a minimum. In consequence, ERP modules have to take into account requirements of processes for specific businesses and, on the other hand, they should also be flexible enough to be implemented in different industry. To satisfy this requirement, ERP vendors have developed reference models, where industry processes and best practices are encompassed. As a result, reference models may ease the implementation stage and lead the company to more efficient business process reengineering (Bertoloni et al. 2004).

Skok and Legge (2002) nicely modeled ES adoption considerations and their potential interrelations in a form of rich picture. In doing so, they identified the following main parties/stakeholders of ES implementation process: Management, Users, Consultants, and Developers. Further, the authors emphasized the potential conflicts of interest between the identified stakeholders.

A wide range of research deals with critical success factors (CSFs) of ES implementation (Finney & Corbett 2007). Among a variety of approaches to CSFs, those attempting to model interrelations and potential mutual impact of CSFs deserve special attention from the perspective of enterprise modeling. With this respect, Somers and Nelson (2001) proposed a list of critical success factors that was later thoroughly tested on empirical data by Akkermans and Helden (2002).

Prior literature suggests that there is a scarcity of research on enterprise modeling in the context of ERP adoption (Esteves & Bohorquez 2007). The particular areas where more research is needed include the improvement of business modeling techniques, analysis of business models' fit, and adequacy of ERP systems to business models.

Ontologies

Ontologies in philosophy refer to studies of the nature and structure of reality as it was defined firstly by Aristotle (Guarino et al. 2009). However, the term "ontology" was coined in seventeenth century (Øhrstrøm et al. 2005). It was then adopted by computer science domain where the definition of ontology as "an explicit specification of a conceptualization" introduced by Gruber (1993) is the most cited one. Conceptualization is perceived as "an abstract, simplified view of the word that we wish to represent for some purpose" (Gruber 1993, p.199). The "explicit" notion requires that ontology should be coded in a formal, transparent way. In practice, ontologies comprise a basic vocabulary for a certain domain with recorded semantics. Hence, they can be automatically processed by computers and be understandable by computers.

From a formal point of view, ontologies belong to a graph knowledge representation models. They consist of a set of concepts from a certain domain called classes, a set of relationships between these classes, and a set of class attributes. Some researchers perceive ontologies as a structure that contains also instances, that is objects described by ontology (Ehrig et al. 2005). The World Wide Web Consortium standard language for ontology representation, OWL (McGuinness & van Harmelen 2004), is based on description logics, which facilitate the possibility of automatic reasoning. Therefore, on the basis of facts recorded/written in an ontology the new facts can be revealed.

Currently, ontologies are used mainly in knowledge based systems, to represent the knowledge from a certain domain and facilitate semantic interoperability (García & Pariente 2009; Gonçalves et al. 2011), multi-domain knowledge sharing (Liu et al. 2011; Rezgui et al. 2011), and business modeling (Kang et al. 2010; Spies 2010).

Ontologies in Enterprise Modeling

The idea of ontology usage to model an enterprise emerged in the nineties of the last century, when the term Enterprise Ontology was coined. Specifically, Uschold, King, Moralee and Zorgios (1998) defined the Enterprise Ontology as "a collection of terms and definitions relevant to business enterprises" (p.31). Further, Fox and Gruninger (1998) developed a comprehensive model of an enterprise in the form of the TOVE (TOronto Virtual Enterprise) ontology. Other approaches to model the whole enterprise included (Dietz 2006), (O'Leary 2010), and there emerged also conception of modeling of some specific domains of enterprise activities, including life cycle management (Matsokis & Kiritsis 2010), supply chain modeling (Grubic et al. 2011; Ye et al. 2008), accounting (McCarthy 1982), products descriptions (Lee et al. 2009; Vegetti et al. 2011), and ERP project description (Macris 2011).

Prior studies also concentrated on developing conceptual models of using ontologies in enterprise applications (Motik et al. 2002). The issue of ontology applications in ES adoption has been previously investigated by Rosemann, Vessey, Weber and Wyssusek (2004) who, on the basis on the Bunge-Wand-Weber Ontology (Weber 1997), developed an ontology that formalizes the requirements for the information systems. This ontology can be used to measure the alignment of ES to enterprise expectations and demands, adopting the idea of ontology distance defined by Rosemann, Vessey and Weber (2004). Further, Nach and Lejeune (2008) on the basis of the literature review identified 395 terms associated with implementation of ERP systems in small and medium sized enterprises (SMEs) and organize them in a form of an ontology. Next, Peng and Nunes (2009; 2010), following the same research method (literature review) proposed the 'barrier and risk ontology' of ES implementation that proved useful in the identification of the relationships between barriers and risk in Chinese companies.

The review of extant literature suggests that despite various attempts to ontology-based enterprise modeling, a complete, holistic approach is missing. To the best of the authors' knowledge, at the moment there is a lack of a comprehensive ontology, which is based on empirical data and describes an enterprise system implementation process.

A Proposition of an Ontology of Enterprise System Adoption

Methodology of Ontology Building

The process of ontology building can be characterized as a combination of top-down and bottom-up approaches. In general, it can be perceived as a two-phase process encompassing both building conceptual models and discovering issues that emerge from empirical data. The process described has been a long-term research and this paper attempts to summarize its current outcome.

In the first phase, on the basis of prior literature review and the authors' professional experience in the enterprise system adoption domain, the conceptual model of main concepts/classes of enterprise system implementation project and their attributes were formulated. The analysis of prior research resulted in the formulation of main dimensions that should be covered by the model, such as project participants/stakeholders, success, adoption scope, benefits, and barriers. These concepts have been captured by classes of the ontology and next relationships between the proposed classes were defined. Additionally, the classification of implementation project phases elaborated in (Cooper & Zmud 1990) was incorporated into the proposed ontology in order to capture the system lifecycle-related dynamics.

The second phase of the process was data-driven. In particular, on the basis of empirical data, benefit- and problem-related parts of the ontology were developed. These data where obtained from a survey conducted among Polish practitioners who expressed their opinions about ES implementation projects. The classification of problems was elaborated on the basis of the opinions of 82 respondents from 65 ES implementation projects and was introduced in (Soja & Paliwoda-Pękosz 2009). Problem subclasses emerged as a result of grounded theory approach and an iterative open coding procedure (e.g. Corbin & Strauss 1990; Strong & Volkoff 2010). The solution being developed in this study draws also from the ontology of ES benefits which was built on the basis of 164 interviews among 137 ES adoption projects (Soja & Paliwoda-Pękosz 2013).

The Ontology

The main objectives of the proposed ontology are the following:

- to describe key stakeholders of an ES adoption process and make visible relationships between them,
- to model considerations of an ES adoption.

In order to achieve these goals the classes and attributes presented in Table 1 were defined. The list of classes starts with the class whose instances will represent adoption projects. These projects are implemented in certain companies, are supported by a system provider, and involve a number of stakeholders. Each stakeholder has his/her own perception of the implementation project and can evaluate ES implementation success in terms of her/his subjective satisfaction connected with information needs, system efficiency, system effectiveness, and overall satisfaction with the system (e.g. Seddon & Kiew 1994). Additionally, project success can be measured with the use of attributes whose values are counted on the basis of data stored in instances of classes ProjectDuration, ProjectBudget, and ProjectScope. Finally, the last three classes, refined by sets of subclasses, allow us to categorize project phase, problems encountered during adoption, and project benefits.

Class	Description	Attributes
AdoptionProject	description of an adopted system	• name (name of the system) • origin (possible values: “local”, “global”)
Company	basic company data	• numberOfEmployees • industry • revenues
Provider	description of the system and implementation service provider	• name • type (possible values: “local (national)”, “global”) • yearsOfExperience • rangeOfServices (portfolio of services)
Stakeholder	description of stakeholders involved in the project	• department • currentWorkExperience • overallWorkExperience • stakeholderRole (possible values: “member” (of the project team), “project manager”, “supervisor”, “user”, “none” (lack of participation)) • position (possible values: “specialist”, “manager”, “director”, “top management”, “n/a”),
StakeholderSuccess	evaluation of project success/benefits according to a certain stakeholder	• meeting information needs • system efficiency • system effectiveness • overall satisfaction with the system These attributes are evaluated by a stakeholder on the

		Likert scale 1-7. The average of their values gives a measure of a system implementation success perceived by a stakeholder.
ProjectSuccess	description of overall evaluation of implementation project success using three dimensions: budget, time, and scope	• relativeBudget • relativeDuration • relativeScope Values of these attributes will be counted on the basis of attributes defined for classes: ProjectBudget, ProjectDuration, and ProjectScope, i.e. relative=planned/actual.
ProjectDuration	information about planned and actual project duration time	• monthsOfProjectDurationPlanned • monthsOfProjectDurationActual
ProjectBudget	information about planned and actual project budget	• plannedBudget • actualBudget
ProjectScope	description of a planned and actual scope of the project	• numberOfDepartmentsPlanned/numberOfModulesPlanned (a number of company departments/modules that were planned to be influenced/introduced during ES adoption) • numberOfDepartmentsActual/numberOfModulesActual • departmentListPlanned/modulesListPlanned • departmentListActual/modulesListActual (a list of departments/modules that were influenced/introduced during ES adoption)
ProjectPhase	contains a set of subclasses that represent project phases	• monthsFromStart (number of months after the start of implementation project) • monthsFromRollout (number of months after the start of new system operation)
Problem	contains a set of subclasses that represent the classification of problems	• problemDescription • sourceProblem (possible values: Yes, No)
Benefit	contains a set of subclasses that represent the classification of benefits	• benefitDescription • timeOfRealisation/numberOfMonths (number of months from the start after which the benefit was revealed)

Table 1 Ontology classes with attributes

The classes in the ontology are connected via relationships. These relationships are presented in Figure 1. It is important to note that for every depicted relationship an inverse relationship exists. However, this has not always been shown in order to make the graph clearer. In particular, the class Stakeholder is in the relationship *perceives* (inverse relation: *isPerceivedBy*) with the class Benefit that means that some stakeholder (formally an instance of the class Stakeholder) can perceive certain benefit that is an instance of the class Benefit. Inversely, some benefit (formally an instance of the class Benefit) is perceived by a stakeholder that is an instance of the class Stakeholder.

Following the same pattern, the class AdoptionProject is connected with the class Stakeholder via relationship *involves* (inverse relation: *isInvolvedIn*), with the class ProjectSuccess via relationship *hasEvaluationOf* (inverse relation: *isEvaluationOf*), with ProjectScope via *hasScope* (inverse relation: isScopeOf) and finally with the class Company via relationship *isImplementedIn* (inverse relation: *implements*).

The class Benefit is in the relationship *subClassOf* (inverse relation: *isA*) with eight subclasses (Figure2). In the same vein, the class Problem has nine subclasses (Figure 3), and the class ProjectPhase has six subclasses (Figure 5). Further, the relationships between problems that might appear when one problem caused other problem are depicted in Figure4.

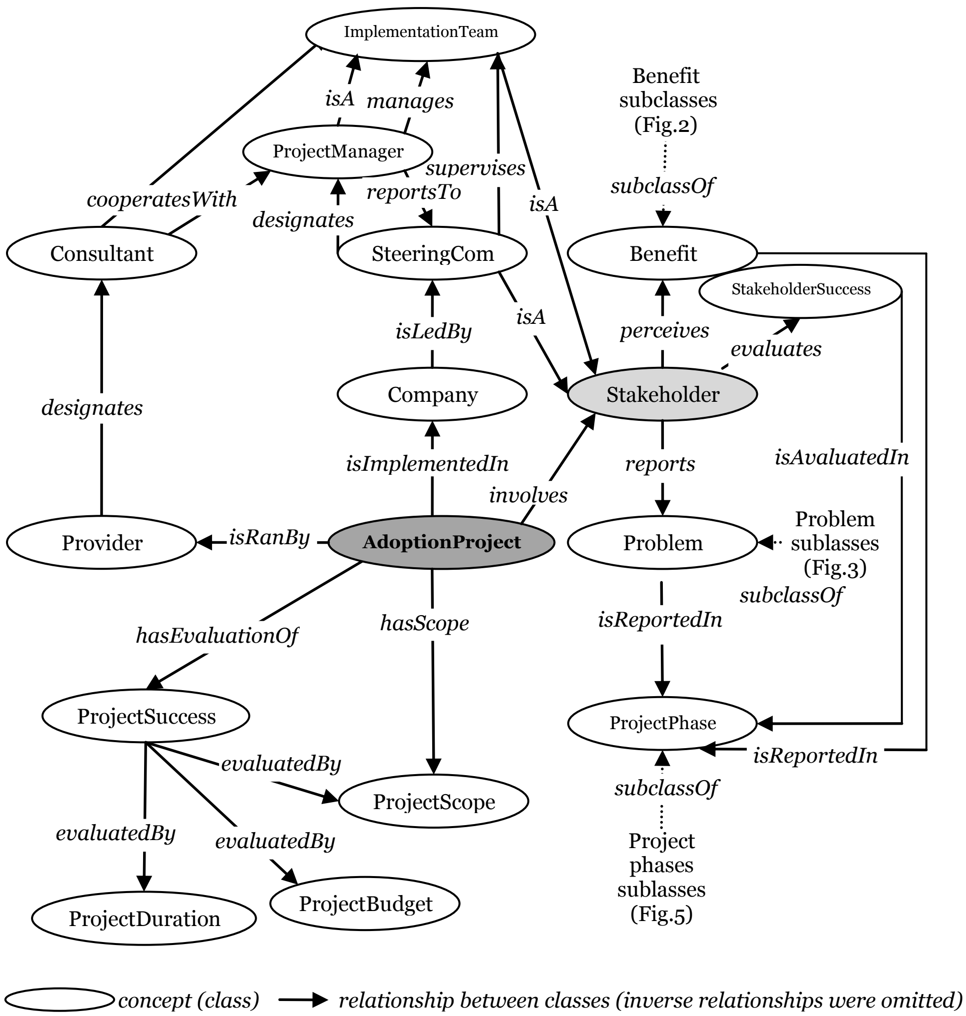

Figure 1 A proposed (preliminary) ontology of enterprise system implementation

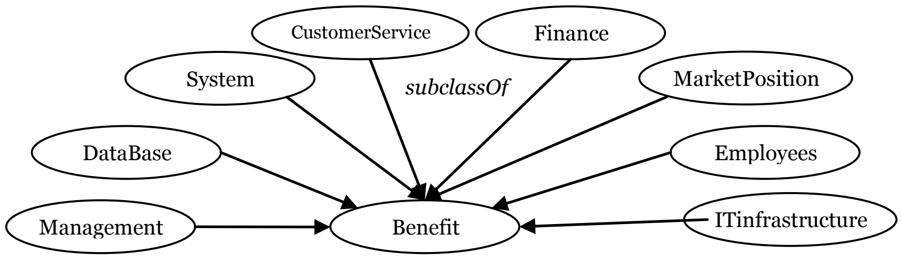

Figure 2 Subclasses of the class Benefit

Source: based on (Soja & Paliwoda-Pękosz 2013).

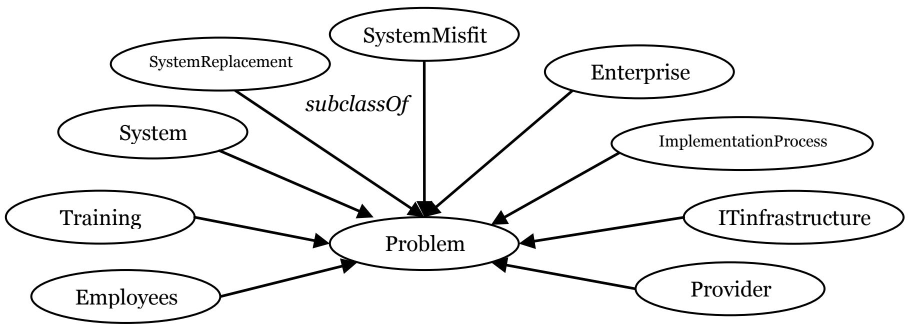

Figure 3 Subclasses of the class Problem

Source: based on (Soja & Paliwoda-Pękosz 2009).

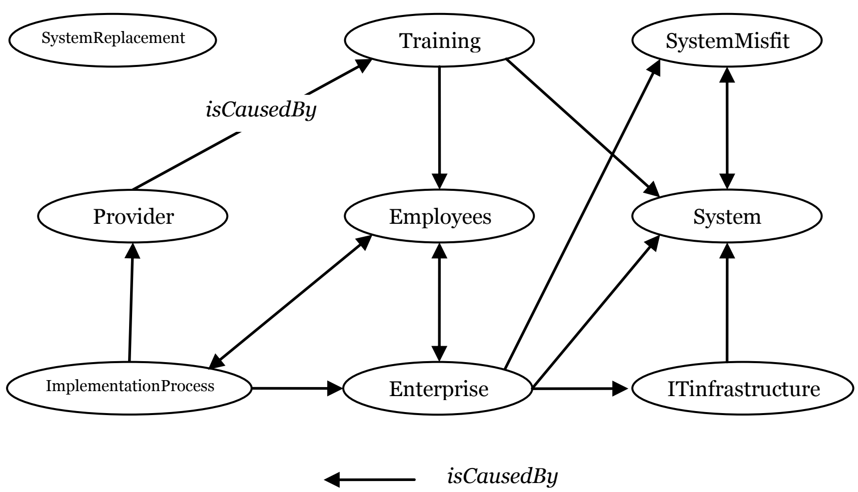

Figure 4 The relationships between class problems

Source: based on (Soja & Paliwoda-Pękosz 2009, p. 617).

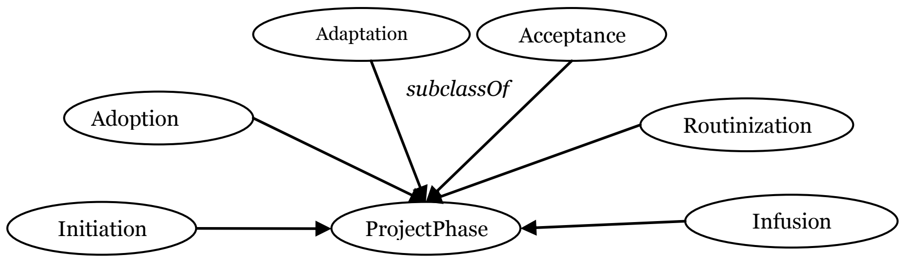

Figure 5 Subclasses of the class ProjectPhase

Source: based on (Cooper & Zmud 1990).

Example of ES implementation project description

Figure 6 illustrates a possible usage of the ontology to define an ES implementation project. Due to limited space, in the example the part of the ontology concerning stakeholders and benefits is depicted. One instance of the class AdoptionProject was created that represents an implementation project in a utility company. Two stakeholders involved in the implementation project recognized benefits from DataBase and Management categories.

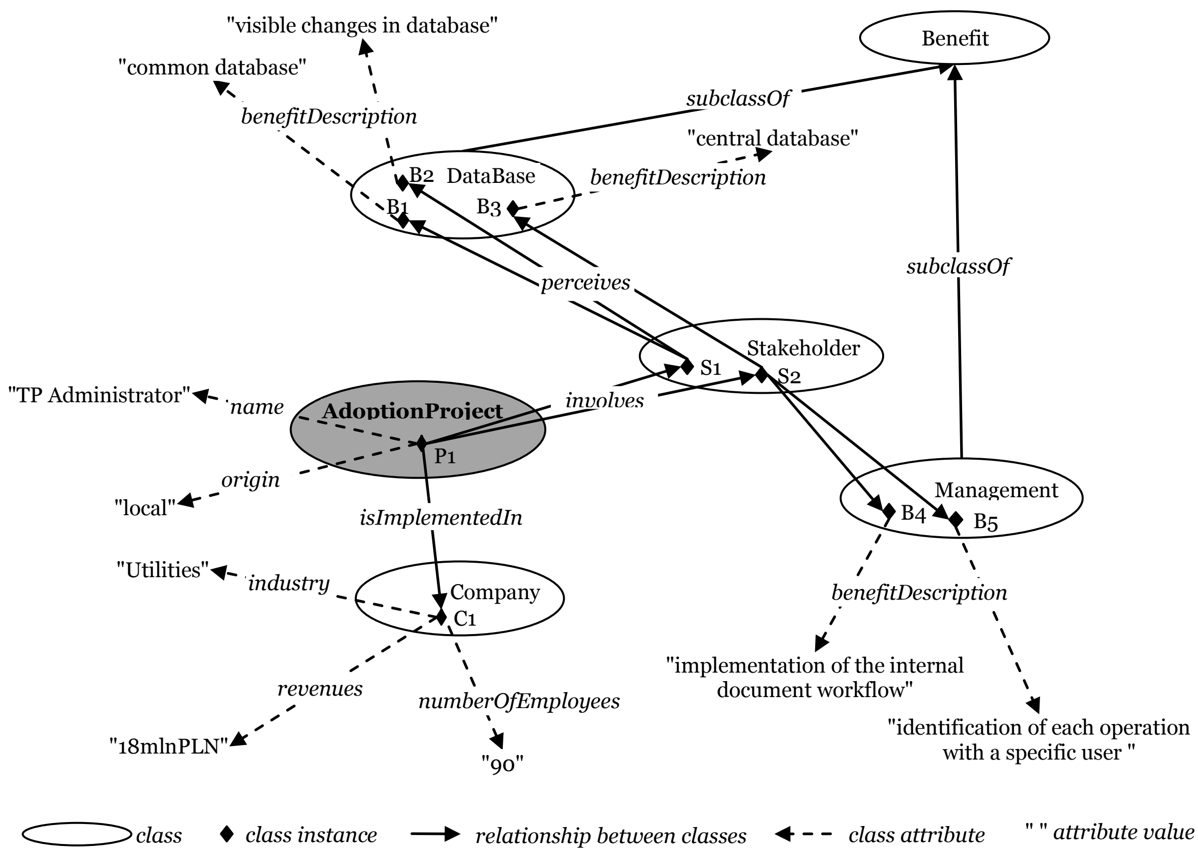

Figure 6 An example of enterprise system implementation project description

Discussion

Overview and Implications

The proposed ontology is a starting point for a comprehensive modeling of enterprise system implementation. It defines main stakeholders of ES adoptions and makes explicit relationships between them. Further, this ontology facilitates a complex analysis of ES implementation project, including evaluation of project success, encountered problems, and perceived benefits. In this way, the researchers and practitioners may gain a deep insight into the performance of ES adoption and efficiency in overcoming impediments.

The proposed preliminary ontology seeks to capture the most important considerations of ES adoption projects. It is worth noting that, apart from building a static model of ES adoption, the ontology tries to depict the project dynamics. In doing so, the ontology incorporates the project lifecycle and attempts to describe problems and benefits in time. Such an approach is important since, as suggested by prior research, ES adoption benefits require time to accrue (Legare 2002) and companies usually experience performance dip after the new enterprise system start (Ross & Vitale 2000).

Another interesting issue set forth by the proposed ontology refers to the credibility of the provider of the enterprise system and implementation services. With this respect, the ontology suggests the distinction between global, multinational companies and local, national providers. This distinction draws from the findings of Dobija, Klimczak, Roztocki and Weistroffer (2012) who, analyzing stock market reaction to ICT (Information and Communication Technology) investment announcements, conclude that investments involving well-established providers with good reputation are better estimated by the stockholders.

In general, while discussing the implications of the proposed ontology, we might indicate a range of possible applications of the model. In particular, possible areas of applications of the ontology include:

- description of implementation projects using a complete set of concepts,
- comparison of different implementation projects; finding similarities between implementation projects (ontological similarity measures),
- clustering of implementation projects,
- discovering critical phases of an implementation projects,
- automatic generation of surveys for the use of organization diagnosis and project feasibility appraisal,
- supporting evaluation of ES implementation project on the basis of automatic extractions/matching of respondents answers in open-ended questions to concepts in ontology,
- extracting characteristics/parameters of successful implementations (benchmarking).

In order to facilitate abovementioned possibilities, implementation projects need to be described as instances of the proposed ontology. To some extent, this process can be done automatically with the use of tools that transform data from relational databases to RDF format, e.g. RDBToOnto (Cerbah 2008) or tools that automatically populate ontology from text, e.g. GATE (Cunningham 2002). Further analysis of ontology-described data can be performed with support of a variety of tools, e.g. OBCAS (Tuchowski et al. 2011) designed specifically for assessing similarities between objects described by ontology.

Results Scope

This paper is based on empirical research conducted among Polish practitioners, which might raise some interesting issues connected with the transferability of the results to other countries. This is related with the fact that Poland is a transition economy, i.e. an economy in transition from communist style central planning to a free market system (Roztocki & Weistroffer 2011) and extant research suggests that ES adoptions in transition economies may differ from those conduced in highly developed countries with reference to a number of aspects. In particular, prior literature reveals that ES adoptions in transition economies are characterized by lack of strategic approach (Ketikidis et al. 2008; Soja 2011; Soja &

Paliwoda-Pękosz 2013), greater problems with planning activities and resources (Soja 2008), greater impact of people and their roles (Soja & Paliwoda-Pękosz 2009; Themistocleous et al. 2011), and expected higher levels of external support (Bernroider et al. 2011; Soja 2010).

In consequence, we should generalize the results for other countries or regions with caution. In general, we might put forward that the scope of this study's findings should cover first and foremost organizations from Poland and other transition economies from Central and Eastern Europe, i.e. countries which belonged to the Communist Bloc after the World War II but recently joined the European Union and are now undergoing economic transition. Nevertheless, the proposed approach seems to be open and flexible enough to capture differences imposed by different economic contexts.

Another issue is connected with the evolution of enterprise systems and the fact that they are now becoming inter-organizational solutions exchanging data with external entities such as customers and suppliers. Such a situation may impose new requirements on the proposed model, which might be connected with redefinition of several classes such as Stakeholder, Provider, or ProjectScope. Although the presented model is already prepared to capture multiple stakeholders of ES adoption, the growing importance of inter-organizational character of contemporary enterprise systems might result in the introduction of new classes to the ontology.

Limitation and Further Research

The main limitation of the current research is connected with its exploratory character and the fact that the proposed ontology has not yet been used in practical applications. Although some main possible areas of its usage were indicated in the previous section, real-life application tests remain for further work. In addition, the ontology is based mainly on data that came from enterprises that operated in Poland. However, it can be further extended in the direction of incorporation of other views on ES implementation that can be retrieved from research works conducted in different economic contexts. Specifically, other classification of benefits and problems can be easily added and equivalence relationships between existing classes can be defined.

Overall, the ontology should be perceived as a preliminary version of a comprehensive ES implementation ontology. In the current version it does not include several important determinants of ES adoptions such as motivations for ES implementation, barriers, and critical success factors. Furthermore, external stakeholders should also be incorporated as the current version of the ontology covers mainly internal stakeholders. These issues were left for future work. In future research the authors would like also to concentrate on upgrading the presented ontology to the emerging models of cloud computing enterprise systems and new considerations connected with these models.

Conclusion

The paper addresses the issue of using ontology to model an enterprise system implementation. The proposed ontology is based mainly on the empirical data gathered from implementation projects conducted in Poland, literature review and the authors' professional experience. Specifically, it reveals the main components of ES adoption (e.g. AdoptionProject, Company, Stakeholder, Provider, Problem, Benefit) and relationships between them (e.g. isImplementedIn, isLedBy, isRanBy). From the formal point of view these components are defined as classes of ontology. The application of such an ontology in describing ES implementation brings a number of benefits, including a clear visualization of the main considerations and their mutual relationships. Also, the applied approach allows the researchers to use the tools designed for automatic analysis of knowledge described via ontologies. Hence, various aspects of benchmarking can be supported and enhanced.

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