ABSTRACT
The Semantic Business Process Management (SBPM) aims at automation of the Business Process Management life cycle with use of semantics and Semantic Web services technology. The key issue to fulfil this aim is to provide an adequate machine-processable representation of processes. In this article we present one of the most important elements of process description, namely the organizational ontologies. Moreover, we discuss their role in the early phases of SBPM and illustrate it with a set of application scenarios.

Categories and Subject Descriptors
I.2.4 Knowledge Representation Formalisms and Methods: Representations.

General Terms
Design, Economics, Languages

Keywords
Semantic Business Process Management, organisational ontologies, application scenarios

1. Introduction
Business Process Management (BPM) includes methods, techniques and tools to support modelling, implementation, execution and analysis of business processes [23]. Nowadays, BPM is often combined with the Service Oriented Architecture (SOA) paradigm, as together these two approaches offer additional benefits. While BPM specifies business directions, goals and processes that define how the organizational resources (including IT resources) are used to achieve business goals, SOA offers a flexible IT architecture that may be easily adapted to changing business requirements and helps to leverage IT investments through provision of reusable components [19].

Although BPM together with SOA are believed to provide a comprehensive approach to manage business processes in an enterprise, currently the duet offers only little support for automation of the BPM lifecycle. It is especially apparent when it comes to smooth (automatic) transition from one phase of the lifecycle to another. For instance, the automatic transition from the modelling to implementation is impossible due to insufficient technical description of a process provided by a business analyst, resulting from different perceptions of a process held by a business expert and an IT engineer. Similar problems may be also observed in other transitions, e.g. when the execution data (low level technical data) needs to be presented to a business analyst in order to allow for process re-engineering.

Another important issue in business process modelling is caused by the freedom that business analysts have to name and describe process artefacts. Current business process modelling tools support neither restricting names nor using ontologies to describe process artefacts. Business experts when modelling processes often: use the same term with a different meaning (homonym); use different terms for the same concept (synonym); use inappropriate expressions. In addition, different definitions of the same term may be used by various business analysts i.e. process creators. This leads to the fact that the modelled business process is fully understandable only to its creator. Furthermore, if multiple roles are involved in process modelling, they often use terms at different abstraction levels what results in non-consistent process models that are difficult to compare. In addition, if one would like to translate a business process model into another language, for instance from English to German, more problems would appear. Some terms are recognized as synonyms and the proper meaning of homonyms cannot be identified. Also, subtle differences in wording are very hard to translate.

The research community postulates that an unambiguous and technically-sufficient description of processes modelled by business analysts could allow not only for assuring its common understandability and comparability, but also for their automated implementation which could decrease the effort of IT engineers required to implement the process, and in consequence lower costs of implementation of processes in general. This issue motivates further research in the area of the BPM lifecycle automation.

The research on combining BPM and SOA, and ensuring the appropriate level of automation, is conducted by several research
groups working in a European consortium SUPER\(^1\). The main aim of SUPER is to bridge the gap between business and IT worlds and enable at least semi-automation of the BPM lifecycle. The automation would enable shortening the implementation time and allow increasing the flexibility of enterprises understood as a quick adaptation to changes in business environment as well as customers’ preferences. In order to fulfill this aim, the use of semantic technologies within the BPM lifecycle, namely a concept of Semantic Business Process Management (SBPM), was proposed [11].

In order to implement SBPM, a few requirements need to be met. First of all, the main artefacts used within the BPM and SOA life cycle need to be semantically annotated and adequate interactions operating on these artefacts need to be defined. Therefore, as the main concept of SOA is a service, the Semantic Web services technology is utilised. Similarly, as a process is the core concept of BPM, the main semantic enhancements of BPM concern the description of processes, i.e. the description of control flow of a process as well as description of its content. By process content we understand all artefacts that a process definition may refer to and that specify the business environment and organizational context of the process.

The main goal of this article is twofold. First, the goal is to present the notion of organizational ontologies being a part of the semantic process representation for the needs of SBPM and aiming at providing vocabulary and constraints for describing the environment in which processes are carried out from the organizations’ perspective. Second, the goal is to demonstrate how the organizational ontologies may be used to support SBPM.

In order to fulfill the defined aims, the article is structured as follows. Firstly, the related work in the area of representation of a process and process artefacts is discussed. In the following section the idea of SBPM is presented. Then, the description of ontology stack for the needs of SBPM based on the example of SUPER follows. Finally, organizational ontologies are presented, along with scenarios showing their possible application. In the last section, conclusions and insight into the future work are given.

2. Related work
The process content depends on an organisation and its characteristics. Many researchers focused on development of models cataloguing an appropriate scope of information on companies that should be considered when describing organizations or their processes e.g. [4, 13, 24].

The mentioned initiatives focused not only on the scope of information to be considered, but also on how it should be represented. In the last few years there have been numerous initiatives attempting to capture the process-related, and in consequence also organization-related, information in a machine-friendly manner. Most of them focused on possible application of semantics, as ontologies were, and still are, perceived as a good way to capture the domain along with its relations, and in consequence bridge the gap between business and IT worlds [6, 10, 5, 22, 3, 2]. These various initiatives differ when it comes to the scope of the process description they intend to cover, the level of details of the ontology created, as well as the formalism used.

One of the earliest initiatives was the TOVE project [7] that aimed at development of a set of integrated ontologies for modelling all kinds of enterprises (i.e. commercial and public ones) [6]. TOVE Common Sense Model of Enterprise included three levels: reference model with typical business functions (finance, sales, distribution, and administration), generic model (with such concepts as time, causality, space, resources), and concept model (e.g. role, property, structure). However, the granularity of developed ontologies may be perceived inconsistent and that hampers their potential application.

The REA enterprise ontology [8], based on elements of the REA (Resource-Event-Agent) model, theoretical background of which comes from the field of microeconomics [18], is a specification of the semantics involved in a business process. The REA concepts and definitions are applied to the collaborative space between enterprises where the market exchange among two or more trading partners occurs. Although this ontology is considered to be one of the most promising business domain ontologies, a lack of a commonly accepted formal representation makes it useless for practice. Moreover, it is criticized for the lack of clarity and inconsistencies [14].

The main aim of the e3-value project [9] was to propose the methodology to help in eliciting, analyzing, and evaluating ecommerce ideas. Therefore, the e3-value ontology was introduced as a tool to help explaining the concepts used to represent e-commerce ideas. The ontology provides concepts for describing economic exchange among partners. Other e3-value extensions like e3forces, e3competences should be of particular attention as they intend to model more advanced organizational aspects.

In another work [15] a contextual approach to ensure high flexibility of the enterprise ontology was proposed. The context involves seven domains: purpose, actor, action, object, facility, location, and time. The enterprise ontology provides a unified view of the enterprise as an aggregate of these domains. This ontology can be specialized into task ontologies or domain ontologies to meet particular needs of the enterprises.

Although much work and effort was devoted to the creation of business and enterprise ontologies and the abovementioned initiatives may definitely provide an inspiration and foundation for developing organizational ontologies, to the best of our knowledge, there is no commonly accepted model that could be reusable in various domains. The development of a single organizational ontology describing all kinds of company’s activities is difficult, if at all possible. Therefore, there exists a need for creation of a coherent ontology stack that would provide necessary semantics and, as organizational domain is subject to changes, also provide required flexibility. In consequence, it is better to apply modular approach to ontology development rather than to develop a single organizational ontology. Such an organizational ontology stack should be designed in such a way that there would always be a possibility to extend it, should a need for applying it in another domain emerge. Moreover, the ontologies should be developed bearing in mind their future application.

\(^1\) http://ip-super.org

3.1 The notion of SBPM and the targeted lifecycle

The aim of SBPM is to increase the level of automation within the BPM lifecycle and to provide support for both business users as well as IT engineers. These aims may be fulfilled taking advantage of the Semantic Web technologies (ontologies and reasoning mechanisms) and using Semantic Web services (SWS).

As already mentioned, four phases of BPM may be identified, namely: modelling, implementation, execution and analysis. As the usage of semantic technologies does not affect these stages but rather increases the level of their automation and provides new functionalities, the division into the above mentioned phases applies to SBPM as well [25].

In order to fulfil its aims, SBPM needs a semantic representation of various artefacts used within all four phases. Within the first phase of SBPM, i.e. Semantic Business Process Modelling, ontologies are used to annotate business process models. The goal of semantic annotation is to specify semantics of tasks and decision points in the process flow. Within Semantic Business Process Configuration phase, semantic business process models are transformed in order to be deployed to a process engine. The ontological representation of a model provides a complex description of a process that allows for automated assignment of a composition of Semantic Web services able to fulfil the goal of each task. After this operation the executable process model is created and may be deployed to the process engine. Then, within Semantic Business Process Execution phase, the process model becomes ready for instantiation (i.e. execution). Taking advantage of its semantic description, it is externalized as SWS and made accessible to clients. Finally, Semantic Business Process Analysis phase involves the monitoring of processes aiming at providing relevant information on running process instances as well as process mining analysing already executed process instances in order to enable improvement of existing process models. The semantic annotation of the process and its space ensures that the process description is machine-readable and enables utilization of reasoning in order to query the process space on the higher level.

In this paper, we primarily focus on the two first phases of SBPM and the scope of the semantic description of a process content that is required by them, as it is further discussed within the next section.

3.2 Ontology stack for the needs of SBPM

The required semantic representation of a process, utilized during all phases of SBPM, mentioned in the previous subsection, may be divided into three main groups: process, organization-related and domain-specific ontologies. Process ontologies are created in order to describe the structure of a process (i.e. its control flow), whereas organisation related ontologies provide a description of artefacts that are utilised by or involved in the process (i.e. description of actors, resources, systems etc.). The domain ontologies provide additional information specific to an organization from a given domain. Thus, the domain ontologies extend the organisation related ones. Such an approach allows for future reusability of the developed solutions. The high-level view on the process description for the needs of the Semantic Business Process Management is depicted in Figure 1.

In order to define more detailed dependencies between these general layers, the specific ontology stack defined for the needs of SUPER is considered. The SUPER modelling ontology stack, depicted in Figure 2, clearly indicates dependencies between process and organization-related ontologies. For the sake of clarity, the domain ontologies that extend the concepts of organization related ontologies are not depicted in the figure.
The Process Mining Ontology and Events Ontology were developed in order to support the analysis phase of the entire cycle. Moreover, the UPO (Upper Level Ontology), being the upper ontology to the all mentioned ontologies, provides general concepts for description of processes, such as Business Domain, Business Goal, Business Function that are to be extended by organisation-related ontologies.

The BPMO, sEPC, sBPMN and Events Ontology, in order to describe processes, are to use the concepts/instances defined within organization-related ontologies. Exemplary concepts/properties from the process modelling ontologies that currently point to the elements of organisation-related ontologies are shown in Table 1.

Table 1. Exemplary concepts/properties from the process modelling ontologies that currently point to the elements of organization-related ontologies.

<table>
<thead>
<tr>
<th>BPMO</th>
<th>sEPC</th>
<th>sBPMN</th>
</tr>
</thead>
<tbody>
<tr>
<td>hasBusinessGoal (a property of a Process and task, etc.);</td>
<td>Resource (InformationResource, Document, ElectronicDocument, PhysicalDocument, MaterialResource, ITSystemOrApplication, Material, PhysicalAsset, DataRepository); OrganizationalUnit.</td>
<td>Swimlane; Lane; Participant; Role.</td>
</tr>
<tr>
<td>hasBusinessDomain (a property of a Process, task, etc.);</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hasBusinessFunction (as above);</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hasActor and hasRole properties.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

They provide an additional inspiration and requirements to the organizational ontology layer defined in the next section.

4. Organizational ontologies layer

The organizational ontologies should provide a basic vocabulary and structure for describing organizations and resources, define common types of divisions, roles and tasks, and define common types of business resources [12]. Therefore, they aim at providing vocabulary and constraints for describing the environment in which processes are carried out from an organization’s perspective.

As this environment is quite complex and encompasses various areas and different points of view on the organization, taking into account other approaches described in section 2, the organizational ontologies layer has been divided into a few subontologies. Each of the subontologies focuses on and describes different parts of the process space and may be easily extended if such a need occurs. In order to make sure that we create a consistent network of ontologies reflecting various spheres of enterprise structure and operations, the subontologies are based on compatible paradigms, have compatible degree of details, and include sets of alignment relations which allow data interoperability.

The following subontologies were developed:

1. Organizational Structure Ontology (OSO). This ontology focuses on organizational structure (hierarchy) of a company at the same time aiming at achieving domain independency. The OSO shows how elements of organization’s structure work together in order to achieve organization’s goals. It encompasses such information as: departments, employees, their responsibilities, resources used etc. as well as relations among them.

2. Organizational Units Ontology (OUO). This ontology provides specification of typical units that may be found in a company. Along with the other ontologies (Business Functions, Business Roles and Business Resources Ontology) it provides extensions to OSO.

3. Business Roles Ontology (BROn). This ontology provides a common meaning of concepts related to roles featured by organizational members (i.e. actors). Each actor may play more than one role and these roles may change depending on the context. It also allows modelling both internal as well as external roles fulfilled by various actors.

4. Business Functions Ontology (BFO). This ontology provides a hierarchy of different functions that may be carried out within the company. It is supposed to enable vendor and domain independent classification of company processes and process fragments providing abstraction over single tasks constituting processes.

5. Business Resources Ontology (BRO). This ontology describes applications and resources that should be involved when carrying out certain processes or that may be results of certain task within a process.

6. Business Goals Ontology (BGO). Goals may explain why the processes exist in the organization; examples include customer satisfaction, growth, etc. BGO models a hierarchy of business goals and provides a set of relations between them to enable goal-based reasoning. We distinguish between a strategic goal, which tend to be long term and defined qualitatively rather than quantitatively, and an operational goal which is a step along the way (a milestone) towards a strategic goal. Goals can conflict with each other (if they cannot be satisfied simultaneously) and can positively or negatively influence other goals. There can be different levels of influence between goals.

We use WSML [26] as the representation language for the ontologies2. It offers a variety of language variants to be used depending on the desired application scenario. In particular, we have utilized WSML-Flight language variant as the most appropriate choice to meet our representation requirements.

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2 Organizational ontologies can be found at http://www.ip-super.org/ontologies
5. Application scenarios

This section provides examples of application and benefits that can be obtained by using organizational ontologies within the Business Process Management.

5.1 Use Case description

Let us consider an example of a Digital Asset Management scenario presented in Figure 4. The aim of this process is the provision of digital content to end users. The entities collaborating in this scenario are as follows:

i) DRM provider responsible for management of content rights;
ii) Content provider, providing interested parties with relevant digital content;
iii) Service provider responsible for storing the offer of the available content and distributing it via a service portal.
iv) Content distributor, providing a final user with an access to digital content;
v) Customer, representing the final user of the digital content.

The service provider, based on a customer query on the digital content specifying among others the type of digital rights license the user is interested in, searches for the relevant digital content from several content providers. The search results are then presented to the user, who selects the content to preview or purchase.

When modelling a process within SUPER Modelling Tool, its ontological description in the BPMO is automatically created. However, as it was already mentioned, BPMO describes mainly process structure and in order to obtain a full business process description also functions, resources, roles etc. need to be properly described. While annotating the process, a business analyst takes advantage of the organizational ontologies and the following aspects of the scenario are described using the proposed ontologies set:

![Figure 4. Product Delivery Business Process](image-url)
each actor in the scenario is defined by pointing to a concept from the Business Roles Ontology e.g. instance DRMProvider memberOf bront#Supplier

to each process the following attributes are attached (this information is further used when reasoning about the process):
  o a business function pointing to a functional area of an organization and activities performed e.g. bpmo#hasBusinessFunction hasValue bfo#Delivery;
  o a business domain pointing to relevant products and area of organization activities e.g. bpmo#hasBusinessDomain hasValue bfo#DigitalAssetManagement;
  o a business goal defining the aim of the process and the KPI to be achieved or business policy to be obeyed as defined within the ontology e.g. bpmo#hasBusinessGoal hasValue goals#orderDelivered;

to each task resources required by it in order to realize its goal are specified e.g. bpmo#hasResource hasValue breo#CRMSystem.

The organizational ontologies used during the modelling phase to annotate processes are utilized by several functionalities of SBPM (cf. Figure 5), which:

i) support decision making,
ii) facilitate reuse of modelling artefacts,
iii) help ensuring compliance of process models to relevant regulations,
iv) enable advanced analysis of process models, as further described.

5.2 Scenario 1: Decision making support

The key challenge in decision making is having access to relevant information which is to be assessed in a particular situation. Such information is scattered in organizational processes and has to be manually collected from diverse sources for each individual case. By using the information and reasoning capabilities provided by the organizational ontologies used during annotation process, we enable business experts to quickly and expressively query the process artefact repository of their organization (cf. Figure 5, top). Some example queries for this scenario include: “List all processes in the fulfilment area”, “Which processes use system x?”, “What resources are needed for running process y?”, “List all processes with conflicting goals.”, “How many transactions are carried out with a partner z on a monthly basis?” [11].

5.3 Scenario 2: Reuse of process artefacts

This scenario describes how the business expert can more effectively and efficiently query the process artefact repository in order to reuse the process patterns, models and fragments in process design (cf. Figure 5, centre). By using the machine processable representation of already modelled processes, when designing a new process the business expert can first query for existing business process patterns, generic high level process designs emphasizing business goals [16, 17], in search for the best modelling practices in the given domain. An example query for business patterns can be: “Give me all business patterns related to Fulfilment Business Function where Business Goals involved are profileObtained and serviceActivated”. An example business pattern that matches the query is shown in Figure 6. Annotations (denoted by circles) represent business goals that mark different milestones of the end-to-end process.

Figure 6. Service provisioning business process pattern

The business expert can also query in the same way for existing models or process fragments - self-contained, coherent building blocks of a process model with a clear business meaning. In case there are existing process models or fragments that are similar to the desired end design, business experts can use them in their design in order to achieve a higher degree of reuse, compared to reuse of patterns. Based on the annotations from Figure 6, the user can perform further queries for finding existing process fragments that refine specified business goals. For instance, when selecting the task Provision Order for refinement, the query looks for models or fragments annotated by the goal Order Provisioned, enabling the user to embed the Digital Asset Provision: Download Process in the model, as shown in Figure 7.

5.4 Scenario 3: Autocompletion of business process models

In our work, we define autocompletion as a technique for finding and proposing subsequent process activities or process fragments to the modeller on the fly, during modelling. While the modeller creates the model, new activities are suggested to him by the modelling tool - based on the semantic process context information. Process context is comprised of Business Function and Business Goal annotations of the process model. All process activities or fragments matching the process context of the modelled process are suggested to the user during modelling in form of a list. The modeller can select an activity/fragment from the list which best matches his intention and include it in the current model. In this way, we provide modelling guidance to the
modeller which leads to process models of higher quality and reduction of the actual modelling time.

In this paper, we have presented an organizational ontology framework for SBPM which integrates different views of an enterprise. It consists of six ontologies describing different aspects of an organization. They are as follows: functions, structure, roles, units, resources and goals. Our ontology framework, in contrast to other approaches discussed in the related work section, is consistent and operational. Consistent in this case means that we have made sure that the ontologies are based on compatible paradigms, have a compatible degree of detail, and finally include at least partial sets of alignment relations which allow data interoperability. Operational means that the ontology specifications are available in a single, current ontology formalism (i.e. WSML notation) for which scalable repositories, reasoning support, APIs, and tools are available. By fulfilling the criteria of being consistent and operational network of ontologies reflecting various spheres of enterprise structures and operations, the described framework has been successfully applied in the Semantic Business Process Management field. By providing a use case on collaborative Digital Asset Management in the telecommunication sector, we illustrated the process of applying the organizational ontology stack and demonstrated the potential benefits of using the proposed ontology framework for modelling, reusing and querying tasks in BPM. By utilizing the organizational ontologies we have achieved better readability and consistency of process models, provided guidance to the design of domain specific ontologies, enabled improved management support and facilitated the design of process models of higher quality in less time.

Our future work considers further alignment between the proposed ontologies as well as their extension in order to allow for their application also in more specialized domains requiring some specific description of the organization related aspects.

7. ACKNOWLEDGMENTS

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8. References


5.6 Scenario 5: Goal-based business process analysis

Explicit modelling of organizational business goals allows us to assign one or more business goals to each defined business process [17]. The Business Goal Ontology provides relevant properties and relations required for creating business goal specifications. BGO defines the following goal properties: description, measure, deadline, priority, and goal relations: subgoal_of, supports, hinders, conflicts. In this scenario we utilize the concepts, properties and relations provided by the BGO in order to detect conflicts, redundancies, perform queries and gap analysis on process models. Example queries that can be answered using the business goal ontology include: “Show me all processes that support a specific goal. Filter goals on the basis of a given deadline and/or priority. Show me all goals that have no business process linked (gap analysis). Show me all processes that hinder the achievement of a specific goal. Show me all conflicting/redundant goals”. In this way we i) make sure that the conceptual business process models are consistent with the organizational business goals and ii) enable top-down traceability and bottom up linkage from processes to business goals.

6. Summary

The challenge of combining BPM and SOA has attracted a lot attention both from the academia and the industry. One critical requirement is to build machine-readable and machine-interpretable representation of the processes and their organization related content so as to improve the automation within the BPM lifecycle.

Figure 7. Digital asset provision: download process

5.5 Scenario 4: Querying business policies

This scenario covers querying for business policies – defined according to the company strategy, which apply orthogonally to all processes of an organization (cf. Figure 5). Queries involved in this scenario retrieve all business policies (both mandatory and conditional) which match context annotations of the model being checked. This reduces the manual effort of creating an inventory of such policies for any given model. For checking which policies are relevant in a digital content provisioning process, the example query can be: “Give me all business policies for Digital Asset Management Business Function where clients are minors and Business Goal associated belongs to Fulfilment”.

5.4 Scenario 3: Process analysis

By explicit modelling of organizational business goals we make sure that the conceptual business process models are consistent with the organizational business goals and requirements. All models that support or hinder the achievement of a specific goal are detected. This reduces the manual effort of creating an inventory of such goals. This scenario retrieve all business policies (both mandatory and conditional) which match context annotations of the model being checked. This reduces the manual effort of creating an inventory of such policies for any given model. For checking which policies are relevant in a digital content provisioning process, the example query can be: “Give me all business policies for Digital Asset Management Business Function where clients are minors and Business Goal associated belongs to Fulfilment”.

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