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Ontology-based standards development: Application of OntoStanD to ebXML business process specification schema

Heravi, B.R., Lycett, M. and de Cesare, S.

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Ontology-Based Standards Development: Application of OntoStanD to ebXML Business Process Specification Schema

Abstract: Business-to-Business (B2B) interoperations are an important part of today's global economy. Business process standards are developed to provide a common understanding of the information shared between trading partners. These standards, however, mainly capture the syntax of the transactions and not their semantics. This paper proposes the use of ontologies as the basis for standards development and presents an ontology for the ebXML Business Process Specification Schema (ebBP) with the aim of empowering the capture and sharing of semantics embedded within B2B processes as well as enabling knowledge deduction and reasoning over the shared knowledge. The paper utilises the Ontology-based Standards Development methodology (OntoStanD) as a methodological approach for designing ontological models of standards. This research demonstrates how Semantic Web technologies can be utilised as a basis for standards development and representation in order to improve standards-based interoperability between trading partners.

Keywords: Ontology-based Standards, OntoStanD, B2B Process, Semantic Business Process, Process Interoperability, Process Automation, ebBP, ebXML.

1. Introduction

In today's global business environment, companies need to interact with various trading partners and, in order to do so, their business processes need to be understood and aligned across organisational boundaries. Business process standards are aimed at providing a common understanding and agreement on the information shared among trading partners. One such standard is the ebXML Business Process Specification Schema (ebBP), a Business-to-Business (B2B) process standard, standardised by the Organisation for the Advancement of Structured Information Standards (OASIS, 2006).

XML-based standards, such as ebBP, are designed to provide a common language between their users. However such standards are only capable of providing syntactic representations of transactions rather than semantic representations. The lack of semantic expressiveness of XML-based standards constitutes a significant problem when automated processes of different organisations are required to integrate with one another in wider collaborative business processes.

In such a scenario the collaborating organisations' information systems should ideally interoperate by automatically understanding the semantics of one another's underlying process models. This is known as semantic interoperability and it represents an essential factor for effective B2B integration. Semantics require that the meaning of the terms and their relationships as well as the restrictions and rules defined in a standard be clearly defined in the early stages of standards development and act as a basis for the latter stages. By implication, therefore, it is important to model the terms of a standard in a clear, precise and unambiguous way.

Ontologies are considered as an appropriate means for data integration and their application to practical problems of semantic interoperability has proven to reduce the amount of work needed to agree on a shared model based on the assumptions made by different parties (Firat et al., 2005). Ontological models can improve the capture, representation and sharing of domain models by more precisely defining the terms adopted as well as their relationships (Singh et al., 2005). This, as a consequence enhances semantic reasoning and knowledge deduction, which facilitates the transparent flow of semantically enriched information and knowledge in B2B collaborations, with the effect of improving the collaboration itself (Rebstock et al., 2008).

This paper utilises the Ontology-based Standards Development (OntoStanD) methodology (Heravi and Lycett, 2012) for defining an ontology for ebBP that enables the capturing and sharing of semantics embedded in B2B processes as well as knowledge deduction and reasoning over the shared knowledge. The ebBP ontology presented in this paper not only covers the syntax of the ebBP XML schema but also provides facilities for uncovering informal semantics embedded in the textual specification and formalising such semantics in an ontology language. This is fundamentally different from an automatic transformation of XML to an ontology language, such as the Web Ontology Language (OWL), since automatic transformation cannot readily interpret the semantics embedded in both the schema and the textual specifications.

The remainder of this paper is structured as follows. Section 2 provides a background on business processes and discusses the importance of ontologies and Semantic Web technologies for B2B process interoperation. Section 3 reviews the related work followed by Section 4 which presents the research methodology employed for this work. In Section 5 the ebBP ontology and its development process is presented. Section 6 evaluates the ebBP ontology derived with OntoStanD assessing for consistency and completeness. Section 7 provides a discussion on the evaluation and presents the limitations of the work. Section 8 concludes the paper and discusses topics for further research.

2. Business Process Standards and Ontologies

Business process standards are aimed at providing a means for clearly defining the public aspects of B2B processes. One such standard is the OASIS ebXML Business Process Specification Schema or ebBP (OASIS, 2006), which has the benefit of having been specifically designed for defining the public aspects of an e-Business automated collaboration. ebBP is a royalty-free, open standard, which adds to its usefulness for defining collaborations and transactions in a way that would be correctly understood by each party involved in the business processes.

ebBP is one of five components of the ebXML (Electronic Business using eXtensible Markup Language) framework. ebXML is a modular suite of XML-based specifications, sponsored by OASIS and the United Nations Center for Trade Facilitation and Electronic Business (UN/CEFACT). ebXML's mission is to provide an open, XML-based infrastructure that enables the global use of electronic business information in an interoperable, secure, and consistent manner. The other four components of the ebXML framework are as follows:

- *ebXML Core Components*, which provide basic and reusable building blocks for describing specific concepts in business documents. ebXML Core Components are not meant to be fomal representations of such concepts (unlike what occurs in an ontological model).
- *ebXML Registry/Repository (ebReg/Rep)* whereby the ebXML Repository manages and maintains the shared information as objects in a repository while the ebXML registry is an interface for accessing and discovering shared business semantics.
- *Collaboration Protocol Profiles and Agreements (CPP/A)* whereby the CPP describes the specific capabilities that a trading partner supports while a CPA is a document that represents the intersection of two CPPs and is mutually agreed upon by both trading partners.

- *ebXML Messaging Service (ebMS)*, which is designed for the secure, reliable exchange of e-business information.

The ebXML framework is designed in a way that specifications of each component can be used independently, composed as desired, or integrated with other evolving technologies (OASIS, 2006).

The focus of this paper is on standards of business processes and therefore on the ebBP as a self contained unit, which may be used in conjunction with other specifications or technologies. The ebBP metamodel is based on prior work of the UN/CEFACT Modeling Methodology (UMM, 2003; OASIS, 2006). UMM is a UN/CEFACT modeling methodology for capturing the business requirements of inter-organisational business processes (UMM, 2003; Huemer, 2011; Zapletal et al., 2010). ebBP provides facilities for defining machine processable business processes, which themselves are aligned with guiding principles relevant to business processes such as the UMM.

Each ebXML business process is realised through Business Collaborations between parties, which themselves are a choreographed set of Business Transactions and their document flows (OASIS, 2006; Huemer, 2011). Figure 1 below depicts the basic structure of an ebBP business process.

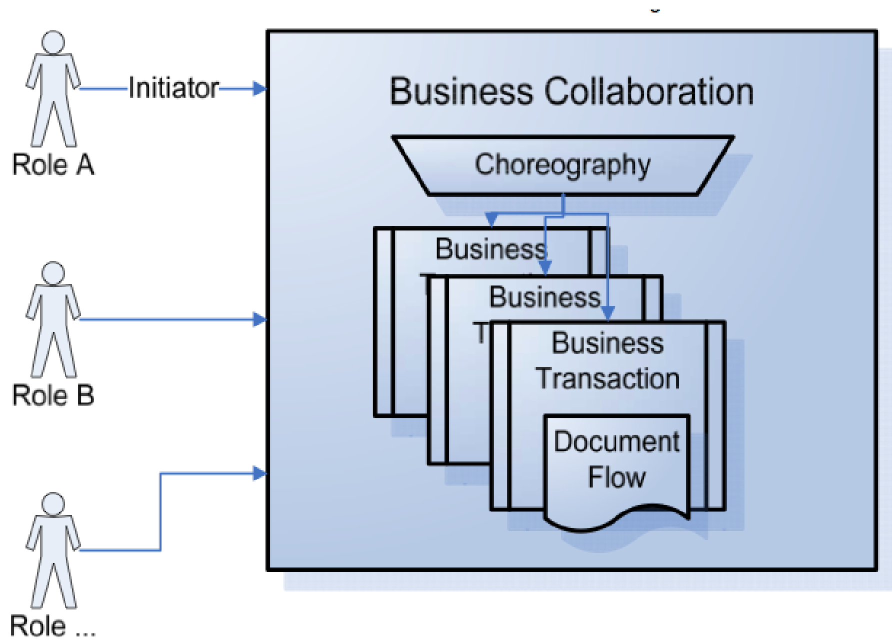

Figure 1. Basic semantics of an ebBP Business Collaboration (OASIS, 2006)

Standards specifications are usually written by a community and over a relatively long period of time. This would inevitably lead to a certain degree of ambiguity and inconsistency due to the way different people use and interpret natural language. Among all other factors, ambiguity and miscommunication can considerably hinder the quality of standards. Sherif et al. (2005) note that using formal representation languages for standards would substantially help in producing less ambiguous and clearer specifications and therefore higher quality standards along with a higher degree of interoperability.

An ontology is "an explicit specification of a conceptualisation" (Gruber, 1995). Ontologies provide a formal description of real world objects and their relationships within a domain (W3C, 2011), thus resulting in a shared understanding across that domain. This shared understanding, also expressed by the use of formal logic, can be utilised to infer new explicit knowledge from implicit knowledge that exists in the domain ontology.

This paper proposes that ontologies, as an appropriate means for capturing knowledge in a domain, should be utilised in the process of standards development and that the conceptual model of standards and their restrictions and rules be modeled in an ontological manner. When a formal expression of the semantic information is required, ontology provides an important tool. Having an ontological model of a standard makes the semantics accessible to automated processing and to engineers not expert in the e-business domain. Ontological representations of standards allow to precisely define and constrain the meaning of concepts with axiomatisations which enable the automatic detection of formal errors as well as the ability to infer and classify new knowledge. This would not be possible with pure XML-based technologies which merely provide the syntactic support for representing conceptual models and not the semantic capabilities. While in some instances pure XML-based solutions may appear effective enough and simpler to use, they are not however capable of, for example, defining the intension (definition) of classes, expressing fundamental relationships (such as super-subclass) or providing support for in-built inferencing. The latter would necessarily need to be programmatically developed in a non-standard manner. Hence standard ontology languages enable greater semantic interoperability and, as a consequence, potential for increased collaboration among business organisations.

When an ontology is produced for a standard such as ebBP, it allows the architects to write expressions based on clear, unambiguous terms and categories. An ontology-based standard development approach not only would bring all the bits and pieces of a standard specification under one single umbrella, but it would also formalise the representation of the real world entities and relationships to which the standard (and its instantiations) refer. Among the benefits of such an approach are logic-based reasoning, automated consistency and conformance checking, improved change management and reduction of errors in the specification and their instantiated conceptual models. The ultimate aim is to achieve higher quality standards and tighter interoperability.

Another benefit of using ontology to support specifications relating to ebBP and its uses is that, once the ontology has been produced, an expression based on that ontology, such as one written using some queries, for example in the Web Ontology Language - Description Logics (OWL DL), can be evaluated. One way to evaluate the completeness of an ontology is to sketch a set of questions that the ontology must be able to answer. These questions are called competency questions and are considered to be an acceptable means of evaluating the completeness of an ontology (Gruninger and Fox, 1995; Yu et al., 2009).

Ontologies require a standard means of representation. The Web Ontology Language (OWL) is a W3C recommendation for expressing ontologies that can be processed by software. OWL DL is a sublanguage of OWL, based on Description Logics and supports those users who need maximum expressiveness while retaining computational completeness, hence making it ideal for the ebBP ontology.

There are different ways to query an ontology, most popular of which are the Simple Protocol and RDF Query Language (SPARQL) (W3C, 2008) and Protégé OWL DL Query. SPARQL is a query language mainly designed for the Resource Description Framework (RDF), which is less expressive than OWL; SPARQL, therefore is not considered as the most appropriate means to query OWL ontologies. Protégé 4.0 (and later versions) provides a DL Query tab, which is a powerful and easy to use feature for searching a classified OWL DL ontology. The Protégé DL Query language is basically an OWL class expression and is based on the Manchester OWL syntax, a user-friendly syntax for OWL DL.

This approach has benefits where a specification can include such DL Queries but it also allows a knowledge base to store and retrieve information related to a process defined using ebBP. It may be one step towards storing process definitions not just defined with ebBP but also with other business process languages such as the Business Process Execution Language (BPEL).

3. Related work

Business process interoperability is repeatedly mentioned as one of the most important aspects of B2B integration in the literature. B2B processes, also referred to as 'collaborative', 'inter-organisational' or 'public' processes, are those focusing on the interactions between different partners and are not concerned about internal processes. E-Business process standards are aimed at providing a shared understanding between trading partners. These shared aspects require a shared definition and need to be specified using principles essential to automation (Milner, 1980) so that all systems involved have the same understanding of the state of those collaborations at certain stages in the process.

Business process interoperability is founded on the assumption that organisations must share a common semantic model of business processes. A clear example of such a model is the Resource-Event-Agent Enterprise (REA) Ontology which provides "a pattern for the semantic definition of business processes" (Geerts and McCarthy, 2002; Geerts and McCarthy, 2006). While REA was initially designed to provide a new conceptual foundation to accounting (McCarthy, 1982), the framework has grown. Its extension provides support for modeling any aspect of the business domain. REA underpins the ISO 15944-4 Standard on "Business transaction scenarios – Accounting and economic ontology" (ISO, 2007). With specific reference to business process and enterprise modeling, REA now supports the modeling of policy and accountability structures. The basis of this extension are two modeling constructs, typification and grouping, which enable the representation of possible activities and events or put differently "what should, could or must be" as opposed to "what actually happens or what is". Compared to existing business process modeling standards, REA operates at a higher level with its foundation grounded in Sowa (1999). Consequently, it can provide the semantic underpinning to existing business process standards (Gailly and Poels, 2009) and a common shared model for semantic interoperability (Gailly and Poels, 2007). An example of such an endeavor is represented by the work carried out on using REA to extend the eXtensible Business Reporting Language (XBRL) by Amrhein et al. (2009).

Legner and Wende (2007) stress the importance of public process integration in the future success of businesses and suggest that inter-organisational business process design has to provide conceptual mechanisms to support organisations in aligning the semantics that underlie business processes. They also suggest that compliance with B2B process standards will become more important in the near future. Gong et al. (2006) introduce inter-organisational business process collaboration as one of the most significant factors in today's global business and recognise Semantic Web technologies as a promising direction for integration and collaboration. They provide a semantic agent-based approach for achieving inter-organisational process interoperability. Wu and Yang (2006) also highlight the importance of ontologies for business processes in today’s B2B interactions and provide an e-business process modeling framework that outlines the required building blocks for enabling e-business process automation.

The use of ontologies as a means of formalising the structure of standards has gained momentum in the last few years. There are a growing number of ontologies developed for various standards and specifications. Examples are oXPDL, an ontology for the XML Process Definition Language (XPDL) (Haller et al., 2008), an ontology for WS-BPEL (Nitzsche et al., 2007), an ontology for event-driven process chains (EPC) (Thomas and Fellmann, 2007), an ontology for Petri Nets (Gašević and Devedžić, 2006) and the Business Management Ontology (BMO version 1.0), which was a vision for an ontological approach for defining business processes and mainly focused on private processes (Jenz, 2003). Furthermore there are some projects working on semantic aspects of Business Process Management, such as the SUPER Integrated Project (Semantics Utilised for Process Management within and between Enterprises) (SUPER, 2009), STASIS (Thomas and Fellmann, 2007), and m3po (Haller et al., 2006). Table 1 summarises the existing work related to the domain under study. For each standard the table indicates whether the ontology is aimed primarily at modeling private (internal) processes, public (inter-organisational) processes or both. Table 1 also indicates the type of things that the ontology is capable of modeling, e.g. only processes or workflows, only business (process-related) documents and their patterns or capable of modeling also the wider enterprise (with a full-fledged ontology or implicitly via a notation).

Grenon and De Francisco (2009) claim that ontology-strength industry standards facilitate knowledge representation and sharing. They present an ontologisation of a set of telecommunication and clinical trial standards (Grenon and De Francisco, 2009; Grenon et al., 2011). They support the view that producing ontologies for standards has the potential of furthering and enhancing standards’ development, dissemination, and operationalisation and postulate that the ontologisation of standards should be part of the standards development life-cycle. They however, do not provide a methodological approach for such convergence.

There is some work that focuses on utilising ontologies in conjunction with standards. Anicic et al. (2006) propose a methodology for Semantic Enterprise Application Integration Standards, which utilises Semantic Web technologies for achieving interoperability between two business document standards - STAR and AIAG - both of which are based on the Open Applications Group Integration Specification (OAGIS) standard. Their methodology requires developing ontologies for each standard in the first place, which is done by using automated tools in this project. No implementation of their automated tool was available at the time of this research in order to test the richness of the ontological models created using the automated transformation. Conrad et al. (2004) provide a case for the ontological expression of e-business standards and the way ontologies may improve such standards. They present a set of potential benefits from adopting ontologies in the process of standards development and in particular for conceptual modeling. They suggest using upper ontologies for standards ontological development, but do not provide a methodological approach - neither for developing ontologies for existing standards nor for using ontologies in the process of standards development and conceptual modeling.

On the other hand, there exist a few ontology related efforts regarding ebXML related specifications. The ebXML Registry Profile for OWL (OASIS ebXML Registry Technical Committee, 2006) provides specifications for publishing and discovering OWL ontologies in the ebXML Registry/Repository. OntologUBL provides an ontology for the Universal Business Language (The Ontolog Forum, 2003). OASIS SET (Support for Electronic Business Document Interoperability Technical Committee) (OASIS SET TC, 2009) also provides an ontology for business documents, which are based on the ebXML Core Components Technical Specification (CCTS). Another relevant Technical Committee in OASIS, which may be considered as the first official ontology oriented standards Technical Committee (TC), is the OASIS Quantities and Units of Measure Ontology Standard (QUOMOS) TC (OASIS QUOMOS TC, 2010), which aims at developing an ontology to specify the basics of systems of quantities and measurement units.

Table 1

A summary of related work in the area of business process ontologies.

Standard	Private/Public	Type
REA (McCarthy, 1982, Geerts and McCarthy, 2002)	Both	Enterprise Ontology
WS-BPEL ((Nitzsche et al., 2007))	Private	Process
XPDL (Haller et al., 2008)	Private	Workflow
EPC (Thomas and Fellmann, 2007)	Private	Process
PetriNet (2008)	Private	Process

BMO (Jenz, 2003)	Private	Process
OASIS SET (OASIS SET TC, 2009)	Public	Business Documents
UBL Ontology (The Ontolog Forum, 2003)	Public	Business Documents - Patterns
Rhizomik ebBP (García and Gil, 2007)	Public	Business Process
BPMN (2011)	Both	Notation Language

None of the works above, except for Rhizomik, are targeted at the public aspect of business processes and do not provide neither a comprehensive ontology development methodology, nor an ontology for B2B process interoperation. They are either focused on ontologies for private processes or business documents and registry aspects of B2B transactions.

The Rhizomik project (García and Gil, 2007), however, provides facilities for automatic transformation of XML schema and XML documents to RDF and OWL documents respectively. They have specifically mapped an ebBP schema to an OWL ontology. However, with the first examination of the ontology, it is quite clear that it does not cover both the semantics and the syntax of the model. For example, none of the data properties in the ontology have domains and ranges, none of the object properties have a domain and most of the object properties do not have a range. The data types that exist in OWL, such as *int*, *string* and *IDREF*, are ignored in this ontology and for each data type a class is defined. This is a result of automatic translation, without paying attention to the semantics of the entities involved. Furthermore the way the classes and properties are defined is different from the ebBP ontology presented in this paper, which pays more attention to the semantics. The Rhiaomik ebBP ontology therefore, is not able to model a B2B Process in an appropriate way and also is unable to answer the competency questions defined in this paper.

Heravi and Lycett (2012) and Heravi (2012) provide an extensive Ontology-based Standards development methodology (OntoStanD), which addresses the same problem while providing a methodological approach for developing ontology-based standards from the start. This paper uses a part of their methodology, which addresses the Domain Conceptualisation of a standard.

4. Research Methodology

The research methodology adopted in this paper is Design Science Research (DSR) (Hevner, 2004; March and Smith, 1995; Peffers et al., 2008; Vaishnavi and Kuechler, 2008). DSR is a methodology that traditionally applies to disciplines like engineering and architecture and more recently to Information Systems (IS) research (Geerts, 2011). DSR is aimed at resolving problems that require designed solutions, which are produced as a set of artifacts. An IS design research artifact typically takes the form of constructs, models, methods, instantiations and arguably design/utility theories (March and Smith, 1995).

The primary aim of this research is to demonstrate the application of a previously developed standards development methodology called OntoStanD (Heravi and Lycett, 2012) to developing ontologies of standards in the area of Business Process Modeling and Collaboration. Specifically the standard that is semantically modeled here is the ebXML Business Process Specification Schema (ebBP). Therefore, while this work represents design research that is self-contained, at the same time it builds upon previous DSR which developed the OntoStanD methodology (Heravi, 2012; Heravi and Lycett, 2012), forming an artifact network as introduced by Vaishnavi and Kuechler (2008) and operationalised by Geerts (2011). More specifically this paper, compared to previous work (Heravi et al., 2010), demonstrates how the ebBP ontology was derived via the application of the OntoStanD methodology and provides a reasoned analysis of the benefits and limitations of the adoption of OntoStanD in the specific area of business process modeling and collaboration.

The main artifact developed by this research is a set of ontological models of the OASIS ebXML Business Process Specifications (ebBP) and its instantiations. The ebBP ontology is developed using OntoStanD (specifically the Domain Conceptualisation phase) and evaluated via: (1) the formalisation of the standard's normative statements enabling the use of a reasoner to determine the model's consistency and (2) competency questions which represent a recognised and widely applied ontology evaluation technique to assess completeness of an ontology against its declared purpose (Gruninger and Fox, 1995; Yu et al., 2009). Therefore the criteria against which the ebBP ontology (as an artefact of this research) is evaluated against are consistency and completeness. This evaluation is carried out in Section 6 followed by a discussion of the evaluation itself.

Figure 2 depicts the DSR phases as represented by Peffers et al. (2008). As part of the artifact network that builds on Heravi and Lycett (2012), this research contributes toward demonstrating the relevance of the overall problem (i.e., improving the development and evaluation of standards through ontologies) by applying OntoStanD. As a consequence the DSR phases that are of significance here are 'Demonstration' and 'Evaluation' as explained in the following sections.

This ‘demonstration’ is considered DSR, and not solely an application of OntoStanD, for three reasons: (1) it is the first time that the methodology is applied to the representation of a standard deliberated by a recognised Standards Body such as OASIS; (2) it is the first time that OntoStanD is being applied to a modeling language whose purpose is to create new artifacts (models) rather than prescribe the properties that physical things should have (e.g. the length of a screw) and (3) this work provides the test bed and learning experience necessary for underpinning future work on using OntoStanD to compare and integrate ontologies of different business process modeling languages as described in Section 6. The final phase, ‘Communication, is manifested through this paper. Figure 2 indicates the artifacts that this research either uses (as inputs) or produces (as outputs). In the terminology of March and Smith (1995), who distinguish between constructs, models, methods and instantiations, the research presented here uses ebBP constructs, applies these as inputs to an instantiation of the OntoStanD methodology to produce an ontological model of ebBP and adopts evaluation methods such as test assertions and competency questions to assess the primary output artifact (the ebBP ontology).

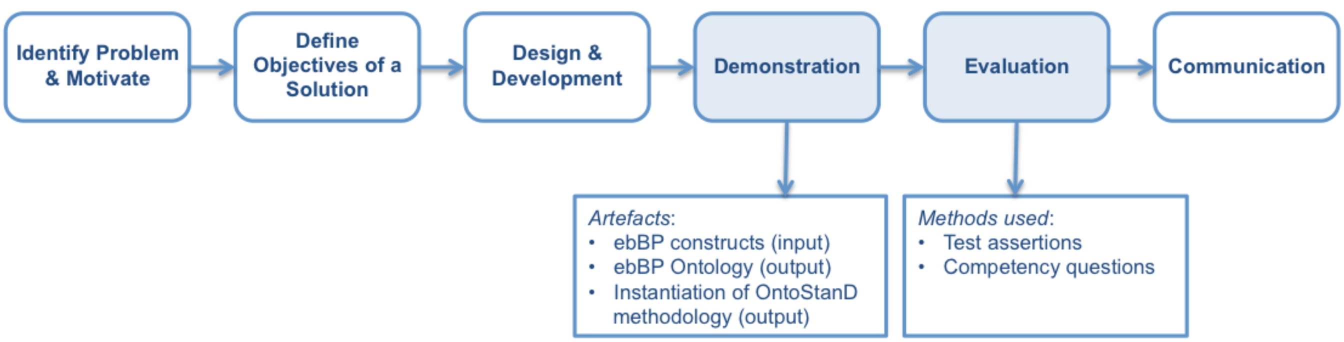

Figure 2. Adopted Design Science Methodology

The evaluation in this paper is an ex post descriptive approach (Pries-Heje et al., 2008) that utilises a realistic scenario example and informed arguments. The evaluation directly assesses the quality of the ontological models produced in this work and, at the same time, indirectly assesses the OntoStanD methodology. The models resulting from the application of OntoStanD on the selected scenario are evaluated for their consistency and completeness, i.e. criteria derived from an extensive analysis of various aspects of the quality for such models (Heravi, 2012) and deemed appropriate for this study.

5. Ontology-based representation of ebBP

This section presents an ontology for the ebXML Business Process Specification Schema v2.0.4 and its development process. The ebBP ontology is defined using OWL DL and covers both syntax, included in ebBP XML schema, and the informal semantics of the ebBP specification. Protégé 4.0.1 is used for developing the ontology, queries are written using Protégé DL Query and Pellet is used as a reasoning engine. As a methodological approach OntoStanD guidelines for developing an ontology for an existing standard (and specifically its domain conceptualisation phase) is adopted (Heravi and Lycett 2012). Figure 3 presents the Domain Conceptualisation phase of OntoStanD, which is the main focus of this paper.

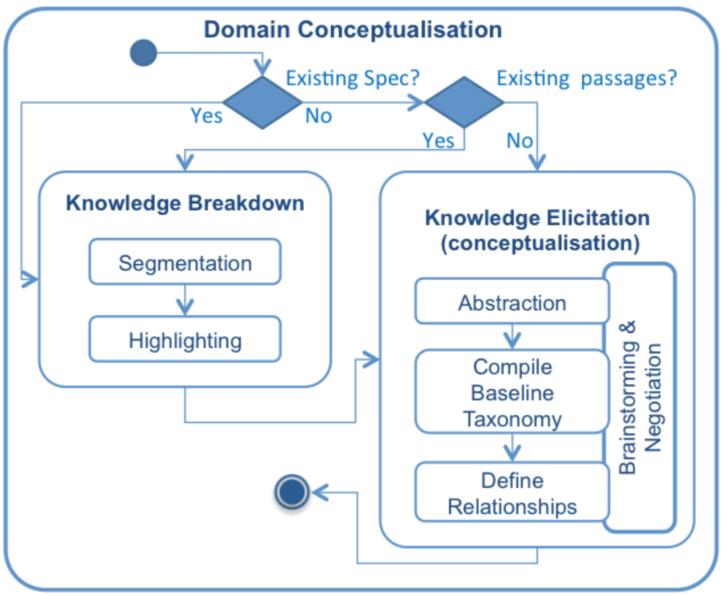

Figure 3. Domain Conceptualisation phase of OntoStanD

5.1. The method: OntoStanD Domain Conceptualisation

The aim of domain conceptualisation is to structure and formally describe the domain knowledge into a conceptual model. According to OntoStanD, the process of defining an ontology for an existing standard starts by 'Knowledge Breakdown', which aims at decomposing the standards' specification into smaller structural conceptual blocks, which are more easily manageable. To do this, the specification is first segmented into a set of smaller passages and then the selected passages need to be highlighted in order to discover the important concepts and their relationships and rules (Heravi, Lycett 2012). Spyns (2008) suggests that three types of phrases should be highlighted: noun phrases, verbal phrases and prepositional phrases. OntoStanD expands their suggestion, proposing that restriction keywords, such as ’MUST‘, ’SHOULD‘ and ’MAY‘, should also be highlighted since they are fundamental in the standards specifications and significant for creating axioms in the ontology.

‘Knowledge Breakdown’ in OntoStanD is followed by ‘Knowledge Elicitation’ which is concerned with the conceptual modeling of a standard and leads to the development of the baseline taxonomy of the terms used in a standard and later the ontology base layer, according to the definition provided by Spyns et al. (2002), which represents the domain terms and their relationships as explained below.

‘Knowledge Elicitation’ is composed of three sequential activities with brainstorming as a parallel activity running throughout the phase as illustrated in Figure 3. The first activity in the ‘Knowledge Elicitation’ phase is ‘Abstraction’. This activity aims to create a set of proper binary fact types, which can be formalised as a quadruple and called lexon in DOGMA (Spyns et al., 2002). A lexon is defined as (t_1, r_1, r_2, t_2), where t_1 and t_2 $(t_1, t_2 \in T)$ are two terms naming classes in the ontology to be derived and r_1 and r_2 represent the relationships between t_1 and t_2. An example of a lexon is *(Student, studies, isStudiedBy, Book)*, which contains a fact that a student studies a book and a book is studied by a student. Note that in the activity of ‘compile baseline taxonomy’ the pair (r_1, r_2) is specified as *(is-a, supertypeOf)*. In the activity of define relationships, the pair (r_1, r_2) will be specified with domain relationships. In this activity, the set *T* is defined in a lexon table.

Based on the output from the activity of abstraction, a taxonomy of terms in the domain is compiled in the ‘Compile Baseline Taxonomy’ activity. A baseline taxonomy contains only subtype relations represented by $(t_1$, *is-a*, *supertypeOf*, $t_2)$ in the lexon table. Brainstorming and negotiation also support this activity.

The subtype relationships were defined during the *Compiling Baseline Taxonomy* activity. At this stage, the remaining relationships between the terms are added to the ontological model of a standard. They include:

- Mereological/aggregation relations (whole-part relations): *’part-of‘/ ’has‘*.
- Domain relationships: already defined as roles (r_1, r_2) in the lexon base.
- Annotation relationships, if any.

5.2. Demonstration: Application of the method

This subsection demonstrates the application of the OntoStanD methodology on the ebXML Business Process Specification Schema, which in addition to the textual specification has an XML Schema, as a structured resource, which should be considered in the abstraction process. The Abstraction activity of the ebBP specification therefore starts by processing the structured resources and then proceeds to the highlighted segments of the textual passages. It is important at this stage to ensure that the lexon table defined in this activity covers all the concepts in the existing XML schema, if it is believed to be a correct model of the domain by the standards developer. This is the case with the ebBP specification since an ontological model of an existing standard is being developed.

The general rule taken in processing the XML schema is to define a term in the lexon table for each element and each complex type in the XML schema. However, to make the ontology more meaningful, this rule is not followed for each and every construct. The ebBP schema is specified using both XML elements and complex types. The latter are hidden in an ebBP XML instance and have little or no semantic value since they merely represent 'syntactic containers'; therefore the complex types themselves are not semantically interpreted but only their elements are. This will keep the ontology simple and easier to understand, while covering the semantics.

Each element in the XML schema is composed of zero or more elements and zero or more attributes. For defining the roles in the lexon table, the elements and attributes of each entity are translated to roles/relationships. In this paper the ordinary OWL naming convention is followed, and therefore the name of the roles in the lexons start by '`has`' or '`is`' followed by the name of the role. For example a BusinessTransaction entity in the ebBP XML schema has one or more RequestingRole(s) and one or more RespondingRole(s). These two are modeled as follows in the lexon table:

(BusinessTransaction, hasRequestingRole, isRequestingRoleOf, RequestingRole) and
(BusinessTransaction, hasRespondingRole, isRespondingRoleOf, RespondingRole).

OntoStanD however, does not recommend any specific naming conventions and leaves it to the standards developers themselves. Table 2 presents the lexon table for Section 3.4.2 of the ebBP Specification.

Table 2. The ebBP lexon table (see Heravi (2012), Appendix V, for the complete ontology).

t_1	r_1	r_2	t_2
Business Transaction	hasRespondingRole	isRespondingRoleOf	RespondingRole
Business Transaction	hasRequestingRole	isRequestingRoleOf	RequestingRole
Business Transaction	hasState	isStateOf	BusinessSuccess
Business Transaction	hasState	isStateOf	ProtocolSuccess
Business Transaction	hasState	isStateOf	BusinessFailure
Business Transaction	hasState	isStateOf	ProtocolFailure
RespondingRole	is-a	supertypeOf	Role
Commercial Transaction	is-a	supertypeOf	Business Transaction
Information Distribution	is-a	supertypeOf	Business Transaction
Notification	is-a	supertypeOf	Business Transaction
Query Response	is-a	supertypeOf	Business Transaction
Request Confirm	is-a	supertypeOf	Business Transaction
Request Response	is-a	supertypeOf	Business Transaction
Success	is-a	supertypeOf	State
Failure	is-a	supertypeOf	State
BusinessSuccess	is-a	supertypeOf	Success
ProtocolSuccess	is-a	supertypeOf	Success
BusinessFailure	is-a	supertypeOf	Failure
ProtocolFailure	is-a	supertypeOf	Failure

When modeling in OWL, XML elements are defined using OWL Object Properties and XML attributes are defined using OWL Data Properties. OWL supports most XML types and therefore the range of the data properties are generally based on the type of XML attributes. However, similar to class definitions, some exceptions are considered in defining the data properties; there are attributes in the XML schema whose type is *IDREF*. Following the general rule, they should be translated to data properties with range *IDREF*. *IDREF* is used in XML to refer to an *ID* type defined for another element. However, in the ontology design it does not make sense as we can simply define the range of an Object Property to be another class. For example in the ebBP XML schema, a `DocumentEnvelope` refers to a `BusinessDocument` whose `BusinessDocumentRef` attribute is of type *IDREF*. This should basically match the `nameID` of a `BusinessDocument`, which is of type *ID*. In the ontology however, the `hasBusinessDocument` property of a `DocumentEnvelope` is not defined as a Data

Property of type *IDREF*, but as an Object Property with the range `BusinessDocument`. This makes reasoning over the ontology much more precise and makes more sense as the two classes have a proper relationship in the ontology rather than being related based on string matching. In addition the `'Ref'` part of the property is ignored since it is referring to another class and therefore not necessary. This also simplifies the ontology.

Figure 4 depicts a part of the baseline taxonomy of the ebBP specifications, which is derived based on the lexons defined in Table 2. The types highlighted in grey ellipses are the ones which are extracted from lexons in Table 2 and the others are the ones which are related to the Business Transaction and are not mentioned in the selected subsection, but are included in other parts of the specification, XML schema, or are defined to categorise some related concept during the brainstorming sessions. All the relationships at this stage are '*is-a*' relationships.

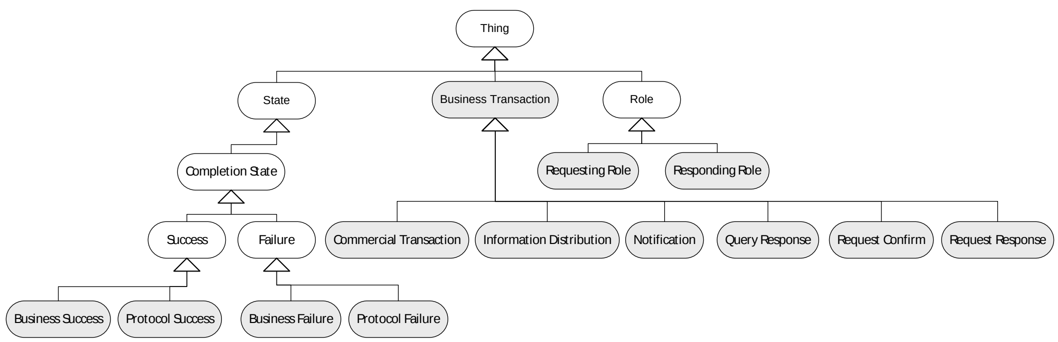

Figure 4. An example of type hierarchy for selected part of ebBP specification

After defining the taxonomy, the other relationships, defined as r_1 and r_2 in the lexon table, are to be added to the ontology. An example of such a relationship, extracted from Table 2, is as follows:

`(BusinessTransaction, hasRespondingRole, isRespondingRoleOf, RespondingRole)`

Figure 5 depicts part of the ebBP ontology in three different layouts: Class Definitions, Object Properties and Data Properties. Listing 1 demonstrates two Object Properties of the ontology which represent relationships between different classes using the OWL Manchester syntax. The complete ontology can be found in Heravi (2012), Appendix V.

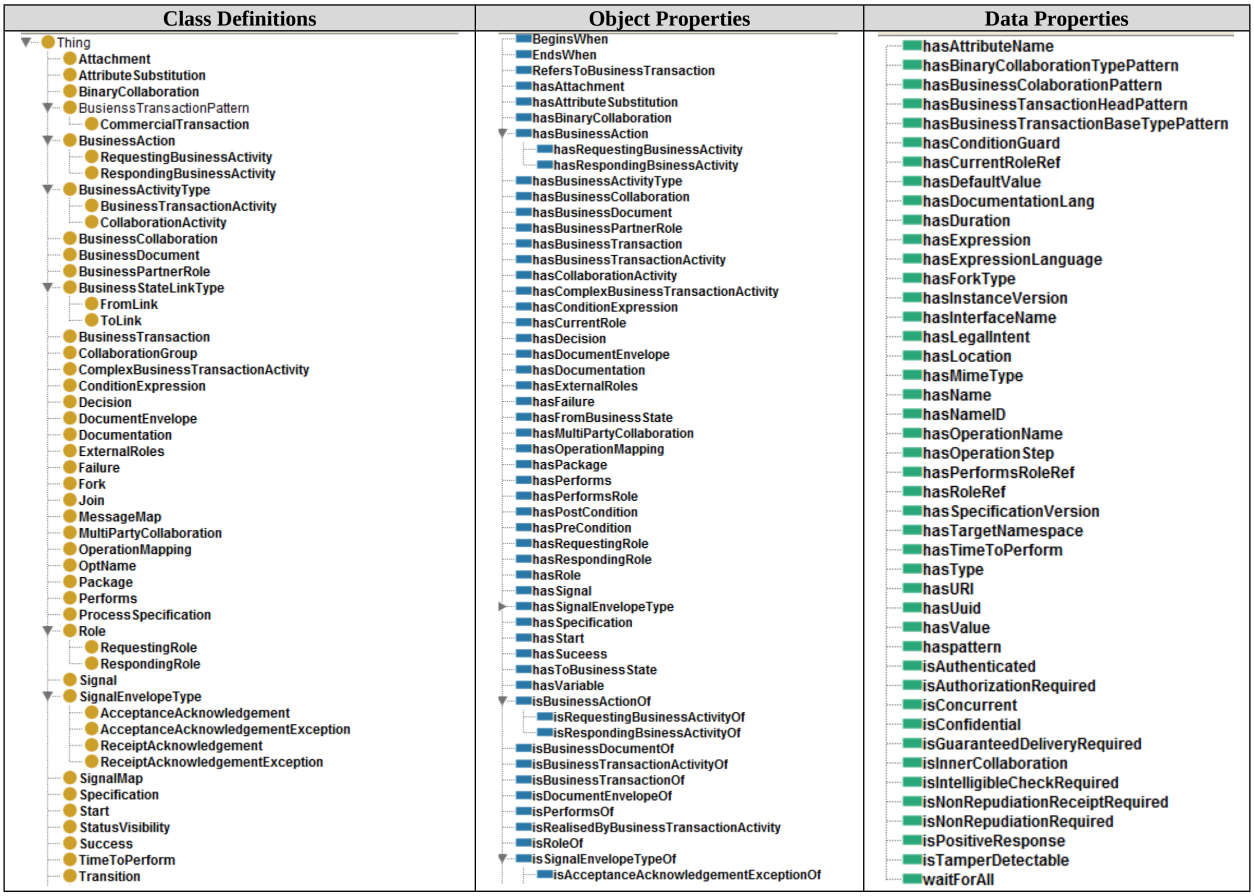

Figure 5. Part of ebBP ontology in three different layouts: Class Definitions, Object Properties and Data Properties.

```
ObjectProperty:
hasRequestingBusinessActivity

Characteristics:
    Transitive
Domain:
    BusinessTransaction
Range:
    RequestingBusinessActivity
InverseOf:
    isRequestingBusinessActivityOf
SubPropertyOf:
    hasBusinessAction
=====================================
ObjectProperty:
hasAcceptanceAcknowledgement

Characteristics:
    Transitive
Domain:
    BusinessAction
Range:
    AcceptanceAcknowledgement
InverseOf:
    isAcceptanceAcknowledgementOf
SubPropertyOf:
    hasSignalEnvelopeType
```

Listing 1. Two examples of Object Properties in the ebBP ontology in Manchester Syntax.

6. Evaluation of the ebBP Ontology

A standard is a technical specification approved by a recognised standardisation body. Standards are designed to be used consistently, as a rule, a guideline, or a definition across particular communities of interest (ETSI, 2010). Each specification/standard is composed of a set of Normative Statements, often with a Conformance Clause and associated Test Assertions. A Normative Statement defines the prescriptive requirements on a conformance target (Green and Kostovarov, 2009). In the standardisation terminology, conformance refers to the fulfillment of specified requirements by an implementation of the standard. Furthermore, a Test Assertion is an independent, complete, testable or measurable statement for evaluating the adherence of part of an implementation to a Normative Statement in a specification (OASIS TAG TC, 2010; Durand et al., 2009).

In this section the ebBP ontology is evaluated. The assessed criteria are consistency and completeness. Consistency is assessed by starting with the test assertions defined in the standard for each normative statement and defining axioms in OWL DL for each test assertion. The reasoner (Pellet) is then executed in order to determine the consistency of the ontology. In section 6.1, for limitations of space, only one example is shown.

Section 6.2 assesses the completeness of the ontology. Completeness is evaluated with competency questions which were defined with a member of the ebXML Business Process Specification Schema Technical Committee; therefore an expert of the domain as well as the standard itself. The competency questions were defined in relation to a specific business-to-business (B2B) scenario defined within the standard. The fact that the competency questions were formulated with an expert (of the domain and the standard) on the basis of a general B2B scenario described in the specification justifies the robustness of the questions to evaluate the ontology.

The test assertions and competency questions were derived from the normative statements contained in the OASIS Standard titled "ebXML Business Process Specification Schema Technical Specification v2.0.4". The normative statements that we focused on were the mandatory ones recognised in the standard by the keyword 'MUST' in the statement. Overall there are 112 mandatory statements in the document. Our work focused on a specific section, namely 3.4 titled "Key Concepts of this Technical Specification". The reason for concentrating on this part of the standard is this section's focus on the fundamental constructs necessary to model processes and collaboration (for example, for our purposes we were not interested in issues such as reliability and security). In section 3.4 37 mandatory statements were identified and represented with competency questions. In this paper, for reasons of space, clarity and readability, we present five of these questions in Section 6.2.

In selecting the five competency questions defined in Section 6.2 the intention is to provide a demonstration that is able to test the most important and general concepts of the standard (i.e., business document, collaboration, signal, transaction and party) since typically it is these concepts that are most frequently used to model processes in ebBP. In other words any information that would be queried from the instantiated models would most likely include at least one of the concepts listed above. At the same time the set of questions were also designed to include either a combination of at least a pair of this base set of concepts or relate one of the concepts to the overarching process specification or package defined to bundle them. This rationale was agreed with the expert and, as a consequence, a subset of normative statements from the standard specification was chosen to inform the competency questions.

Section 7 will discuss the evaluation in more detail.

6.1 Consistency Assessment

As mentioned above the consistency assessment starts with defining Test Assertions for a standard specification's normative statements. It is followed by axiomatisation of these test assertions in ontological terms, concluded with a consistency check by running an OWL reasoner - Pellet in this paper. The following provides an example of such an axiomatisation and consistency check.

a. Define Test Assertions

The following is a test assertion defined for one of the normative statements defined as N1:

```
Normative Source: N1 - A Business Transaction MUST succeed or fail
from both a technical and business protocol perspective
Target = Business Transaction
Prerequisite = (Business Transaction is executed)
Predicate = Succeed OR Fail
Prescription Level: mandatory
```

b. Define Axioms

There is already a lexon defined for the things taking part in the above normative statement and its test assertion as *(Business Transaction, hasState, isStateOf, Success)*. This normative statement is a mandatory statement and an existential constraint is suitable to formalise this normative statement as follows:

```
BusinessTransaction ((hasState some Failure) or (hasState some
Success)) and (hasState some CompletionState)
```

The above normative statement is formalised in OWL and implies that a Business Transaction has to have either at least one 'Failure' or at least one 'Success' and that it has to have a 'CompletionState'. The class of CompletionState(s) is the union of the classes of 'Success' states and 'Failure' states. In addition, it is necessary to define that 'Failure' and 'Success' are disjoint. The above normative statement causes an inconsistency as it is forcing an individual of a class to be both a Successful and Unsuccessful state. In the specification it is mentioned that Success and Failure states belong to the Business Collaboration and not the Business Transaction. While the normative statement indicates that a Business Transaction MUST have one of either Success or Failure states. These are considered to be contradictory in the specification, which is recognised by the reasoner when only the above is defined for the normative statement. This is the only test assertion that failed (or was found to be inconsistent) of the test assertions defined for Section 3.4 of the ebBP v2.0.4 technical specification.

6.2 Completeness Assessment

In order to evaluate the completeness of the ebBP ontology, in this section a set of competency questions are considered as being important to answer. A subset of these competency questions is provided in this section and answered in Section 6.2.2 on the basis of an example process introduced in Section 6.2.1

As depicted in Figure 1, in ebBP, a Business Process is realised by one or more Business Collaborations. Business Collaborations are composed of Business Transactions, which are expressed as the exchange of Business Documents. A Business Transaction in ebBP consists of a Requesting Business Activity, a Responding Business Activity, each of them associated with a role, and one or two document flows between partners. A Business Transaction may also involve the exchange of one or more Business Signals that govern the use and meaning of acknowledgements (OASIS, 2006). Figure 6 depicts the semantics of ebBP Business Transactions.

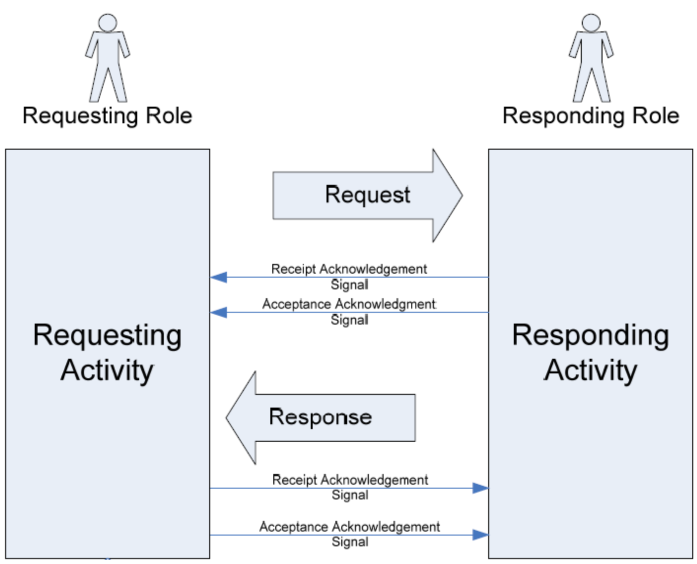

Figure 6. Schematic of core Business Transaction semantics, adopted from (OASIS, 2006).

In a B2B interaction, as per Figure 6, it is usually very important to know:

1. Which Business Documents are used in a particular Process Specification?
2. Which Business Documents are used in a particular Package?

3. Which collaborations in a particular Process Specification use a Business Document with a specific target namespace?
4. Which signals do the transactions in a particular Business Collaboration use?
5. In which transactions of a particular process does a particular party take a requesting role?

In order to answer these questions in the context of this paper using the developed ebBP ontology, an example B2B process is introduced in the following section and these questions are answered in the context of this process.

6.2.1 A Motivating Example

A 'Simple Ordering Process', defined in ebBP v2.0.4 and based on UBL (Universal Business Language) (OASIS UBL TC 2008), is illustrated in Figure 7. This process is publicly available on the OASIS UBL[1]. UBL is a library of standard electronic XML business documents, such as purchase orders and invoices, developed by OASIS. This example is used throughout the rest of the paper to present the ebBP ontology and relevant instances as well as to evaluate the ontology with regards to the competency questions.

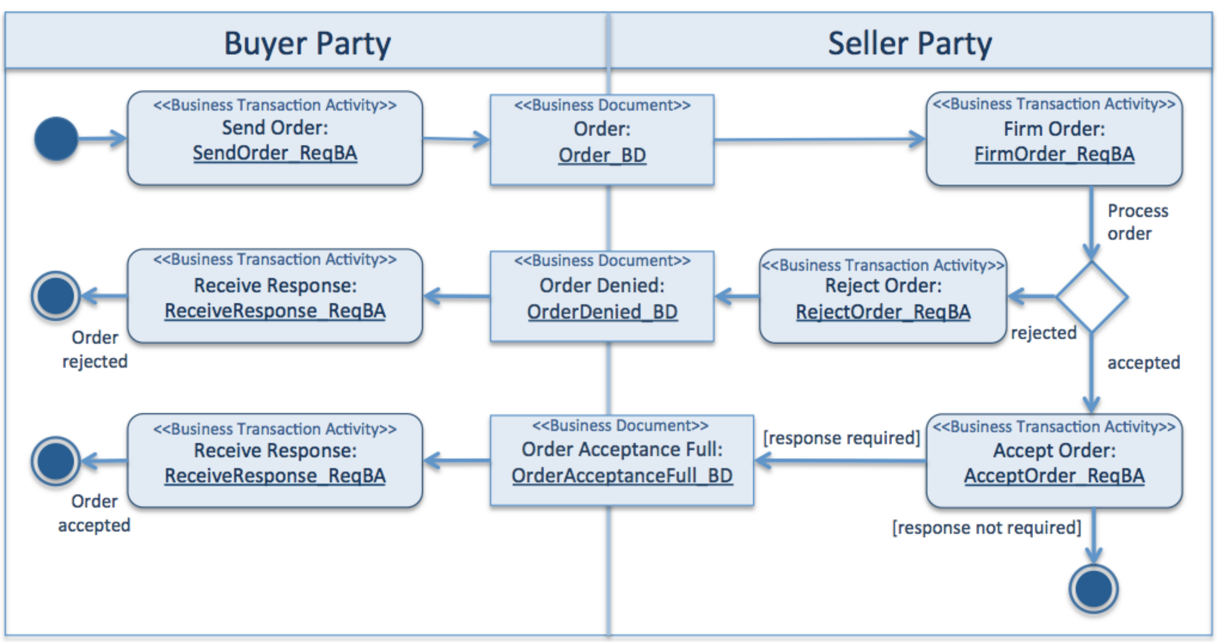

Figure 7. Simple Ordering Process (OASIS UBL TC, 2008).

With regards to the ontological representation of ebBP, one should differentiate between the representation of the business process modeling language and the representation of a specific

[1] http://docs.oasis-open.org/ubl/cs-UBL-1.0-SBS-1.0/universal-business-process-1.0-ebBP/ebxmlbp-2.0_ubl-1-order-with-simple-response-1.xml

process model. Business process modeling language constructs in an ontology can be represented by classes and properties, while specific processes are defined as instances of classes in an ontology. In the ebBP ontology, the language constructs are modeled using OWL and the Simple Ordering process itself and its instances are modeled as individuals of the ebBP ontology. To test the completeness of the ontology the above competency questions are answered for this specific process using DL Queries over the ebBP ontology and its individuals.

The Simple Ordering Process is defined as individuals of the relevant classes and their relationships in the ebBP ontology. Listing 2 shows two individuals of the ontology and depicts their relationship: an instance of a '`RequestingBusinessActivity`' and an instance of a '`CommercialTransaction`'. The names of all instances (e.g., AA2, RAE2 and AAE2) derive from the 'Simple Ordering Process' as defined in ebBP v2.0.4.

```
Individual: SendOrder_ReqBA
    Types:
        RequestingBusinessActivity,
        owl:Thing

    Facts:
        hasAcceptanceAcknowledgement  AA2,
        hasDocumentEnvelope  Order_DE,
        hasReceiptAcknowledgementException  RAE2,
        hasReceiptAcknowledgement  RA2,
        hasAcceptanceAcknowledgementException  AAE2,
        isIntelligibleCheckRequired  "true"^^xsd:boolean,
        hasName  "Send Order",
        isAuthorizationRequired  "true"^^xsd:boolean,
        isNonRepudiationReceiptRequired  "true"^^xsd:boolean,
        hasNameID  "SendOrder_ReqBA",
        isNonRepudiationRequired  "true"^^xsd:Boolean
==============================================
Individual: CreateOrder_CT
    Types:
        CommercialTransaction,
        owl:Thing

    Facts:
        hasRequestingRole  OrderInitiator,
        hasRequestingRole  OrderResponder,
        hasRespondingBusinessActivity  FirmOrder_ResBA,
        hasRequestingBusinessActivity  SendOrder_ReqBA,
        hasName  "Create Order",
        hasNameID  "CreateOrder_CT"
```

Listing 2. Two individuals of ordering process in the ebBP Ontology.

6.2.2 Competency questions in the context of the Simple Ordering process

With regards to the Simple Ordering process, there are several key 'drill-down' type knowledge questions that are important to answer. In this section the competency questions provided in Section 6.1 are answered in the context of the Simple Ordering process. Each competency question is answered using a DL Query provided in the following.

Competency question 1. Which Business Documents are used in the Simple Ordering process?

```
BusinessDocument and isBusinessDocumentOf some
 (ProcessSpecification and hasNameUuid value
"bpid:urn:oasis:names:draft:bpss:ubl-2-order-with-simple-
response-process-2")
```

Listing 3. DL Query for competency question 1.

According to the 'Simple Ordering Process' XML instance introduced earlier in this section, the result of this query should be and is: 'orderAcceptedinFull_BD', 'Order_BD' and 'OrderDenied_BD'. These are the name of individuals in the UBL Simple Ordering Process.

As seen in Listing 3 the '`isBusinessDocumentOf`' Object Property is used for querying the ontology to answer the competency question. This property is the inverse property of '`hasBusinessDocument`'. Without this inverse property answering this question would not be possible when there is more than one process defined in the knowledge base. This competency question shows how important inverse properties are for 'drill down' queries. Inverse properties are used in most of the competency questions discussed in this paper.

Competency question 2. Which Business Documents are used in Package "`OrderWithSimpleResponse`"?

```
BusinessDocument and isBusinessDocumentOf some
 (Package and hasNameID value "OrderWithSimpleResponse")
```

Listing 4. DL Query for competency question 2.

The result of this query should be and is: 'OrderAcceptedinFull_BD', 'Order_BD' and 'OrderDenied_BD'.

Competency question 3. Which Signals do the transactions in collaboration "`Create Order`" use?

```
Signal and isSignalOf some
 (SignalEnvelopeType and isSignalEnvelopeTypeOf some
  (BusinessAction and  isBusinessActionOf some
   (CommercialTransaction and isBusinessTransactionOf some
    (BusinessTransactionActivity and
     isBusinessTransactionActivityOf some
      it(BusinessCollaboration and hasNameID value
"CreateOrder_BC")))))
```

Listing 5. DL Query for competency question 3.

The result of this query should be and is: ‘ra2’,’aa2’,’aae2’ and ‘rae2’.

Competency question 4. Which collaborations in the Simple Ordering process use the Business Document whose target namespace is "urn:oasis:names:specification:ubl:schema:xsd:OrderResponse- Simple-2"?

```
BusinessCollaboration and
 (hasBusinessTransactionActivity some
  (BusinessTransactionActivity and
   refersToBusinessTransaction some
    (BusinessTransaction and hasBusinessAction some
     (BusinessAction and hasDocumentEnvelope some
      (DocumentEnvelope and hasBusinessDocument some
       (BusinessDocument and hasSpecification some
        (Specification and hasTargetNamespace value
"urn:oasis:names:specification:ubl:schema:xsd:OrderResponseSim
ple-2" ^^ anyURI ))))))))
and (BusinessCollaboration and
      isRealisationOfProcessSpecification some
      (ProcessSpecification and hasUuid value
"bpid:urn:oasis:names:draft:bpss:ubl-2-order-with-simple-
response-process-2")
```

Listing 6. Optimised DL Query for competency question 4

The result of this query should be and is ‘CreateOrder_BC’.

The Object Property `hasBusinessAction is defined` as a superproperty of `hasRequestingBusinessActivity` and `hasRespondingBusinessActivity` in the ebBP Ontology. Furthermore they all have inverse properties called `isBusinessActionOf`, `isRequestingBusinessActivityOf` and `isRespondingBusinessActivityOf` respectively. This allows the competency questions to be answered. Additionally if the superproperty did not exist the query in Listing 6 would have been similar to Listing 7.

It is clear that although it would have been possible to answer competency question 4 without optimisation, the query would have been longer and less clear. This was achieved with a simple superproperty added to the ontology. These added semantics are only achievable through the systematic engineering of the ontology and impossible with automatic transformation of a XML schema to an ontology.

```
BusinessCollaboration and
 (hasBusinessTransactionActivity some
  (BusinessTransactionActivity and
refersToBusinessTransaction some
   (CommercialTransaction and
    (hasRequestingBusinessActivity some
     (RequestingBusinessActivity and  hasDocumentEnvelope
some
      (DocumentEnvelope and  hasBusinessDocument some
       (BusinessDocument and hasSpecification some
(Specification and hasTargetNamespace value
"urn:oasis:names:specification:ubl:schema:xsd:OrderResponseSi
mple-2" ^^ anyURI ))))))))
or
BusinessCollaboration and
 (hasBusinessTransactionActivity some
  (BusinessTransactionActivity and
refersToBusinessTransaction some
   (CommercialTransaction and
    (hasRespondingBsinessActivity some
     (RespondingBusinessActivity and hasDocumentEnvelope some
      (DocumentEnvelope and  hasBusinessDocument some
        (BusinessDocument and hasSpecification some
          (Specification and hasTargetNamespace value
"urn:oasis:names:specification:ubl:schema:xsd:OrderResponseSi
mple-2" ^^ anyURI ))))))))
and
BusinessCollaboration and isRealisationOfProcessSpecification
some
 (ProcessSpecification and hasUuid value
"bpid:urn:oasis:names:draft:bpss:ubl-2-order-with-simple-
response-process-2")
```

Listing 7. Non-optimised DL Query for competency question 4.

Competency question 5. In which transactions in the Simple Ordering process does the "Buyer" party take a requesting role?

```
CommercialTransaction and
 isBusinessTransactionOf some
  (ProcessSpecification and hasUuid value
"bpid:urn:oasis:names:draft:bpss:ubl-2-order-with-simple-
response-process-2")
and
 isRealizedByBusinessTransactionActivity some
  (BusinessTransactionActivity
   and  hasPerforms some
     (Performs and hasCurrentRole some
      (Role and hasName value "Buyer")and
       hasPerformsRole some
        (RequestingRole and
          hasNameID value "OrderInitiator")))
```

Listing 8. DL Query for competency question 5.

Competency question 5 is basically addressing the relationship between Business Transactions and Business Transaction Activities, which are their realisation and their corresponding roles. The result of this query should be and is ‘CreateOrder_CT’.

7 Discussion of Evaluation

The previous section presented an evaluation of the ebBP ontology produced by applying the OntoStanD methodology. The specific criteria that the ontology was evaluated against are completeness and consistency. The evaluation directly assesses the ebBP ontology and indirectly assesses OntoStanD. In fact a methodology is as good as the artifacts it produces. While it is possible to provide in this paper an evaluation of the ontology, this evaluation must also be considered as part of the long-term evaluation of OntoStanD. As with any methodology, OntoStanD must necessarily be evaluated over many projects, in the context of either standards development or the usage of such standards. The work presented in this paper contributes toward this longer-term evaluation.

As for the evaluation of the ebBP ontology it is based on the use of competency questions and their formal representations in DL query as a means to determine whether the ontology contains a sufficient set of axioms to satisfy the requirements expressed by the competency questions. The use of competency questions is a recognised approach to the evaluation of ontologies. Specifically competency questions represent a way to evaluate the ‘completeness’ of an ontology with respect to the functions (or requirements) it was designed for. This definition of completeness accords with much of the literature on ontology evaluation (Gruninger and Fox, 1994) and is constrained to the intended purposes of an ontology as defined by an organisation like a Standards Body or the actual users of the standard. Here completeness does not refer to coverage of the domain modeled (for example, business processes). This kind of completeness would be quite difficult, if not impossible, to evaluate after only one ontology engineering project. In fact, coverage of an entire domain would only be possible by testing the ontology systematically over time against considerable amounts of domain data derived from, for example, industrial projects in which business processes and collaborations are developed anew or re-engineered. Data derived from such projects would be tested against existing ontologies to identify weaknesses in the models. Over time there would be a point in which the ontological models reach a certain level of 'maturity' or 'saturation' whereby the models do not change regardless of any new data they are tested against (Daga et al., 2005). At that stage the ontologies can be considered complete with respect to a whole domain with a very high level of confidence. While the evaluation in the previous section provides us with the necessary confidence to state that the ebBP ontology is complete with respect to its intended purposes, the ontology would need to be tested more thoroughly over time against data of business process engineering projects in order to ascertain its 'domain completeness'.

The evaluation of ebBP also assessed the consistency of the ontology. This was carried out by defining formal test assertions derived from normative statements contained in the ebBP standard specification. This part of the evaluation is aimed at identifying logical inconsistencies in: (1) the specification and (2) the way the ontology was developed. In other words consistency checks serve the purpose of highlighting logical errors in the standard itself or in the ontological artifact produced by applying OntoStanD. An example of the former was provided in Section 6.1. This demonstrates one of the uses of OntoStanD which is to identify inconsistencies in the standard's normative statements and feed this information back to the Standards Body that developed the standard and its definition so as to correct or integrate the specification a posteriori. An approach like OntoStand would similarly help standards developers test their normative statements during development in order to define and release a logically consistent specification (i.e., a priori consistency checks).

Expandability (Gómez-Pérez, 2001) or fruitfulness (Daga et al., 2005), here defined as the extent to which an ontology can grow further, integrate with other ontologies and cope with future requirements, was not explicitly assessed in this paper. The reasons are twofold.

First, expandability can only be assessed in relation to models of other domains (or in our case standards or instantiations of standards) (Daga et al., 2005). For example, OntoStanD could be used to model the ontology of another business process standard such as the Business Process Modeling Notation (BPMN). The two ontologies of ebBP and BPMN would then be compared for overlapping class and property definitions leading to possible integration points. Such integration points would not only enable the translation of one type of model into the other, but also allow for the development of a higher-level ontology derived as a superset of the two original languages. This type of expandability goes from lower levels to higher ones.

Second, expandability can occur also by the ability of an ontology to relate to a higher level domain ontology or a foundational ontology (for example, see de Cesare and Geerts (2012)). For example, as mentioned in Section 3, REA could form the basis of a high-level business process ontology independent of any modeling language. In this way an ontology produced with OntoStanD (e.g., the above ebBP ontology) would then be able to relate its classes and properties to the REA-based process ontology. If the standard is capable of being defined also in terms of the higher-level ontology then, all things being equal, it could be considered to possess a high degree of expandability given that all its constructs are defined in terms of an upper-level domain ontology. As it will be noted in the next section, this is among the future work that we intend to carry out.

As the above discussion noted, OntoStanD can help Standards Bodies and Committees to: (1) assess the logical consistency of their normative statements, (2) test the (proposed) standard against its intended purposes via its formalisation in an ontology and the definition of its requirements (competency questions) in formal queries, and (3) help to compare against existing formalised standards of a similar type or assess the standard's expandability against a higher-level ontology (if one exists). Similar benefits also ensue for individual organisations. For example, normally an organisation does not adopt only one standard language or approach. This is especially true of large organisations in which various departments may adopt different standardised 'conceptual technologies' to design their processes. In such a scenario being able to produce formal models (in the form of ontologies) of such standards would help in automatically converting models produced in different languages. Similarly for organisations that collaborate with one another, being able to interoperate, regardless of different modeling languages or schemas, can be achieved more effectively by relating ontologies of the respective standards. OntoStanD provides the method for deriving the ontologies in the first place.

Alongside such benefits there are, however, limitations that must be considered. First, adopting a methodology like OntoStanD may produce an overhead in terms of extra time and cost to produce a standard. In the case of individual organisations this overhead equates to the development of the ontology and its subsequent use. Second, OntoStanD is strongly based on Semantic Web ontologies, therefore heavily oriented toward the development of ontological models that tend to favor formal semantics over real-world semantics. The former can be defined as referring to the logical internal consistency of a set of statements or axioms. The latter can be defined as the mapping between the symbols in a model and the things in the real world. While formal semantics is fundamental especially for computers to process such models, it is also important to ground ontological models in the real world. One way to do so is to ground a domain ontology into a foundational or upper-level ontology (i.e., an ontology that defines the kinds of things that exist and what it means to exist). While at this stage OntoStanD does not ground the ontologies it produces into a foundational ontology, future work will seek to investigate how this can be introduced into the methodology and the effects it would have on the ontologies produced and the way in which they are subsequently utilised.

8 Conclusion and future research

This paper presented an ontology for the ebXML Business Process Specification Schema (ebBP) which is a public B2B process standard developed by OASIS. To develop this ontology the OntoStanD methodology was utilised as a methodological approach. This ontology is richer than an automatic transformation of an XML schema to OWL and captures syntactic and semantic aspects of ebBP, extracted from the ebBP XML schema as well as its textual specifications. The ebBP ontology is intended to facilitate standards-based B2B interoperability and is evaluated against a set of competency questions, which are designed in collaboration with the developers of ebBP standard. The approach represents an important step in facilitating B2B process alignment between trading partners given that it enables the derivation of formal ontological models from the standards themselves. This represents the first step toward complete interoperability based on ontologies. As discussed in Section 7 an upper-level business process ontology would then be required to connect the ontologies of different standards. Future steps in this research are as follows:

- Developing an upper ontology for B2B processes, which covers ebBP processes and general enough to cover all B2B transactions.
- Explore how ontologies can be utilised in the process of developing B2B process standards.
- Conduct a more coherent evaluation of the ontology based on industrial data.
- The economic benefits of using ontologies as a basis for standards development should be further analyzed and studied.
- Explore how the ebBP ontology can be integrated with standards of business process patterns such as UBL and UBP.
- This paper provides an ontological model of the ebBP standard, i.e. its ontology base layer. Developing the commitment layer, i.e. axioms and rules as stated in OntoStanD, is out of the scope of this paper and is being addressed in our future work.
- Finally, contribute methodologically in the definition of novel evaluation approaches for Design Science Research in the areas of ontology and conceptual modeling.

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