Choosing a BPMN 2.0 Compatible Upper Ontology

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***Abstract* — Nowadays, linkage of BPMN 2.0 business process models with ontologies to achieve consistency and semantic compatibility is still a challenge. This paper addresses a question of finding BPMN 2.0 meta-model compatible upper ontology for the analysis of the completeness of BPMN 2.0 model. Upper ontologies are meta-structures for domain ontologies and based on the correspondence between BPMN 2.0 meta-model and upper ontology a link between BPMN 2.0 models and domain ontology can be provided. A comparison of 5 existing upper ontologies showed that the Bunge-Wand-Weber ontology is the most compatible with the BPMN 2.0 meta-model.**

Keywords-BPMN 2.0; upper ontologies; BWW ontology.

I. INTRODUCTION

Business processes are one of the most valuable assets of any organization. Business processes require applying existing business process knowledge. According to Grant [1], knowledge is the most strategically important resource of the firm and primary role of any organization is application of knowledge in its everyday activities. However, the application of existing knowledge has always been a sophisticated task. A holistic view of end-to-end business process knowledge is required because knowledge of cross-functional processes is distributed across departments, documents, regulations and applications. Different stand-alone applications and documents contain explicit process knowledge and tacit knowledge is “stored” in heads of employees. Business process knowledge must be reusable and applicable across many business processes.

According to Xiao et al. [2], ontologies use a formal way to represent knowledge as a set of concepts and relationships among the concepts. As described by Xiao et al. [2] ontologies are widely used for knowledge representation and sharing. There exist many definitions about what ontology is; however, in the scope of this paper, ontology is a formal specification of a shared conceptualization, as described by Gomez-Perez et al. [3]. According to Gomez-Perez et al. [3], there exist different types of ontologies identified in the literature based on their conceptualization.

Ontologies exist at several levels of abstraction. According to Semy et al. [4], upper ontology is defined as a high-level, domain-independent ontology from which more domain-specific ontologies may be derived. Domain ontologies are reusable in a given specific domain (e.g., medical, law, enterprise, engineering, etc.) providing vocabularies about the activities taking place in that domain and their relationships, as described by Gomez-Perez et al. [3]. As described by Mascardi et al. [5] upper ontology contains general concepts that are the same across all domains. Thus, upper ontology can be used as a meta-structure for defining domain ontologies.

Motivation for this research is described as follows. BPMN 2.0 (or Business Process Model and Notation 2.0 [6]) is the de-facto standard for representing in a very expressive graphical way the processes occurring in virtually every kind of organization, as described by Chinosi et al. [7]. However, the goal of any modelling activity is a complete and accurate understanding of the real-world domain. Hence business process modelling requires a background knowledge e.g., domain ontology that complements behavioural aspect of an information system. Providing linkage between BPMN 2.0 and domain ontology will facilitate consistency between information system models and domain requirements. Nowadays, linkage between BPMN 2.0 and domain ontology is still a challenge. However the new BPMN 2.0 specification [6] allows integration with third party components using XML-based representation languages (e.g., OWL, RDF) [8]. This new BPMN 2.0 “plug-and-play” feature opens the potential for linking domain ontologies represented as XML structures with BPMN 2.0 models. But, firstly, it is necessary to provide consistency and semantic compatibility between BPMN 2.0 and ontology at the meta-level, namely, linking BPMN 2.0 meta-model with upper ontology that is used as a basis for deriving domain ontology.

Figure 1 depicts the idea of linking BPMN 2.0 process models with domain ontology that is based on compatibility between BPMN 2.0 meta-model and upper ontology that is used as a meta-structure for defining domain ontology. In order to implement the proposed approach for linking BPMN 2.0 process models with domain ontology it is necessary to choose an upper ontology that is compatible with BPMN 2.0 meta-model. The chosen BPMN 2.0 compatible upper ontology will be used as a meta-structure for deriving domain ontology that will be linked with BPMN 2.0 process models in order to sustain the consistency and semantic compatibility between business process models and ontology. Hence, the goal of this research is to choose a BPMN 2.0 meta-model compatible upper ontology by evaluating the most popular upper ontologies described in the literature.

Linking BPMN 2.0 process models with domain ontology will contribute to:

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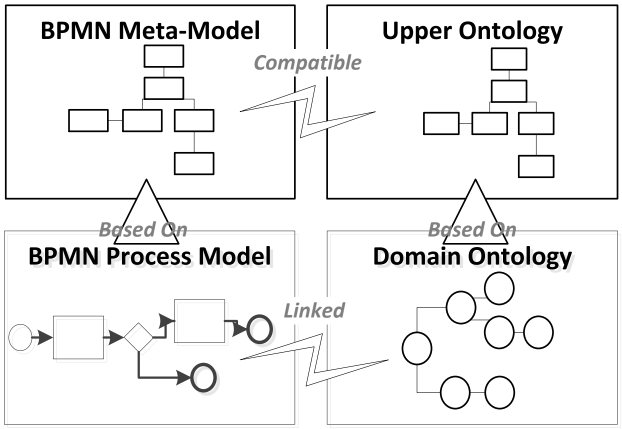

Figure 1. Proposed approach for BPMN and Domain Ontology compatibility

- Consistency between process models and domain ontology - as a result domain ontology and business process models can be validated against each other.
- Analysis of the completeness of BPMN 2.0 models.
- Monitoring of changes introduced to process models or domain ontology and the effects of these changes.
- Establish a semantic consistency and interoperability between process models and domain ontology.
- Gaining better understanding of processes and reasoning capabilities (as ontologies play one of the most important roles in semantic web).

The paper is structured as follows. Section II presents related works. Section III describes the procedure of comparing existing upper ontologies. Section IV describes BPMN 2.0. Section V describes candidate upper ontologies. Section VI presents comparison of upper ontologies. Section VII presents conclusion and future works.

II. RELATED WORKS

Semy et al. [4] examine standard upper ontologies and assess their applicability for a U.S. Government or U.S. Military domain. In this research authors evaluate the state of the art and applicability of upper ontologies using consideration of the ontology purpose, ontological content decisions, licensing restrictions, structural differences, and maturity [4]. Mascardi et al. [5] are finding correspondences between entities belonging to different ontologies describing a set of algorithms that exploit upper ontologies. The analysis presented by Mascardi et al. [5] shows under which circumstances the exploitation of upper ontologies gives significant advantages with respect to traditional approaches that do not use them.

Mascardi et al. [9] are analysing 7 upper ontologies namely BFO, Cyc, DOLCE, GFO, PROTON, Sowa's ontology and SUMO, according to a set of standard software engineering criteria. Rosemann et al. [10] address the issue of modelling information systems by presenting a meta model of the BWW ontology using a meta language that is familiar to information systems professionals facilitating the application of the BWW theory to other modelling techniques that have similar meta models defined.

Francescomarino et al. [11] propose an automated technique to support the business designer both in domain ontology creation/extension and in the semantic annotation of process models expressed in BPMN 2.0. Natschläger et al. [12] present BPMN 2.0 ontology. The defined BPMN 2.0 ontology can be used as a knowledge base for learning BPMN, as a syntax checker to validate separate BPMN 2.0 models and to identify contradictions in specification.

sBPM (or Semantic Business Process Management) was introduced to solve the problem of inconsistency between various process models in a domain using semantic annotating of process models with concepts from ontology. That facilitates reusing of process model parts and unambiguity of the domain concepts. Francescomarino et al. [13] show how semantic web techniques can be applied to formalize, verify and integrate the domain knowledge in BPMN 1.1 diagrams. Wang et al. [14] propose the approach of ontological descriptions of semantics of supply chain processes. Nicola et al. [15] propose the approach of representing a BPMN diagram by using ontology based formalism.

The SUPER EU project (or Semantics Utilised for Process Management within and between Enterprises) created the technological framework constituting BPM enriched with machine readable semantics by employing Semantic Web technology [16].

This research is based on the results of related works and related works have encouraged this research and showed that linkage between BPMN 2.0 and ontologies is an important issue to facilitate information system modelling consistent with the real-world domain. However, to the best of author's knowledge there is no research that compares existing upper ontologies for the compatibility with BPMN 2.0 meta-model.

III. PROCEDURE FOR COMPARISON OF UPPER ONTOLOGIES

To compare existing upper ontologies and choose upper ontology compatible with BPMN 2.0, the following steps were carried out:

- During the mapping of BPMN 2.0 elements to elements of upper ontologies the correspondence link *MAPS* introduced by Etien et al. [17] has been applied. Etien et al. [17] define two correspondence links - *MAPS* and *REPRESENTS*, *MAPS* link was selected because it is defined as following: "one class X maps another class Y if there exist an isomorphism between the set of properties of X. In other terms, each property of X corresponds to one of Y even (domains being eventually different)." *REPRESENTS* link is defined as an association when two constructs of different nature can be linked. In this research *MAPS* link is applied to obtain an upper ontology that is compatible with BPMN 2.0.
- Meta-model for BPMN 2.0 analytical level or level 2, as defined by Silver [8], is created using UML

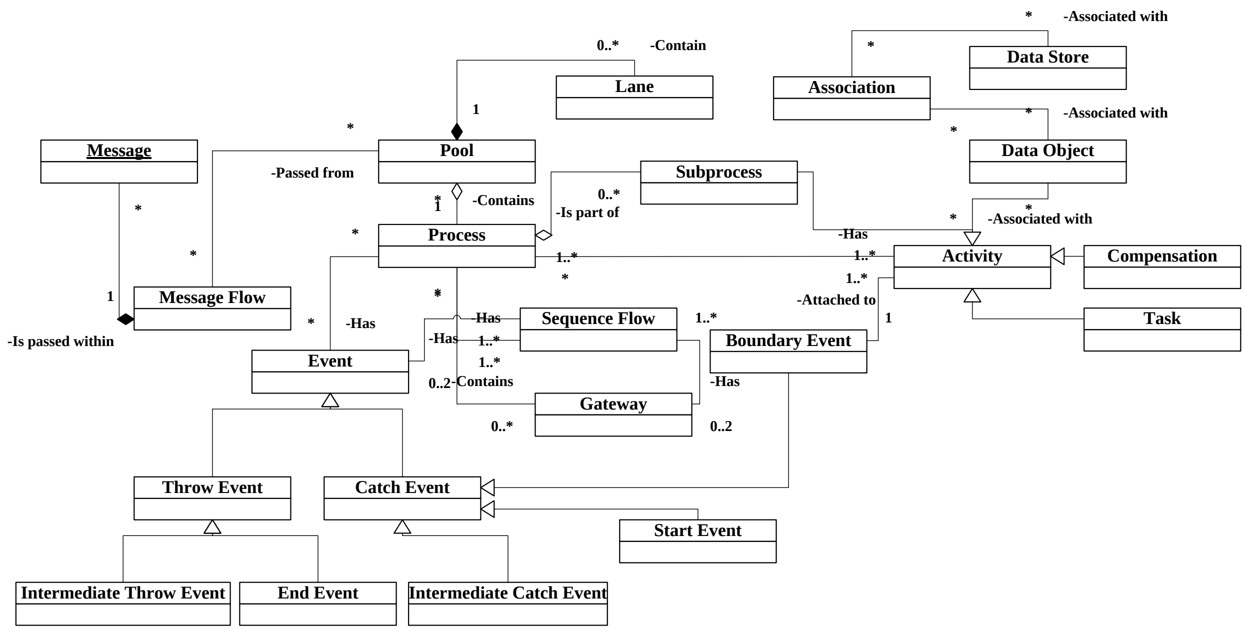

Figure 2. Simplified BPMN 2.0 meta-model

class diagram. BPMN 2.0 meta-model is built to use it as a base for comparison of upper ontologies.

- Candidate upper ontologies are chosen based on whether upper ontology is free to use and whether upper ontology is still being maintained.
- Meta-models for chosen upper ontologies are created using UML class diagrams in order to explicitly compare them with created BPMN 2.0 meta-model.
- A table showing compatibility between chosen upper ontologies and BPMN 2.0 meta-model is presented.
- The upper ontology the meta-model of which supports all main BPMN 2.0 elements is chosen.

IV. BPMN 2.0

Business Process Model and Notation (BPMN 2.0) [6] is the de-facto standard for representing in a very expressive graphical way the business processes occurring in virtually every kind of organization, as described by Chinosi et al. [7].

BPMN 2.0 core elements can be grouped in the following groups of elements [6]:

1. *Swimlanes* – pools and lanes allow grouping BPMN 2.0 model elements according to participants of the process, information systems, organization structure, etc.

2. *Flows* – message and sequence flows between BPMN 2.0 elements.

3. *Data* – data in BPMN 2.0 is represented through data objects and data stores.

4. *Flow objects* – events, activities, and gateways are main BPMN 2.0 flow objects.

According to Silver [8] BPMN 2.0 allows integrating business process model with third party components (e.g., database, web services etc.). BPMN 2.0 defines formal mechanisms to link business process data with a process model using XML Schema Definition language (XSD) or Web Service Definition language (WSDL), as described by Silver [8]. BPMN 2.0 allows linking, sharing and re-using existing business process data across BPMN 2.0 models. This BPMN 2.0 feature can be extended to provide not only process data linkage with a BPMN 2.0 model, but also linking a domain ontology with a BPMN 2.0 model to enable semantic compatibility and consistency between process models and domain ontology. To achieve this linkage it is necessary to represent domain ontology as a BPMN 2.0 compatible structure in order to be able to associate it with related BPMN 2.0 model elements.

Based on a method described in Section II, in this section, a simplified BPMN 2.0 level 2 (as defined by Silver [8]) meta-model is presented in Figure 2.

V. Upper Ontologies

The concepts expressed in upper ontologies are basic and universal concepts and are used to ensure generality and, for a wide range of domains, represent common sense.

Two main parameters were established for choosing candidate upper ontologies - openness of upper ontology (meaning whether ontology is free available) and continuing development of upper ontology (whether upper ontology is still maintained). Based on these criteria the following 5 upper ontologies were chosen for the assessment:

- Basic Formal Ontology (BFO) [18]
- Sowa's Top level ontology, as described by Sowa [19]
- Bunge-Wand-Weber ontology (BWW), as described by Allen et al. [20]
- Suggested Upper Merged Ontology (SUMO) [21]
- Cyc's Upper Ontology [22].

A. Basic Formal Ontology (BFO)

The BFO project was initiated in 2002 and is maintained to this day [18]. BFO is focused on the task of providing a

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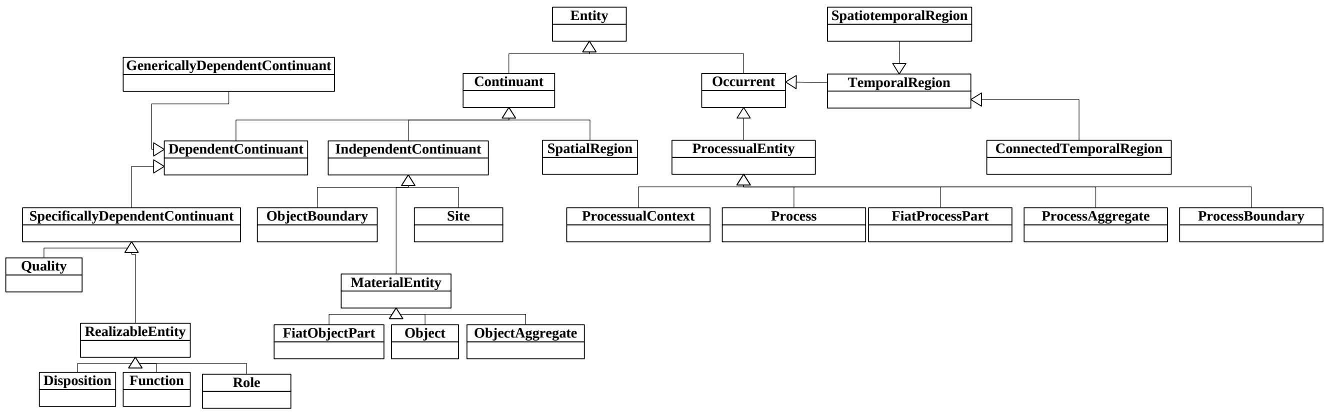

Figure 3. BFO Meta-model.

genuine upper ontology which can be used in support of domain ontologies [18]. BFO consists in a series of sub-ontologies but in this research the upper ontology of BFO is addressed. Figure 3 represents BFO upper ontology meta-model created using UML class diagram.

At the core of BFO consists of is *Entity*. *Entities* are either *continuants* or *occurrents*. A *continuant* is something existing at an instant in time, an *occurrent* is something that has temporal parts. A *spatial region* is three-dimensional. A *processual entity* is something that occurs or happens.

B. Sowa's Top Level Ontology

Sowa's top level ontology includes the basic categories and distinctions that have been derived from a variety of sources in logic, linguistics, philosophy and artificial intelligence, as described by Gomez-Perez et al. [3]. Sowa's top-level ontology includes 12 central categories which are generated from primitive categories. Figure 4 represents Sowa's top level ontology meta-model created using UML class diagram.

C. BWW Ontology

Rosemann et al. [10] describe BWW ontology as useful for description of information systems. As described by Davies et al. [23] an ontology presented by Bunge has been extended and applied to the modelling of information systems. Figure 5 represents BWW Ontology meta-model created using UML class diagram.

D. SUMO Ontology

The Suggested Upper Merged Ontology (SUMO) [21] is an upper level ontology that has been proposed as a starter document for The Standard Upper Ontology Working Group, an IEEE-sanctioned working group [24] of collaborators from the fields of engineering, philosophy, and information science, as described by Niles et al. [25]. Figure 6 represents SUMO meta-model created using UML class diagram.

E. Cyc's Upper Ontology

Cyc's Upper Ontology is contained in the Cyc Knowledge Base, which holds huge amount of common sense knowledge, as described by Gomez-Perez et al. [3]. According to Mascardi et al. [9], the Cyc Knowledge Base is a formalized representation of facts, rules of thumb, and heuristics for reasoning about the objects and events of everyday life. Figure 7 represents Cyc's Upper Ontology meta-model created using UML class diagram.

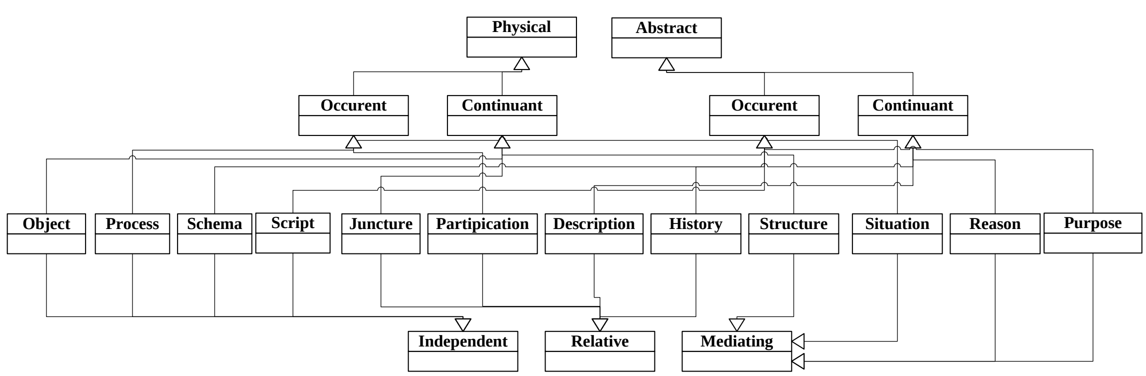

Figure 4. Sowa's Ontology meta-model.

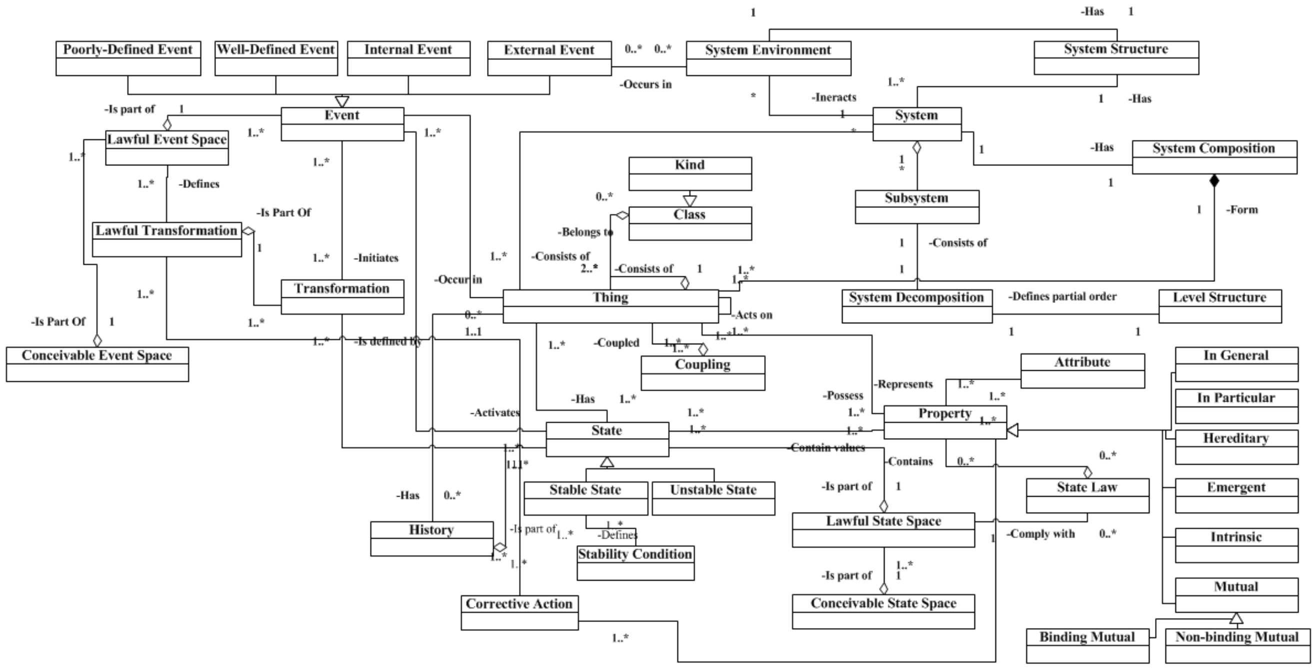

Figure 5. BWW Ontology.

F. Requirements for Upper Ontologies

The requirements that should be fulfilled by an upper ontology that is compatible with BPMN 2.0 can be summarized as follows:

- Ability to represent the notion of a process.
- Ability to represent the notion of an atomic activity.
- Ability to represent the performer of activities and processes.
- Ability to represent artifacts processed.
- Ability to represent internal and external events occurring in the process.
- Ability to represent the sequence flow and logic of activities.
- Ability to represent message flows between various processes.

VI. COMPARISON OF UPPER ONTOLOGIES FOR COMPATIBILITY WITH BPMN 2.0

This section presents a comparison of upper ontologies for their compatibility with BPMN 2.0 meta-model. The analysis is presented in a Table I showing which elements of upper ontologies described in Section V correspond to BPMN 2.0 meta-model elements.

From Table I, the following can be concluded:

- BWW upper ontology supports most of the presented BPMN 2.0 elements.
- SUMO upper ontology is not compatible with BPMN 2.0 meta-model because one of the most important notions of process modelling - the Event notion - is not supported by SUMO upper ontology.
- BPMN 2.0 meta-model element Gateway is supported only by BWW upper ontology with its State Law element which restricts the values of the properties of a thing to a subset that is deemed

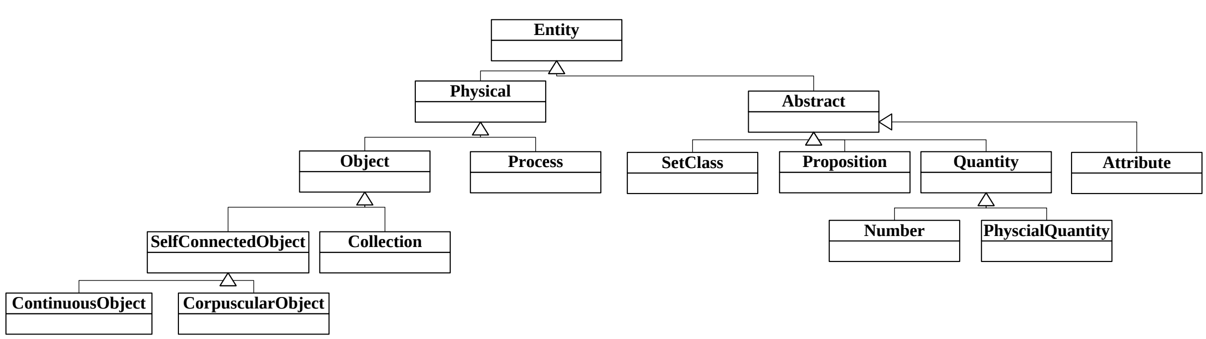

Figure 6. SUMO Ontology.

lawful, as described by Rosemann et al. [26]. According to Silver [8], a Gateway element in BPMN 2.0 has conditions attribute defined controlling the flow of the process.

- BPMN 2.0 elements *Process, Subprocess, Activity, Call Activity, Loop Activity, Compensation, and Task* are supported by all reviewed upper ontologies.
- For particular BPMN 2.0 elements relationship to upper ontology elements is 1 to many - one BPMN 2.0 element can be associated with several upper ontology elements, e.g., BPMN 2.0 *Event* element can be mapped to BFO ontology elements *ProcessBoundary*, *TemporalRegion* and *ConnectedTemporalRegion*.
- BPMN 2.0 element *Loop Activity* is supported only by BFO ontology, which defines *ProcessualContext* element as "(..) consisting of a characteristic spatial shape inhering in some arrangement of other occurrent entities" [18].
- Some elements of upper ontologies are not represented in BPMN 2.0 meta-model.

Based on the comparison presented in Table I, BWW upper ontology is concluded to be the upper ontology supporting BPMN 2.0 meta-model at most.

VII. CONCLUSIONS AND FUTURE WORK

In order to link BPMN 2.0 models with domain ontology to provide consistency it is necessary to ensure compatibility between BPMN 2.0 meta-model and upper ontology that domain ontology is derived from. The paper presented a comparison of existing upper ontologies in order to choose BPMN 2.0 meta-model compatible upper ontology. As a result BWW upper ontology was concluded to be BPMN 2.0 compatible upper ontology supporting most of the basic BPMN 2.0 elements.

By linking BPMN 2.0 process models with domain ontology, the enterprise may achieve the consistency and semantic compatibility between process models and existing ontology. This will help business process modellers across organization to identify, share and reuse existing knowledge explicitly and conduct qualitative process analysis to make decisions concerning new process development. With ontologies supplying the context of process, this contextual information can be exploited to perform semantic analyses of the process.

Practical implications of the presented research can be summarized as follows. Connecting BPMN 2.0 models with ontology will contribute to more precise requirements definition and possibly reducing the time of development and implementation of changes. The BWW representation might be used to analyse the completeness of BPMN 2.0 for software requirements.

However, the BWW ontology does not fully comply with the BPMN 2.0 meta-model. In the future research extensions of BWW and BPMN 2.0 will be addressed to tackle this issue. The author does not propose a new custom upper ontology, because the reviewed upper ontologies are largely recognized, especially BWW ontology in the IS modelling domain, as described by Rosemann et al. [10].

The conducted research has mostly been of a purely theoretical nature. Technical linkage and consistency checking between BPMN 2.0 and upper ontology is a concern of further research. The future work will also address building of algorithms for evaluating the completeness of business process models based on the metrics developed by Etien and Rolland [17]. The future research includes development of the prototype of the proposed solution using existing Open Source solutions, as well as validation of the implemented prototype in the real information systems projects.

In the future work implementation of the proposed approach will be addressed by using BPMN 2.0 existing capability to connect to third party components (e.g., to connect to domain ontology represented as a XML based structure - OWL). The paper has some limitations, namely, no verification or test for validity of this mapping is considered, which will be addressed in the future research.

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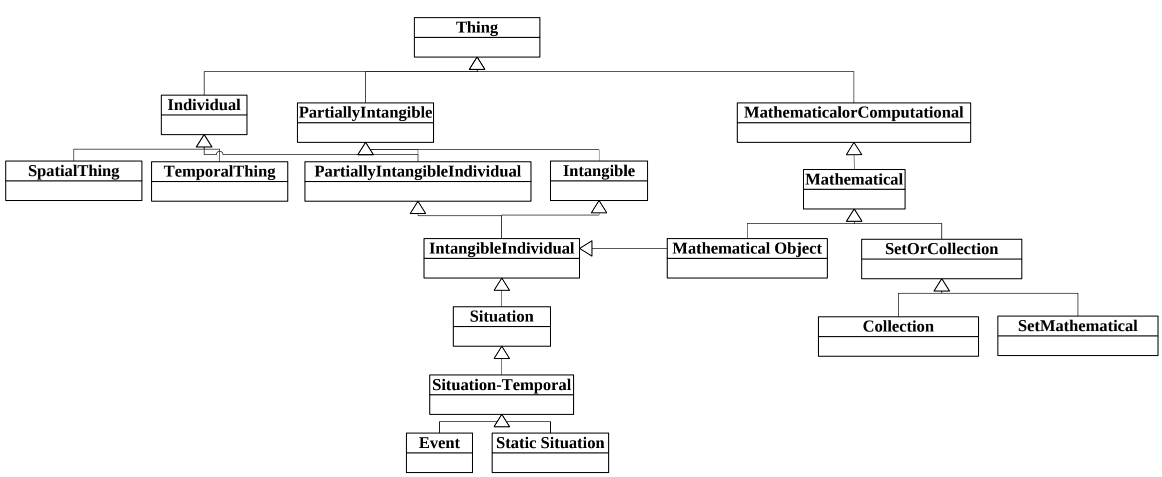

Figure 7. Cyc's Upper Ontology meta-model [5].

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TABLE I. COMPARISON OF UPPER ONTOLOGIES

BPMN 2.0 Element	**BFO Element**	**Sowa's Element**	**BWW Element**	**SUMO Element**	**Cyc's Element**
Process	ProcessualEntity	Process	Transformation	Process	TemporalThing
Subprocess	Process	Process	Transformation	Process	TemporalThing
Activity	Process Function	Process	Transformation	Process	TemporalThing
Compensation	Process	Process	Transformation Well-Defined event State	Process	TemporalThing
Task	Function Disposition	-	Transformation	Process	TemporalThing
Event	ProcessBoundary TemporalRegion ConnectedTemporalRegion	Situation Reason	Event	-	Event
Throw Event	ProcessBoundary	Situation Reason	Internal Event Poorly-Defined Event	-	Event
Catch Event	ProcessBoundary	Situation Reason	External Event Poorly-Defined Event	-	Event
Intermediate Throw Event	ProcessBoundary	-	Internal Event Poorly-Defined Event	-	Event
End Event	ProcessBoundary	Reason	Event Well-Defined Event State	-	Event
Start Event	ProcessBoundary	Purpose Reason	Event Poorly-Defined Event	-	Event
Intermediate Catch Event	ProcessBoundary	-	External Event Poorly-Defined Event	-	Event
Boundary Event	ProcessBoundary	-	Event Poorly-Defined Event	-	Event
Message	-	Reason	External Event	-	-
Message Flow	-	Juncture	Coupling Acts on	-	
Pool	Role Site	Object	Thing Kind Class System	Object Collection	Individual PartiallyIntangible
Lane	Role Site	Object	Subsystem Kind Class	Object Collection	Individual PartiallyIntangible
Association	-	Juncture	-	-	-
Data Store	ObjectAggregate	Object	Thing	Object	Thing
Data Object	MaterialEntity Object FiatObjectPart	Object	Thing	Object	Thing
Sequence Flow	-	Juncture	Lawful transformation	-	-
Gateway	-	-	State Law	-	-