A METHOD AND TOOL SUPPORT FOR INTEGRATED BUSINESS PROCESS MODELING AND ONTOLOGY DEVELOPMENT

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF INFORMATICS
OF
THE MIDDLE EAST TECHNICAL UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
THE DEPARTMENT
OF INFORMATION SYSTEMS

AUGUST 2016

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ABSTRACT

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August 2016, 133 pages

From knowledge management point of view, business process models and ontologies are two essential knowledge artifacts for organizations that consume similar information sources. In this sense, building and managing the relationships between ontologies and business process models provide benefits such as enhanced semantic quality of both artifacts and effort savings. A method and tool support could guide integrated business process modeling and ontology building, and therefore enhance their semantic quality and increase the benefits gained from both. In this study, PROMPTUM method for integrated process modeling and ontology development that integrates well-established practices of business process modeling and ontology development is presented. This study also introduces the PROMPTUM toolset, which enables PROMPTUM method to be effective by supporting to model relations between the ontologies and the labels within the process model collections. In establishing these relations, the PROMPTUM toolset enables definition and management of labels and terms within labels of the process models and the process model elements as resources of domain ontologies. Thus, a related resource is managed as a single resource representing the same real-world object in both artifacts in both creation and maintenance once PROMPTUM toolset and method are utilized.

Keywords: Business Process Modeling, Ontology Development, PROMPTUM, Integrated Development.

ÖZ

BÜTÜNLEŞİK İŞ SÜRECİ MODELLEME VE ONTOLOJİ GELİŞTİRME İÇİN BİR YÖNTEM VE ARAÇ DESTEĞİ

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Ağustos 2016, 133 sayfa

Bilgi yönetimi bakış açısından, organizasyonlar için iş süreci modelleri ve ontolojiler benzer bilgi kaynaklarından beslenen iki temel bilgi artefaktıdır. Bu bağlamda, ontolojiler ve iş süreci modelleri arasındaki ilişkilerin kurulması ve yönetilmesi her iki artefaktın anlamsal kalitelerinin artması ve işgücü tasarrufu gibi faydalar getirir. Bir yöntem ve araç desteği, bütünleşik iş süreci modelleme ve ontoloji geliştirmeye kılavuzluk sağlayabilir ve bu şekilde anlamsal kalitelerini çoğaltabilir ve her ikisinden elde edilen faydaları arttırabilir. Bu çalışmada, bütünleşik iş süreci modelleme ve ontoloji geliştirme için iş süreci modelleme ve ontoloji geliştirmenin köklü pratiklerini bir araya getiren PROMPTUM yöntemi sunulmaktadır. Bu çalışma ayrıca, ontolojiler ve süreç modeli koleksiyonlarındaki etiketler arasındaki ilişkilerin modellenmesine olanak sağlayarak PROMPTUM yöntemini etkin kılan PROMPTUM araç setini tanıtmaktadır. PROMPTUM araç seti bu ilişkileri kurarken, süreç modelleri ve süreç model öğelerinin etiketlerinin ve etiketlerde geçen terimlerin alan ontolojilerinin kaynakları olarak tanımlanması ve yönetilmesine olanak sağlamaktadır. Böylece, PROMPTUM yöntem ve araç seti kullanıldığında, hem yaratılışta hem de bakım sırasında, ilişkili bir kaynak her iki artefakt içinde aynı gerçek dünya nesnesini temsil eden tek bir kaynak olarak yönetilmektedir.

Anahtar Kelimeler: İş Süreci Modelleme, Ontoloji Geliştirme, PROMPTUM, Bütünleşik Geliştirme.

to my beloved wife, Duygu
and my one year old son, Erdem

ACKNOWLEDGEMENTS

First of all, I express my sincere gratitude to my supervisor Onur Demirörs for his insight and guidance during my study. I am thankful to him for his continuous stimulation, suggestions, and support. He has been an excellent mentor.

This thesis would not have been possible without the support I received from my colleagues and friends, Özge Gürbüz and Erdem Eser Ekinci. For their contributions and friendship, I am grateful forever.

I am deeply grateful to Ali Yıldız, Murat Salmanoğlu, Ahmet Dikici, and Selim Gökçe for their contributions to this work and being good friends.

My sincere thanks also go to my mother Hafize, my father Hasan, my aunt Aysel, my sister Merve, and last but not the least to my late grandmother Mürvet. They have always supported me and I could not have done this without them.

Lastly, I would like to thank my wife Duygu for her endless love, support, and encouragement. I am always grateful to Duygu for being the most incredible mother and to my son Erdem for being the most precious thing in my life.

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LIST OF ABBREVIATIONS

ANSI	American National Standard Institute
API	Application Programming Interface
BPEL	Business Process Execution Language
BPMN	Business Process Model and Notation
BPMO	Business Process Modeling Ontology
eEPC	Extended Event-Driven Process Chain
EMF	Eclipse Modeling Framework
EPC	Event-Driven Process Chain
EPF	Eclipse Process Framework
EU	European Union
EXP	Exploration
DAML+OIL	DARPA Agent Markup Language and Ontology Interchange Language
FT	Function Tree
GMF	Graphical Modeling Framework
IDEF	Integrated Definition for Functional Modeling
KIF	Knowledge Interchange Format
METU	Middle East Technical University
MS	Microsoft
OWL	Web Ontology Language
PA	Preliminary Analysis
POBA	Process Ontology Based Approach
RAD	Role Activity Diagram
RDF	Resource Description Framework
RDFS	Resource Description Framework Schema
SD	Scope Definition
SUPER	Semantics Utilized for Process Management within and between Enterprises
UML	Unified Modeling Language
UPROM	Unified Business Process Modeling
VC	Value Chain
V&V	Verification and Validation

CHAPTER 1

INTRODUCTION

Business process modeling has a central role in business process management domain. According to van der Aalst, ter Hofstede, and Weske (2003), business process management aims to design, enact, control and analyze operational processes, which involve people, organizations, applications, documents and other information, by supporting business processes with methods, techniques and software. Minoli (2008) defines the purpose of business process modeling as to seek standardization in business process management where the related business processes might include several applications, data repositories, corporate departments or even companies. Stolfa & Vondrak (2004) states the main purpose of business process modeling as managing and stimulating processes.

Ontologies are formal representations of domain knowledge that includes concepts and relations between them. "Ontology is a formal, explicit specification of a shared conceptualization" (Gruber, 1993). Practical uses of ontologies include (Uschold & Gruninger, 1996):

- Improving communication between entities (people and organizations),
- Enabling interoperability between systems,
- Providing system engineering benefits in terms of improving reusability, reliability and specification.

Similarly, Noy and McGuinness (2001) suggest that purposes to develop ontologies include:

- Enabling people and software reach a shared understanding of the structure of information,
- Reuse of domain knowledge,
- Making domain assumptions explicit,
- Differentiating domain and operational knowledge,
- Analyzing domain knowledge.

Ontologies development is an essential part of Knowledge Management domain in terms of creating domain knowledge. Business process models, on the other hand, can be regarded as important for organizations to create formal knowledge (Kalpic & Bernus, 2006) from knowledge management perspective. So, both activities are utilized as a part of knowledge creation. They also share similar development processes that consume similar resources. In this sense, building and managing the relationships between ontologies and business process models in development would provide several benefits. A method and tool support could guide integrated business process modeling and ontology building, and therefore enhance their semantic quality and increase the benefits gained from both. In this study, PROMPTUM method and toolset for supporting integrated business process modeling and ontology development is presented.

The rest of the first chapter introduces the background of the problem, purpose and significance of the study, research strategy, and structure of the study.

1.1 Background of the Problem

Research regarding the relations between business process modeling and ontology development has gained pace in recent years. Some (I. G. Davis, Rosemann, & Green, 2004; Jr, Almeida, & Guizzardi, 2010) investigate the process modeling notations based on foundational ontologies, whereas others (Haller, Marmolowski, Oren, & Gaaloul, 2008; Höfferer, 2007; Sönmez, Canlı, Gökçe, Ünver, & Güçlü, 2010) focus on the importance and practical uses of process related ontologies. Mapping or transformation approaches between business process models and ontologies has also been widely studied (Belecheanu et al., 2007; Cimpian, Komazec, Lintner, Blamauer, & Evenson, 2008; Eisenbarth, 2013; Fan, Hua, Storey, & Zhao, 2016; Francescomarino, Ghidini, Rospocher, Serafini, & Tonella, 2009; Koschmider & Oberweis, 2005; Leopold et al., 2015; Thomas & Fellmann, 2009). However, software tools to support integrated ontology development and business process modeling is not reported in any of the surveyed academic and industrial sources. Although there are some studies (Cherfi, Ayad, & Comyn-Wattiau, 2013; Fan et al., 2016) that base their approaches of process modeling on discovering process model elements by matching them with entities in domain ontologies, there are no methods reported in related research to guide integrated process modeling and ontology development.

In practice, organizations performing both process modeling and ontology building activities, allocate duplicated efforts for each development activity conducted using same or similar knowledge sources. Moreover, neither activity benefits from the knowledge created in the other, thus the resulting products have the potential to be inconsistent with each other. Furthermore, the use of ontologies in process modeling would ease preventing and detecting redundancies and inconsistencies between labels of process model elements (W. M. P. van der Aalst, 2013) and business process models would serve as a source of process knowledge that would increase the completeness of domain ontologies when used in ontology development.

In terms of making use of process models in ontology development, related research is rather poor and stagnant. However, process models are prominent sources of knowledge that can be used in ontology development. In knowledge acquisition, which is eliciting knowledge about the domain from sources such as experts, books, handbooks, and figures (Fernández-López, Gómez-Pérez, & Juristo, 1997), and in identifying the key concepts and their properties and relationships in a domain as part of conceptualization (Garcia et al., 2010), process models are viable knowledge source candidates to be used in ontology development.

In recent research, behavioral semantics of business process models has received much more attention than the textual content of process models (Mendling, Leopold, & Pittke, 2014). However, the textual content representing the process elements such as activities, inputs, outputs, and actors are as important for the semantic quality of process models as the behavioral semantics that represent the process flow. Thus, it would be beneficial to use domain ontologies for the sake of semantic quality of process models in representing the correct information regarding the domain they reside in. This would also enable semantic enrichment of business process models which offers the promise of integration and collaboration of business processes across enterprises (Hoang, Jung, & Tran, 2013).

Challenges of semantic process modeling, as identified by Mendling et al. (2014), include challenges that could potentially be resolved with the use of ontologies. Our study mostly focuses on the label challenges of semantic business process modeling that relate to interpretation, analysis, and improvement of the grammar and terms within the process model element labels and the process model labels. Some of the label challenges are related to issues about identification of semantic components of labels (C1 in Mendling et al. (2014)), recognizing the meaning of terms from labels (C3), identifying homonymous or synonymous terms (C4), and assessing the similarity of labels (C6). Our study presents opportunities for resolving these issues as integrated process modeling and ontology development with tool support provides means to define and manage labels and terms in labels of the process models and the process model elements as resources within a formal domain ontology. Another challenge our study relates is about "discovering a formal ontology from a collection of process models" (C24). This is a challenge our study addresses by suggesting business process models and domain ontologies be developed as integrated.

1.2 Purpose of the Study

This study intends to bridge the gap between ontology development and business process modeling by presenting a method and tool support for integrated development. As shown in Figure 1, the method will guide the analysts in integrated development of process model collections and ontologies and the tool support will enable the development of related and consistent ontologies and process models.

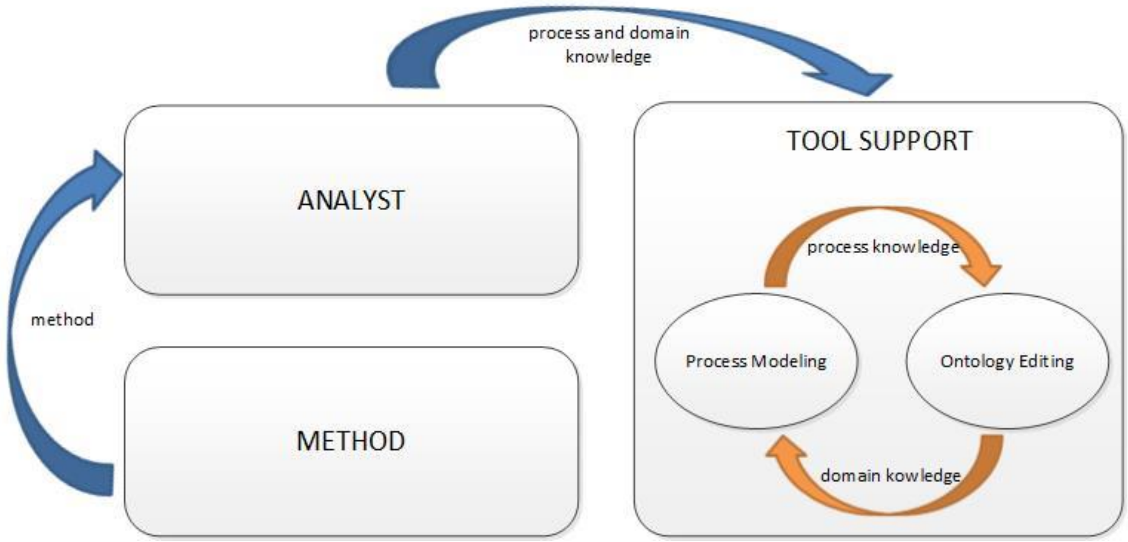

Figure 1 Relationships between the analyst, method and tool support

The method for integrated business process modeling and ontology building will guide practitioners in creating business process models and ontologies that are compatible in creation and maintenance. It will bring together standards and best practices in academia and industry in defining a set of processes to guide integrated development. The method will support developing and maintaining ontologies and process models together.

The method will be composed of a set of processes that include activities, tasks, and guidelines. In initial phases of this study, we assessed that several practices regarding the scope, stakeholders, information elicitation, verification, and verification of ontology building and process modeling share similarities in terms of their applications and methods utilized in their target discipline. Thus, the method will bring together the practices that are specific to the process modeling or ontology building disciplines and consolidate these practices as to be applied for both process modeling and ontology building where possible.

The tool support will enable relations to be established between ontologies and process model collections in integrated development. We envisioned the tool support to have several components. The tool support will incorporate industry standard basic features for process modeling and ontology development. So that, analysts, who do not intend to perform integrated development, would be able to perform process modeling or ontology building using the tool support.

The major features of the tool support will enable to model relations between the ontologies and the labels within the process model collections. In establishing these relations, the tool support will enable definition and management of labels and terms within the labels of the process models and the process model elements as resources of a formal domain ontology. Thus, in both development and maintenance, a related resource will be managed as a single resource representing the same real-world object in both ontology and process model collection.

1.3 Significance of the Study

In this study, we present the PROMPTUM method and toolset for integrated business process modeling and ontology development.

PROMPTUM method is developed to guide practitioners in integrated development of process model collections and ontologies. There is another study, POBA (Fan et al., 2016), that provides a 3-phased method for process modeling by discovering the process model elements from a domain ontology. However, PROMPTUM method differentiates itself by suggesting both artifacts can be developed with an integrated approach. And in doing so, PROMPTUM method reuses and adopts several best practices in academic and industrial sources.

In terms of matching the ontology resources with labels within process model collections, Cherfi et al. (2013) claims the matching rules exist between the whole labels in process model collections and ontology resources. This is a similar matching approach to the one discussed in POBA (Fan et al., 2016). However, PROMPTUM method, with the support of PROMPTUM toolset, describes the matching not only between labels in process model collections and ontology resources but also between terms and phrases within labels in process model collections and ontology resources.

The PROMPTUM toolset is composed of a process modeling tool, an ontology editor/server, and a plugin for managing the relations between process models and ontologies. The PROMPTUM toolset provides support for integrated and/or sequential development and maintenance of business process models and ontologies. It does this by enabling the relations between ontology resources, and process model labels and process model element labels and the terms within the labels be established and managed. It is the first tool reported in literature to semantically manage the ontology resources, and the labels and terms within labels in business process models as integrated.

The PROMPTUM method and toolset provides features to address the label challenges in business process modeling (Mendling et al., 2014) such as identifying the semantic components of labels, meaning of terms within labels, homonymous and synonymous terms, and similarity of labels. Previous studies (Cherfi et al., 2013; Fan et al., 2016) have suggested that establishing relationships between ontologies and labels in process model collections even without tool support would increase the semantic quality of the process models. We anticipate that using the business process knowledge that reside in process model collections would also improve the quality of ontologies. The benefits to both ontologies and process models upon managing and developing these two artifacts with an integrated approach by tool support is investigated in this study.

1.4 Research Strategy

The research questions that will be provided answers for in this study are as follows:

- Is integrated business process modeling and ontology development a feasible practice in terms of the cohesion between ontologies and business process models in same or similar domains?
- What are the requirements of tool support for integrated business process modeling and ontology development?
- Does consistency between business process models and ontologies improve with integrated development?
- Does integrated business process modeling and ontology development improve the semantic quality of the process models or ontologies when compared with separate traditional development?
- How would the development effort be affected with integrated business process modeling and ontology development?
- What are the perceived benefits of integrated business process modeling and ontology development compared with separate traditional development?

First step of this study was to formulate the problem, propose a solution, and plan the research agenda. In this step, an extensive review of related research studies and industry practices regarding relations between business process models and ontologies was performed to identify the gap to be filled with this study.

Then, an exploratory study including two case studies for investigating the first two research questions provided above was planned, designed, and performed. It was performed by using traditional methods and tools for developing process model collections and ontologies that belong to similar or same domains. The exploratory study not only validated the problem identified and revealed the necessity of the proposed solution but also identified the tool support requirements for integrated business process modeling and ontology development.

Next, the PROMPTUM method that will guide practitioners in performing integrated business process modeling and ontology development was developed. In developing the method, we utilized the academic literature, industrial best practices and experiences. The PROMPTUM method specified the processes, activities within processes, tasks within activities, definitions, guiding notes, guidelines, form templates, and references to the state of the art practices.

The tool support for integrated business process modeling and ontology development (i.e. PROMPTUM toolset) integrating an ontology editor and process modeling tool, and conforming to the requirements identified in exploratory study was developed in the next step of the research. Two of the three components of the PROMPTUM toolset (i.e. PROMPTUM Ontology Server and PROMPTUM Process Modeling Plugin) were developed for this study, while an existing process modeling tool (i.e. UPROM tool) was integrated into the PROMPTUM toolset as a third component.

Finally, the explanatory study finding answers to the last four research questions specified above was carefully planned, designed, performed and analyzed. The explanatory study was conducted with the overall goal of identifying the benefits and pitfalls of integrated business process modeling and ontology development with the support of PROMPTUM method and toolset. It included two case studies that focus on integrated and separate development process model collections and/or ontologies for a real domain.

1.5 Structure of the Study

The rest of this study includes six more chapters.

Next (i.e. second) chapter provides a discussion about the state of the art on business process modeling and ontology development. It also includes a summary of related research on relations between process models and ontologies.

Third chapter describes tha exploratory study performed to identify the necessity and tool support requirements of integrated business process modeling and ontology development.

Fourth and fifth chapters specify the PROMPTUM method and toolset, respectively, developed for supporting integrated business process modeling and ontology development.

Sixth chapter describes the explanatory study conducted to evaluate the necessity and benefits of PROMPTUM method and toolset in real-world cases.

Last (i.e. seventh) chapter provides an overall discussion of the contributions, limitations and future work regarding this thesis.

CHAPTER 2

STATE OF THE ART

This chapter consists of four sections. First section describes business process modeling languages and tools in industry and academia. Second section provides a summary of ontology development methodologies, ontology definition languages, and ontology tools. Related research on relations between business process modeling and ontology development is discussed in third section. Final section provides a brief discussion of the most related studies and comparison in terms of the suggested methods, tool support, and benefits.

2.1 Business Process Modeling

Mainstream business process modeling languages and tools in the industry and academia are depicted in this section.

2.1.1 Business Process Modeling Languages

Some of the business process modeling languages that are most referred in research are Event-driven Process Chain (EPC), Business Process Modeling Notation (BPMN), Role Activity Diagram (RAD) and Petri Nets. All of these notations represent functional and behavioral perspectives, all except Petri Nets represent organizational perspective, BPMN and EPC represent informational perspective while none of them represents business process context perspective (List & Korherr, 2006). Some other notations used in business process modeling include ETVX, BPEL (Business Process Execution Language), UML Activity Diagram, ANSI flowcharts, and IDEF3.

Event-driven process chain (EPC) is a business process modeling notation that became popular in 1990s and used to define logical and temporal dependencies between activities that are performed in business processes (Mendling, 2008; Scheer & Schneider, 2006). Extended EPC (eEPC) notation is based on activity flow combining static resources of business, such as organizations, systems, rules, input and outputs (R. Davis & Brabander, 2007). eEPC is regarded as a business process modeling notation that does not require much modeling expertise by describing the business processes with business logic instead of formal process specification logic (W. M. P. van der Aalst, 1999).

2.1.2 Business Process Modeling Tools

There are many tools for process modeling aiming to support various aspects in process modeling. Some of the well-known tools used in business process modeling are SoftwareAG's ARIS Platform, EPF (Eclipse Process Framework) Composer, MS Visio, QPR ProcessDesigner, iGrafx FlowCharter, Rational System Architect, Lombardi's Blueprint and Sparx Enterprise Architect (Norton, Blechar, & Jones, 2010). Others include Visual Paradigm, Signavio Process Editor, Bizagi, and Savvion.

UPROM (Aysolmaz & Demirörs, 2015) is another process modeling tool that also enables generating system requirements and size estimations from process models with a unified approach. UPROM is developed upon bflow* Toolbox (Laue, Storch, & Höß, 2015) which is an open source modeling tool. UPROM is extendable by further development or plug-ins.

2.2 Ontology Development

Ontology development can be explored in three perspectives, namely development methodologies, definition languages, and tools.

2.2.1 Ontology Development Methodologies

Some of the most well-known ontology development methodologies are TOVE, METHONTOLOGY, On-To-Knowledge, DILIGENT, UPON, Melting Point and NeOn.

Toronto Virtual Enterprise (TOVE) methodology (Uschold & Gruninger, 1996) specifies a methodology for building ontologies, but lacks in suggesting an ontology development life cycle. Methodology includes the following parts; identify purpose and scope, building the ontology (ontology capture, ontology coding, and integrating existing ontologies), evaluation, documentation and guidelines for each phase.

METHONTOLOGY provides an ontology development life cycle that is inspired by classic waterfall like software life cycle (Fernández-López et al., 1997). It consists of the life cycle phases as specification, conceptualization, formalization, integration, implementation and maintenance.

On-To-Knowledge (Staab, Studer, Schnurr, & Sure, 2001) specializes in application driven ontology development. It defines 5 steps for ontology development as feasibility study, ontology kick-off, refinement, evaluation and maintenance. The methodology follows an evolutionary prototyping like life cycle.

DILIGENT (Pinto, Staab, & Tempich, 2004; Tempich, Pinto, Sure, & Staab, 2005) presents a methodology for building a single ontology in a collaborative environment. Collaboration in DILIGENT is established by using an argumentation framework that is based on Rhetorical structure theory. DILIGENT does not provide a comprehensive ontology development process.

UPON (De Nicola, Missikoff, & Navigli, 2005) is inspired from Unified Process. It includes several cycles, four phases in each cycle, iterations that divide phases and five workflows (requirements, analysis, design, implementation, and test) in each iteration.

Melting Point (Garcia et al., 2010) is designed by learning from existing methodologies and to facilitate ontology development in decentralized communities. Methodology describes five main activities; specification, conceptualization, formalization, implementation and evaluation. Between these activities, there exist control and quality assurance activities performed by domain experts. Life cycle is reported as incremental evolutionary spiral.

NeOn Methodology (Suárez-Figueroa, 2010) is a scenario based ontology development methodology. It provides nine ontology development scenarios and guidelines for them. Main focus of the scenarios in NeOn is reusing, reengineering and merging ontologies.

2.2.2 Ontology Definition Languages

There are two categories of ontology languages. These categories are traditional ontology languages and web-based ontology languages (Kalibatiene & Vasilecas, 2011). Traditional languages are based on first-order predicate logic, frame-based languages, description logic based languages and other languages. Web-based languages are based on a Web standard. Many languages are both traditional and web-based. Some of the most popular ontology definition languages are OWL, RDF, RDF(S), DAML+OIL and KIF. Many of these languages are very mature and they are useful in integrating and reusing different systems and ontologies that are built upon these languages.

2.2.3 Ontology Tools

Ontology tools can be classified in three categories as ontology editors, triple stores and ontology visualization tools.

Ontology definition languages, with their roots from description logic, provide several advantages in representing knowledge. However, defining knowledge by using these languages requires specialized tools. Ontology editors are the tools that ontology engineers define knowledge with these languages. Some of the well-established ontology editors (Buraga, Cojocaru, & Nichifor, 2006) include Protégé, Web-Protégé, OntoStudio, SWOOP, NeOn Toolkit and TopBraid Composer.

All of these tools except TopBraid are developed by universities or university researchers. TopBraid[1] is a commercial tool that has powerful reasoning capabilities and a wide variety of supported languages. Protégé[2] is an open source tool for editing ontologies. It is one of the most popular ontology editors with its significant properties such as being open source and free and capable of being extended with plug-ins. Web-Protégé[3] is web application that inherits most of the functionality provided by Protégé and is intended for supporting collaboration. SWOOP[4], NeOn Toolkit[5] and OntoStudio[6] are other powerful ontology editors.

Triple stores are the storage tools for ontologies. They can be referred as databases for ontology. Different from traditional databases which store records in different structures, triple store tools focus on storing triples which are simple in structure and basic data for ontologies. Triples are composed of three parts. These are "subject predicate object" such as in the example "John Knows Mary". Examples for triple store tools[7] are BigData, BigOwlim, Apache TDB and Virtuoso.

There are many ontology visualization tools existing as plug-ins to ontology editors or as web-based tools. These tools specialize in one or many ontology visualization techniques. Techniques for ontology visualization can be grouped in six categories (Katifori, Halatsis, Lepouras, Vassilakis, & Giannopoulou, 2007) as Indented list, Node-link and tree, Zoomable, Space-filling, Focus + context or distortion, and 3D Information landscapes.

2.3 Related Research on Relations between Business Process Modeling and Ontology Development

Researchers have focused on various topics regarding the relations between business process models and ontologies. Several (Haller et al., 2008; Höfferer, 2007; Sönmez et al., 2010) have highlighted the importance and practical uses of process related ontologies.

Höfferer (2007) suggests in his work that process models when supported by ontologies can lead interoperability. He provides some basic guidelines for creating ontologies based on process models.

Another related research is performed by Haller et al. (2008) for creating process ontologies in XML Process Definition Language (XPDL) in order to enable interoperability between organizations performing processes that have interfaces with each other.

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[1] http://www.topquadrant.com/products/TB_Composer.html
[2] http://protege.stanford.edu
[3] http://webprotege.stanford.edu/
[4] https://code.google.com/p/swoop/
[5] http://neon-toolkit.org/wiki/Main_Page.html
[6] http://www.semafora-systems.com/en/products/ontostudio/
[7] http://wifo5-03.informatik.uni-mannheim.de/bizer/berlinsparqlbenchmark/results/V7/index.html

Sönmez et al. (2010) utilize a restricted and controlled model elements set of EPC notation and provides an ontology that supports this notation. This study suggests a government services ontology and service execution by using this ontology and process models.
Manual and automated transformations from process models to ontologies is one of the most popular topics in research bringing business process modeling and ontologies together. Such transformations are described for following process modeling languages:

- Petri Net by Koschmider and Oberweis (Koschmider & Oberweis, 2005),
- BPMN by Belecheanu et al. (2007), Eisenbarth (2013), and Francescomarino et al. (2009),
- EPC by Belecheanu et al. (2007), Eisenbarth (2013), and Thomas and Fellman (2009),
- BPEL by Belecheanu et al. (2007),
- Other languages by Cimpian et al. (2008).

Koschmider and Oberweis (2005) puts forth an ontology for Petri Net notation and a primitive tool support that enables business process modeling and extracting OWL code.

SUPER (Belecheanu et al., 2007) is a project financed by EU and aiming at providing techniques and tools for deploying Semantic Business Process Management. Semantic Business Process Management integrates semantic web service frameworks, an ontology infrastructure and business process management tools and techniques together. SUPER project defines a set of project work products to reach these goals. With these purposes SUPER produced some process modeling notation ontologies (e.g. sEPC, sBPMN, sBPEL) and tool support for annotating process models with individuals of built-in ontology classes (Dimitrov, Simov, Stein, & Konstantinov, 2007).

SemBiz (Cimpian et al., 2008) is a project that performed contemporaneously to SUPER project. Business Process Modeling Ontology (BPMO) is a product of SemBiz project. BPMO is based on syntax and structure of Web Services Modeling Ontology (WSMO), so that resulting process descriptions can be mapped into web services. BPMO provides a modeling ontology based on a fixed business process modeling notation whereas SUPER suggests modeling ontologies for several notations such as EPC and BPMN. However, both SUPER and SemBiz BPMO require ontology extensions for supporting additional process modeling notations.

The study of Thomas and Fellmann (2009) describes how to map process models modeled with EPC (Thomas & Fellmann, 2007)) or BPMN to ontology. They utilize a modeling tool, an ontology editor (i.e. Protégé) and an ontology server (i.e. Jena) alongside two applications developed within the study (i.e. a script that transforms process models to ontology definition and an application that enables querying and validating ontology) in implementation of their query workflow.

Eisenbarth (2013) presents an ontology for process models to which process models are automatically transformed. Such transformation is enabled for processes defined with EPC, BPMN or Eclipse Java Workflow Tooling (JWT). Transformation performs a mapping between process models and the meta-model and then places this mapping data into a process ontology. Eisenbarth (2013) also proposes a resource knowledge base within an ontology, so that enterprise resources can be defined, resource requirements of a process can be identified and optimized.

A group of researchers, who have been actively studying semantic business process modeling are Francescomarino and her colleagues. Their early studies (Francescomarino, Ghidini, Rospocher, Serafini, & Tonella, 2008; Francescomarino et al., 2009; Francescomarino, 2011) provide a BPMN based ontology called BPMNO that defines the structural parts of process models. This ontology is populated automatically from process models via tool support. Annotations to this process ontology can be established from a domain ontology through axioms, so that process knowledge is annotated with semantics and querying is possible on the structured process knowledge for correct labeling, verification of semantic labeling and query answering. Later in 2011, features enabling collaborative specification of semantically annotated business process models are introduced (Francescomarino, Ghidini, Rospocher, Serafini, & Tonella, 2011). In an experimental study (Francescomarino, Rospocher, Ghidini, & Valerio, 2014), using semantic annotations in collaborative process modeling is claimed to improve the quality of modeling process and the modelled processes, but not to affect time spent on modeling.

One of the studies (Cherfi et al., 2013) that is more relevant with our study in terms of their approach to the problem of managing the relations between the ontology resources and labels in process model collections aims to align domain ontologies and business process models in order to improve semantic quality of business process models. They propose four matching rules between process models and domain ontologies, which are Equivalence, Synonymy, More General and More Specific. Equivalence rule considers concepts that are syntactically equivalent in ontologies and process models whereas Synonymy rule considers concepts that are synonyms. More General and More Specific rules are applied to concepts that have superiority and inferiority relationships respectively.

In another highly related research in terms of the researchers' approach, Process Ontology Based Approach (POBA) introduces three phases for modeling business processes modeling by using domain ontologies (Fan et al., 2016). In phase 1 (i.e. Development of domain process ontology), an existing or new domain ontology is chosen and transformed to a domain process ontology by following a manual transformation procedure. In the resulting domain process ontology, terms are classified as role, activity, and non-role terms, and relationships are established between the terms based on the term classification. In phase 2 (i.e. Model generation), business processes are modeled by using the domain process ontology and following a top-down approach. In phase 3 (i.e. Model validation), business process models are validated by following validation procedures that utilizes the relationships between terms defined within the domain process ontology. So, completeness of the domain process ontology in terms of the role, activity, and non-role terms and the relationships between them is required in POBA. POBA claims to improve semantic ambiguity of business process models by preventing and detecting ambiguity issues such as inappropriate role or activity selection, activity sequencing, or information delivery. Results of a laboratory experiment claim that POBA reduces semantic ambiguity in business process models by improving the quality of the logic and content as compared to traditional business process modeling. Qualitative and quantitative analysis results of a survey confirm this claim and suggest that POBA ease modeling, reduce complexity of conceptualization of modeling constructs, and helps analysts to focus on process logic.

Some other contemporary studies that have focused on establishing label based relations between process models and ontologies are as follows.

Peters and Weidlich (2011) presents an approach for generating a glossary from the labels of an existing business process model collection and using the generated glossary in process modeling.

Cesare, Juric, and Lycett (2014) present a method and tool support to populate a business ontology automatically from documents to guide process analysts in constructing business process models. Visualization of the data to further assist business process modeling is reported to be currently under study.

Leopold et al. (2015) presents an approach for automatic annotation of process model elements and their labels with the concepts in a taxonomy. A prototype enables to generate automatic annotations to the models.

2.4 A Brief Discussion of the State of the Art

The most related and inspiring research in terms of managing the relations between ontologies and business process models by associating the labels in process model collections with ontology resources are Cherfi et al. (2013) and Fan et al. (2016).

Cherfi et al. (2013) does not suggest a development method and Fan et al. (2016) provides a method for developing process models by using existing domain ontologies. Our study differentiates itself by providing an explicitly defined method for developing ontologies and process model collections together that would be consistent with each other. These two studies also only focus on matching process model element labels with ontology resources. In terms of matching, the method in this study supported by a toolset will enable matching ontology resources with the labels of process model elements and process models and also the terms and phrases within the labels.

Another difference is that our study provides a tool support specifically developed for supporting integrated business process modeling and ontology development. The tool support in this study is pioneer in the tool market and academia in providing the features to manage the labels and terms within the labels in process model collections as consistent with ontology resources. Also in the scope of our review of the state of the art, this is the first report of a tool support in managing the descriptions of real-world objects represented in both the process model collections and the ontologies synchronously.

Cherfi et al. (2013) suggests that improvement of semantic quality of process models could be possible with the use of domain ontologies. Fan et al. (2016), on the other hand, suggests that by following their three phased approach in process modeling by using ontologies the semantic ambiguity and complexity of process models could be reduced. Via case studies and interviews, our study differentiates itself by identifying the benefits of integrated development such as the improvements in the consistency between process models and ontologies, semantic quality of both types of artifacts (i.e. process models and ontologies), the development effort, and other additional aspects suggested by experts from the industry.

CHAPTER 3

EXPLORATORY STUDY

In terms of its contribution to the state of the art, this study depends on the assumption that there are shared resources between ontologies and labels within process model collections whose relations need to be managed. In order to investigate this assumption, the exploratory study including case studies for finding answers to the first two research questions specified in Chapter 1 is described. Exploratory study was performed for validating the problem this study focuses on to resolve and so revealing the necessity of the proposed solution, and for identifying the tool support requirements for integrated business process modeling and ontology development. Two case studies were utilized for assessing the cohesion between process model collections and ontologies developed for the same domain. The other purpose of these case studies was to elicit the needs for the tool support by experiencing and learning from integrated process modeling and ontology building.

Excerpts from these case studies are also provided as motivating examples in Chapter 5 for describing the features of PROMPTUM Process Modeling Plugin.

3.1 Exploratory Study Planning

3.1.1 Research Questions in Exploratory Study

Research question 1: Is integrated business process modeling and ontology development a feasible practice in terms of the cohesion between ontologies and business process models in same or similar domains?

Proposition 1: Integrated business process modeling and ontology development is a feasible practice where there exists a high level of cohesion between labels within process model collections and ontologies in similar or same domains. This proposition would be validated by assessing the cohesion between the ontologies and business process models developed as integrated by using state of the art tools and methods.

Validation method for proposition 1: Assessment of cohesion based on the labels within process model collections represented as ontology resources is to be made on the resulting process models and ontologies in exploratory study.

Research question 2: What are the requirements of tool support for integrated business process modeling and ontology development?

Proposition 2: Experimenting integrated business process modeling and ontology building for the same or similar domains using existing tools would reveal the requirements of a tool to support development activities.

Validation method for proposition 2: Operational scenarios of integrated development are to be identified based on observed actions and logs kept for development activities.

3.1.2 Activity Planning in Exploratory Study

The following activities were planned to be performed within the case studies.

- Case selection: Case selection criteria will be applied for selecting cases that are effective in reaching the research goal and satisfy case study validity concerns. Also, development goals and competency questions would narrow down the scope of the selected cases for serving the study's goals. Three case study selection criteria were established. First criterion is that the selected case should represent real-life context. Thus, the case study would be focusing on resolving a real-world problem in a real setting. Second criterion is that knowledge sources for processes and domain should be available. This is critical since both business process modeling and ontology building are formalization activities that require elicitation of less formal knowledge from where it resides. Last criterion is that the selected case should incorporate complexity leading to observing a wide range and number of development patterns to be analyzed for identifying the needs of tool support and cohesion between the two artifacts.
- Establishing case study environment: Case study will include business process modeling and ontology building, so tools that support these activities should be selected and ready along with some other components of the case study environment.
- Identifying information sources: Process and domain related knowledge reside in a variety of sources, which will be identified and allocated prior to development.
- Developing process models and ontologies: Integrated process modeling and ontology development will be performed based on intuitive approaches due to lack of guidelines for such integrated development and by using existing tools.
- Analyzing the conduct of the case studies: Evaluations will be made based on observed actions and logs kept for development activities. They will be analyzed and evaluated for identifying the operational scenarios of integrated development and the cohesion between resulting process model collections and ontologies.

3.1.3 Mitigation of Threats to Validity in Exploratory Study

In research that is based on case studies, it is crucial to foresee the potential threats to validity and take cautions to prevent these threats to occur. With this motivation, we planned the mitigations of threats to validity for the case studies in both exploratory study and explanatory study. Potential threats to the validity of exploratory study, which are categorized as internal validity, construct validity, external validity, and reliability, are discussed below by using a checklist from Wohlin et al. (2012).

Internal validity considers whether an outcome is a result of factors all of which we have control on (Wohlin et al., 2012). One of the potential threats to internal validity relates to the effect that subjects tend to react differently throughout the study due to getting tired or learning. To avoid the effect due to boredom, a rather small size case was selected for case study 2 and only ontology development was planned to be performed by using existing process models in case study 1 that covers a larger scope. The negative effects such as boredom troubles the research. And also the positive effects that grow over time hinders internal validity. Such an effect based on learning over time was planned to be avoided by selecting the participants that have the required skills and experience that would be sufficient to prevent the participants' performance to be affected significantly due to learning. Another threat to internal validity to exploratory study was regarding instrumentation. The case study environment (e.g. software tools, computers, room, required documents) and the scope of the case studies were carefully planned and established before case study execution in order to avoid the study to be affected negatively by bad instrument design.

Construct validity of a study is concerned with how well the treatment and outcome reflects the construct of the cause and effect respectively (Wohlin et al., 2012). In exploratory study in order to avoid any negative effects based on insufficient definition of the constructs, we identified the goals, the research questions, the cases, propositions, and the validation methods to analyze the data collected for reaching answers to research questions. In order to avoid mono-operation bias, we performed two case studies none of which is too small in representing the construct. For preventing confounding constructs in case study based research, familiarity of the selected case to the participants is as important as the participant skills required to perform the case study. To mitigate such a threat, in case study 1, since the domain experts were not available for participation, an analyst, who has the skills and experience in ontology development and also has knowledge about the domain based on his process modeling experience in the domain, was selected to participate. In case study 2, a domain expert that works in the domain and an analyst that has process modeling and ontology building skills participated.

External validity is concerned with generalizing the results of a research to real-world (Wohlin et al., 2012). A threat to external validity lies in the interaction of setting and treatment. For preventing this threat to occur, we reviewed the related research on the ontology and process modeling and identified the capabilities and background of the tools and languages in selecting the ones to be used in exploratory study. The experimental environment of the case studies such as the tools and methods are reported. Another threat related to the setting would be about the case selected. For selecting the cases, we identified three case selection criteria. The case selection criteria (i.e. real-life context, resource availability, and problem complexity) made sure the selected cases are not toy problems by ensuring the selected cases reside in real contexts, make necessary information resources available, and include a problem scope that is complex enough to be worth investigating.

Reliability in qualitative research, which is a counterpart to conclusion validity in quantitative research, deals with whether the data or the analysis depend on the researcher in charge (Wohlin et al., 2012). In exploratory study that incorporated two case studies, the reliability was planned to be ensured by including external experts to the data analysis. For both case studies, two experts that did not participated in the execution reviewed the conduct, analysis, and results of the case studies (i.e. the functional requirements specified and the analysis results regarding consistency between ontologies and process models). Moreover, regarding the conduct of the exploratory study, the domain expert participated in case study 2 validated the resulting products and the process models used retrospectively in case study 1 were subject to acceptance review by several domain experts that were also the owners of the processes. Additionally, the exploratory study including two case studies was part of an industry research and development project funded by an external research organization that assured the conduct and results are reported to and reviewed by an external referee with a proven competency in the research area.

3.2 Exploratory Study Design and Execution

3.2.1 Case Selection in Exploratory Study

As shown in Table 1, the cases were selected based on real-life context, resource availability, and problem complexity by using a Likert scale of three (1 = Poor, 2 = Fair, 3 = Good). Evaluation revealed that the first case lacked information resource availability while second one was short in satisfying the complexity criterion. Therefore, the selection criteria were relaxed and both case studies were performed.

First case (i.e. Case 1) includes a “public investment planning” ontology developed by using an already existing process model collection for “public investment planning” processes. Information resource availability was deficient in this case, as domain experts, who participated in modeling the processes, did not contributed to ontology building. So, the ontology was mainly built based on the documented resources.

Table 1 Case selection in exploratory study

Case characteristics	Case 1	Case 2
Focus domain	Public investment planning	Short term assignment of academic staff members
Focus organization	Turkish Ministry of Development	Middle East Technical University
Real-life context	Good	Good
Resource availability	Fair	Good
Problem complexity	Good	Fair

Public investment planning service, which is performed by Ministry of Development with significant participations of Ministry of Finance and Under-secretariat of Treasury, includes following top-level processes:

- Determining proposal ceilings for organizations
- Finalizing allocations
- Publishing investment program
- Gathering project details
- Revising investment program

The goal for developing the public investment planning ontology is to make knowledge about public investment planning explicit. The goal description and competency questions were established for this respective goal.

Second case (i.e. Case 2) consists of a process model collection for “short term assignment of academic staff members” and an “academic assignments” ontology developed simultaneously. The problem space to be addressed in this case was rather unsophisticated as it covered simple work-flows, few roles, and a single organization. Following processes are included in second case:

- Assigning without allowance and expense and with duration of less than one week
- Assigning without allowance and expense and with duration of between seven and fifteen days
- Assigning with allowance and expense or with duration of more than fifteen days

The goal definition of academic assignments ontology, for which a set of competency questions were defined, is to identify the information used in academic assignments of academic staff and making this information reusable.

3.2.2 Case Study Environment in Exploratory Study

Both studies were to use the same software and hardware configuration. Except using two display units, no special requirements were identified for hardware configuration. Process modeling tool and ontology editor were critical components of the work environment for case studies. Rest of the software such as a word processor for keeping action logs and pdf-reader for navigating electronic documents were standard software of a regular computer.

Protégé v4.3[8], which is an open-source ontology editor available to be extended and used free of charge, was selected to be used in developing ontologies. Resulting ontologies were to be represented with Resource Description Framework (RDF).

UPROM tool[9] is a process modeling tool that produces system requirements, quality manuals and software size measurements with an integrated approach. UPROM was selected for modeling the business processes.

In selecting a business process modeling language, Extended Event-driven Process Chain (eEPC) and Business Process Model and Notation (BPMN) were highlighted for being among the most established languages both in the industry and academia. eEPC provides strong analysis of business domain, behavioral, information and organizational perspectives with the set of model elements included in the notation. It is also user friendly by enabling business people to read and understand the models easily. Some other languages were eliminated since the case does not have process execution purposes. As a result, eEPC was chosen as the business process modeling language to be used.

eEPC does not have a standard notation except for lean EPC model elements such as function, event and logical connectors, which are obligatory for work flow perspective and thus could be further extended or narrowed in terms of model elements to be used. This is why selecting the modeling language should also cover selecting the model elements and modeling rules. Following model element types were selected to serve modeling purposes; Function, Event, Logical Connectors (AND, OR, XOR), Information Carriers, Application Systems, Organizational Elements, Process Interface, Improvement Offer, and Technical Term. Process modeling palette of UPROM for eEPC notation was revised with respect to the selected set of model element types.

3.2.3 Information Sources in Exploratory Study

Information about processes can exist in various representations and formats, even if it is not defined in process models. Same applies for domain knowledge as it exists somewhere in organizations waiting to be formalized. This knowledge might be present in regulatory documents, automated within information systems, or owned by business people as tacit

[8] http://protege.stanford.edu
[9] http://www.bg.com.tr/j3/index.php/tr/uprom

knowledge. Usually analysts elicit data from these sources and process them into formal knowledge representations such as business process models and domain ontology specifications as depicted in Figure 2.

We followed a similar path, therefore it was important to identify sources which possess information that is correct, complete and relevant. For both case studies; related documents, templates, forms, application systems, databases and people were identified (Table 2 and Table 3).

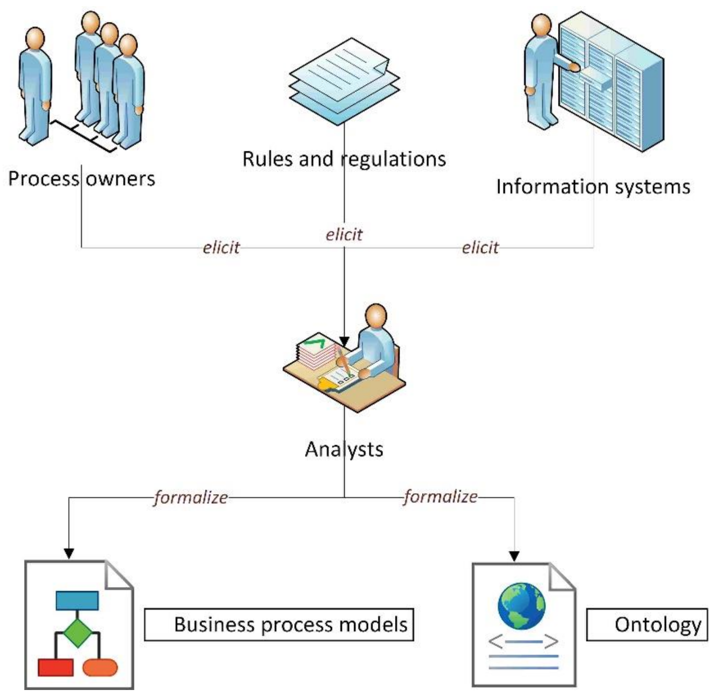


Figure 2 Flow of information from information sources to ontology specification and business process models in case studies

Human resources for case study 1 had contributed in all phases of business process modeling and validated the resulting models. However, they were not allocated for ontology building activities, so ontology building was performed using the rest of the sources and already developed process models.

Table 2 Information sources in Case 1 of exploratory study

Source Type	Information Source
Person	Investment programming and analysis expert
Person	Sector expert
Legislation	Cabinet Decree on Application, Coordination and Monitoring the Program of 2014

Regulation	Investment Program of 2014
Regulation	Investment Program Preparation Guide of 2014-2016 Term (with 16 appendices and 14 tables attached that include lists, forms and templates)
Regulation	Book for Allocation of Public Investments per Cities in 2013
Regulation	Circular on Preparations for Investment Program of 2014-2016 Term
Regulation	Booklet on General Economic Goals and Investments for 2013
Application	Public investment information system components

Table 3 Information sources in Case 2 of exploratory study

Source Type	**Information Source**
Person	Academic staff member
Regulation	Regulation on the Principles for Domestic and Abroad Assignments
Form	METU Academic Assignments Directorate forms

3.2.4 Development in Exploratory Study

In both case studies, we kept a log of all actions in development to use in analyzing findings.

Case study 2 was performed before case study 1 for piloting case study application, as it is less complicated and small in size. It started with examining the available documented sources, which led to creation of initial resources of the ontology and definition of the process hierarchy. This case study was performed by developing process models and ontology synchronously. Thus, after modeling a few process model elements in process models, analysts went on specifying relations to the resources in ontology before going back to process models, and so on. The resulting process model collection included 3 process models with a total of 12 functions and the resulting ontology specifications (TBox) included 88 resources.

Case study 1 was performed on pre-established business process models. Models had been developed with participation of domain experts and by utilizing documented and electronic sources. Within case study 1, by walking through business process models and also by examining the documents at every related step, public investment planning ontology was developed. This ontology contains terminological knowledge as it includes the schema but not data. Inputs were 9 business process models with a total of 59 functions and the output was 262 ontology resources including classes, object properties and data properties.

3.3 Exploratory Study Analysis and Results

Analysis is performed on case study outcomes to infer answers to research questions of exploratory study.

3.3.1 Analysis and Results for Research Question 1 of Exploratory Study

Table 5 provides the number of shared resources between ontologies and labels within process model collections in each case study. For some of these resources, there are more than one instance of the same label or term within a label in process model collections, so the numbers presented do not reflect unique shared resource instances. Data about the resource descriptions are not presented in this table to avoid redundancy, as each process model and process model element label that is associated to an ontology resource has a description represented as a literal annotation in respective ontologies.

Table 4 Exploratory study summary

Metrics	**Case study 1**	**Case study 2**
Number of process models	9	3
Number of functions in process models	59	12
Number of process model elements	273	42
Number of ontology resources	262	88

A high level of cohesion between business process models and ontologies observed from the data presented in Table 4 and Table 5 highlights the importance of managing shared resources in ontologies and process model collections with tool support. For instance, 79 process model element labels and 175 terms within process model element labels are represented as ontology resources in the first case study that contains 273 process model elements and 262 ontology resources. In other words, about 29% of the process model element labels and terms within the 64% of the process model element labels had the same semantics with resources in the ontology. This high cohesion might exist due to the fact that the selected domains for ontology development are highly correlated to the selected processes. However, it still demonstrates that the necessity of the PROMPTUM method and toolset with its aforementioned features for managing the resources shared between ontologies and process model collections is valid in many, if not all, circumstances.

Table 5 Relations between resources in ontology and labels in process model collections in exploratory study

Related resources	Case study 1			Case study 2		
	Number of relations	**% of process models or model elements**	**% of ontology resources**	**Number of relations**	**% of process models or model elements**	**% of ontology resources**
Process model labels	0	0% (0/9)	0% (0/262)	3	100% (3/3)	3% (3/88)
Terms within process model labels	5	56% (5/9)	2% (5/262)	9	300% (9/3)	10% (9/88)
Process model element labels	79	29% (79/273)	30% (79/262)	23	55% (23/42)	26% (23/88)
Terms within process model element labels	175	64% (175/273)	67% (175/262)	42	100% (42/42)	48% (42/88)

3.3.2 Analysis and Results for Research Question 2 of Exploratory Study

Action logs kept in both case studies were devised to analyze the observed actions and then elicit the tool requirements for integrated business process modeling and ontology building. After filtering through common process modeling tool and ontology editor requirements that also exist in the state of the art, following operational scenarios specific to aforementioned integrated business process modeling and ontology development tool support were identified.

- Managing process model labels as ontology resources
- Managing process model element labels as ontology resources
- Managing terms within process model labels as ontology resources
- Managing terms within process model element labels as ontology resources
- Managing process model and process model element descriptions

Based on these operational scenarios identified, tool support requirements for integrated business process modeling and ontology development are later specified as provided in Appendix D - Functional Specifications. For avoiding redundancy, more information regarding the scope and examples of these operational scenarios and how they were implemented within the PROMPTUM toolset is given in Chapter 5.

3.4 Overall Findings of the Exploratory Study

An exploratory study including two case studies was performed and analyzed for exploratory purposes. In this section, the overall findings derived from the exploratory study are discussed.

As suggested by the analysis and results of the exploratory study, following findings were identified:

- Necessity of a method and tool support for integrated business process modeling and ontology development is validated as a high level of cohesion was observed between process models and ontologies developed for similar or same domains. The level of cohesion was assessed based on the semantic matching between resources of the ontologies and labels and terms within labels in process model collections.
- Five operational scenarios, which are not supported by the state of the art process modeling and ontology editing tools, were identified. This also validates the necessity of a tool support for integrated business process modeling and ontology development.

CHAPTER 4

METHOD FOR INTEGRATED BUSINESS PROCESS MODELING AND ONTOLOGY DEVELOPMENT

The PROMPTUM method for supporting integrated business process modeling and ontology development is presented in this chapter. The PROMPTUM method requires tool support (i.e. PROMPTUM toolset) for being effective in performing the unique activities of the method.

The PROMPTUM Method for Integrated Business Process Modeling and Ontology Development is developed with the aim of guiding practitioners who develop consistent business process models and ontologies (i.e. domain, task, or application ontologies). The method would be used for developing both artifact types (i.e. process model collections and ontologies). Moreover, the method would potentially be useful in developing one of the artifacts by using the other that is existing.

In following sections, method provides descriptions for its processes. Within the method structure, processes include activities and activities include tasks.

Method consists of five main processes:

- Scope definition (SD)
- Stakeholder management (SM)
- Preliminary analysis (PA)
- Exploration (EXP)
- Verification and validation (V&V)

These processes are not necessarily performed sequentially as their order depends on the development life cycle model choice and activity planning. Development Life Cycle Models guideline is provided in Appendix A – Development Life Cycle Models Guideline. Activity and task descriptions for these processes are provided in following sections. In practice, these five processes are required to be performed but related activities and tasks within processes could be tailored as per practitioners' needs. Therefore, planning and monitoring are important for a successful development.

4.1 Scope Definition (SD)

Within this process, scope of the ontology and business process models to be developed is defined. Scope might include developing both the process model collections and ontologies, or one of them by using an existing other. Main purpose is to identify product expectations so that scope volatility related deviations from planned schedule and resources could be prevented.

4.1.1 Define Development Goals

Goals are defined to identify purposes for developing ontology and business process models and to identify expected impacts to be created by the products under development.

Identify organizational units to be focused.

Note 1: Development might focus on one or many organizational units. Some parts of an organizational unit might be excluded if necessary.

Identify information needs of the organizational unit(s).

Prioritize information needs.

Note 2: Focus organization might have several information needs and it might not be always feasible to satisfy them all, due to organization's objectives and limited resources.

Identify development goals.

Note 3: Information needs to be addressed by development are identified considering prioritizations. As per prioritized information needs, one or several development goals are identified. Appendix B – Goal Definition Form could be used for documenting development goals.

4.1.2 Define Competency Questions

Competency questions defined in this activity are usually used in ontology development, but can also be used in business process modeling. They are utilized in evaluating (as in V&V) the ontology and business process models.

Identify competency questions.

Note 4: Informal competency questions are questions in natural language that are expected to be provided answers by the products under development. In some cases, competency questions are identified at high-level and are elaborated later as development progresses

(Gruninger & Fox, 1995). Competency questions could be documented by using Appendix B – Goal Definition Form.

Manage competency questions.

Note 5: Managing changes in competency questions is a part of managing scope. Keeping revision history of competency questions enables practitioners to trace their prior decisions back to scope.

4.1.3 Establish Commitment to Scope

Establishing top level management commitment is necessary for ensuring allocation of adequate resources, whereas employee commitment is needed for enhancing motivation.

4.2 Stakeholder Management (SM)

Stakeholders are important for both business process modeling and ontology development. Purpose of stakeholder management is to identify and manage stakeholders. Primary stakeholders playing an active role in development and secondary stakeholders that do not have an active role but have an impact during, before or after development are identified.

4.2.1 Identify Primary Stakeholders

Note 1: Domain experts and analysts are primary stakeholders. One or a few analysts and several domain experts shall participate in development. They are characterized as direct opposite roles as domain experts have domain knowledge that analysts lack and analysts have system abstraction capabilities that domain experts usually lack (Frederiks & van der Weide, 2006).

Note 2: Domain experts are selected among experts who have profound knowledge about the domain within the scope and perform the tasks within the related domain. They usually do not possess sufficient knowledge and experience about process modeling and ontology building. Thus, analysts' abstraction skills are required in formalizing the knowledge domain experts provide.

Note 3: Analysts are capable in business process modeling and ontology building. They are expected to have extended knowledge about methods, languages and tools for business process modeling and ontology building and shall have experience and training necessary for performing development. Analysts usually do not have sufficient knowledge about the domains, so they rely on the knowledge that is provided by domain experts or exists in documented or electronic sources.

4.2.2 Identify Secondary Stakeholders

Note 4: Secondary stakeholders might include top-level management, IT experts and administrators, software development experts and leaders, process management experts and leaders, knowledge management experts and leaders, and customers and end users. Top-level management is responsible for tasks such as launching development activities, allocating necessary resources, approving final products and disseminating results in focus organization.

Note 5: Information technology (IT) experts and administrators might be needed to get information systems available for studying by analysts.

Note 6: Software development experts and leaders might require process models and ontologies in developing software systems.

Note 7: Process management experts and leaders might be responsible for publication, application, audit, and revisions of business process models within the organization.

Note 8: Knowledge management experts and leaders might be responsible for maintenance and revision of the ontologies developed.

Note 9: Customers and end users are stakeholders who would be affected by the results of development activities directly or indirectly.

4.3 Preliminary Analysis (PA)

In preliminary analysis process, high level designs for business process models and ontologies are identified to determine architecture of the solution for defined scope.

4.3.1 Establish Process Architecture

High level process architecture is established prior to exploration process. Following tasks describe a business service/product based approach by Dumas et al. (Dumas, La Rosa, Mendling, & Reijers, 2013), but also any goal-based, action-based, object-based, function-based, or reference model based approached could be followed (Dijkman, Vanderfeesten, & Reijers, 2011).

Identify products and services of the organization.

Note 1: Products and services causing different behaviors are identified.

Identify functions related to product and service types.

Note 2: Business functions performed for different product and service types are identified.

Establish products and services / functions matrix.

Note 3: Organization is functionally decomposed by establishing a matrix that traces the products and services of the organization to its business functions (Dumas et al., 2013).

Identify business processes.

Note 4: Business processes are identified by using combinations of products and services, and business functions. A business process is usually formed from several product/service and business function intersections within the matrix. However, there might be cases where a single intersection corresponds to a business process.

Define process architecture.

Note 5: Business processes and their sub-processes are identified with their essential inclusion and flow relationships. Process architecture could be defined with function tree or value added chain diagrams (R. Davis & Brabander, 2007).

4.3.2 Enumerate Noteworthy Terms

Noteworthy terms that are meaningful within the focus domain describes the problem and its solution. These terms include concepts, verbs, properties and instances (Fernández-López et al., 1997). Lists of terms are not expected to be stored after development is completed.

Identify terms.

Note 6: A list of terms that are related to the focus domain are identified by establishing the domain lexicon and application lexicon. Application lexicon is established by analyzing documents, information systems, databases and other information sources. Domain lexicon is established by analyzing related standards, thesauri, regulatory documents and existing ontologies. List of terms is established as domain experts evaluate the terms in both application and domain lexicons (De Nicola et al., 2005). List of terms are further refined by omitting terms that are out of scope or duplicated.

Note 7: Terms could be identified in a Glossary of Terms (Fernández-López et al., 1997). Output is a list of terms which does not necessarily imply the classes and properties in the resulting ontology to be built (Noy & McGuinness, 2001).

Identify concepts.

Note 8: Concepts are identified by using the list of terms and a hierarchy of concepts is established. Concept hierarchy could be identified by establishing Concept Classification Trees (Gómez-Pérez, Fernandez, & De Vicente, 1996).

Identify verbs.

Note 9: Verbs within the list of terms are identified and described using tables or diagrams.

Identify instances.

Note 10: Instances within the list of terms are identified.

4.3.3 Consider Reuse

Reusable ontologies and business process models are considered for reuse.

Consider reuse of process models.

Note 11: Reuse of process models is usually performed by defining frequently observed sequential activity groups as a global process and calling this global process from related processes. Candidate global processes are identified and evaluated for reuse.

Consider reuse of ontologies.

Note 12: Reusing existing ontologies or ontology resources is a priority in ontology engineering. As a rule of thumb, a new ontology shall be built if there is not an existing ontology satisfying the needs. Considering the list of noteworthy terms and scope of the ontology, existing ontologies are evaluated for complete or partial reuse.

4.4 Exploration (EXP)

Business process models and ontologies are explored with an integrated approach. Any two or more of the following activities could be performed in an iterative manner. Practitioners shall decide on the order and number of recurrences of following activities.

4.4.1 Elicit Information

Information about the processes and domain within scope is elicited.

Note 1: Information elicitation might be performed before or during process modeling or ontology building. Based on the selected life cycle, it can be performed throughout exploration as cycles.

Note 2: Techniques such as brainstorming, interviews, and text analysis, and knowledge acquisition tools could be used for eliciting information (Fernández-López et al., 1997). Some of these methods are provided in Appendix C – Information Elicitation Methods.

4.4.2 Perform Reuse

Reusable ontologies and business process models are analyzed and used.

Reuse process models.

Note 3: Process reuse is performed as global process models, which are models not embedded within any process model, are invoked by other process models (Dumas et al., 2013). Defining the global process models would also ease reuse in future process modeling efforts. Another type of process reuse is by using embedded sub-processes where the analyst would embed sub-processes within process models if some parts of the process to be reused are specific to the business units.

Reuse ontologies.

Note 4: Existing ontologies might be reused by inclusion, polymorphic refinement, restriction, or circular dependencies (Farquhar, Fikes, Pratt, & Rice, 1995). Nine scenarios for building ontology networks by Suarez-Figueroa provide guidelines for reuse and reengineering of resources (Suárez-Figueroa, 2010). Making the ontologies public by publishing would be important in developing reusable ontologies, so that the knowledge created via ontologies would be globally open for extension and validation.

4.4.3 Model Business Processes

Business processes within the scope are modeled. Following tasks were tailored using the process modeling procedure by Dumas et al. (Dumas et al., 2013).

Identify process boundaries.

Note 5: Process boundaries are identified by determining triggering and outcome events of each business process in the process architecture.

Identify activities and events.

Identify roles.

Note 6: Roles performing each activity shall be identified.

Identify control flow.

Note 7: Control flow specifies when activities and events happen. More precisely their orders, decision points, parallel flows and loops are identified.

Identify other process model elements.

Note 8: Other process model elements might include information carriers, information systems, databases, technical terms, key performance indicators (KPIs), business rules based on the selected modeling language and organization’s needs.

4.4.4 Build Ontology

Ontology within the scope is built.

Define classes.

Note 9: Classes are ontology resources sharing similar properties in a domain. Defining classes usually starts with selecting terms that describe objects having independent existence from the list of noteworthy terms enumerated in section 4.3.2 (Noy & McGuinness, 2001).

Note 10: Class hierarchy is defined by considering if a class is a subclass of another class. In creating class hierarchy one of top-down, bottom-up, or middle-out approaches could be chosen (Uschold & Gruninger, 1996).

Define properties.

Note 11: Properties (slots) for a class specifies the attributes and features of the individuals belonging to that class. Generally, properties include intrinsic and extrinsic properties, physical and abstract part specifications and relationships to other individuals (Noy & McGuinness, 2001).

Define restrictions.

Note 12: Value sets and types that properties can take, maximum and minimum values, and other information about properties are set.

Create individuals.

Note 13: Individuals belonging to classes are created as ontology resources and values for pre-established properties are set.

4.4.5 Associate Ontology and Process Model Collections

Ontologies and process model collections are associated during exploration.

Associate process model labels and ontology resources.

Note 14: Processes might be represented as models in business process models and resources in ontologies. In such a case, as they represent the same object of the real world, label of the process model and the ontology resource shall be the same.

Note 15: Also, the process models usually have a sub-diagram relation through function objects in process models which have the same label with the process model. In such cases, labels of both process models and activities shall be associated with ontology resources.

Associate terms within process model labels and ontology resources.

Note 16: The terms and phrases within the process model labels would represent the same real-world object that a resource in an ontology represents.

Associate process model elements and ontology resources.

Note 17: A process model element and an ontology resource shall be associated if they are representations of the same object of the real world.

Associate terms within process model element labels and ontology resources.

Note 18: Association is established in cases where a term or phrase within the label of a process model element is also represented as a resource in an ontology.

Associate properties in process models and literal annotations in ontologies.

Note 19: Ontology resources can be described with literal annotations. A similar description is possible in business process modeling where process models and process model elements are assigned properties. If there exists an association between process models (or process model elements) and ontology resources, these literal descriptions shall also be consistent.

4.5 Verification and Validation (V&V)

Purpose of verification and validation process is to ensure business process models and ontologies conform to their requirements and intended use.

4.5.1 Verification

Business process models and ontologies are evaluated for conformance to development goals and competency questions. Issues detected in verification shall be recorded and managed until closure.

Verify business process models.

Note 1: Verification of process models is usually performed as a review. In business process model reviews, domain experts and analysts should evaluate quality of models in terms of syntactic and semantic correctness, relevance of content, economic efficiency, clarity of representation, comparability to content, and systematic design (Becker, Rosemann, & Uthmann, 2000).

Verify ontologies.

Note 2: Verification of ontologies includes using one or more of specification evaluation, application-dependent evaluation, terminology evaluation, or taxonomy evaluation (Garcia et al., 2010). Evaluations might be performed based on quality metrics in (Tartir, Arpinar, Moore, Sheth, & Aleman-Meza, 2005).

4.5.2 Validation

Users evaluate business process models and ontologies for fitness to their intended purposes. Issues detected in validation shall be recorded and managed until closure.

Note 3: Validation of process models is usually performed as a review, whereas validation of ontologies includes using both reviews and formal test queries based on competency questions.

CHAPTER 5

TOOL SUPPORT FOR INTEGRATED BUSINESS PROCESS MODELING AND ONTOLOGY DEVELOPMENT

This chapter presents the PROMPTUM toolset to support integrated business process modeling and ontology building. PROMPTUM toolset contribute in making the PROMPTUM method effective. Components and system interfaces of the PROMPTUM toolset are shown in Figure 3.

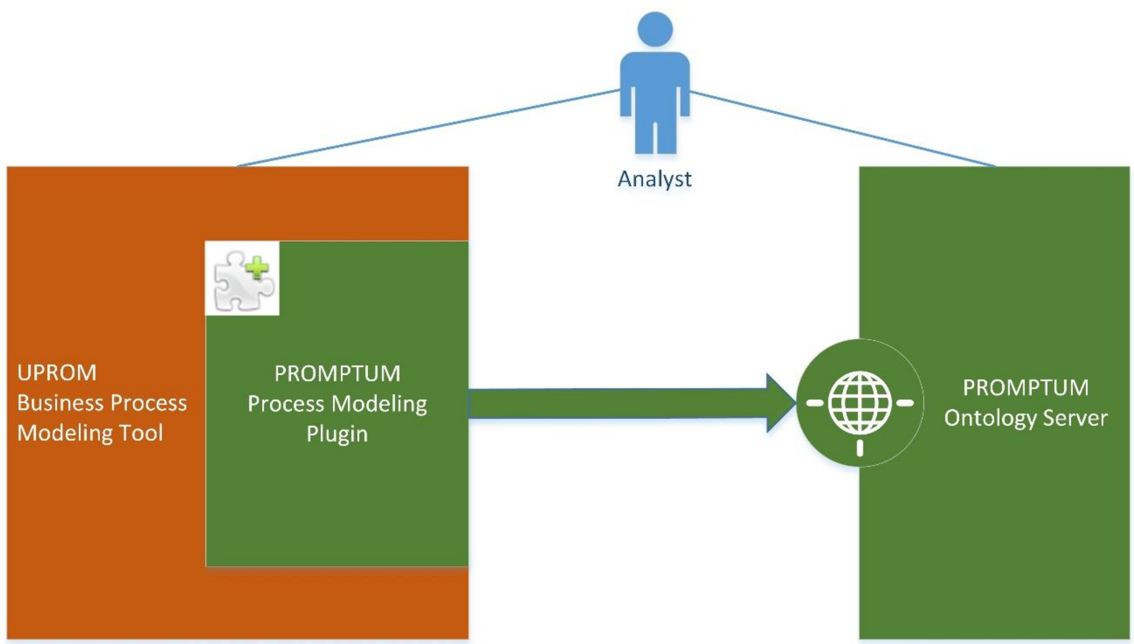


Figure 3 Components and system interfaces of PROMPTUM toolset

Analyst is the expert in business process modeling and ontology development who models the processes via UPROM tool and/or builds the ontologies via PROMPTUM Ontology Server. Analyst also uses PROMPTUM Process Modeling Plugin via Ontology View on the UPROM tool for associating labels in process model collections with ontology resources. The three components of the PROMPTUM toolset are described with details in the following sections.

5.1 UPROM Tool

UPROM tool, user interface of which is shown in Figure 4, is the medium where business process models are developed and stored within the PROMPTUM toolset.

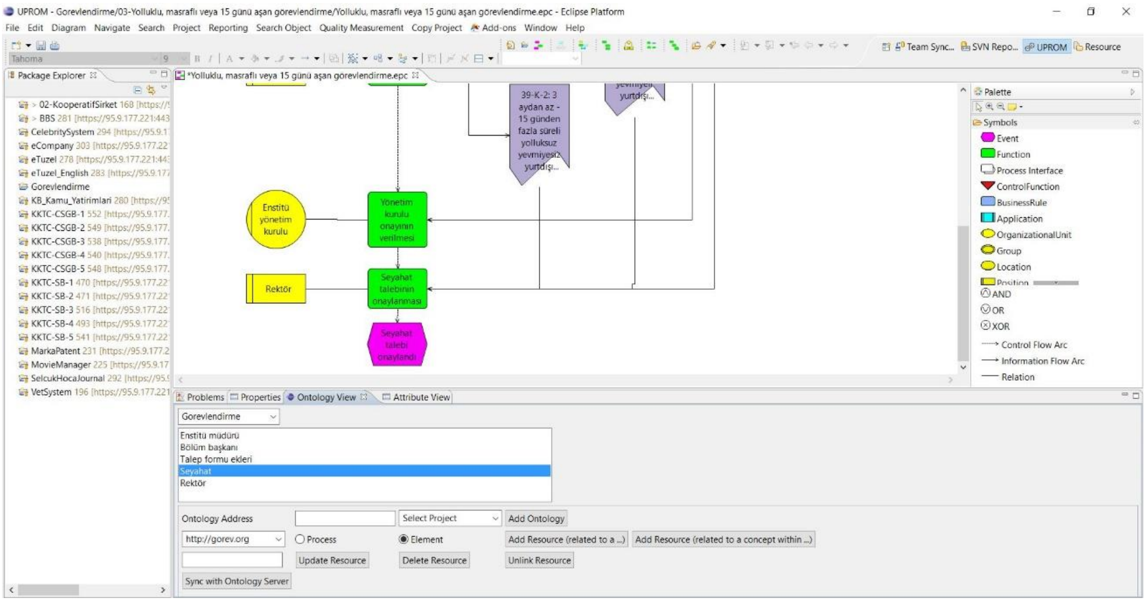


Figure 4 User interface of UPROM tool

UPROM tool (Aysolmaz & Demirörs, 2015) is a desktop graphical business process modeling software that provides modeling editors for several diagram types such as extended Event Driven Process Chain (eEPC), Value Chain (VC), and Function Tree (FT). UPROM was originally developed to supports business process analysis, improvement and modeling while incorporating an integrated approach for generating system requirements and software size estimations. UPROM possesses the common characteristics of process modeling tools such as ease of model building, formal semantics and verification of correctness, workflow patterns, resource and data perspective, and level of detail, transparency and suitability for communication (Jansen-Vullers & Netjes, 2006). UPROM provides core process modeling tool features such as a process model repository for storing and structuring the modeling projects, sub-diagram decomposition, continuous syntactic verification based on diagram meta-models, unique object assignment, and defining attributes for process models and elements. UPROM tool was developed based on bflow* Toolbox (Laue et al., 2015) by following Eclipse Modeling Framework (EMF) and Eclipse Graphical Modeling Framework (GMF).

Reuse of existing process models are possible in UPROM by either defining global process models or embedding existing process models as sub-processes in the process model collection.

5.2 PROMPTUM Ontology Server

Most ontology editors have the following functionalities (Stojanovic & Motik, 2002):

- Adding/removing/modifying ontology classes, class hierarchy, object and data properties and their hierarchy, property domain and range, individuals, property individuals and literal annotations,
- Propagating a change in one part of the ontology to other parts of it and associated individuals,
- Undoing a change in ontology such that all previously propagated changes are also undone.

The PROMPTUM Ontology Server, which features the above mentioned functionalities, is developed as a component of the PROMPTUM toolset. It serves not only as a Web-based ontology editor but also as a triple store. It is based on AngularJS application framework, uses Jetty as web server and stores ontologies in Apache Jena TDB. Web front-end of the PROMPTUM Ontology Server, shown in Figure 5 and Figure 6, is a simple Web-based ontology editor that enables analysts to build ontologies.

Reuse of existing ontologies, which is an important practice in ontology engineering, would be performed by adding the ontologies or some of the resources of ontologies via the user interface of PROMPTUM Ontology Server.

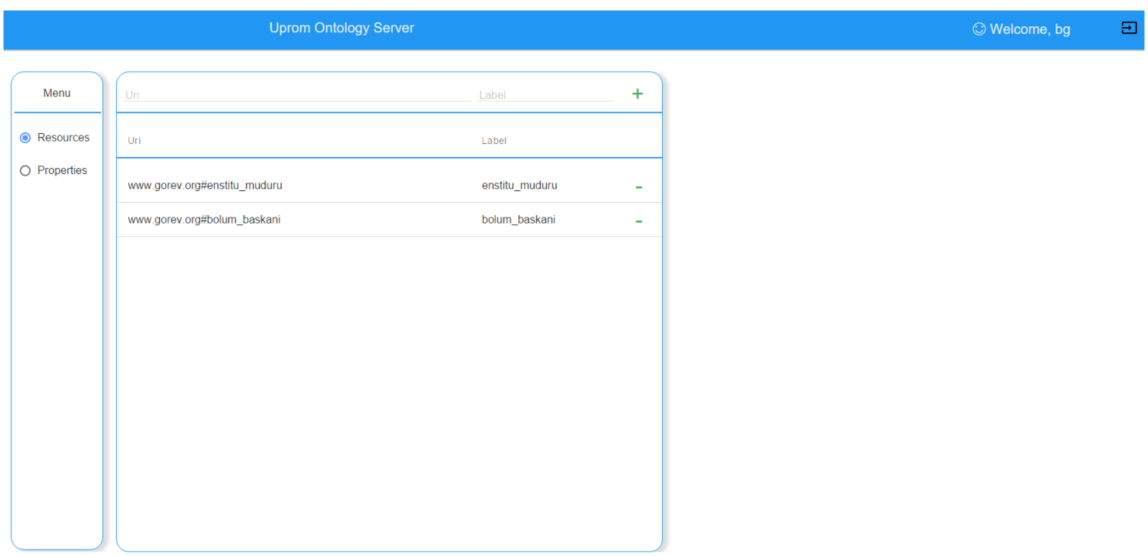


Figure 5 Web front-end of PROMPTUM Ontology Server for managing resources

The PROMPTUM Ontology Server provides web services, which are described in Appendix E – Web Services Provided by PROMPTUM Ontology Server, based on RESTful APIs for adding, listing, and removing resources, data type properties and object type properties, updating resource labels, listing changes in ontologies, and getting the whole model. These services are consumed by the PROMPTUM Process Modeling Plugin.

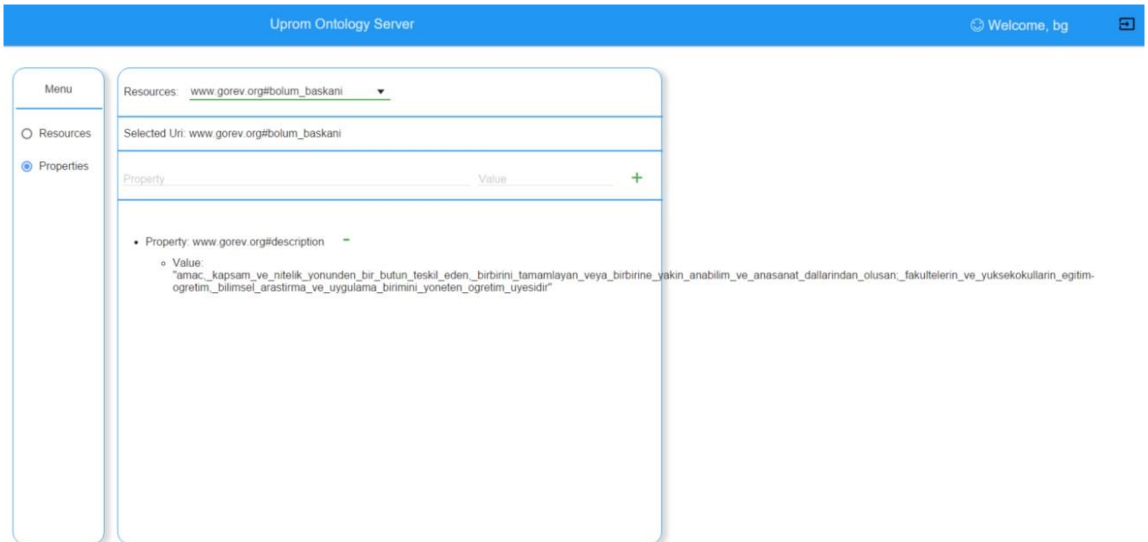


Figure 6 Web front-end of PROMPTUM Ontology Server for managing properties

5.3 PROMPTUM Process Modeling Plugin

The PROMPTUM Process Modeling Plugin is a plugin to the UPROM tool and follows the same principles in terms of the development technology used. It provides the "ontology view" shown in Figure 7 on the UPROM tool that enables analysts to perform operational scenarios in integrated development of the process models and ontologies, except the regular process modeling and ontology editing operations described for UPROM tool and PROMPTUM Ontology Server above.

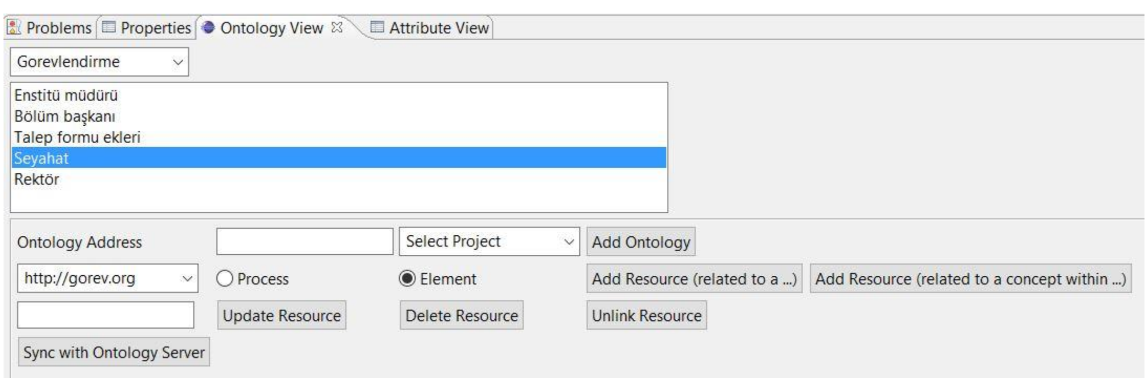


Figure 7 Ontology view user interface in UPROM tool

These operational scenarios are depicted with motivating examples from "public investment planning" and "short term assignment of academic staff members" processes and domains in following sub-sections. Detailed functional specifications are provided in Appendix D - Functional Specifications and the data model is provided in Appendix F – Data Model of PROMPTUM Process Modeling Plugin.

5.3.1 Ontology Selection

In PROMPTUM toolset, a label or a term in the label of a process model or a process model element within a process model collection can be added as a resource to an ontology only if a restriction is already established between the process model collection and the ontology in question. Therefore, this restriction permits that the resources can be added from only selected process model collections to the selected ontologies. A many-to-many relation between the process model collections and ontologies is possible in defining these restrictions. In other words, once the required restrictions are established, an ontology can take input from several process model collections and a process model collection can have resources defined in several ontologies. Analysts define these restrictions using the Ontology View by entering a valid ontology address, selecting a process model collection from the "Select Project" list and clicking the "Add Ontology" button shown in Figure 7.

5.3.2 Managing Process Model Labels as Ontology Resources

An ontology resource and a process model label would represent the same real-world object. Figure 8 exemplifies a process model with the label "Assignment without allowance and expense and with duration of between 7-15 days" within business process models for "short term assignment of academic staff members". The object that represents this process model is also a resource that is a sub-class of the "short term assignment" class in "academic assignments" ontology.

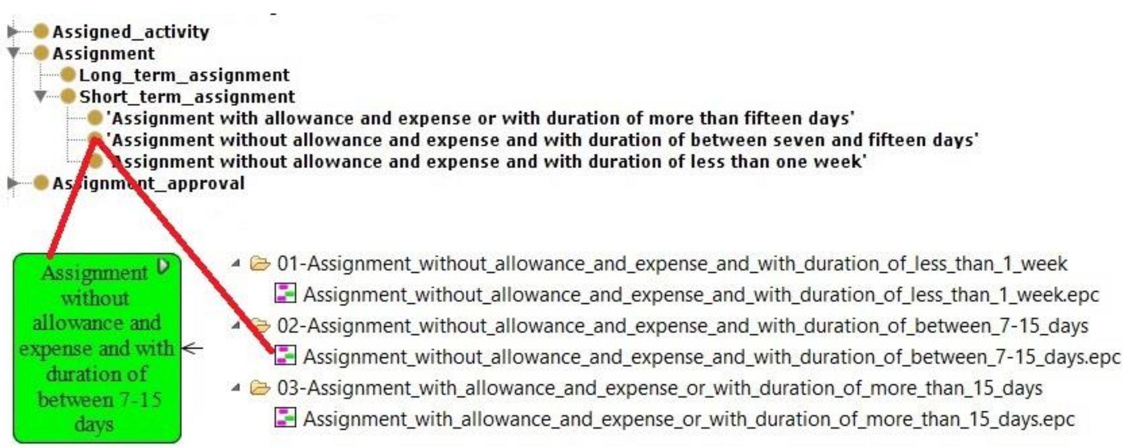


Figure 8 Motivating example of a process model label as an ontology resource

Such ontology resources that represent the same real-world object as a process model label can be added to an ontology via Ontology View (Figure 7). In order to add the resource, analyst clicks “Add Resource (related to a…)” button while the ontology from the ontology list, “Process” radio button, and the process model on the package explorer remain selected. Then the resource is added to the PROMPTUM Ontology Server and the label of resource is listed in the linked resources list. If the resource already exists in the ontology, which might be the case in utilizing existing ontologies, the PROMPTUM Process Modeling Plugin still keeps record of the relation between the ontology resource and the process model label.

Once a resource listed in the linked resources list, several other functions are available. Ontology resource URI and label, and the label of process model is updated by using the “Update Resource” button. The “Delete Resource” button deletes the selected ontology resource from the ontology and the “Unlink Resource” button removes the link between the process model and the ontology resource without deleting the resource from the ontology. And if the analyst deletes a linked resource by using the web interface of the PROMPTUM Ontology Server, upon clicking on “Sync with Ontology Server” on the Ontology View, the resource is removed from linked resources list.

5.3.3 Managing Process Model Element Labels as Ontology Resources

In Figure 9, “Faculty member” is a role in a process model and also a class in “academic assignments” ontology. Such process model element labels can be added to an ontology via Ontology View by using the “Add Resource (related to a…)” button while the ontology from the ontology list, “Element” radio button, and the process model element are selected.

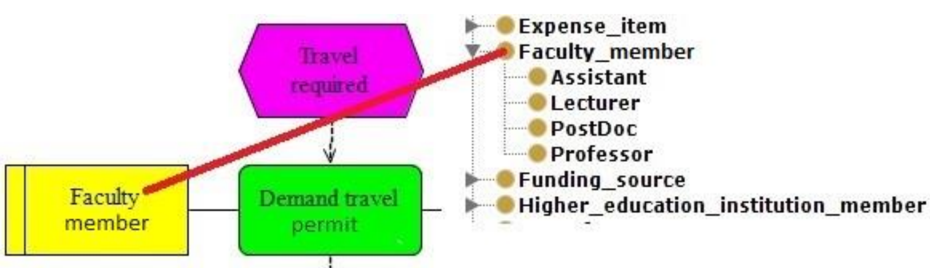


Figure 9 Motivating example of a process model element label as an ontology resource

After the resource related to a process model element label is created in ontology and listed in the linked resources list, analyst can update the process model element label by (1) clicking the “Update Resource” button and changing the label, (2) changing the process model element label in modeling area, or (3) updating the label of resource in the PROPMTUM Ontology Server and clicking the “Sync with Ontology Server” button on Ontology view. All three alternatives ensure that all instances of the process model element in the same process model collection, the linked resources list, and the resource in ontology are updated respectively. The “Sync with Ontology Server” button also ensures a deleted resource in the PROMPTUM Ontology Server is removed from the linked resources list.

“Delete resource” and “Unlink Resource” buttons perform the same functions described in previous sub-section for the resources associated with process model element labels. Moreover, if the last existing instance of a process model element is deleted from the process model collection, the associated resource is also removed from the linked resources list but it remains in the ontology.

5.3.4 Managing Terms within Process Model Labels as Ontology Resources

Not only the whole labels but also the terms and phrases within the labels would represent the same real-world object that a resource in an ontology represents. Figure 10 provides a motivating example for such cases. The phrase “investment proposal” within the process model label “Gather and evaluate investment proposals” is also a resource in “public investment planning” ontology.

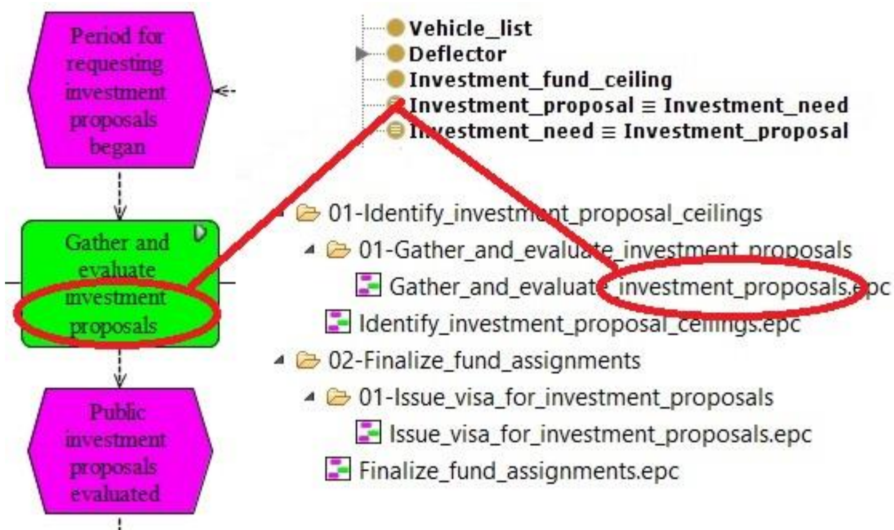


Figure 10 Motivating example of a term within a process model label as an ontology resource

In adding a term or phrase within a process model label, analyst clicks “Add Resource (related to a concept within…)” button while the process model is selected in the UPROM package explorer, and the ontology where the resource will be added and the “Process” radio button remain selected. Then the PROMPTUM Process Modeling Plugin displays a pop-up dialog box where the analyst needs to enter the term or phrase included in process model label. The PROMPTUM Process Modeling Plugin verifies whether the input phrase is included in the process model label or not.

The rest of the functionality related to managing terms within process model labels as ontology resources (i.e. updating, deleting, unlinking, and synchronizing actions) are similar to the ones described above for managing process model labels as ontology resources.

5.3.5 Managing Terms within Process Model Element Labels as Ontology Resources

Similar to the terms and phrases within the process model labels, the terms and phrases within the process model element labels would also be ontology resources in the relevant domains. The motivating example depicted in Figure 11 shows the term "sector" as a part of a process model element label (i.e. "Identify investment needs on the basis of sectors") and a resource in "public investment planning" ontology.

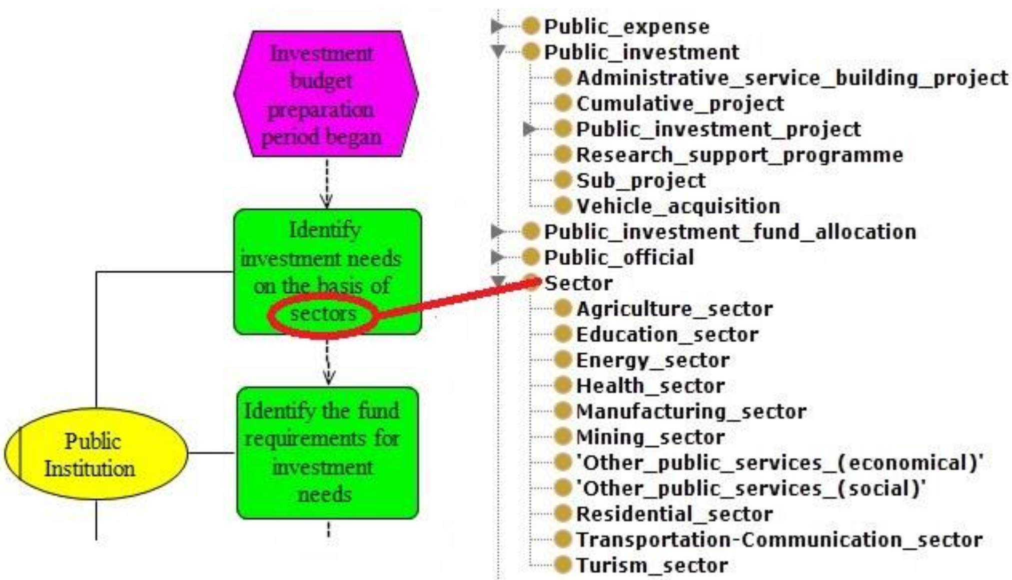


Figure 11 Motivating example of a term within a process model element label as an ontology resource

For adding such resources to the ontology, analyst clicks "Add Resource (related to a concept within…)" button while the process model element, the ontology, and the "Process" radio button are selected and enters the valid phrase (i.e. that exists within the label of selected process model element) on the dialog box that pops up. Remaining actions related to an ontology resource that is linked to term within a process model element label are similar to those described for managing process model element labels as ontology resources.

5.3.6 Managing Process Model and Process Model Element Descriptions

Descriptions exist both for process models and process model elements in business process model collections and for resources in ontologies. For instance, the ontology resource and its related process model element, “faculty member”, in Figure 9 is described as “the professors, lecturers, assistants, and PostDocs working in higher education institutions”.

The PROMPTUM Process Modeling Plugin enables the descriptions of the process models and the process model elements to be added as data type properties to the related ontology resources in adding a new ontology resource via Ontology View on the UPROM tool.

As the description of a process model or process model element is revised, the value of the data type property representing the description is also changed on the PROMPTUM Ontology Server. Moreover, if the value of the data type property representing a description is revised on the PROMPTUM Ontology Server, upon clicking the “Sync with Ontology Server” button, the PROMPTUM Process Modeling Plugin updates the description of the related process model or the process model element on the UPROM tool.

CHAPTER 6

EXPLANATORY STUDY

In this chapter, the explanatory study performed for investigating the last four research questions provided in Chapter 1 is described. The explanatory study, which includes case studies and a semi-structured interview, was conducted for identifying the benefits and pitfalls of using PROMPTUM method and toolset for integrated business process modeling and ontology development.

In order to assess the validity of assumptions behind developing the method and tool support proposed in this study, two case studies were applied on the same case:

- Case study 1: Separate development of process models and an ontology in two threads of study performed by different analysts and domain experts:
    - Business process modeling based on traditional approaches and tool support,
    - Ontology development based on traditional approaches and tool support,
- Case study 2: Integrated development of business process models and an ontology based on PROMPTUM method and toolset.

6.1 Explanatory Study Planning

6.1.1 Research Questions in Explanatory Study

Following research questions, and related propositions and validation methods are characterized for validating the feasibility and benefits of applying PROMPTUM method and toolset for integrated business process modeling and ontology development. Four research questions are introduced for explanatory study.

Research question 1: Does consistency between business process models and ontologies improve with integrated development?

Proposition 1: With integrated business process modeling and ontology development, label-based consistency between process models and ontologies would improve.

Validation method for proposition 1: Similar to the first research question of exploratory study, this research question will be investigated by assessing the cohesion based on the labels within process model collections and ontology resources in explanatory case. Also a review of outputs will identify the inconsistency issues. Findings will be derived by analyzing the issues identified in the review and comparing the cohesion between process models and ontologies developed by using PROMPTUM method and toolset, and using traditional methods and tools.

Research question 2: Does integrated business process modeling and ontology development improve the semantic quality of the process models or ontologies when compared with separate traditional development?

Proposition 2: Semantic quality, which relates to developing artifacts that contain true statements that are complete and correct about the focus domain (Dumas et al., 2013), of process models and ontologies would improve with an integrated development approach introduced in this study. This proposition depends on the assumption that using explicit domain knowledge would improve semantic quality of business process models and also using process knowledge would improve semantic quality of domain ontologies. Previous research (Fan et al., 2016) has supported this proposition to an extend by showing that using ontologies would increase semantic quality of business process models.

Validation method for proposition 2: Both artifacts developed by with and without using PROMPTUM toolset and method is to be evaluated and compared. A reviewer should make the evaluation based on completeness and validity of the produced artifacts, and the analysis should compare the number of issues identified related to these aspects.

Research question 3: How would the development effort be affected with integrated business process modeling and ontology development?

Proposition 3: Development effort, which is a measure of required effort for a unit of artifact size, for integrated business process modeling and ontology development would not exceed the total effort required to develop business process models and ontologies separately. Previous research (Fan et al., 2016) has provided partial support for this proposition by claiming that using ontologies would decrease the effort requirement for business process modeling.

Validation method for proposition 3: Effort spent for integrated against traditional separate development approaches in developing process models and ontologies are to be measured and compared.

Research question 4: What are the perceived benefits of integrated business process modeling and ontology development compared with separate traditional development?

Proposition 4: Integrated business process modeling and ontology building by using PROMPTUM toolset and method would bring benefits such as improved semantic quality and reduced development effort.

Validation method for proposition 4: Perceived benefits of using PROMPTUM toolset and method are based on subjective statements of experts that will examine the steps of integrated development on a case study. Semi-structured interviews are to be used in collecting opinions from experts in the field and academia, and the interview records will be analyzed to cathegorize the stated benefits and report.

6.1.2 Activity Planning in Explanatory Study

The following activities were planned to be performed within the explanatory study.

- Case selection: Case selection will be based on selection criteria and development goals and competency questions will be used in identifying the scope. The case selection criteria used in exploratory study (i.e. real-life context, resource availability, and problem complexity) were also used in case selection in explanatory study.
- Establishing case study environment: Process modeling and ontology development tools will be selected and get ready.
- Identifying information sources: Information sources for the selected case will be identified and allocated.
- Developing process models and ontologies: Development activities for the two case studies will be performed.
- Analyzing the conduct of the case studies: Analysis and evaluation of the research questions will be performed by using the case study outputs and performance.

6.1.3 Mitigation of Threats to Validity in Explanatory Study

Potential threats to the validity of explanatory study and steps taken to minimize them are discussed below. Four types of validity threats (i.e. internal, construct, external, and reliability) are considered based on a checklist adopted from Wohlin et al. (2012).

In terms of internal validity in explanatory study, one of the threats is related to the length of the case studies. The scope of the case selected for case studies was established by considering that the length of the case study execution would not push the endurance limits of the participants. On the other hand, the participants (i.e. domain experts and analysts) were selected from people that are skilled and experienced for the tasks they were expected to perform, so that their learning during the course of the studies would not affect the execution positively as time passes. For mitigating another internal threat to validity, case study environments were planned and established beforehand. Thus, the documented and online information sources, software tools to be used, the scope of the studies, and the location were made ready before the execution of the case studies.

Regarding the construct validity, which relates to the relationships between theory and observation, one threat is related to the adequateness of the preoperational explication of constructs (Wohlin et al., 2012). For relieving this threat, before performing the case studies and comparing the resulting artifacts across case studies, the validation methods of the research questions detailing which data will be collected and how the data analysis will be conducted were defined. A critical threat to validity of explanatory study in this research is related to mono-operation bias. This threat arises from the fact that a single case is included in explanatory study that includes two case studies performed on the same case. Avoiding mono-operation bias based on the number of cases in case study research is troublesome, as the case studies are much costlier in terms of allocating the effort and time of participants and finding real-world cases than other research methods such as surveys and experiments. Even if we admit that it does not offer a complete resolution, we planned to relieve the mono-operation threat to some extent by supporting the findings of the case studies with the results of a semi-structured interviews performed with experts from the industry. The semi-structured interviews were planned to introduce the method and tools used in case studies and the artifacts produced. However, the carefully selected experts were planned to be encouraged to comment about applicability and potential benefits of the PROMPTUM method and toolset based on not only the case study products introduced but also their own experiences regarding other cases in process modeling and ontology building fields. Another utility to be had from performing the semi-structured interviews was planned to be about mitigating the mono-method bias in explanatory study. The results of the semi-structured interviews were planned to be compared with and to support the findings of the case studies regarding the first three research questions in explanatory study. Mitigating actions for another threat to construct validity, the confounding constructs, in explanatory study were planned with same principles described for exploratory study. Lastly, a major threat to validity lies in the potential bias that could be introduced by the experimenter by asking the questions in semi-structured interview so that the answers would match the expectations of the study. To avoid this threat, we adopted the semi-structured interview questions from a published research performed on a similar subject by Fan et al. (2016), and planned to pose follow-up questions only about the content of the interviewees' comments and strictly not about the subjects that are not mentioned by the interviewees.

We also planned actions to reduce the threats to external validity of the explanatory study. Basically, the mitigating actions for external threats to validity planned and taken for explanatory study are similar to those discussed for relieving the external validity threats in exploratory study. With the same research approach, we decided on the tools and languages based on the state of the art and applied the same case selection criteria for selecting the case.

In terms of reliability of a research, most threats to validity are concerned about how the researcher in charge would affect the results and to what extent the independent parties are involved in ensuring the reliability. In explanatory study regarding the research methods utilized, we performed both case studies and semi-structured interviews. In two case studies, to assure reliability, an independent external expert, who would not participate in case studies, with sufficient knowledge about the selected domain (i.e. the selected case) and disciplines (i.e. process modeling and ontology development) was planned to review the conduct, analysis, and results. Also an additional post-mortem review was planned to be introduced in semi-structured interviews by asking the four experts from the industry about how well the process models capture the process knowledge and how well the ontology captures the domain knowledge (i.e. questions 23 and 24 in Appendix H – Survey and Semi-Structured Interview Questions Regarding Integrated Business Process Modeling and Ontology Development) after giving them a walkthrough of the case, the PROMPTUM method and toolset, and the resulting artifacts in case study 2. The threats to validity regarding reliability for semi-structured interviews are also critical. One of them is about reliability of measures (e.g. poor question wording and bad instrument layout), which was planned to be avoided in semi-structured interviews by utilizing a question set from another published research. Heterogeneity of subjects, which is another reliability related threat, was planned to be relieved by selecting the experts for interview based on their background information regarding their expertise in process modeling and ontology development disciplines, and reporting this background information within the study.

6.2 Explanatory Study Design and Execution

6.2.1 Case Selection in Explanatory Study

The candidate case was evaluated as good on all three criteria as shown in Table 6.

Processes included the case were as follows:

- Establishing a graduate program without thesis
- Application and admission to graduate programs without thesis
- Initial Enrollment to a graduate program without thesis
- Semester registrations

The goal of developing an ontology was to make the information about graduate studies without thesis explicit.

Table 6 Case selection in explanatory study

Case characteristics	**Case**
Focus domain	Graduate studies without thesis
Focus organization	METU Informatics Institute
Real-life context	Good
Resource availability	Good
Problem complexity	Good

6.2.2 Case Study Environment in Explanatory Study

As mentioned above, there are two case studies to be performed in scope of explanatory study. For case study 1 that focuses on separate development, same environment utilized in exploratory study will be used.

Signavio was selected for business process modeling in process modeling thread of case study 1, since the analyst, who will perform process modeling, was more familiar with this tool. Signavio was evaluated to have the process modeling capabilities required for this case study. For similar reasons described in exploratory study, eEPC was selected as process modeling language to be used in case study 1 of explanatory study.

For ontology development thread of case study 1 of explanatory study, Protégé v4.3 was selected to be used in ontology development and the resulting ontology was to be represented with RDF

In case study 2, which includes integrated business process modeling and ontology development, PROMPTUM toolset was to be used. As described in Chapter 5, PROMPTUM toolset is composed of UPROM tool, PROMPTUM Process Modeling Plugin, and PROMPTUM Ontology Server. Among these components UPROM tool and PROMPTUM Ontology Server requires installation as PROMPTUM Process Modeling Plugin is included in UPROM tool setup. For avoiding bias with case study 1, eEPC and RDF were selected for representing process models and ontology respectively in case study 2.

6.2.3 Information Sources in Explanatory Study

In development of both ontologies and process models in each of the case studies; a domain expert, documented information sources, and application system shown in Table 7 were allocated as information sources. In each of case study 2 and the two threads of case study 1, a different domain expert was used since the same domain expert providing information and validating the outputs of several case studies would have introduced bias to the study.

Table 7 Information sources in explanatory study

Source Type	**Information Source**
Person	Academic staff member
Regulation	Middle East Technical University Rules and Regulations Governing Graduate Studies
Regulation	Guidelines for Middle East Technical University Graduate Programs without Thesis
Regulation	Guidelines for Registration of Graduate Students
Form	Required documents for application

Lexicon	A set of definitions and most frequent words in Rules and Regulations Governing Graduate Studies
Application	METU Student Affairs Information System

6.2.4 Development in Explanatory Study

As mentioned above, within the explanatory study there were two case studies each of which were performed by a different analyst having the required skills and experience summarized in Table 8. In process modeling thread of case study 1 (i.e. business process modeling based on traditional approaches and tool support), an analyst that has the skills and experience in business process modeling was paired with a domain expert in modeling the selected set of processes. In ontology development thread of case study 1, an analyst developed a "graduate studies without thesis" ontology by utilizing traditional approaches and tool support. PROMPTUM method and toolset were used in case study 2 in integrated business process modeling and ontology development by an analyst.

Table 8 Summary of the background information of analysts in explanatory study

Background profile information	**Analyst in process modeling thread of case study 1**	**Analyst in ontology development thread of case study 1**	**Analyst in case study 2**
Age	31-35	26-30	31-35
Education	Business administration and Information systems	Computer engineering and Information systems	Industrial engineering and Information systems
Job title	Research assistant	Research assistant	Research assistant
Process modeling skills	Very good (5 out of 5)	Good (4 out of 5)	Very good (5 out of 5)
Enrolled in a process modeling course?	Yes	Yes	Yes
Process modeling experience?	Yes	Yes	Yes
Ontology development skills	Moderate (3 out of 5)	Good (4 out of 5)	Good (4 out of 5)
Enrolled in an ontology development course?	No	Yes	Yes
Ontology development experience?	Yes	Yes	Yes

6.3 Explanatory Study Analysis and Results

The metrics that are indicators of the size of the products developed in explanatory study are provided in Table 9.

In the analysis and results of the explanatory study, we investigated the last four research questions provided in Section 1.4. Each of the research questions was addressed by using the data collected in case studies and semi-structured interview performed in explanatory study.

Table 9 Explanatory study summary

Metrics	**Process modeling thread of case study 1**	**Ontology development thread of case study 1**	**Case study 2 (integrated development)**
Number of process models	4	-	4
Number of functions in process models	34	-	37
Number of process model elements	94	-	77
Number of ontology resources	-	73	76

6.3.1 Analysis and Results for Research Question 1 of Explanatory Study

For identifying the consistency between process model collections and ontologies in the analysis regarding the first research question in explanatory study, ontology resources are matched with labels and terms within labels in process model collections. In case study 2, as PROMPTUM method and toolset were used, most relations were already established. On the other hand, matching the ontology resources in ontology development thread of case study 1 with the labels and terms within labels in process models developed in process modeling thread of case study 1 was done by searching each ontology resource label in process models one by one.

The ontology resources matching with process model elements that have multiple instances in the process model collection are counted only once (e.g. a role, “institute board”, has several instances in the process model collection, but its associated matching with the ontology resource is counted as one).

Moreover, especially in the analysis of case study 1, label matching was made based on semantics rather than syntax. For example, in the resulting process models of process modeling thread of case study 1, the terms “program” and “lisansüstü program (graduate program)” represent the same real-world phenomena that is represented as an ontology resource labeled “graduate program” in ontology development thread of case study 1. So, although these are syntactically different, they have the same meaning and counted as a match with the related ontology resource. Another example of two terms having the same meaning but a more significant difference in syntax is between “not çizelgesi (grade chart)” and “transkript (transcript)” in process modeling thread of case study 1.

A review of process model collections and ontologies developed in case studies of explanatory study was performed and the issues identified in the review are provided in in Appendix G – Issues Identified in the Review of Products in Explanatory Study.

Table 10 shows the number of ontology resources that represent the semantically same terms with the labels and terms within labels in process model collections in case study 1 and case study 2. Based on these figures and the issues detected in the review of the products, following consistency related findings were identified between business process models and ontologies:

- Ontology and process model collection developed in case study 1 respectively include 14 (fourteen) inconsistent use of terms and phrases between the ontology resources and labels within process model collection. However, no such issues were identified for ontology and process model collection developed with PROMPTUM method and toolset in case study 2.
- In case study 1, 2 (two) ontology resources were identified to be needed to be represented in process model collection. No such issues were identified for case study 2.
- According to the review, in case study 1, the ontology developed should have represented 12 (twelve) terms and phrases included in the process model collection. In case study 2, there are 6 (six) such issues between the process model collection and ontology developed as integrated.

Table 10 Relations between resources in ontology and labels in process model collections in explanatory study

Related resources	**Case study 1 (separate development)**	**Case study 2 (integrated development)**
Process model labels	2	1
Terms within process model labels	6	6
Process model element labels	12	20
Terms within process model element labels	62	68

The findings summarized above suggest that the proposition for the first research question in explanatory study holds. In other words, the findings support the claim in this study that compared to the process model collections and ontologies developed separately, process model collections and ontologies developed as integrated with the support of a method and tool support are more consistent with each other.

6.3.2 Analysis and Results for Research Question 2 of Explanatory Study

Semantic quality of process models is related to validity and completeness (Dumas et al., 2013). Validity focuses on whether the information represented in the models are correct and relevant to the problem, whereas completeness is a measure of extend to which the models include all correct statements on processes. For assessing semantic quality of ontologies, same semantic quality aspects are utilized in this study. As pointed out in previous studies (Dumas et al., 2013; Fan et al., 2016), assessing the semantic quality of these artifacts requires a subjective evaluation usually performed via reviews. However, for mitigating the potential bias accommodated in reviews to some extent, the reviewer was provided a set of review criteria. Also the conduct and results of the review was later evaluated by the author of this study.

Review results provided in Appendix G – Issues Identified in the Review of Products in Explanatory Study were used in the analysis regarding research question 2.

Some results and findings regarding the validity of process models and ontologies identified based on the issues detected in review are as follows:

- In both case study 1 and 2, there exists one issue related to incorrect information in process models. So, in terms of correctness of the process related information in process models, integrated and separate development do not differ at all. Yet, it is noteworthy that number of issues to generalize this proposition to any extend is not enough.
- There are no issues related to incorrect information in ontologies developed in either of case studies 1 or 2.
- Internal consistency in work products can be regarded as a type of issue related to correctness of the products. There are 3 (three) issues regarding internal consistency in case study 1. To be exact about these issues, they are related to naming the process model elements that represent the same concepts in processes. These issues are also related to the information in process models being incorrect. Related process model element labels were represented in ontology developed in case study 1. So if the ontology had been used in the development of process models in case study 1, it is possible that these issues would have been avoided. No such issues exist in process models of case study 2. Yet, since internal consistency issues are not many in both case studies 1 and 2, a strong proposition about how internal consistency of process models would improve with integrated business process modeling and ontology development would not be valid. However, it is worth noting that there is at least weak evidence that would be the case.
- There are no issues related to internal consistency in ontologies developed in either of case studies 1 or 2.

The issues identified in the review were used in generating the following results and findings regarding the completeness of process models and ontologies:

- As described for the first research question, the 2 (two) ontology resources identified in case study 1 were in scope of the process model collection in case study 1, but not represented in it. This constitutes a problem for the completeness of the process model collection developed. However, such issues were not identified in case study 2.
- As discussed in first research question, 12 (twelve) terms and phrases used in process model collection in process modeling thread of case study 1 should have been defined as ontology resources in ontology development thread of case study 1. On the other hand, there were 6 (six) terms and phrases belonging to process models needed to be represented as ontology resources in case study 2. So, in terms of completeness of resulting ontologies, review results show that integrated development performs better than separate development.
- 1 (one) out of scope entity exists in ontology developed in case study 1.
- 6 (six) issues about missing (or out of scope) information exist in process models in case study 1, whereas 4 (four) exist in case study 2.

Overall, the explanatory study results reveal that semantic quality of the ontologies and business process models developed with PROMPTUM method and toolset are higher compared to separate traditional development. Especially, completeness of process models and ontologies seems to improve with integrated development. This would suggest that usage of formal domain knowledge in process modeling and structured process knowledge in ontology development would improve completeness and so that the semantic quality of both artifacts.

6.3.3 Analysis and Results for Research Question 3 of Explanatory Study

Third research question was interested in the development effort required for integrated business process modeling and ontology development. In explanatory study, effort data was collected for development activities in order to compare the total effort required for integrated and separate development. Analysts' effort, domain experts' effort, and durations of case studies are provided in Table 11. As one analyst and one domain expert, who contributed development simultaneously, were assigned to each case study, effort per actor and duration values within each case study are equal.

So, in total 220 person-minutes were spent by analysts for developing process models and ontology separately (i.e. 95 person-minutes for process modeling and 125 person-minutes for ontology development in case study 1), whereas analyst in case study 2 spent an almost equal 215 person-minutes to develop both products with an integrated approach. Therefore, the explanatory study does not suggest a major development effort gain or loss via integrated business process modeling and ontology development.

Table 11 Effort and duration data in explanatory study

Metrics	Process modeling thread of case study 1	Ontology development thread of case study 1	Case study 2 (integrated development)
Analyst's effort	95 person-minutes	125 person-minutes	215 person-minutes
Domain expert's effort	95 person-minutes	125 person-minutes	215 person-minutes
Duration	95 minutes	125 minutes	215 minutes

Based on explanatory study results, similar to the findings for development effort, total duration of development seems not be affected much when process models and ontologies are developed as integrated rather than as separated.

Another aspect in this research question's context that would be worth investigating was to shed light on the distribution of effort spent for ontology development and for process modeling in integrated development. However, it was not possible to decompose the cognitive effort to smaller chunks of data in case study 2, as the process modeling and ontology development activities were mostly intertwined rather than discrete.

The results raise some new questions to investigate in the future regarding the factors that cause the increase in total cognitive effort in integrated development of more than one product, phases of development (e.g. information elicitation, modeling, validation) that would enjoy the development effort gains most in integrated development, and the impact of the tool capabilities on the development effort.

6.3.4 Analysis and Results for Research Question 4 of Explanatory Study

Appendix H – Survey and Semi-Structured Interview Questions Regarding Integrated Business Process Modeling and Ontology Development was designed to find answers to the fourth research question in explanatory study. It presents the survey questions (i.e. questions from 1 to 22) that are designed to assess the background profile of the participants and the semi-structured interview questions (i.e. questions from 23 to 28) that are adopted from Fan et al. (2016) in order to identify the perceived benefits of integrated business process modeling and ontology development compared with separate traditional development.

The semi-structured interview was performed with four interviewees from the industry. These four interviewees were carefully selected from different backgrounds (e.g. different companies, expertise, and work experiences). A summary of background profiles of the interviewees that participated in the semi-structure interview is provided in Table 12.

Table 12 Summary of background profiles of the interviewees

Background profile information	**Interviewee 1**	**Interviewee 2**	**Interviewee 3**	**Interviewee 4**
Age	36-40	46-50	31-35	36-40
Education	Computer engineering	Electronic engineering and Computer engineering	Industrial engineering	Computer engineering
Job title	Software project manager	Software engineer and Process improvement consultant	Process analyst and consultant	Software architect
Process modeling skills	Good (4 out of 5)	Very good (5 out of 5)	Very good (5 out of 5)	Bad (2 out of 5)
Enrolled in a process modeling course?	Yes	Yes	Yes	No
Process modeling experience?	Yes	Yes	Yes	Yes
Ontology development skills	Bad (2 out of 5)	Very bad (1 out of 5)	Moderate (3 out of 5)	Very good (5 out of 5)
Enrolled in an ontology development course?	No	No	No	Yes
Ontology development experience?	No	No	Yes	Yes

Before the background survey and semi-structured interview was performed, each interviewee was given an extensive introduction about PROMPTUM method and toolset. They were also given a walkthrough about the conduct and the resulting process models and ontology in case study 2 of explanatory study.

In the semi-structured interview, interviewees were asked the semi-structured interview questions. They were asked some additional questions where a clarification and additional information was needed regarding the points they made. However, they were not given any keywords or hints about the potential benefits the author of this study had envisioned. Thus the potential benefits stated by the interviewees are strictly based only on their own perceptions.

The interviews were recorded and then the voice records were transcripted to text. The comments made by all interviewees were read and the statements about the perceived benefits and justifications of benefits were identified and classified. The statements describing similar benefits were identified to report different opinions on the subject in reaching the results.

Based on the classification of comments, following perceived benefits were identified as suggested by the interviewees. The quotes of the interviewees are given in Turkish and with an accompanying translation to English.

Discovery: One of the benefits that was suggested by all interviewees was about how PROMPTUM method and toolset is easing the information discovery in selected domains. The interviewees highlighted both improved process discovery and domain knowledge discovery during process modeling and ontology building activities. One of the interviewees in suggesting the benefits to process discovery stated that:

> "The information resources discovered in ontology development will establish a base for process modeling. The answers to some 5W1H questions to be asked about the process would be hidden in the ontology resources and their relationships. / *Ontoloji geliştirmede ortaya çıkan bilgi kaynakları süreç modelleme için bir taban oluşturacaktır. Süreç ile ilgili sorulacak 5N1K sorularının cevaplarının bir kısmı ontolojideki kaynaklarda ve ilişkilerde saklı olabilir.*"

Another interviewee highlighted that putting a cognitive effort to ontology building would improve process discovery by stating:

> "It (i.e. the method) enables to discover the processes and activities, and find out the inputs and outputs, and actors of the activities. It is like brain storming. It enables to think like; "What is this entity used for? It is used for this.". It encourages thinking deeper during process modeling. / *Süreç ve aktivite keşfi ve daha çok aktivitelerin aldıkları girdi ve çıktıları ve aktivitelerin aktörlerini bulduruyor. Daha çok beyin cimnastiği gibi. "Buradaki varlık ne için kullanır? İşte şunun için kullanılır" diye düşünmeyi sağlıyor. Süreç modellerken daha derin düşünmeye teşvik ediyor.*"

Regarding domain knowledge discovery in ontology building, interviewees think that PROMPTUM method and toolset would be beneficial. One interviewee states this benefit by also claiming that the improvement in domain knowledge discovery would be dependent on the granularity and quality of process models:

> "Actually, inputs and outputs are always a bit easy to omit in process models. Of course, if the inputs and outputs are defined, they are very strong candidates to be defined in the ontology. Still, if required detail level is not existing, we might not find out for example what the application documents are. In terms of the roles, we sometimes cannot discover the actor of an activity due to the use of passive voice. Discovering the ontology resources would be affected by the level of detail and quality of process models. / *Süreç modellerinde girdi ve çıktılar aslında her zaman biraz kolay atlanabiliyor. Tabi girdi ve çıktılar tanımlıysa, bunlar çok güçlü aday ontolojide tanımlanmak için. Yine de, örneğin başvuru evraklarının ne olduğunu bulamayabiliriz bu detay yoksa. Rollerde de bazen edilgen çatı kullanılırsa aktiviteyi kimin yaptığı açığa çıkmıyor. Süreç modellerinin detay seviyesi ve kalitesine göre ontoloji varlıklarını keşfetmemiz etkilenir.*"

Consistency: A benefit two of the interviewees mentioned is related to consistency between the two artifacts. According to these interviewees the consistency between process model collections and ontologies in the similar domains would improve. One of the interviewees suggest that:

> "It enables the products to be consistent with each other. Same terminology would be used. So, there would not be difference in naming the same concept. / *Ürünlerin birbiriyle tutarlı olmasını sağlar. Aynı terminoloji kullanılır. Yani aynı kavram için farklı isimlendirme yapılmaz.*"

Effort: All four of the interviewees mentioned the benefits regarding the development effort. One of the interviewees claimed that integrated development would prevent "duplicated analysis effort". Another stated this benefit as:

> "There would be significant effort savings by eliciting information in a single go in integrated process modeling and ontology development. The interviews with domain experts would take shorter, the domain experts would be prevented to stay away from their work, and they would not face the same questions for several times. / *Süreç modelleme ve ontoloji geliştirmenin bütünleşik yapılmasıyla bilgi alımı safhası tek bir defada yapılarak önemli işgücü kazanımı elde edilir. Alan uzmanlarıyla yapılacak görüşmeler daha kısa sürede tamamlanır, alan uzmanlarının işlerinden kalması engellenebilir ve alan uzmanlarının aynı sorularla birden fazla karşılaşması önlenebilir.*"

Another interviewee introduced a different point of view by suggesting effort savings would be possible by enabling different teams to work on the shared aspects in two artifacts:

> "Database team and web-services team would work together and they would not have to model the same data several times. Besides, it (PROMPTUM method) provides a method to enable the teams to work together asynchronously. / *Veritabanı ekibiyle webservis ekibi beraber çalışır ve tekrar tekrar aynı veriyi modellemezler. Ayrıca, ekiplerin asenkron bir şekilde birarada çalışabilmeleri için (PROMPTUM method) bir yöntem sunuyor.*"

Automation: Another frequently mentioned benefit was related to the support to automation potential. Interviewees' claims about the automation potential range from stating that the resulting process models and ontologies would be used in requirements and design of information systems to suggesting that both products would be used for execution purposes. In terms of the benefits to software development processes, one of the interviewees stated that:

> "It (PROMPTUM method and toolset) will provide an integration within software development by enabling traceability, documentation, and verification of all intermediate phases (e.g. analysis, design, testing). / *Gereksinim analizinden, yazılım geliştirimine kadar tüm ara aşamaların (analiz, tasarım, test gibi) izlenebilirliğini, dokümantasyonunu ve doğrulanmasını sağlayarak yazılım geliştirme içinde bir bütünlük sağlayacaktır.*"

Gap in the tool market: Two of the interviewees highlighted that PROMPTUM toolset has the potential to fill a gap in the software tools market. One of them stated that he had not seen such a support in existing tools to support integrated process modeling and ontology development. The other interviewee by focusing more on process modeling support stated that:

> "When we look at the market and the literature, it is seen that the systems or methods, which provide data for process modeling activities or help in verification, are inadequate. Thus, we can see that the method and tool produced would contribute to compensating this deficiency. / *Piyasaya ya da literatüre baktığımızda süreç modelleme çalışmalarına veri sağlayacak ya da doğrulamalarda yardımcı olacak sistem ya da yöntemlerin yetersiz olduğu gözükmektedir. Bu bağlamda ortaya konulan yöntem ve aracın bu eksikliğin giderilmesinde katkı sağlayacak bir çalışma olduğu görülmektedir.*"

Verification: In terms of the benefits to verification of the artifacts, two interviewees had comments. As both interviewees highlighted the benefits to verification of process models, one stated that:

> "Ontology studies in the subject domain would be a source for verification about the process (models). Subject domain related information and relationships in the ontology would provide information about the missing or incorrect statements in process flow or process business rules. / *Süreç (modelleri) ile ilgili doğrulama*

> *kaynaklarından biri de konuyla ilgili ontoloji çalışmaları olabilir. Ontolojide yer alan konuyla ilgili bilgi ve ilişkiler sürecin akışı ya da sürecin iş kurallarında eksik veya hatalı bir durum söz konusu olup olmadığı ile ilgili bilgi sağlayabilir.*"

The other interviewee agrees by stating that:

> "The semantic constraints defined between concepts with ontologies would be directly used in verification of process (models). The constraints in the ontology will be guiding and prevent incorrect definitions to be made. / *Ontolojiler ile tanımlanan kavramlar arasındaki anlamsal kısıtlar süreçlerin (modellerinin) doğrulanmasında da doğrudan kullanılabilecektir. Ontolojideki kısıtlar yol gösterici olup, yanlış tanımlar yapılmasının önüne geçecektir.*"

Same interviewee in suggesting the benefits in verification of ontologies claimed that:

> "(By using the process models) soundness of the ontology will be tested, and it will be approved that the ontology corresponds the needs; completeness. / *(Süreç modelleri kullanılarak) ontolojinin geçerliliği test edilmiş olacak; soundness, ve ihtiyaçları karşıladığı onaylanmış olacak; completeness.*"

Definition (and making knowledge explicit): One of the perceived benefits three of the interviewees were enthusiastic about was related to the definition of process and domain knowledge. This benefit is mostly about how definition would lead to transforming implicit knowledge about the process and domain to explicit knowledge. One interviewee states that:

> "It is not possible to represent all information regarding the process in process models. When they are represented, it makes relationships and models so complex to read that tracking the process flow, which is the main objective of modeling, becomes impossible. On the other hand, it is necessary to keep some process related information. This information is kept in process cards and process attributes, but the relationships between these information and processes could not be traced due to complexity and the relationships could not be maintained. Thus, the ontologies provide a new manageable environment for providing and managing the information needed to be kept on process (models), and tracing these relationships. / *Süreç modelleri üzerinde süreç ile ilgili her türlü bilgiyi yansıtmak mümkün olmamamaktadır. Yansıtılmaya çalışıldığında ise ilişkiler ve model okunmayacak karışıklıkta ortaya çıkmakta modellemenin asıl amacı olan iş akışının takibini olanaksız kılmaktadır. Diğer taraftan da süreç ile ilgili bir takım bilgileri tutmak gerekmektedir. Bu bilgiler süreç kartları denilen yapılarda ya da süreç özniteliklerinde takip edilmekte ancak bu bilgilerle süreç arasındaki ilişkiler karmaşıklıktan dolayı takip edilemeyecek ve ilişkileri korunamayacak durumdadır. Bu doğrultuda ontolojiler süreç (modelleri) üzerinde tutulması*

gereken bilgileri sağlamada, yönetmede ve ilişkilerini takip edecek yeni yönetilebilir bir ortam sağlamaktadır."

Another interviewee agrees that PROMPTUM method and toolset would provide improved definitions for process models by suggesting:

> "It will become possible to define resources that are much far beyond the definitions that would be made with regular process modeling languages. / *Sıradan süreç modelleme dilleriyle yapılabilecek tanımların çok daha ötesinde kaynak tanımlamak mümkün olacaktır.*"

Yet, he also suggests an improvement proposal regarding definition of ontologies by stating:

> "Transferring process specific concepts (e.g. event, actor, process) to the ontologies would directly bring in all the advantages I listed for ontologies to the process modeling domain too. / *Süreçlere özel kavramları (örneğin olay, aktör, süreç) da ontolojilere aktarıyor olmak ontoloji için saydığım tüm avantajları süreç modelleme alanına da doğrudan kazandıracaktır.*"

Besides the perceived benefits described above based on the comments of several interviewees, each of the following benefits were suggested by one of the interviewees.

Completeness: One interviewee mentioned that the completeness of process models would improve by using PROMPTUM method and toolset. He stated that "percentage of real life activities represented in process models would improve / *süreç modellerinde yansıtılacak gerçek hayattaki aktivitelerin yüzdesi artabilir*". He also argued that "the most important effect on the process models would be the increased quality of models in terms of completeness / *süreç modelleri üzerinde en önemli etki tamlık açısından modellerin kalitesini arttırmak olacaktır*".

Ambiguity and Understandability: One of the interviewees claimed that the understandability of the process models would improve, whereas ambiguity would decrease with integrated process modeling and ontology development. He suggested that "some terms in process models would not be understood, but a formal and structured knowledge included in ontologies would help in decreasing the ambiguity and increase the understandability / *süreç modellerindeki bazı terimler anlaşılmayabilir, ama ontolojilerdeki formal ve yapısal bilgi muğlaklığı azaltmaya ve anlaşılabilirliği arttırmaya yardımcı olabilir*".

Abstraction: A major benefit according to an interviewee would be about the abstraction of domain knowledge from process knowledge. The interviewee claimed that the PROMPTUM method and toolset would; "provide the process models an abstraction from the variety of concepts and concept instances. For example, variety of "English proficiency exam types" would be handled as separated from process model development / *kavram ve kavram örneklerinin çeşitliliğinden süreçleri soyutlar. Örneğin, "İngilizce yeterlilik sınav türlerinin" çeşitliliği süreç modelleri geliştiriminden ayrı ele alınabilir*".

Reuse: According to one of the interviewees the reuse of ontologies would improve process modeling. He stated that; "by reusing the existing ontologies and integrating them with process models, there would be effort savings in process modeling / *mevcut ontolojileri yeniden kullanarak ve süreç modelleriyle bütünleştirerek, süreç modellemede işgücü kazançları sağlanabilir*". He also suggested the benefits to the ontology as; "this approach will help discovering the relationships between two concepts (e.g. abstraction such as in rdfs:subClassOf property) and discovering semantic constraints / *bu yaklaşım iki kavram arasındaki ilişkileri (örneğin, rdfs:subClassOf gibi soyutlama) ve anlamsal kısıtları keşfetmeye yardımcı olacaktır*".

Integration: An interviewee stated his belief that there would be improved integration between process models. He claimed that; "the ontologies will provide a major contribution to establishing relationships between pre-established process models / *daha önce tanımlanmış süreç modelleri arasındaki bağlantıların kurulmasında ontolojiler önemli katkı sağlayacaktır*".

Change management (and maintenance): An interviewee stated that the benefits regarding improved maintenance would be exiting for both process models and ontologies. He suggested that; "changes in concepts will be easily propagated to process models / *kavramlardaki değişimi kolaylıkla süreç modellerine dahil edebileceğiz*". However, he also stated some drawbacks as; "reengineering should require caution and some special tools as the change propagation would not be so smooth between two artifacts. For example, the process models might demand such a concept that would eliminate the old one and put two new concepts at its place in ontology. The opposite of this would also be possible when process models might require major updates upon a change in ontology / *değişimi yansıtmak iki ürün arasında çok kolay olmayabileceği için yeniden yapılandırma dikkat ve bazı özel araçlar gerektirecektir. Örneğin, süreç modeli öyle bir kavram talep eder ki mevcut kavram ortadan kalkacak ve yerine ontolojide iki yeni kavram gelecek. Tersi de geçerli; ontolojide değişiklik yaptığımızda süreç modellerinde önemli güncellemeler gerekebilir*".

Modularity: An interviewee suggested that the modularity of different ontologies might improve. He stated that; "it will guide ontology modularity by defining the concepts belonging to different processes in different ontologies and therefore considering the balance between high cohesion versus low coupling / *farklı süreçlerde kullanılan kavramların farklı ontolojilerde tanımlanarak high cohesion vs low coupling dengisi göz önüne alınarak ontoloji modülerliğine yol gösterecektir*".

Adoption: According to an interviewee; "an ontology that is relatable to processes will be easier to be adopted by external sources / *süreçlerle ilişkilendirdiğim ontoloji dış kaynaklar tarafından da kullanılabilir olacaktır*".

Required skills: An interviewee claimed that; "even a process analyst, who do not have the ontology development skills, would enjoy the benefits of integrated process modeling and ontology development. If there are existing ontologies, the process analyst would perform process modeling by applying ontology reuse / *ontoloji mühendisliği yeteneklerine sahip olmayan bir süreç analisti bile bütünleşik süreç modelleme ve ontoloji geliştirmenin söz edilen fayalarına sahip olabilir. Halihazırda ontolojiler varsa, yeniden kullanma avantajı ile süreç modelleyebilir*".

Reasoning: An interviewee stated that; "with the reasoning capabilities that come with the ontologies, it would be possible to develop semi-smart mechanisms to be used in execution of the processes / *ontolojilerle gelen çıkarsama yetenekleri sayesinde süreçlerin işletiminde yarı akıllı mekanizmaların geliştirilmesi sağlanabilecektir*".

Complexity: As a possible detrimental effect of PROMPTUM method and toolset, one of the interviewees claimed that complexity of process models would increase. He stated that; "if the analyst tends to represent a lot of information (taken from the ontology) in process models, the complexity of process models would grow exponentially / *eğer analist süreç modellerinde çok fazla bilgi göstermeye yönelirse, süreç modellerinin karmaşıklığı kontrolsüz bir şekilde artar*". However, he also states that; "the extend of this detrimental effect is strongly related to the experience level of the analyst and how the analyst sticks to the development objectives of the process models / *bu zararlı etki, analistin tecrübesi ve süreç modellerinin geliştirme hedeflerine bağlı kalmasına güçlü bir şekilde bağımlıdır*".

6.4 Overall Findings of the Explanatory Study

In scope of evaluationg the research outputs of this study, an explanatory study including two case studies (i.e. one for separate development and one for integrated development) and a semi-structured interview was performed and analyzed. The overall findings identified in addressing the four research questions in explanatory study are discussed below:

- Process models and ontologies developed as integrated with PROMPTUM method and toolset are more consistent with each other than separately developed process models and ontologies.
- In terms of validity of the artifacts, which is an aspect of semantic quality, evaluation results show that process models and ontologies developed integrated do not include more incorrect information that the ones developed separately.
- Again in terms of validity of the artifacts, process models developed as integrated with an ontology are slightly more internally consistent than the process models

developed with traditional approaches. However, the ontologies that are developed integrated with process models and separately do not differ in terms of internal consistency.

- Evaluation results reveal that both ontologies and process model collections developed by using PROMPTUM method and toolset were evaluated better in terms of completeness, which is an aspect of the semantic quality of the artifacts, than their counterparts that were developed separately. So, a claim that can be made based on the evaluation results is that PROMPTUM method and toolset helps improve the completeness of resulting process modeling and ontologies.
- Another finding based on evaluation results suggests that integrated development with PROMPTUM method and toolset would not require more development effort compared to the total required development effort for separated process modeling and ontology development.
- According to the results of a semi-structured interview and comments of several interviewees, PROMPTUM method and toolset would potentially provide improved information discovery, consistency between different artifacts, required development effort, automation potential, tool market diversification, verification of the artifacts, and definition of knowledge.
- Although they were not suggested by more than one interviewees, the following potential benefits of PROMPTUM method and toolset were also claimed; improved completeness of products, abstraction, reuse, integration opportunities between process model collections, change management and maintenance, modularity of ontologies, adoption of ontologies, and reasoning, decreased ambiguity and increased understandability in products, and not necessitating ontology engineering skills for using the method and toolset in process modeling.
- The interviewees asserted the benefits suggested by the case studies in explanatory study, which are improved consistency between process models and ontologies, improved semantic quality in terms of completeness, and the integrated development not exceeding the total effort requirements for separate development.

CHAPTER 7

CONCLUSION

In this study, PROMPTUM method and toolset for integrated business process modeling and ontology development are described. The implications of using the proposed method and toolset were investigated in exploratory and explanatory studies. In this chapter, the results and findings of the research is discussed, and then the limitations of the study and recommendations for future research are presented.

7.1 Contributions

The exploratory study performed in the initial phases of this research was aiming at revealing the necessity of methodological and software support for integrated business process modeling and ontology development. Two case studies were performed by using state of the art tools, languages, and methods in process modeling and ontology building. In one of the case studies the process modeling and ontology building activities were performed simultaneously, while in the other case study an ontology was built by utilizing the process knowledge in an existing process model collection. The analysis and results of the exploratory study revealed that ontologies and process models developed for same or similar domains would be highly cohesive in terms of semantics. To be exact, the number of instances where ontology resources would share the same semantic meaning with the labels, and terms and phrases within the labels of process models and process model elements was high. This result led to a finding regarding the high cohesion between process models and ontologies in same or similar domains that justify the necessity of integrated business process modeling and ontology development. The other contribution of the exploratory study results was in identifying the requirements of tool support for integrated business process modeling and ontology development. This is also a contribution since neither such tool support nor the expectations from the tool support exist in the state of the art.

The methodological support for integrated business process modeling and ontology development in the state of the art is scarce. Fan et al. (2016) provides a method for process modeling by using existing ontology resources in labeling process model elements. However, they do not describe how to develop process model collections and ontologies together and how to build ontologies by utilizing the labels in existing process model collections. Another related study by Cherfi et al. (2013) describes matching rules between ontology resources and labels in process model collections, but does not provide a method for integrated development. Moreover, none of the studies describe the matching between ontology resources, and terms and phrases within labels in process model collections. The PROMPTUM method developed in this study brings together best practices and methods from the state of the art in ontology development and business process modeling disciplines. It provides the guidance needed for integrating business process modeling and ontology development. Aside from being a pioneer method for supporting integrated process modeling and ontology development, one of the PROMPTUM method's contributions is in integrating shared development processes and activities in process modeling and ontology building such as scope definition, reuse, information elicitation, verification, and validation for guiding integrated development. Another contribution is in guiding associating labels, and terms and phrases within labels in process model collections with ontology resources.

Tool support for process modeling and ontology building is sufficiently many and diverse in the state of the art. However, in terms of label based associations between process models and ontologies, which is important for supporting integrated development as identified in exploratory study, there are no tool support available in reviewed academic literature and commercial tools. The PROMPTUM toolset's contribution in this sense is in enabling the management of labels, and terms and phrases within labels in process model collections with ontology resources. Thus, the features provided by PROMPTUM toolset enables consistency in synchronizing the ontology resources and terms in process model collections. Moreover, the PROMPTUM toolset enables descriptions for ontology resources and process model elements managed synchronously.

PROMPTUM method and toolset together provides guidance and support for integrated process modeling and ontology development. Their value in filling a gap in state of the art can be explained with respect to the challenges in semantic process modeling identified by Mendling et al. (2014). With respect to these challenges, PROMPTUM method and toolset provides resolutions for identifying semantic components of labels (C1 in Mendling et al. (2014)), recognizing the meaning of terms from labels (C3), identifying homonymous or synonymous terms (C4), assessing the similarity of labels (C6), and discovering an ontology by using process models (C24).

The explanatory study aimed at identifying the benefits of integrated process modeling and ontology development with the support of PROMPTUM method and toolset. The two case studies; one for separate development of process models and an ontology, and the other for integrated process modeling and ontology development were utilized in identifying these benefits by enabling the opportunity to compare and contrast separated and integrated development practices and products. The results of the explanatory study revealed that consistency between process models and ontologies developed as integrated tend to be more consistent with each other than the ones developed as separated. Another important finding suggested that semantic quality of process models and ontologies developed as integrated tend to be higher especially in terms of completeness of these artifacts. Regarding the development effort, results suggested that integrated development would not require more effort than the total effort required for separate development of process model collections and ontologies. Comments of practitioners from the industry participated in a semi-structured interview asserted these benefits (i.e. regarding internal consistency, completeness of artifacts, and development effort). The results of the semi-structured interview suggested that integrated process modeling and ontology development with the support of PROMPTUM method and toolset would provide other benefits compared to separate development such as improved information discovery, automation potential, tool market diversification, verification of the artifacts, and definition of knowledge.

7.2 Limitations and Future Work

A limitation of this study lies in its capability to generalize the findings to wider domains. The validation of this study relies on case study research, which is costlier in terms of time and effort required than many other research methods such as surveys and laboratory experiments. So, for specifying the implications of the research that would be generalizable to several organization types and situations, increasing the number and diversity of case studies would not always be feasible. As a result, the applicability and benefits of the research products would not be validated enough to assure generalizability. To improve generalizability in this study, the case study method was complemented with another research method (i.e. semi-structured interview) in explanatory study. Moreover, even if the PROMPTUM method and toolset were not used in exploratory study, the exploratory study provides two more case studies revealing the applicability of integrated process modeling and ontology development. Still, as for many case study based research, to further validate the applicability and benefits of the PROMPTUM method and toolset and to improve generalizability, the number and diversity of case studies would be increased.

Another limitation of this study is that the resulting artifacts produced in case studies are yet used for automation and business goals. A major goal of ontologies is to use them in semantic web applications. Business process models are also used in information system development either by requirements analysis or process execution. Also both artifacts are useful in serving business goals by supplying domain and process related knowledge in guiding daily operations. So, a limitation is that we have not observed and analyzed the benefits and shortcomings of the ontologies and process model collections developed with PROMPTUM method and toolset in action where they are actively used for the purposes they are developed for.

The PROMPTUM method and toolset would also potentially support process modeling by using existing ontologies and ontology development by using process models. Similar applications in this sense were performed in exploratory study using traditional methods, tools, and intuition to develop an ontology by using existing process models and by Fan et al. (2016) in process modeling via using existing ontologies. These applications would be considered as evidence that it would be possible the PROMPTUM method and toolset would be used in developing one of the artifact types by using an existing other. However, we have not applied PROMPTUM method and toolset for these purposes yet and not observed the potential benefits and pitfalls. Therefore, application of PROMPTUM method and toolset in process modeling by using existing ontologies and vice versa is required to make valid claims regarding this issue.

This study does not cover the recommendations for discovering ontology resources or process model elements via the support of artificial intelligence and expert system technologies. Like in traditional development approaches, the discovery of related artifacts is in responsibility of the analysts. So, the effectiveness of discovery is strongly tied to the capabilities of the analysts.

The method and tool support in this study supports defining the process and domain related knowledge in organizations. Development of domain ontologies would complement the informational perspective of process models by also abstracting this perspective from process models. This would have implications in terms of process improvement, which is one of the main goals of defining processes. The implications regarding using PROMPTUM method and toolset for process improvement purposes are not addressed in this study and needs to be identified via further research.

Future studies might be designed to improve the method and toolset presented in this study or to introduce new ideas that build upon the ones in this study. Some of the future work ideas that can be in our research agendas are as follows:

- Currently PROMPTUM toolset relies on the analyst to find and associate the terms in ontologies and process model collections. A dynamic search feature enabling to search terms and phrases in ontologies and process model collections would help in improving discovery and preventing mistakes.
- UPROM, which is the process modeling component of PROMPTUM toolset, supports diagram types such as EPC, VC, and FT. Integrating other mainstream process modeling languages such as BPMN and UML Activity Diagram to UPROM would also integrate these languages to PROMPTUM toolset. As theoretically the PROMPTUM method and toolset is process modeling language independent, this improvement would extend the usage rate of the outputs of this study and would help in reaching a wider audience of practitioners.
- The PROMPTUM method encourages ontology reuse, which is a critical practice is ontology engineering. The PROMPTUM toolset enables reuse by manually adding the resources to be used. An RDF or OWL importer would ease ontology reuse with the PROMPTUM toolset.
- Ontologies in theory and practice can incorporate a wide variety of relationships between concepts and semantic constraints. Some of these relationships defined as properties in ontologies, would enrich the process knowledge if they are represented on related elements of process models. An exploratory study would reveal such properties that would enrich the process models and an enhancement

of the PROMPTUM toolset would enable them to be managed synchronously with ontologies.

- Ontologies that represent process knowledge based on meta-models of process modeling languages was a direction we avoided in this study. We avoided this since the ontology resources based on process modeling language meta-models would contradict with the goals of domain ontologies. However, in semi-structured interviews, an interviewee suggested that some ontologies would better represent some process related information such as in which processes a resource exists and with which activities a resource representing an information carrier is related to. So, extending this study by offering the option to represent process related meta data in ontologies would be a future study. However, the analyst, who controls the scope of ontologies, should decide which meta data to be represented and the operational scenarios of this extension should be depicted with care in order not to damage the abstraction of process models and ontologies.

REFERENCES

Aysolmaz, B., & Demirörs, O. (2015). Unified Process Modeling with UPROM Tool. In *Information Systems Engineering in Complex Environments* (Vol. 204, pp. 250–266).

Becker, J., Rosemann, M., & Uthmann, C. Von. (2000). Guidelines of Business Process Modeling. *Business Process Management*, *1806*, 30–49. doi:10.1007/3-540-45594-9_3

Belecheanu, R., Cabral, L., Domingue, J., Gaaloul, W., Hepp, M., Filipowska, A., … Stein, S. (2007). *Semantics Utilized for Process Management within and between Enterprises*.

Buraga, S. C., Cojocaru, L., & Nichifor, O. C. (2006). Survey on Web Ontology Editing Tools. *Transactions on Automatic Control and Computer Science*, *NN*(ZZ), 1–6. Retrieved from http://www.aifb.uni-karlsruhe.de/WBS/ysu/publications/OntoWeb_Del_1-3.pdf

Cesare, S. De, Juric, D., & Lycett, M. (2014). Toward the Automation of Business Process Ontology Generation. In *2014 IEEE 16th Conference on Business Informatics* (pp. 70–77). doi:10.1109/CBI.2014.20

Cherfi, S. S. S., Ayad, S., & Comyn-Wattiau, I. (2013). Aligning Business Process Models and Domain Knowledge: A Meta-modeling Approach. In *Advances in Intelligent Systems and Computing* (Vol. 186 AISC, pp. 45–56). doi:10.1007/978-3-642-32741-4_5

Cimpian, E., Komazec, S., Lintner, D., Blamauer, C., & Evenson, M. (2008). *Business Process Modeling Ontology BPMO final version*. *SemBiz Deliverable, …*. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:D1+.+3+.+Business+Process+Modeling+Ontology+BPMO+final+version#0

Davis, I. G., Rosemann, M., & Green, P. F. (2004). Exploring proposed ontological issues of ARIS with different categories of modellers. In *Proceedings of the Australasian Conference on Information Systems*.

Davis, R., & Brabander, E. (2007). *ARIS Design Platform: Getting Started with BPM* (1st ed.). Springer Publishing Company, Incorporated. Retrieved from http://dl.acm.org/citation.cfm?id=1535319

De Nicola, A., Missikoff, M., & Navigli, R. (2005). A Proposal for a Unified Process for Ontology Building: UPON. In *Database and Expert Systems Applications* (Vol. 3588, pp. 655–664). Springer-Verlag Berlin Heidelberg. doi:10.1007/11546924_64

Dijkman, R., Vanderfeesten, I., & Reijers, H. a. (2011). *The Road to a Business Process Architecture: An Overview of Approaches and their Use*. *Architecture* (Vol. 350). Retrieved from http://cms.ieis.tue.nl/Beta/Files/WorkingPapers/wp_350.pdf

Dimitrov, M., Simov, A., Stein, S., & Konstantinov, M. (2007). A BPMO Based Semantic Business Process Modelling Environment. In *Proceedings of the Workshop on Semantic Business Process and Product Lifecycle Management (SBPM 2007)*.

Dumas, M., La Rosa, M., Mendling, J., & Reijers, H. A. (2013). *Fundamentals of Business Process Management*. Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-33143-5

Eisenbarth, T. (2013). *Semantic Process Models*. University of Augsburg.

Fan, S., Hua, Z., Storey, V. C., & Zhao, J. L. (2016). A Process Ontology Based Approach to Easing Semantic Ambiguity in Business Process Modeling. *Data and Knowledge Engineering, 102*(March 2016), 57–77. doi:10.1016/j.datak.2016.01.001

Farquhar, A., Fikes, R., Pratt, W., & Rice, J. (1995). *Collaborative Ontology Construction for Information Integration*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.50.5303&rep=rep1&type=pdf

Fernández-López, M., Gómez-Pérez, A., & Juristo, N. (1997). METHONTOLOGY: From Ontological Art Towards Ontological Engineering. In *AAAI-97 Spring Symposium Series* (Vol. SS-97–06, pp. 33–40). doi:10.1109/AXMEDIS.2007.19

Francescomarino, C. Di. (2011). *Semantic Annotation of Business Process Models*. University of Trento.

Francescomarino, C. Di, Ghidini, C., Rospocher, M., Serafini, L., & Tonella, P. (2008). Reasoning on Semantically Annotated Processes. In *Service-Oriented Computing – ICSOC 2008* (pp. 132–146). Retrieved from http://selab.fbk.eu/tonella/papers/icsoc2008.pdf

Francescomarino, C. Di, Ghidini, C., Rospocher, M., Serafini, L., & Tonella, P. (2009). Semantically-Aided Business Process Modeling. In *International Semantic Web Conference (ISWC 2009)* (pp. 114–129).

Francescomarino, C. Di, Ghidini, C., Rospocher, M., Serafini, L., & Tonella, P. (2011). A Framework for the Collaborative Specification of Semantically Annotated Business Processes. In *Journal of Software Maintenance and Evolution* (Vol. 23, pp. 261–295). doi:10.1002/smr.525

Francescomarino, C. Di, Rospocher, M., Ghidini, C., & Valerio, A. (2014). The Role of Semantic Annotations in Business Process Modelling. In *2014 IEEE 18th International Enterprise Distributed Object Computing Conference* (pp. 181–189). doi:10.1109/EDOC.2014.33

Frederiks, P. J. M., & van der Weide, T. P. (2006). Information modeling: The process and the required competencies of its participants. *Data & Knowledge Engineering*, *58*(1), 4–20. doi:10.1016/j.datak.2005.05.007

Garcia, A., O'Neill, K., Garcia, L. J., Lord, P., Stevens, R., Corcho, O., & Gibson, F. (2010). Developing Ontologies within Decentralised Settings. *Semantic E-Science*, 99–139. doi:10.1007/978-1-4419-5908-9_4

Gómez-Pérez, a, Fernandez, M., & De Vicente, A. (1996). Towards a Method to Conceptualize Domain Ontologies. In *Workshop on Ontological Engineering* (pp. 41–51). Budapest. doi:10.1.1.24.167

Gruber, T. R. (1993). A Translation Approach to Portable Ontology Specifications. *Knowledge Acquisition*, *5*(2), 199–220. doi:10.1.1.101.7493

Gruninger, M., & Fox, M. (1995). Methodology for the Design and Evaluation of Ontologies. In *IJCAI'95, Workshop on Basic Ontological Issues in Knowledge Sharing* (pp. 1–10). Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.44.8723

Haller, A., Marmolowski, M., Oren, E., & Gaaloul, W. (2008). A Process Ontology for Business Intelligence. *Business*, (April), 19. Retrieved from http://sib.deri.ie/fileadmin/documents/DERI-TR-2008-04-01.pdf

Hoang, H. H., Jung, J. J., & Tran, C. P. (2013). Ontology-based approaches for cross-enterprise collaboration: a literature review on semantic business process management. *Enterprise Information Systems*, *8*(6), 648–664. doi:10.1080/17517575.2013.767382

Höfferer, P. (2007). Achieving Business Process Model Interoperability Using Metamodels and Ontologies. In *Proceedings of the 15th European Conference on Information Systems (ECIS 2007)* (pp. 1620–1631). University of St. Gallen. Retrieved from http://www.dke.at/fileadmin/DKEHP/publikationen/metamodell/Hoefferer_BP_interoperability_ontologies.pdf

Jansen-Vullers, M., & Netjes, M. (2006). Business process simulation–a tool survey. In *Workshop and Tutorial on Practical Use of Coloured Petri Nets and the CPN*.

Jr, P. S., Almeida, J., & Guizzardi, G. (2010). An ontology-based semantic foundation for ARIS EPCs. In *Proceedings of the 2010 ACM Symposium on Applied Computing* (pp. 124–130). Retrieved from http://dl.acm.org/citation.cfm?id=1774114

Kalibatiene, D., & Vasilecas, O. (2011). Survey on Ontology Languages. *Perspectives in*

Business Informatics Research, 124–141.

Kalpic, B., & Bernus, P. (2006). Business Process Modeling Through the Knowledge Management Perspective. *Journal of Knowledge Management*. doi:10.1108/13673270610670849

Katifori, A., Halatsis, C., Lepouras, G., Vassilakis, C., & Giannopoulou, E. (2007). Ontology Visualization Methods - A Survey. *Acm Computing Surveys*, *39*(4), 10. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.79.7581&rep=rep1&type=pdf

Koschmider, A., & Oberweis, A. (2005). Ontology Based Business Process Description. In *Proceedings of the CAiSE* (Vol. 5, pp. 321–333). Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.85.3988&rep=rep1&type=pdf

Laue, R., Storch, A., & Höß, F. (2015). The bflow* Hive - Adding Functionality to Eclipse-based Modelling Tools. In *Proceedings of the BPM Demo Session 2015 Co-located with the 13th International Conference on Business Process Management (BPM 2015)* (pp. 120–124). Innsbruck, Austria.

Leopold, H., Meilicke, C., Fellmann, M., Pittke, F., Stuckenschmidt, H., & Mendling, J. (2015). Towards the Automated Annotation of Process Models. In *Advanced Information Systems Engineering: 27th International Conference, CAiSE 2015* (pp. 401–416). doi:10.1007/978-3-319-19069-3_25

List, B., & Korherr, B. (2006). An Evaluation of Conceptual Business Process Modelling Languages. In *2006 ACM symposium on Applied computing* (pp. 1532–1539). New York: ACM. doi:10.1145/1141277.1141633

May, L. E., & Zimmer, A. B. (1996). The evolutionary development model for software. *HP Journal*, *47*, 39–41.

McCracken, D. D., & Jackson, M. A. (1982). Life cycle concept considered harmful. *ACM SIGSOFT Software Engineering Notes*, *7*(2), 29–32.

Mendling, J. (2008). *Metrics for Process Models: Empirical Foundations of Verification, Error Prediction, and Guidelines for Correctness*. *Foundations* (Vol. 6). Retrieved from http://www.amazon.com/Metrics-Process-Models-Foundations-Verification/dp/3540892230

Mendling, J., Leopold, H., & Pittke, F. (2014). 25 Challenges of Semantic Process Modeling. *International Journal of Information Systems and Software Engineering for Big Companies*, *1*(1), 78–94. Retrieved from http://www.uajournals.com/ijisebc/journal/1/6.pdf

Minoli, D. (2008). *Enterprise Architecture A to Z: Frameworks, Business Process Modeling, SOA, and Infrastructure Technology*. (C. Press, Ed.)*Vasa*. Auerbach Publications Boston, MA, USA.

Norton, D., Blechar, M., & Jones, T. (2010). *Magic Quadrant for Business Process Analysis Tools*. Retrieved from papers3://publication/uuid/C8845C5A-4D1B-4F5E-AC8F-952298BEA5AA

Noy, N. F., & McGuinness, D. L. (2001). Ontology Development 101 : A Guide to Creating Your First Ontology. *Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880*. doi:10.1016/j.artmed.2004.01.014

Peters, N., & Weidlich, M. (2011). Automatic Generation of Glossaries for Process Modelling Support. *Enterprise Modelling and Information Systems Architectures*, *6*(1), 30–46.

Pinto, H., Staab, S., & Tempich, C. (2004). DILIGENT: Towards a fine-grained methodology for Distributed, Loosely-controlled and evolving Engineering of oNTologies. In *16th European Conference on Artificial Intelligence (ECAI 2004)* (pp. 393–397). Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.5.8078&rep=rep1&type=pdf

Royce, W. W. (1987). Waterfall. In *ICSE '87 Proceedings of the 9th international* *conference on Software Engineering* (pp. 328–338). IEEE Computer Society Press.

Scheer, A.-W., & Schneider, K. (2006). ARIS—Architecture of Integrated Information Systems. In *Handbook on Architectures of Information Systems* (pp. 605–623). doi:10.1007/3-540-26661-5_25

Sönmez, V. N., Canlı, M., Gökçe, S., Ünver, M., & Güçlü, A. N. (2010). Ontology Driven Government Services Inventory and Business Process Management. In *Enterprise, Business-Process and Information Systems Modeling: 11th International Workshop, BPMDS 2010* (pp. 26–38).

Staab, S., Studer, R., Schnurr, H. P., & Sure, Y. (2001). Knowledge Processes and Ontologies. *IEEE Intelligent Systems and Their Applications*, *16*(1), 26–34. doi:10.1109/5254.912382

Stojanovic, L., & Motik, B. (2002). Ontology evolution within ontology editors. In *EKAW02 Workshop on Evaluation of Ontology-based Tools (EON2002)* (pp. 53–62). Sigüenza.

Stolfa, S., & Vondrak, I. (2004). A Description of Business Process Modeling as a Tool for Definition of Requirements Specification. In *Systems Integration 12th Annual International Conference* (pp. 463–469).

Suárez-Figueroa, M. (2010). *NeOn Methodology for Building Ontology Networks: Specification, Scheduling and Reuse*. Universidad Politécnica de Madrid. Retrieved from http://oa.upm.es/3879

Tartir, S., Arpinar, I., Moore, M., Sheth, a, & Aleman-Meza, B. (2005). OntoQA: Metric-Based Ontology Quality Analysis. In *IEEE Workshop on Knowledge Acquisition from Distributed, Autonomous, Semantically Heterogeneous Data and Knowledge Sources* (pp. 45–53). doi:10.1.1.131.2087

Tempich, C., Pinto, H. S., Sure, Y., & Staab, S. (2005). An Argumentation Ontology for DIstributed , Loosely-controlled and evolvInG Engineering processes of oNTologies (DILIGENT). *Ibis*, *2005*(1), 241–256. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.59.5591

Thomas, O., & Fellmann, M. (2007). Semantic EPC: Enhancing Process Modeling Using Ontology Languages. In *Workshop on Semantic Business Process and Product Lifecycle Management (SBPM 2007)*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.142.7458&rep=rep1&type=pdf

Thomas, O., & Fellmann, M. (2009). Semantic Process Modeling – Design and Implementation of an Ontology-based Representation of Business Processes. *Business & Information Systems Engineering*, *1*(6), 438–451. doi:10.1007/s12599-009-0078-8

Uschold, M., & Gruninger, M. (1996). Ontologies: Principles, methods and applications. *Knowledge Engineering Review*, *11*(2), 93–155. Retrieved from http://journals.cambridge.org/production/action/cjoGetFulltext?fulltextid=4071856

van der Aalst, W. M. P. (1999). Formalization and Verification of Event-Driven Process Chains. *Information and Software Technology*. doi:10.1016/S0950-5849(99)00016-6

van der Aalst, W. M. P. (2013). Business Process Management: A Comprehensive Survey. *ISRN Software Engineering*, *2013*, 1–37. doi:10.1155/2013/507984

van der Aalst, W., ter Hofstede, A. H. M., & Weske, M. (2003). Business Process Management: A Survey. In W. M. P. Aalst & M. Weske (Eds.), *Business Process Management, Lecture Notes in Computer Science 2678* (Vol. 2678, pp. 1–12). Springer Berlin Heidelberg.

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B., & Wesslén, A. (2012). *Experimentation in software engineering*. *Experimentation in Software Engineering* (Vol. 9783642290). Springer-Verlag Berlin Heidelberg.

Wróblewska, A., Podsiadły-Marczykowska, T., Bembenik, R., Protaziuk, G., & Rybiński, H. (2012). Methods and Tools for Ontology Building, Learning and Integration–Application in the SYNAT Project. In *Intelligent Tools for Building a Scientific Information Platform* (pp. 121–151). Retrieved from

http://link.springer.com/chapter/10.1007/978-3-642-24809-2_9

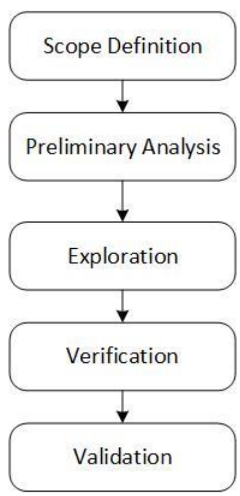
APPENDICES

Appendix A – Development Life Cycle Models Guideline

Following life-cycle models are adapted from software engineering. Guidelines for Waterfall, Incremental, and Evolutionary development life-cycle models are provided below.

Waterfall Life-Cycle Model:

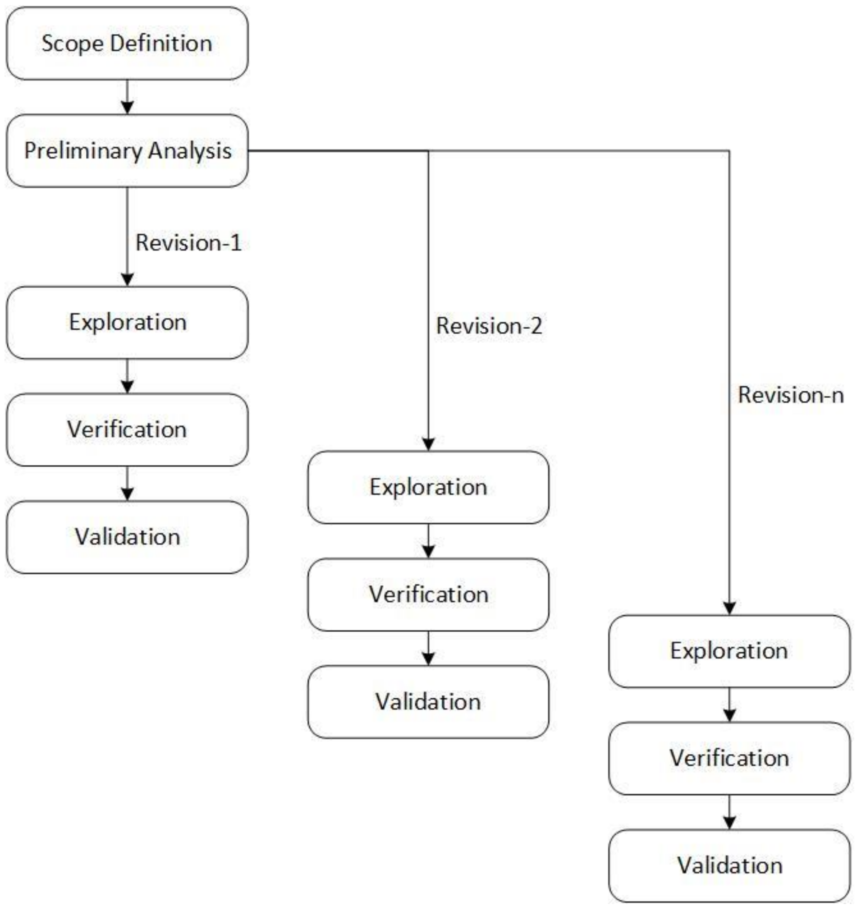
All steps are performed sequentially in Waterfall (Royce, 1987) life-cycle. In certain cases, some activities could be performed in parallel.



Incremental Life-Cycle Model:

Incremental (McCracken & Jackson, 1982) is a life-cycle model where intended products are developed with a series of planned revisions. First revision includes a part of the scope, next revision includes another part, and so revisions follow one another until whole products are developed. Some steps such as scope definition and preliminary analysis are performed once whereas other steps are repeated for each revision.

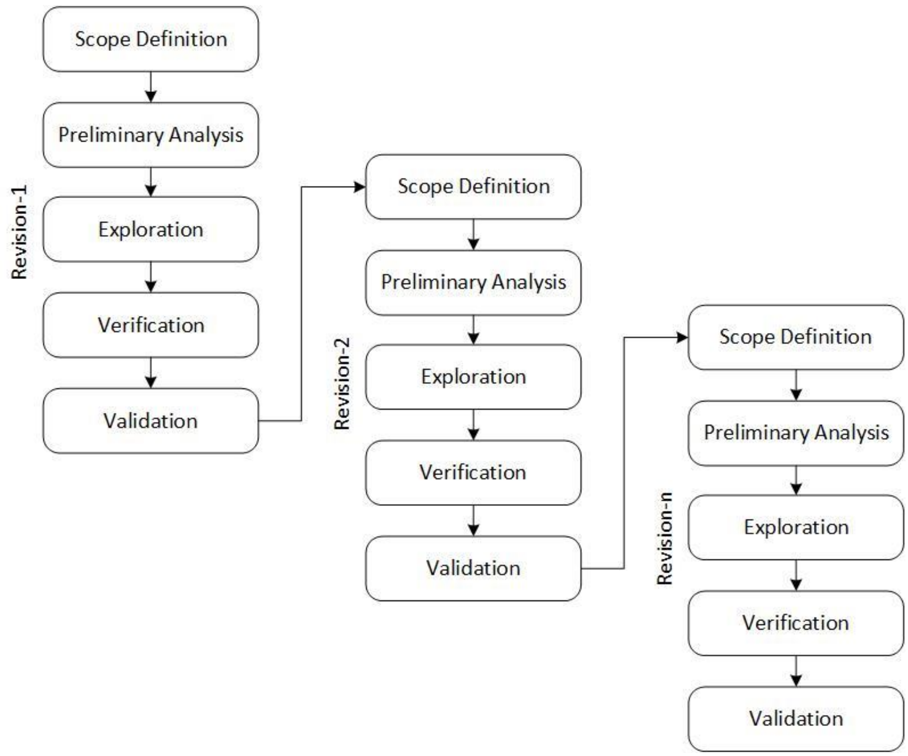
Several revisions could be developed in parallel.



Evolutionary Life-Cycle Model:

Evolutionary life-cycle model (May & Zimmer, 1996) is also based on revision. Its difference from the Incremental model is that it is used in situations where scope (goals and competency questions) cannot be completely understood or established at the beginning of development. Within this model, competency questions are elaborated before each revision.

Similar to Incremental model, several revisions could be developed in parallel.



Appendix B – Goal Definition Form

Goal no.	
Date	
Revision	

1-Goal Definition:

Goal of the products to be developed is summarized in one or a few sentences.

2-Goal Description:

Basic functions and concepts that are within and out of scope, and functional properties of the products to be developed are summarized.

3-Competency Questions:

Questions, which shall be provided answers for by the intended products, are defined.

Appendix C – Information Elicitation Methods

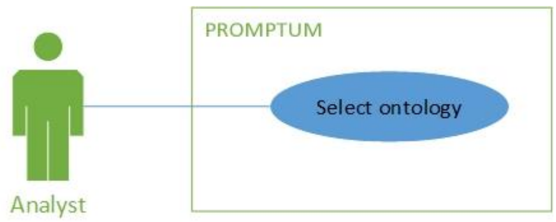
Some discovery methods for eliciting information are (Dumas et al., 2013):

- Evidence-based discovery: Domain and process related information are gathered by studying on existing information sources. There are three sub-methods:
    - Document analysis: Domain and process related information is elicited by analyzing documented sources.
    - Observation: Domain and process related information is elicited by observing real processing or a simulation of the organization.
    - Automated discovery: It includes usage of the methods and techniques within process mining based on event logs, and ontology learning for building or extending ontologies. Automation depends on other domains such as natural language processing, data mining and automated learning. Automated discovery techniques can be applied to structured (e.g. databases), semi-structured (e.g. HTML or XML files), and unstructured (e.g. textual) documents (Wróblewska, Podsiadły-Marczykowska, Bembenik, Protaziuk, & Rybiński, 2012).
- Interview-based discovery: It includes interviews conducted with domain experts.
- Workshop-based discovery: It’s a method that includes more participants compared to interview-based discovery. During workshop sessions process modeling and ontology building are usually performed and instantaneous feedbacks are received.

Appendix D - Functional Specifications

Functional specifications of the PROMPTUM Process Modeling Plugin are provided with use case specifications below.

Ontology selection operations:

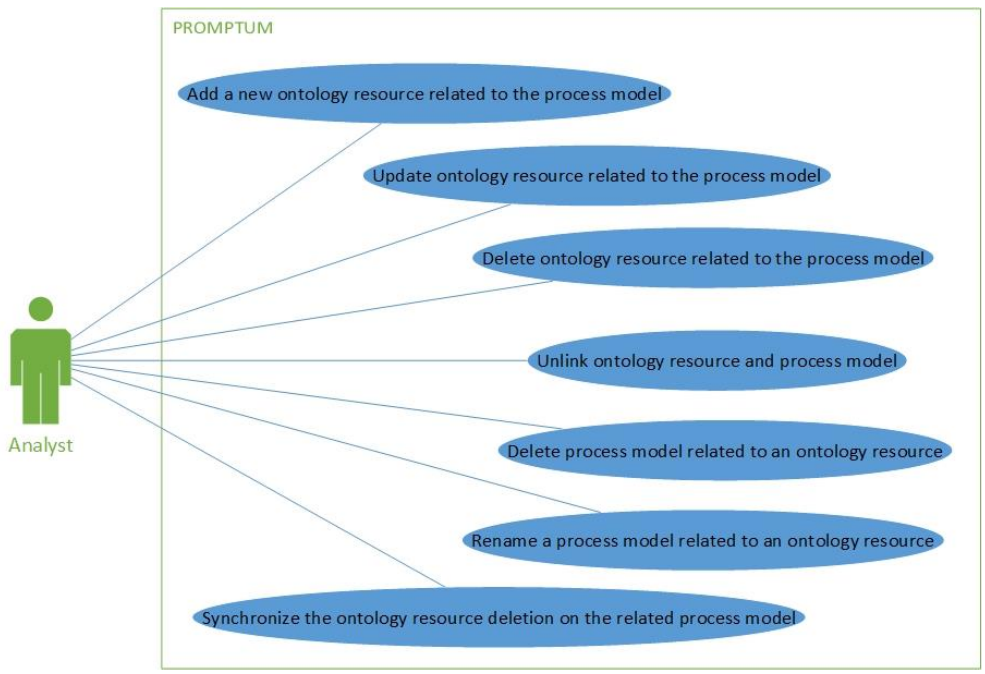


Use Case 1: Select ontology

Use Case Name	Select ontology	
Use Case Description	Selecting ontologies to be developed integrated with business process models.	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Business process modeling project is created on UPROM.	
Success End Condition	Business process modeling project and ontology are associated.	
Main Success Scenario	1	Analyst enters the ontology address, selects project and clicks "Add Ontology" button
	2	System associates the ontology with the business process modeling project and adds ontology's name to "Select Ontology" list
Extensions	1a	Analyst proceeds without selecting business process modeling project
		1a1. System displays "You should choose a process modeling project first" message and returns to its initial status
	2a	Analyst proceeds without entering an ontology address

		2b1. System displays “You should specify an ontology address” message and returns to its initial status
Special Requirements	-	

Process model related operations:



Use Case 2: Add a new ontology resource related to the process model

Use Case Name	Add a new ontology resource related to the process model
Use Case Description	Adding a new ontology resource that represent the same real-world object as a process model
Scope	System
Level	Analyst goal
Primary Actor	Analyst
Preconditions	Process model is created in UPROM. An ontology is associated with the process modeling project and its name is displayed in “Select Ontology” list.
Success End Condition	Ontology resource is created on Ontology Server. Process model and ontology resource are associated.

Main Success Scenario	1	Analyst selects a process model in “package explorer”
	2	Analyst selects an ontology from “Select Ontology” list, selects “Process” and clicks “Add Resource (related to a …)” button
	3	System, creates an ontology resource in ontology server having the same name as the process model
	4	System displays name of the ontology resource in “linked resources list”
Extensions	1a	Analyst proceeds without selecting process model and clicks “Add Resource (related to a …)” button
		1a1. System displays “You should choose a process model element or process model first” message and returns to its initial status
	2a	Analyst selects a process model already related to a resource
		2a1. System displays “Resource already exists” message and returns to its initial status
	2b	Analyst selects a process model having the same label to an existing ontology resource but not related to it and clicks “Add Resource (related to a …)” button
		2b1. System establishes the relation between process model and ontology resource
		2b2. System displays ontology resource in “linked resources list”
	2c	Analyst proceeds without selecting an ontology from “Select Ontology” list clicks “Add Resource (related to a …)” button
		2c1. System displays “You should choose an ontology” message
Special Requirements	-	

Use Case 3: Update ontology resource related to the process model

Use Case Name	Update ontology resource related to the process model
Use Case Description	Updating an ontology resource representing the same real-world object as a process model
Scope	System

Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model is created in UPROM. Ontology resource is created on Ontology Server. Process model and ontology resource are associated.	
Success End Condition	Process model and ontology resource labels are changed.	
Main Success Scenario	1	Analyst changes the label of the process model
	2	Analyst performs "Delete ontology resource related to the process" use case
	3	Analyst performs "Add a new ontology resource related to the process" use case
Extensions		-
Special Requirements	-	

Use Case 4: Delete ontology resource related to the process model

Use Case Name	Delete ontology resource related to the process model	
Use Case Description	Deleting an ontology resource representing the same real-world object as a process model	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model is created in UPROM. Ontology resource is created on Ontology server. Process model and ontology resource are associated.	
Success End Condition	Ontology resource is deleted on Ontology server.	
Main Success Scenario	1	Analyst selects a process model from "package explorer" or ontology resource from "linked resources list"
	2	Analyst clicks "Delete Resource" button
	3	System deletes the ontology resource on Ontology Server
	4	System removes name of the deleted resource from "linked resources list"
Extensions	1a	Analyst selects a process model not related to an ontology resource
		1a1. Analyst clicks "Delete Resource" button

		1a2. System displays “There is no related ontology resource” message and returns to its initial status
	1b	Analyst proceeds without selecting a process model or ontology resource
		1b1. System displays “You should choose a process model element, process model or ontology resource first” message and returns to its initial status
Special Requirements	-	

Use Case 5: Unlink ontology resource and process model

Use Case Name	Unlink ontology resource and process model	
Use Case Description	Unlinking a process model and ontology resource representing the same real-world object	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model is created in UPROM. Ontology resource is created on Ontology Server. Process model and ontology resource are associated.	
Success End Condition	Association between ontology resource and process model is removed.	
Main Success Scenario	1	Analyst selects a process model from “package explorer” or ontology resource from “linked resources list”
	2	Analyst clicks “Unlink Resource” button
	3	System removes the association between process model and ontology resource
	4	System removes ontology resource’s name from “linked resources list”
Extensions	1a	Analyst selects a process model not related to an ontology resource
		1a1. Analyst clicks “Unlink Resource” button
		1a2. System displays “There is no related ontology resource” message and returns to its initial status
	1b	Analyst proceeds without selecting a process model or ontology resource

		1b1. System displays “You should choose a process model element, process model or ontology resource first” message and returns to its initial status
Special Requirements	-	

Use Case 6: Delete process model related to an ontology resource

Use Case Name	Delete process model related to an ontology resource	
Use Case Description	Unlinking process model and ontology resource representing the same real-world object when the process model is deleted	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model is created in UPROM. Ontology resource is created on Ontology Server. Process model and ontology resource are associated.	
Success End Condition	Association between ontology resource and process model is removed. Process model is deleted.	
Main Success Scenario	1	Analyst deletes the process model
	2	Analyst performs “Unlink ontology resource and process” use case
Extensions	-	
	-	
Special Requirements	-	

Use Case 7: Rename a process model related to an ontology resource

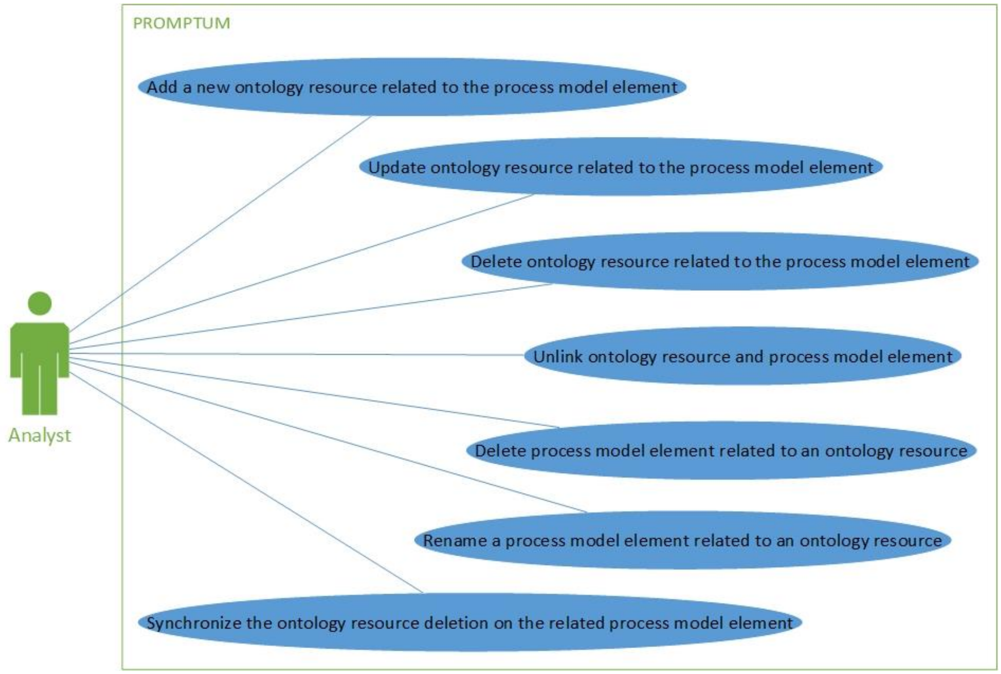
Use Case Name	Rename a process model related to an ontology resource
Use Case Description	Updating ontology resource upon renaming process model representing the same real-world object
Scope	System
Level	Analyst goal
Primary Actor	Analyst
Preconditions	Process model is created in UPROM.

	Ontology resource is created on Ontology Server. Process model and ontology resource are associated.	
Success End Condition	Names of process model and ontology resource are changed.	
Main Success Scenario	1	Analyst renames the process model
	2	Analyst performs “Delete ontology resource related to the process” use case
	3	Analyst performs “Add a new ontology resource related to the process” use case
Extensions	-	
	-	
Special Requirements	-	

Use Case 8: Synchronize the ontology resource deletion on the related process model

Use Case Name	Synchronize the ontology resource deletion on the related process model	
Use Case Description	Removing association between process model and ontology resource upon deletion of related ontology resource	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model is created in UPROM. Ontology resource is deleted in Ontology Server. Process model and ontology resource are associated.	
Success End Condition	Association between ontology resource and process model is removed.	
Main Success Scenario	1	Analyst clicks “Sync with Ontology Server” button
	2	System removes the association between process model and ontology resource
	3	System removes ontology resource’s name from “linked resources list”
Extensions	-	
	-	
Special Requirements	-	

Process model element related operations:



Use Case 9: Add a new ontology resource related to the process model element

Use Case Name	Add a new ontology resource related to the process model element	
Use Case Description	Adding a new ontology resource related to the process model element representing the same real-world object	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model element is created in UPROM. Ontologies are associated with process modeling project and displayed in “Select Ontology” list.	
Success End Condition	Ontology resource is created on Web Protégé. Process model element and ontology resource are associated.	
Main Success Scenario	1	Analyst selects process model element
	2	Analyst selects an ontology from “Select Ontology” list, clicks “Element” button and then clicks “Add Resource (related to a …)” button

	3	System creates an ontology resource by the same name as the selected process model element
	4	System displays added ontology resource in “linked resources list”
Extensions	1a	Analyst proceeds without selecting a process model element
		1a1. System displays “You should choose a process model element or process model first” message and returns to its initial status
	2a	Analyst selects a process model element that already has an association with an ontology resource
		2a1. System displays “Resource already exists” message and returns to its initial status
	2b	Analyst selects a process model element having the same label to an existing ontology resource but not related to it
		2b1. System establishes association between process model element and ontology resource
		2b2. System displays ontology resource in “linked resources list”
	2c	Analyst proceeds without selecting an ontology from “Select Ontology” list
		2c1. System displays “You should choose an ontology” message
Special Requirements	-	

Use Case 10: Update ontology resource related to the process model element

Use Case Name	Update ontology resource related to the process model element
Use Case Description	Updating process model element and ontology resource representing the same real-world object
Scope	System
Level	Analyst goal
Primary Actor	Analyst
Preconditions	Process model element is created in UPROM. Ontology resource is created on Ontology Server. Ontology resource and process model element are associated.

Success End Condition	Names of process model element and ontology resource are changed.	
Main Success Scenario	1	Analyst selects process model element or ontology resource from "linked resources list"
	2	Analyst enters resource's new label in text field
	3	Analyst clicks "Update Resource" button
	4	System changes name of the ontology resource on Ontology Server
	5	System displays updated label of the resource in "linked resources list"
	6	System changes label of all individuals belonging to the same process model element
	7	System displays updated label of the process model element in UPROM
Extensions	1a	Analyst selects a process model element not related with an ontology resource
		1a1. Analyst clicks "Update Resource" button
		1a2. System displays "There is no related ontology resource" message and returns to its initial status
	1b	Analyst proceeds without selecting a process model element or ontology resource
		1b1. System displays "You should choose a process model element, process model or ontology resource first" message and returns to its initial status
Special Requirements	-	

Use Case 11: Delete ontology resource related to the process model element

Use Case Name	Delete ontology resource related to the process model element
Use Case Description	Deleting the ontology resource representing the same real-world object as a process model element
Scope	System
Level	Analyst goal
Primary Actor	Analyst
Preconditions	Process model element is created in UPROM. Ontology resource is created on Ontology Server. Ontology resource and process model element are associated.

Success End Condition	Ontology resource is deleted on Ontology Server.	
Main Success Scenario	1	Analyst selects process model element or ontology resource from “linked resources list”
	2	Analyst clicks “Delete Resource” button
	3	System deletes related ontology resource on Ontology Server
	4	System removes deleted resource’s name from “linked resources list”
Extensions	1a	Analyst selects a process model element not related with an ontology resource
		1a1. Analyst clicks “Delete Resource” button
		1a2. System displays “There is no related ontology resource” message and returns to its initial status
	1b	Analyst proceeds without selecting a process model element or ontology resource
		1b1. System displays “You should choose a process model element, process model or ontology resource first” message and returns to its initial status
Special Requirements	-	

Use Case 12: Unlink ontology resource and process model element

Use Case Name	Unlink ontology resource and process model element	
Use Case Description	Unlinking a process model element and ontology resource representing the same real-world object	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model element is created in UPROM. Ontology resource is created on Ontology Server. Ontology resource and process model element are associated.	
Success End Condition	Association between ontology resource and process model element is removed.	
Main Success Scenario	1	Analyst selects a process model element or an ontology resource from “linked resources list”
	2	Analyst clicks “Unlink Resource” button

	3	System removes the association between process model element and ontology resource
	4	System removes ontology resource's name from "linked resources list"
Extensions	1a	Analyst selects a process model element not related with an ontology resource
		1a1. Analyst clicks "Unlink Resource" button
		1a2. System displays "There is no related ontology resource" message and returns to its initial status
	1b	Analyst proceeds without selecting a process model element or ontology resource
		1b1. System displays "You should choose a process model element, process model or ontology resource first" message and returns to its initial status
Special Requirements	-	

Use Case 13: Delete process model element related to an ontology resource

Use Case Name	Delete process model element related to an ontology resource	
Use Case Description	Unlinking process model element and ontology resource representing the same real-world object when the process model is deleted	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model element is created in UPROM. Ontology resource is created on Ontology Server. Ontology resource and process model element are associated.	
Success End Condition	Association between ontology resource and process model element is removed. Process model element is deleted.	
Main Success Scenario	1	Analyst deletes the last individual belonging to the process model element
	2	System removes the association between deleted process model element and ontology resource
	3	System removes ontology resource's name from "linked resources list"

Extensions	-	
	-	
Special Requirements	-	

Use Case 14: Rename a process model element related to an ontology resource

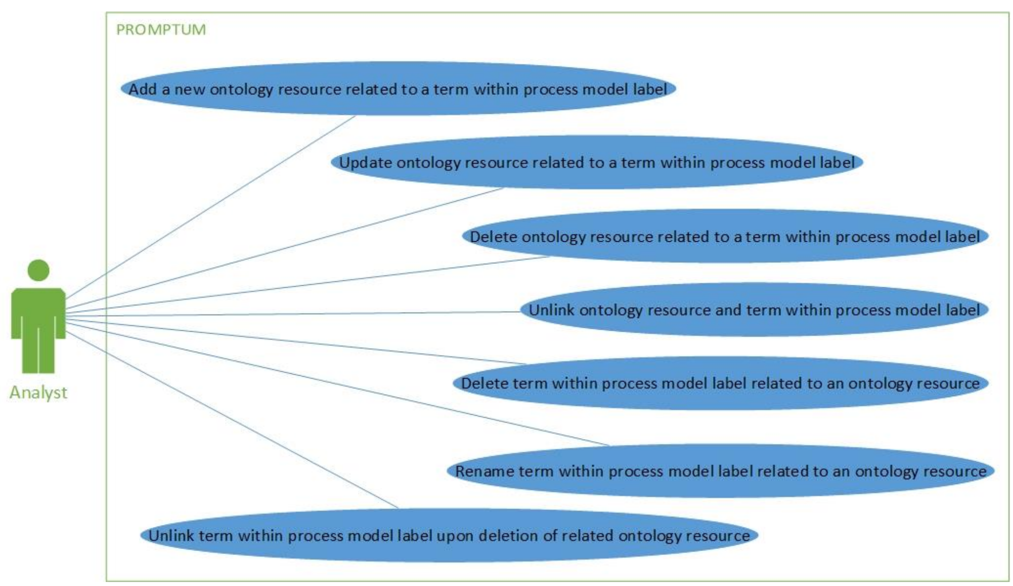
Use Case Name	Rename a process model element related to an ontology resource	
Use Case Description	Updating ontology resource upon renaming process model element representing the same real-world object	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model element is created in UPROM. Ontology resource is created on Ontology Server. Ontology resource and process model element are associated.	
Success End Condition	Labels of process model element and ontology resource are changed.	
Main Success Scenario	1	Analyst renames the process model element
	2	System changes the label of the resource in Ontology Server
	3	System displays updated label of the resource in “linked resources list”
	4	System changes labels of all individuals of the process model element in UPROM
	5	System displays updated label of the process model element in UPROM
Extensions	-	
	-	
Special Requirements	-	

Use Case 15: Synchronize the ontology resource deletion on the related process model element

Use Case Name	Synchronize the ontology resource deletion on the related process model element

Use Case Description	Removing association between process model element and ontology resource upon deletion of related ontology resource	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model element is created in UPROM. Ontology resource is updated in Ontology Server. Ontology resource and process model element are associated.	
Success End Condition	Association between ontology resource and process model element is removed.	
Main Success Scenario	1	Analyst clicks “Sync with Ontology Server” button
	2	System removes the association between process model element and ontology resource
	3	System removes ontology resource’s name from “linked resources list”
Extensions	-	
	-	
Special Requirements	-	

Terms within process model label related operations:



Use Case 16: Add a new ontology resource related to a term within process model label

Use Case Name	Add a new ontology resource related to a term within process model label	
Use Case Description	Adding a new ontology resource representing the same real-world object a term within process model label	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model is created in UPROM. Ontologies are associated with process modeling project and displayed in "Select Ontology" list.	
Success End Condition	Ontology resource is created on Ontology Server Ontology resource and the term within process model label are associated	
Main Success Scenario	1	Analyst selects a process model
	2	Analyst selects an ontology from "Select Ontology" list, clicks "Process" button and then clicks "Add Resource (related to a concept within …)" button and enters the term in pop-up menu
	3	System creates an ontology resource by the same name as the selected term within process model label
	4	System displays added ontology resource in "linked resources list"
Extensions	1a	Analyst proceeds without selecting a process model
		1a1. System displays "You should choose a process model element or process model first" message and returns to its initial status
	2a	Analyst selects a term within process model label that already has an association with an ontology resource
		2a1. System displays "Resource already exists" message and returns to its initial status
	2b	Analyst selects a term within process model label having the same name to an existing ontology resource but not related to it
		2b1. System establishes association between term and ontology resource

		2b2. System displays ontology resource in "linked resources list"
	2c	Analyst proceeds without selecting an ontology from "Select Ontology" list
		2c1. System displays "You should choose an ontology" message and returns to its initial status
Special Requirements	-	

Use Case 17: Update ontology resource related to a term within process model label

Use Case Name	Update ontology resource related to a term within process model label	
Use Case Description	Updating the term within process model label and ontology resource representing the same real-world object	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model is created in UPROM. Ontology resource is created on Ontology Server. Ontology resource and the term within process model label are associated.	
Success End Condition	Names of the term and ontology resource are changed.	
Main Success Scenario	1	Analyst changes the process model label
	2	Analyst performs "Add a new ontology resource related to a term within process model label" use case
	3	Analyst performs "Delete ontology resource related to a term within process model label" use case
Extensions		-
		-
Special Requirements	-	

Use Case 18: Delete ontology resource related to a term within process model label

Use Case Name	Delete ontology resource related to a term within process model label

Use Case Description	Deleting an ontology resource representing the same real-world object as term within process model label	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model is created in UPROM. Ontology resource is created on Ontology Server. Term within process model label and ontology resource are associated.	
Success End Condition	Ontology resource is deleted on Ontology Server.	
Main Success Scenario	1	Analyst selects ontology resource from “linked resources list”
	2	Analyst clicks “Delete Resource” button
	3	System deletes the ontology resource on Ontology Server
	4	System removes name of the deleted resource from “linked resources list”
Extensions	1a	Analyst selects a term not related to an ontology resource
		1a1. Analyst clicks “Delete Resource” button
		1a2. System displays “There is no related ontology resource” message and returns to its initial status
	1b	Analyst proceeds without making a selection
		1b1. System displays “You should choose a process model element, process model or ontology resource first” message and returns to its initial status
Special Requirements	-	

Use Case 19: Unlink ontology resource and term within process model label

Use Case Name	Unlink ontology resource and term within process model label
Use Case Description	Unlinking a term within process model label and ontology resource representing the same real-world object
Scope	System
Level	Analyst goal

Primary Actor	Analyst	
Preconditions	Process model is created in UPROM. Ontology resource is created on Ontology Server. Term within process model label and ontology resource are associated.	
Success End Condition	Association between the term within process model label and ontology resource is removed.	
Main Success Scenario	1	Analyst selects ontology resource from “linked resources list”
	2	Analyst clicks “Unlink Resource” button
	3	System removes the association between the term within process model label and ontology resource
	4	System removes ontology resource’s name from “linked resources list”
Extensions	1a	Analyst selects a term not related to an ontology resource
		1a1. Analyst clicks “Unlink Resource” button
		1a2. System displays “There is no related ontology resource” message and returns to its initial status
	1b	Analyst proceeds without making a selection
		1b1. System displays “You should choose a process model element, process model or ontology resource first” message and returns to its initial status
Special Requirements	-	

Use Case 20: Delete term within process model label related to an ontology resource

Use Case Name	Delete term within process model label related to an ontology resource
Use Case Description	Unlinking term within process model label and ontology resource representing the same real-world object when the term is deleted
Scope	System
Level	Analyst goal
Primary Actor	Analyst
Preconditions	Process model is created in UPROM. Ontology resource is created on Ontology Server.

	Term within process model label and ontology resource are associated.	
Success End Condition	Association between the term within process model label and ontology resource is removed.	
Main Success Scenario	1	Analyst deletes the term within process model label
	2	Analyst performs “Unlink ontology resource and term within process model label” use case
Extensions	-	
	-	
Special Requirements	-	

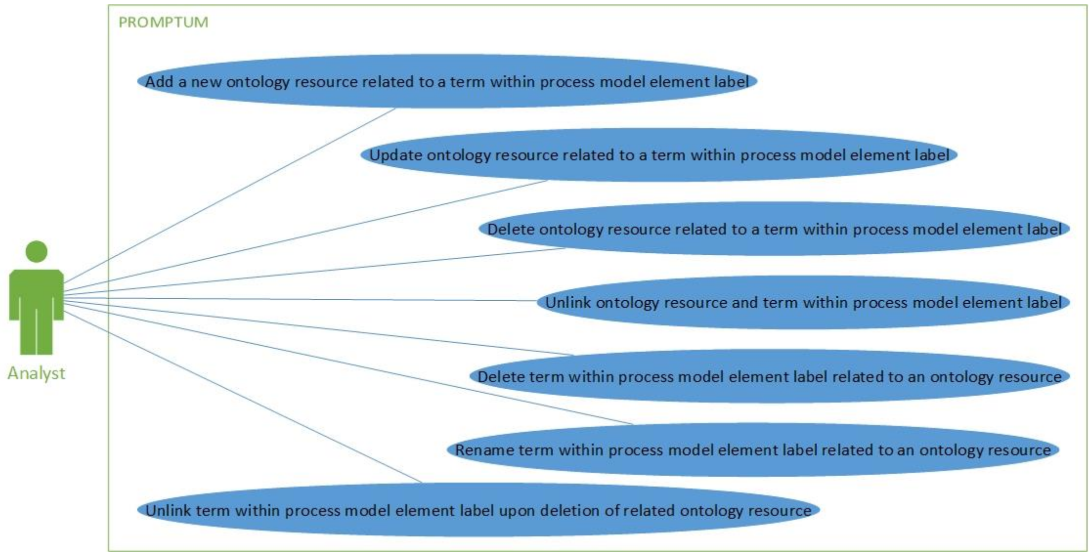
Use Case 21: Rename term within process model label related to an ontology resource

Use Case Name	Rename term within process model label related to an ontology resource	
Use Case Description	Removing association between the term within process model label and ontology resource representing the same real-world object upon renaming the term	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model is created in UPROM. Ontology resource is created on Ontology Server. Term within process model label and ontology resource are associated.	
Success End Condition	Association between the term within process model label and ontology resource is removed.	
Main Success Scenario	1	Analyst renames the term within process model label
	2	Analyst performs “Delete ontology resource related to a term within process model label” use case
	3	Analyst performs “Add a new ontology resource related to a term within process model label” use case
Extensions	-	
	-	
Special Requirements	-	

Use Case 22: Unlink term within process model label upon deletion of related ontology resource

Use Case Name	Unlink term within process model label upon deletion of related ontology resource	
Use Case Description	Removing association between the term within process model label and ontology resource representing the same real-world object upon deletion of ontology resource	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model is created in UPROM. Ontology resource is created on Ontology Server. Term within process model label and ontology resource are associated.	
Success End Condition	Association between the term within process model label and ontology resource is removed.	
Main Success Scenario	1	Analyst clicks "Sync with Ontology Server" button
	2	System removes the association between the term within process model label and ontology resource
	3	System removes ontology resource's name from "linked resources list"
Extensions	-	
	-	
Special Requirements	-	

Terms within process model element label related operations:



Use Case 23: Add a new ontology resource related to a term within process model element label

Use Case Name	Add a new ontology resource related to a term within process model element label	
Use Case Description	Adding a new ontology resource representing the same real-world object a term within process model element	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model element is created in UPROM. Ontologies are associated with process modeling project and displayed in “Select Ontology” list.	
Success End Condition	Ontology resource is created on Ontology Server Ontology resource and the term within process model element are associated	
Main Success Scenario	1	Analyst selects process model element
	2	Analyst selects an ontology from “Select Ontology” list, clicks “Element” button and then clicks “Add Resource (related to a concept within …)” button and enters term in pop-up menu

	3	System creates an ontology resource by the same name as the selected term within process model element label
	4	System displays added ontology resource in “linked resources list”
Extensions	1a	Analyst proceeds without selecting a term
		1a1. System displays “You should choose a process model element or process model first” message and returns to its initial status
	2a	Analyst selects a term within process model element label that already has an association with an ontology resource
		2a1. System displays “Resource already exists” message and returns to its initial status
	2b	Analyst selects a term within process model element label having the same name to an existing ontology resource but not related to it
		2b1. System establishes association between term and ontology resource
		2b2. System displays ontology resource in “linked resources list”
	2c	Analyst proceeds without selecting an ontology from “Select Ontology” list
		2c1. System displays “You should choose an ontology” message and returns to its initial status
Special Requirements	-	

Use Case 24: Update ontology resource related to a term within process model element label

Use Case Name	Update ontology resource related to a term within process model element label
Use Case Description	Updating the term within process model element label and ontology resource representing the same real-world object
Scope	System
Level	Analyst goal
Primary Actor	Analyst
Preconditions	Process model element is created in UPROM. Ontology resource is created on Ontology Server.

	Ontology resource and the term within process model element label are associated.	
Success End Condition	Names of the term and ontology resource are changed.	
Main Success Scenario	1	Analyst selects ontology resource from "linked resources list"
	2	Analyst enters term's new label in text field
	3	Analyst clicks "Update Resource" button
	4	System changes name of the ontology resource on Ontology Server
	5	System displays updated label of the resource in "linked resources list"
	6	System changes all individuals of the process model element
	7	System displays updated label of the process model element in UPROM
Extensions	1a	Analyst proceeds without selecting a resource
		1a1. System displays "You should choose a process model element, process model or ontology resource first" message and returns to its initial status
Special Requirements	-	

Use Case 25: Delete ontology resource related to a term within process model element label

Use Case Name	Delete ontology resource related to a term within process model element label
Use Case Description	Deleting an ontology resource representing the same real-world object as term within process model element label
Scope	System
Level	Analyst goal
Primary Actor	Analyst
Preconditions	Process model element is created in UPROM. Ontology resource is created on Ontology Server. Ontology resource and the term within process model element label are associated.
Success End Condition	Ontology resource is deleted on Ontology Server.

Main Success Scenario	1	Analyst selects ontology resource from “linked resources list”
	2	Analyst clicks “Delete Resource” button
	3	System deletes the ontology resource on Ontology Server
	4	System removes name of the deleted resource from “linked resources list”
Extensions	1a	Analyst proceeds without making a selection
		1a1. System displays “You should choose a process model element, process model or ontology resource first” message and returns to its initial status
Special Requirements	-	

Use Case 26: Unlink ontology resource and term within process model element label

Use Case Name	Unlink ontology resource and term within process model element label	
Use Case Description	Unlinking a term within process model element label and ontology resource representing the same real-world object	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model element is created in UPROM. Ontology resource is created on Ontology Server. Ontology resource and the term within process model element label are associated.	
Success End Condition	Association between the term within process model element label and ontology resource is removed.	
Main Success Scenario	1	Analyst selects ontology resource from “linked resources list”
	2	Analyst clicks “Unlink Resource” button
	3	System removes the association between the term within process model element label and ontology resource
	4	System removes ontology resource’s name from “linked resources list”
Extensions	1a	Analyst proceeds without making a selection
		1a1. System displays “You should choose a process model element, process model or

		ontology resource first" message and returns to its initial status
Special Requirements	-	

Use Case 27: Delete term within process model element label related to an ontology resource

Use Case Name	Delete term within process model element label related to an ontology resource	
Use Case Description	Unlinking term within process model element label and ontology resource representing the same real-world object when the term is deleted	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model element is created in UPROM. Ontology resource is created on Ontology Server. Ontology resource and the term within process model element label are associated.	
Success End Condition	Association between the term within process model element label and ontology resource is removed.	
Main Success Scenario	1	Analyst deletes the term within process model element label
	2	System removes the association between the term within process model element label and ontology resource
	3	System removes ontology resource's name from "linked resources list"
Extensions	-	
	-	
Special Requirements	-	

Use Case 28: Rename term within process model element label related to an ontology resource

Use Case Name	Rename term within process model element label related to an ontology resource
Use Case Description	Removing association between the term within process model element label and ontology resource

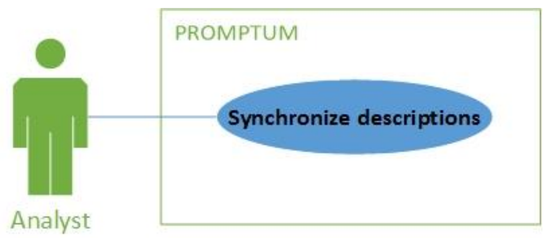
	representing the same real-world object upon renaming the term	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	Process model element is created in UPROM. Ontology resource is created on Ontology Server. Ontology resource and the term within process model element label are associated.	
Success End Condition	Association between the term within process model element label and ontology resource is removed.	
Main Success Scenario	1	Analyst renames the term within process model element label
	2	System removes the association between the term within process model element label and ontology resource
	3	System removes ontology resource's name from "linked resources list"
Extensions	-	
	-	
Special Requirements	-	

Use Case 29: Unlink term within process model element label upon deletion of related ontology resource

Use Case Name	Unlink term within process model element label upon deletion of related ontology resource
Use Case Description	Removing association between the term within process model element label and ontology resource representing the same real-world object upon deletion of ontology resource
Scope	System
Level	Analyst goal
Primary Actor	Analyst
Preconditions	Process model element is created in UPROM. Ontology resource is created on Ontology Server. Ontology resource and the term within process model element label are associated.
Success End Condition	Association between the term within process model element label and ontology resource is removed.

Main Success Scenario	1	Analyst clicks “Sync with Ontology Server” button
	2	System removes the association between the term within process model element label and ontology resource
	3	System removes ontology resource’s name from “linked resources list”
Extensions	-	
	-	
Special Requirements	-	

Description synchronization:



Use Case 30: Synchronize descriptions

Use Case Name	Synchronize descriptions	
Use Case Description	Synchronizing “description” property of an associated resource between UPROM and Ontology Server	
Scope	System	
Level	Analyst goal	
Primary Actor	Analyst	
Preconditions	An association is defined.	
Success End Condition	“Description” property of the resource is updated in Ontology Server.	
Main Success Scenario	1	Analyst updates “description” property of a process model or process model element related to an ontology resource in UPROM
	2	System updates “description” property of the resource in Ontology Server
Extensions	1a	Analyst updates “description” property of a resource in Ontology Server

		1a1. Analyst clicks “Sync with Ontology Server” button
		1a2. System updates “description” property of the related process model or process model element in UPROM
Special Requirements	-	

Appendix E – Web Services Provided by PROMPTUM Ontology Server

PROMPTUM Ontology Server provides following web services to PROMPTUM Process Modeling Plugin.

Add a resource:

Following http request creates a new resource having the provided URI and label.

http://localhost:8080/?role=controller.bg.com.tr&act=addResource&rscUri=”Resource_URI”&rscLabel=”Literal_to_be_assigned_as_RDF#label_property”

List resources:

Following http request lists all resources in ontology server.

http://localhost:8080/?role=controller.bg.com.tr&act=listResource

Remove resource:

Following http request deletes the resource having the provided URI from ontology server.

http://localhost:8080/?role=controller.bg.com.tr&act=deleteResource&rscUri=”Resource_URI”

Update a resource’s name:

Following http request updates the name of a resource having the given URI.

http://localhost:8080/?role=controller.bg.com.tr&act=addResource&rscUri=”Resource_URI”&rscLabel=”New_literal_to_be_assigned_as_RDF#label_property”

Add a data type property:

Following http request adds a literal value to a resource having a provided URI as the value of a given data type property.

http://localhost:8080/?role=controller.bg.com.tr&act=addDTProperty&rscUri=”Resource_URI”&prpUri=”Data_type_property’s_URI”&value=”Literal_to_be_assigned_as_property_value”

Add an object type property:

Following http request adds a binding based on a given object type property between two existing resources.

http://localhost:8080/?role=controller.bg.com.tr&act=addOTProperty&rscUri=”First_resource’s_URI”&prpUri=”Object_type_property’s_URI”&objUri=”Second_resource’s_URI”

List properties of a resource:

Following http request lists given data type or object type properties of a resource.

http://localhost:8080/?role=controller.bg.com.tr&act=listProperties&rscUri=”Resource_URI”&prpUri=”Property_URI”

Delete properties of a resource:

Following http request deletes the given data type or object type property of a resource.

http://localhost:8080/?role=controller.bg.com.tr&act=deleteProperties&
rscUri=”Resource_URI”&prpUri=”Property_URI”

List changes:

Following http request lists the change records in ontology server starting from a given point in time.

http://localhost:8080/?role=controller.bg.com.tr&act=getChanges&timestamp=”yyyy.MM.dd-HH:mm:ss:SSS_(stamp_of_the_last_synchronized_time)”

Appendix F – Data Model of PROMPTUM Process Modeling Plugin

PROMPTUM Process Modeling Plugin keeps data having the following structure for enabling consistency with PROMPTUM Ontology Server.

Ontology list structure:

```
<ontItems>
        <ontologies>
                <ontology>"ontology_name"</ontology>
                <project>"project_name"</project>
        </ontologies>
        ...
</ontItems>
```

Resource list structure:

```
<items>
        <resources>
                <ontology>"ontology_name"</ontology>
                <id>"resource_id"</id>
                <name>"resource_name"</name>
                <linked>"true/false"</linked>
                <project>"project_name"</project>
                <uri>"ontology_name"%23"resource_name"</uri>
                <resource>"resource_name"</resource>
                <description>"description"</description>
                <encodedName>"encoded_resource_name"</encodedName>
        </resources>
        ...
</items>
```

Timestamp data structure:

```
<items>
        <timeStamps>
                <time>"yyyy.MM.dd-
                HH:mm:ss:SSS_(stamp_of_the_last_synchronized_time)"</time>
        </timeStamps>
        ...
</items>
```

Appendix G – Issues Identified in the Review of Products in Explanatory Study

Table 13 Issues identified in the review of process models produced in case study 1 and ontology produced in case study 2 of explanatory study

Issue no	**Related labels or terms within labels in process model collection in case study 1**	**Related ontology resources in case study 2**	**Explanation**
1	Akademik danışman	Danışman	Inconsistency between process model and ontology
2	Resmi internet sayfası	EABD internet sayfası	Inconsistency between process model and ontology
3	Enstitü yönetim kurulu	-	Ontology should have included ”Enstitü yönetim kurulu”
4	Ilgili enstitü kurulu	Enstitü kurulu	Inconsistency between process model and ontology
5	İngilizce yeterlilik sınavı sonucu / ODTÜ İYS sonuç belgesi veya TOEFL/IELTS belgesi	Ingilizce yeterlilik belgesi	Incorrect information in process model collection (process models should have included “Ingilizce yeterlilik belgesi”) and Internal inconsistency in process model collection
6	Diploma	Lisans diploması	Inconsistency between process model and ontology
7	Başvuru	Lisansüstü başvurusu	Inconsistency between process model and ontology
8	Kabul	Lisansüstü kabulü	Inconsistency between process model and ontology
9	Kayıt	Lisansüstü programa kayıt	Inconsistency between process model and ontology
10	Lisansüstü program / Program	Lisansüstü programı	Internal inconsistency in process model collection via using different syntax for same concept

11	Müfredat	Lisansüstü programı müfredatı	Inconsistency between process model and ontology
12	ALES veya eşdeğeri / ALES internet çıktısı veya GRE belgesi	Lisansüstü sınav sonuç belgesi	Incorrect information in process model collection (process models should have included “Lisansüstü sınav sonuç belgesi”) and Internal inconsistency in process model collection
13	Yarıyıl kaydı	Lisansüstü yarıyıl kaydı	Inconsistency between process model and ontology
14	Transcript	Not çizelgesi	Inconsistency between process model and ontology
15	Yüksek lisans öğrencisi	Öğrenci	Inconsistency between process model and ontology
16	Katkı payı	Öğrenci katkı payı	Inconsistency between process model and ontology
17	Kimlik belgesi	Öğrenci kimlik belgesi	Inconsistency between process model and ontology
18	-	Öğrenim vizesi	Out of scope entity exists in ontology
19	YÖK	Yükseköğretim kurulu	Inconsistency between process model and ontology
20	Uluslararası program	-	Ontology should have included “Uluslararası program”
21	Ulusal program	-	Ontology should have included “Ulusal program”
22	Intibak ilkeleri	-	Ontology should have included “Intibak ilkeleri”
23	Program adı	-	Ontology should have included “Program adı”
24	Program süresi	-	Ontology should have included “Program süresi”
25	Haftalık program	-	Ontology should have included “Haftalık program”

26	Etkileşimli kayıt	-	Ontology should have included "Etkileşimli kayıt"
27	Öğrenim ücreti	-	Ontology should have included "Öğrenim ücreti"
28	Ekle bırak	-	Ontology should have included "Ekle bırak"
29	Başvuru koşulları	-	Ontology should have included "Başvuru koşulları"
30	Bilimsel değerlendirme	-	Ontology should have included "Bilimsel değerlendirme"
31	Program açılır	-	An out of scope function, "Program açılır", whose role is not defined, exists in process models
32	Yasal işlem başatılır	-	Role responsible for performing the function is not defined
33	Lisansüstü programa ilk kayıt	-	The function, "kayıt belgelerinin kontrolünün gerçekleştirilmesi" should have been defined
34	Yarıyılda verilecek dersler ilgili düzenlemeleri yapılarak belirlenir	-	The related function is performed by "EABDB", not "ÖİDB"
35	Danışman onayı yapılır	-	The related function is performed on the application system; "OIBS"
36	Yarıyıl kaydı	-	After "mazeret dilekçesi" is evaluated by "EABD", it should be approved by "yönetim kurulu"

Table 14 Issues identified in the review of process models and ontology produced in case study 3 of explanatory study

Issue no	**Related labels or terms within labels in process model collection in case study 3**	**Related ontology resources in case study 3**	**Explanation**
1	Intibak ilkeleri	-	Ontology should have included "Intibak ilkeleri"

2	Yarıyıl kaydı	-	Ontology should have included “Yarıyıl kaydı”
3	Ders ekleme bırakma	-	Ontology should have included “Ders ekleme bırakma”
4	Etkileşimli kayıt	-	Ontology should have included “Etkileşimli kayıt”
5	Katki payı	-	Ontology should have included “Katki payı”
6	Haftalık program	-	Ontology should have included “Haftalık program”
7	Lisansüstü program hazırlama	-	Establishing international programs should be defined
8	Lisansüstü program hazırlama	-	Exceptional paths regarding cases the program is not approved by “Senato” or “Yükseköğretim Kurulu” should be defined
9	Programa ilk kayıt	-	Registeration documents “fotoğraf” and “iyi hal kağıdı (af ile dönüyorsa)” should be defined
10	Kayıt belgelerini teslim et	-	The role performing the activity should be “öğrenci adayı”, not “öğrenci”
11	Dilekçe ile kayıt gerekti	-	Exceptional paths regarding cases when student application for registeration is not approved should be defined

Appendix H – Survey and Semi-Structured Interview Questions Regarding Integrated Business Process Modeling and Ontology Development

1. Gender:
- ☐ Female
- ☐ Male

2. Age: …………………………………………………..

3. Employment: …………………………………………………..

4. Education:
- ☐ BSc
- ☐ MSc
- ☐ PhD

5. Department (graduated from): …………………………………………………..

6. How many years have you been using computers?
- ☐ Less than a year
- ☐ 1-3 years
- ☐ 4-6 years
- ☐ 7-9 years
- ☐ 10 years and more

7. How do you rate your computer skills?
- ☐ Very good
- ☐ Good
- ☐ Moderate
- ☐ Bad
- ☐ Very bad

8. How many years have you been using the internet?
- ☐ Less than a year
- ☐ 1-3 years
- ☐ 4-6 years
- ☐ 7-9 years
- ☐ 10 years and more

9. Have you ever taken a process modeling course?
- ☐ Yes ……………………………………..
- ☐ No

10. Have you ever had a process modeling experience?
- ☐ Yes
- ☐ No

11. How do you rate your process modeling skills?

- ☐ Very good
- ☐ Good
- ☐ Moderate
- ☐ Bad
- ☐ Very bad

12. Which of the following process modeling languages have you heard?

- ☐ Extended Event-Driven Process Chain (eEPC)
- ☐ Business Process Model and Notation (BPMN)
- ☐ Petri Nets
- ☐ Role Activity Diagram (RAD)
- ☐ UML Activity Diagram
- ☐ BPEL
- ☐ Other: ………………………………………………………..

13. Which of the following process modeling languages have you used?

- ☐ Extended Event-Driven Process Chain (eEPC)
- ☐ Business Process Model and Notation (BPMN)
- ☐ Petri Nets
- ☐ Role Activity Diagram (RAD)
- ☐ UML Activity Diagram
- ☐ BPEL
- ☐ Other: ………………………………………………………..

14. Which of the following process modeling tools have you heard?

- ☐ SoftwareAG's ARIS Platform
- ☐ EPF (Eclipse Process Framework) Composer
- ☐ MS Visio
- ☐ QPR ProcessDesigner
- ☐ iGrafx FlowCharter
- ☐ Rational System Architect
- ☐ Lombardi's Blueprint
- ☐ Sparx Systems' Enterprise Architect
- ☐ UPROM
- ☐ Other: ………………………………………………………..

15. Which of the following process modeling tools have you used?

- ☐ SoftwareAG's ARIS Platform
- ☐ EPF (Eclipse Process Framework) Composer
- ☐ MS Visio
- ☐ QPR ProcessDesigner
- ☐ iGrafx FlowCharter
- ☐ Rational System Architect
- ☐ Lombardi's Blueprint
- ☐ Sparx Systems' Enterprise Architect
- ☐ UPROM
- ☐ Other: …………………………………………………………..

16. Have you ever taken an ontology development course?

- ☐ Yes …………………………………………
- ☐ No

17. Have you ever had an ontology development experience?

- ☐ Yes
- ☐ No

18. How do you rate your ontology development skills?

- ☐ Very good
- ☐ Good
- ☐ Moderate
- ☐ Bad
- ☐ Very bad

19. Which of the following ontology definition languages have you heard?

- ☐ RDF
- ☐ OWL
- ☐ RDF(S)
- ☐ DAML+OIL
- ☐ KIF
- ☐ Other: …………………………………………………………..

20. Which of the following ontology definition languages have you used?

- ☐ RDF
- ☐ OWL
- ☐ RDF(S)
- ☐ DAML+OIL
- ☐ KIF
- ☐ Other: …………………………………………………………..

21. Which of the following ontology tools have you heard?

- ☐ Protégé
- ☐ Web-Protégé
- ☐ OntoStudio
- ☐ SWOOP
- ☐ NeOn Toolkit
- ☐ TopBraid Composer
- ☐ Other: …………………………………………………………..

22. Which of the following ontology tools have you used?

- ☐ Protégé
- ☐ Web-Protégé
- ☐ OntoStudio
- ☐ SWOOP
- ☐ NeOn Toolkit
- ☐ TopBraid Composer
- ☐ Other: …………………………………………………………..

23. Compared to the narrative discussion provided, how well does the business process models capture the process knowledge? (Semi-structured interview question)

24. Compared to the narrative discussion provided, how well does the encoded ontology capture the entities and relationships in the domain? (Semi-structured interview question)

25. Do you find the way entities and relationships are structured in the ontology helpful to you in developing the business process models and business process models helpful to you in developing the ontology? Please explain. (Semi-structured interview question)

26. In your opinion, what kind of benefits can the integrated development of the ontology and business process models derive? Please explain all possible impacts of the ontology and business process models relative to the provided artifacts. (Semi-structured interview question)

27. Identify the kinds of value the ontology and business process models can bring to the analysts if they are developed integrated? (Semi-structured interview question)

28. In general, what kind of unique characteristics can you infer with respect to our approach that might be beneficial to business process modeling and ontology building? (Semi-structured interview question)

CURRICULUM VITAE

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MS	METU, Information Systems	2010
BS	METU, Industrial Engineering	2007

WORK EXPERIENCE

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2009-Present	Bilgi Grubu Ltd., Ankara Turkey	Researcher, consultant, software engineer

FOREIGN LANGUAGE

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PUBLICATIONS

1. Coskuncay A., Aysolmaz B., Demirors O., Bilen O., Dogan I. (2010). Bridging the Gap Between Process Modeling and Software Requirements Analysis: A Case Study. Proceedings of 5th Mediterranean Conference on Information Systems (MCIS), Tel Aviv, 12-14 September 2010

2. Coskuncay A. (2010). An Approach for Generating Natural Language Specifications by Utilizing Business Process Models. Master Thesis, Middle East Technical University
3. Coskuncay A., Aysolmaz B., Demirors O., Bilen O., Dogan I. (2010). Eşzamanlı İş Süreci Modelleme ve Gereksinim Analizi için bir Yaklaşım. In. Yazılım Kalitesi ve Yazılım Geliştirme Araçları Sempozyumu (YKGS) 2010, İstanbul, Türkiye
4. Aysolmaz B., Coskuncay A., Demirors O., Yildiz A. (2011). Kamuda İş Süreçleri Modelleme: Gereği ve Yararları. Ulusal Yazilim Muhendisligi Sempozyumu (UYMS) 2011, Ankara, Türkiye
5. Garousi V., Coskuncay A., Betin Can A., Demirors O. (2013). Türkiye'deki Yazılım Test Uygulamaları Anketi. 7. Ulusal Yazilim Muhendisligi Sempozyumu (UYMS) 2013, İzmir, Türkiye
6. Coskuncay A., Gurbuz O., Demirors O. (2014). İş Süreç Modellerinden Ontolojiye Dönüşüm: Bir Durum Çalışması. 8. Ulusal Yazilim Muhendisligi Sempozyumu (UYMS) 2014, Güzelyurt/KKTC
7. Yildiz A., Coskuncay A., Demirors O., Seyrekbasan I., Altay M. (2014). Model Bazlı Süreç İyileştirme Çalışmalarının Kurumlarda Benimsenmesine Yönelik Bir Anket Çalışması. 8. Ulusal Yazilim Muhendisligi Sempozyumu (UYMS) 2014, Güzelyurt/KKTC
8. Demirors O., Coskuncay A. (2015). Software Development in Turkey. IT Professional, vol. 17, no. 3, pp. 10-13, May-June 2015
9. Garousi V., Coskuncay A., Betin Can A., Demirors O. (2015). A Survey of Software Engineering Practices in Turkey. Journal of Systems and Software, vol. 108, October 2015, pp. 148-177
10. Garousi V., Coskuncay A., Demirors O., Yazici A. (2016). Cross-Factor Analysis of Software Engineering Practices Versus Practitioner Demographics: An Exploratory Study in Turkey, Journal of Systems and Software, vol. 111, January 2016, pp. 49-73
11. Coskuncay A., Gurbuz O., Demirors O., Ekinci E.E. (2016). PROMPTUM Toolset: Tool Support for Integrated Ontologies and Process Models, Proceedings of the First Workshop on Business Process Management and Ontologies (BPMO'16) in conjunction with BPM 2016, Rio de Janeiro, Brazil, September 18-22 2016.

CERTIFICATES

1. COSMIC Functional Size Measurer, Certificate, Common Software Measurement International Consortium, April 2010.
2. CMMI for Development v1.3, Mike Bradley, Carnegie Mellon University - Software Engineering Institute (SEI), January 2011.
3. CASE Summer School on Experimentation on Software Engineering, Empirical Analysis of Software Processes and Products, Certificate, Free University of Bolzano, Italy, June 2011.

4. Standard CMMI Appraisal Method for Process Improvement (SCAMPI) v1.3, Mike Bradley, Carnegie Mellon University - Software Engineering Institute (SEI), November 2012.
5. Knowledge Engineering with Semantic Web Technologies, Record of Achievement, Harald Sack, openHPI, July 2014.