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EGLĖ MICKEVIČIŪTĖ

BUSINESS PROCESS REPRESENTATION BASED ON BUSINESS VOCABULARY AND BUSINESS RULES SEMANTICS

Summary of Doctoral Dissertation
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DICTIONARY OF ABBREVIATIONS AND CONCEPTS

Abbreviation	Description
BPM	Business Process Model
BPMN	Business Process Modeling Notation
BR	Business Rule (e.g., SBVR BR)
BV	Business Vocabulary(e.g., SBVR BV)
MDA	Model Driven Architecture
OMG	Object Management Group
QVT	Object Query/View/Transformation/
SBVR	The Semantics of Business Vocabulary and Business Rules
UML	Unified Modeling Language
V&R	Bussiness Process Model Vocabulary and Business Process Model Rules (e.g., BPMN BPM V&R)
XMI	XML Metadata Interchange
XML	Extensible Markup Language

Concept	Definition
BPMN2 concepts metavocabulary	Knowledge structure identifying key BPMN2 concepts to define business process model vocabularies and rules (SBVR knowledge model which was extended with BPMN2 concepts without making changes to metamodels).
Business process	A set of interconnected activities that include business, IT and technical measures with the objective to implement a specific purpose of an organization or its unit.
Business process vocabulary	Knowledge structure identifying the main terms of a domain and their relationships looking from the perspective of business process modeling notation.
Business process modeling	Business process representation and simulation by using special tools seeking to analyze or improve a modeling process.
Business process rule	A logical statement describing certain business constraints that exist in a particular business situation that is related to data flows and the hierarchy of a model.
Business rule	A logical statement describing certain business constraints that exist in a particular business situation.
Business vocabulary	Knowledge structure identifying the main terms of a domain and their relationships.

1. Introduction

1.1. Motivation

The development of an information system starts with business process modeling and identification of the business domain vocabulary and rules. The difficulties in the requirements analysis and business process modeling in many cases arise from the failure to understand and define business logic that is defined by business rules and business processes (Andreescu, Mircea, 2014). In order to develop complete and comprehensive business process specification, it is appropriate to use several business modeling standards that deal with different business aspects and provides any participant with an opportunity to choose the most acceptable method of business representation. The selection of the most acceptable business representation method may speed up and improve communication between domain participants thus helping them avoid misunderstandings due to incorrect interpretations or misuse of terms, especially when the model is large and, therefore, difficult to read/perceive.

Business process modeling is an important step in the process of information systems development (Vasconcelos *et al*., 2001; Sinogas *et al*., 2001; Barjis, 2008; Kovalova, Turcok, 2014) and necessary in order to understand, manage, optimize business processes, add new or existing activities, single out existing activities or their parts. Business vocabulary and business rules are an inherent part of each and every business process model that affects all of its areas (Vasilecas, Lebedys, 2006), and there is hardly a single business system that does not have goals, mission and business rules (Lovrencic *et al*., 2006). The use of business vocabulary and business rules while creating business process models is useful because an organization can obtain a unified domain vocabulary – these are terms that are used in oral or written form adopted as business concepts in the organization. Such vocabulary provides an opportunity to improve understanding and avoid misunderstandings between domain participants and IT experts.

It is not simple to maintain compatibility between separately modeled business processes and business rules due to constantly changing requirements, emergence of new variables, concepts or terms. In such cases, supplementing created models with new knowledge may lead to conflicts, discrepancies or other issues. In addition, difficulties arise when there is a desire to use these two models together because business processes are created by using graphical notations and business vocabulary and business rules are expressed via limited natural language.

This dissertation is devoted to integrating business process and business rules modeling standards so that to get a comprehensive and consistent business process specification. This decision is based on BPMN2 and SBVR modeling standards as the analysis showed that complex application of these two standards allows the best representation of real world objects and processes. Transformation of graphical business process models to business vocabularies and business rules models was implemented in order to ensure the compatibility of these two models.

1.2. Object and scope of research

Object. The objects of this research are models of business processes and business rules, representation methods, modelling languages and tools.

Scope of research. The scope of this research includes the process of business processes and business rules specification, representation, compliance with software models as well as the coverage of all the life cycle of business processes and business rules.

1.3. Problem background and research questions

The problem analyzed in this research is associated with the integration of business processes, business vocabularies and business rules and the description of business processes which have to correspond to the formal model description and be fully understandable by domain experts. Business process modeling and business rules modeling are kept as complementary methods, and their joint usage while modeling complex business processes allows representing different business aspects (dynamic, defining the behavior of the process, and static, defining restrictions and information flows) and including all the involved actors of the process. The problem of compatibility between models arises as business processes are usually expressed graphically while business rules are being expressed in a declarative way; therefore, the use of these two modeling methods together, their compatibility, the extraction of the business vocabulary and business rules from graphical business processes with the possibility to include domain experts at the process design stage currently are widely discussed topics. There is a need to develop comprehensive, consistent specifications of business processes and business rules which would provide the ability to understand and validate business processes and business rules and also reduce misunderstanding between business domain participants within the organization or between/among two/several organizations.

This research is expected to answer the following questions:

1. Is it possible to express graphical business processes in a declarative way by using a limited natural language?
2. What do we need to do in order to derive business vocabularies and business rules from graphical business process models without using any linguistic methods?
3. What features of graphical business process models can help us improve the correct extraction of business vocabularies and business rules?
4. What do we need for mutual transformation between models of business processes and business vocabularies and business rules?
5. Is it possible to implement business vocabularies and business rules extraction from graphical process models with the possibility to link these models' elements into one modeling environment?

1.4. Goals and objectives

The main goal of this work is to allow the creation of integrated business processes and business rules models which would be understandable to all the domain participants by creating a method and providing a tool which should allow creating comprehensive and consistent business process specifications (graphical BPM and BR&BV) in one modeling environment.

The research tasks are the following:

1. To analyze scholarly literature related to modeling methods of business processes, business vocabulary and business rules, their languages, metamodels, their evaluation techniques, integration, transformation, and already existing solutions.
2. To create a method with the intent to define graphical business process models using domain vocabulary concepts and business rules by defining transformation rules and algorithms in addition to assessing the possibilities of reverse transformation.
3. To create a prototype in a CASE tool environment which automatically transforms graphical business process models into business vocabularies and business rules.
4. To conduct an experiment and evaluate the obtained research results.

1.5. Research methodology

The currently existing methods of the business process, business vocabulary and business rules modeling and visual representation along with the research area metamodels, modeling languages and tools are analyzed in this thesis. Our exploration is performed by using information search and analysis, systematic evaluation, comparative analysis, structured analysis and generalization methods.

The methods of conceptual modeling, systemic process analysis, systems engineering processes and modeling methods are used to ensure compatibility and integration between business vocabulary, business rules and the business process model. A conceptual method with the objective to create transformation rules by using EBNF notation is used so that to ensure transformation from the business process model to business vocabulary and business rules.

The developed prototype for transforming the business process model into business vocabulary and business rules created based on defined transformation rules is used in experimental research. Experimental research involves methods of quantitative evaluation, experimental evaluation, systematic and comparison analysis.

The study was carried out by „Design Science“ method (Hevner *et al.*, 2004) where the analysis of existing solutions was made, new artefacts were created, experimental researched was performed, and evaluated research results were outlined.

1.6. Defended propositions

1. The detailed mappings between BPMN2 and SBVR metamodels introduced in this work, allow to create BPM into BR&BV transformation rules, which allows automatic BR&BV extraction from BPM.
2. The developed method allows forming a comprehensive and consistent specification consisting of BPM and BR&BV in two different scenarios.
3. The defined requirements for BPM elements allow obtaining semantically correct and SBVR specification-compliant business vocabulary and business rules during automatic transformation without using any linguistic methods.
4. The transformation algorithm allows obtaining BR&BV from BPM automatically; if we wish to perform reverse transformation, only BR&BV is not enough as it is necessary to use two additional vocabularies in order to save BPMN2 model information.

1.7. Scientific novelty

The novelty of this research lies in the method which provides an opportunity to obtain integral, mutually consistent description of business vocabulary, business rules and business process model rules which is associated with the graphical business process model without using any linguistic methods. That was achieved by applying BPMN2 concept's metavocabulary, defined transformation rules and transformation algorithms and by using the described requirements for the creation of business process models.

1.8. Theoretical and practical relevance

The presented solution suggests a methodology which allows developing integrated more comprehensive, accurate and compatible business process and business rules models. The prototype plugin was implemented in order to check the methodology in the *MagicDraw CASE* tool.

Theoretical relevance: integration and transformation capabilities of business process, business vocabulary and business rules were analyzed in order to associate these two models in a single user-friendly environment; business rules were separated from business process model rules; requirements for the element names of the business process model were defined; transformation rules from the business process model to business vocabulary and business rules were defined; reverse transformation from SBVR business vocabulary and business rules into BPMN2 business process model additionally using BPMN2 business process vocabulary and rules created using BPMN2 concept metavocabulary was described and theoretically analyzed; good business process modeling guidelines were defined.

Practical relevance: the possibility to automatically transform the business process model into business vocabulary and business rules and to provide the obtained result to domain experts for validation; the possibility of reverse transformation by automatically forming business process vocabulary and rules from the business process model in order to save full information of the business process model; the possibility to have two models focusing on different aspects in a single environment in order to reduce the possibility of inconsistencies as their elements are linked; business vocabulary elements can be used in order to change/create a/the business process model; the feasibility of forming the unified vocabulary of an organization.

1.9. Dissertation approbation

The results of the dissertation were presented in seven scientific publications. All the publications are presented in the section *List of Author's Publications on the Dissertation Theme*.

1.10. Dissertation size and structure

The dissertation consists of an introduction, five chapters, conclusions, a list of references, a list of publications on the dissertation theme and appendices. The text of the dissertation consists of 104 pages of explanatory text, 39 pages of appendices, 95 pictures and 30 tables. The reference list contains 154 references; all of its positions refer to foreign language sources.

1.11. Usage of the dissertation results in projects and author's contribution

Integration and transformation analysis and other tasks associated with these research areas related with the dissertation topic were carried out under the project *Integration of Business Processes and Business Rules on the Basis of Business Semantics* (VP131V008F) 2013–2015 (known as VEPSEM) which was funded by the *European Social Fund* (ESF). The SBVR profile, the representation formats of transformation matrices and transformation rules, the representation notations in use and the general idea of creating tracing links have been taken from the VEPSEM project.

The content of all the defined transformation matrices, the defined transformation rules, the BPMN2 concepts metavocabulary, the modeling method using the solution presented in this dissertation, the transformation realization of BPMN2 BPM into SBVR BV&BR by using SBVR profile and defined good BPMN2 business process modeling practice are regarded as author's contribution.

The developed solution is adapted for the English language since English is one of the most widespread languages in the world (including the prevalence of technical literature). The solution is implemented in the widely used *MagicDraw CASE* tool since Lithuania does not possess similar tools. The application of the developed solution to the Lithuanian language would limit the applicability of the solution.

2. Business Process and Business Rules Modeling

2.1. Conception of business vocabulary, business rules, business process and business process modeling

A business vocabulary is defined as a knowledge structure of an organization (Ross, 2003) that contains commonly used concepts and their definitions (Maldonado *et al*., 2013) that are used in oral or written form in particular activities of an organization.

Business rules are statements that affect information/system behavior in an organization (BRG, 2002) and govern the structure of the business process in an organization (Joubert *et al*., 2013). They express special knowledge, procedures as well as various constraints to be considered by each organization (Andreescu, Mircea, 2009) and must be clearly understood and seen as a valuable asset of an organization as they define the core of the organization (Steinke, Nickolette, 2003).

A business process is a set of related activities. Its structure defines a logical execution order of individual activities and their dependencies (Aguilar-Saven, 2004) and has a goal that is pointed to a desired result. Business processes are the basis of each organization and are directly responsible for the successful functioning of an organization (Rajabi, Lee, 2009); therefore, it is fundamentally important to monitor and to respond to any changes in the course of a process. Many processes are dynamic and require a response to changes even during the execution. Information technologies (IT) are closely related to the performance of the processes of an organization. During the last two decades, market changes have led to a business environment that is constantly evolving (Nurcan, 2008) and trying to adapt products to the customers' needs in order to satisfy their expectations so that they could compete in the market.

Business process modeling is the first and the most important step in the cycle of business process management (Rajabi, Lee, 2009) that separates the process logic from the application logic; thus the main business processes can be automated. Typically, the process logic is implemented and managed through a business process management system, whereas the application logic is instilled through underlying application components (Lu, Sadiq, 2007). The life cycle of business process modeling consists of four main stages: process design, system configuration, process enactment and diagnosis (Van Der Aalst *et al*., 2003).

Business process modeling allows obtaining an overall understanding of business processes and analyzing them; thus comprehensive understating about activities in business processes is formed. Business process models have a very important purpose – they allow finding a common language between domain experts, analysts and software developers (Figl, Laue, 2011) although some researches (Reijers, Mendling, 2011; Rodrigues *et al*., 2015) have shown that graphical representation of business processes is better understood by analysts as they have the experience with modeling languages and their notations.

2.2. Evaluation of modeling languages

Modeling complex business processes requires usage of different aspects of business and involvement of all the participants of a domain; therefore, several modeling standards have to be used. In many cases, it is not enough to develop one type of a model of a business process that would be understood by all the domain participants.

There are a variety of modeling languages; thus the most important point is to choose the most suitable one depending on the domain and language specifics. Analysis of standard pairs by employing Bunge-Wand-Weber (BWW) ontology found that the integration of SRML and SBVR standards with the BPMN standard has the best representational capabilities for representing real-world processes, evaluation of the overlapping of elements in use and the completeness of the required set of elements. As SRML is no longer supported, SBVR attracts more and more attention, and SBVR and BPMN are supported by the same OMG. Thus the BPMN and SBVR pair was chosen for the further research.

3. Analysis of Business Process and Business Ruless Integration and Transformation

3.1. Methods of models integration

There is a need to use several modeling standards together because of the necessity to model complex business processes covering different aspects of processes and including all the participants of a domain. This problem can be solved by developing a Domain Specific Modeling Language (DSML) where a new metamodel is created that has all the required characteristics from other metamodels. The disadvantage of such a solution is the loss of the opportunity to reuse standardized metamodels of modeling languages (such as UML, BPMN, SBVR, etc.) that are widely used and attract more and more attention when creating DSML from scratch. Another solution for this problem is to integrate metamodels of different modeling languages thus allowing integration of models which are based on those metamodels. There are several basic methods of metamodel integration (Emerson, Sztipanovits, 2006): Metamodel Merge, Metamodel Interfacing, Class Refinement and UML Profiles. The application of the UML profile mechanism does not change the semantics of UML metamodel elements; it rather complements them according to the specific needs of a business domain. Metamodel integration can thus be implemented without additional structures, by using only three key elements of the extension mechanism: stereotypes, tagged values, and constraints allowing the development of extensions or modifications of UML profiles for specific needs.

3.2. Comparison of existing integration and transformation researches

Analysis of the researches available in scholarly literature allows distinguishing the main already existing solutions in this area. Their advantages and disadvantages along with the proposed solution(s) are presented in Table 3.1.

Table 3.1. Comparison of existing decisions along with the proposed solution

Method	Advantages	Disadvantages
(Koehler, 2011; Koehler, 2012) (1*)	Several balancing scenarios of models integration	No guidance about the implementation
(Ross, 1997) (2*)	Visual modeling of BR	Practical inapplicability due to the large amount of graphical elements and no relation with BPM
(Malik, Bajwa, 2012; Malik, Bajwa, 2013) (3*)	Standard based approach, applicable in CASE tools	Complete solution is still missing; BV is within the BR
(Agrawal, 2011) (4*)	Complete mapping of elements	Maintenance issues as additional meta-model SBPVR to express business process vocabulary and rules is used
(Goedertier, Vanthienen, 2007) (5*)	Formal integration of BR and BPM	Hardly applicable in practice as business processes are better understood and expressed when using graphical models
(Skersys *et al.*, 2012a; Skersys et al., 2012b) (6*)	Applicable without additional requirements for modeling; no changes to SBVR and BPMN metamodels	No guarantee for completeness and reliability, underestimation of the naming schemes; forms only BV; BR can be formed manually
(Friedrich *et al.*, 2011; Leopold *et al.*, 2012) (7*)	No additional requirements for BPM	Requires sophisticated linguistic processing techniques and does not ensure completeness and reliability; BV is within the BR
The proposed solution	Complete integration and mutual transformation between BPM and BR with no meta-model changes; BV&BR consisting of restrictions and process rules; covers full BPD elements; element traceability option; no linguistic methods, BV can obtain the graphical representation form; BPMN V&R is formed separately without using a separate	Additional requirements for naming and using BPM elements

Method	Advantages	Disadvantages
	meta-model	

(1*) BR and BPM integration scenarios
(2*) BR visual representation
(3*) Integration and mutual transformations based on SBVR and BPMN metamodels
(4*) Extension of SBVR metamodel
(5*) Declarative business process modeling
(6*) Usage of supplementary structures; applying linguistic analysis
(7*) Generating natural language texts from BPMN and vice versa

4. BPMN2 and SBVR Integration and Transformations

4.1. Principal solution schema and transformation context

The abstract transformation context between BPMN2 and SBVR is presented in Figure 4.1 (the thicker line represents the transformation of BPMN2 into SBVR which was implemented in the transformation plug-in, while the other transformation was only analyzed but not actually implemented).

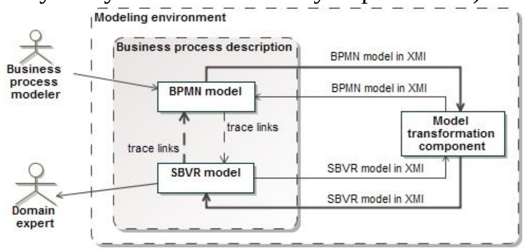

Figure 4.1. BPMN2 into SBVR transformation context

The BPMN2 into SBVR transformation can be executed in the modeling environment whose input is a BPMN2 Business process model in XMI and the output is SBVR XMI. Both BPMN2 and SBVR models can be viewed in the same modeling environment with the ability to create trace links between BPMN2 and SBVR models. Transformation algorithms are presented in section 4.3.

4.2. Compliance of concepts between BPMN2 model and SBVR business vocabulary

Three types of vocabularies were used in order to obtain full and comprehensive description of business processes: the domain business vocabulary that describes business domain using standard SBVR constructions; BPMN2 concepts metavocabulary that describes metamodel elements of the business process diagram using SBVR constructions which are used to form BPMN2 BPM BV, and BPMN2 business process model vocabulary which is described by using the second vocabulary. The two final vocabularies can be treated as a textual representation of BPM.

The compliance of concepts was examined in two degrees: full and partial matching. Analysis of compliance between BPMN2 BPM and SBVR concepts allowed defining BPMN2 BPM into the SBVR BV&BR transformation matrix where transformation rules were presented. The application order of BPMN2 BPM into SBVR BV&BR transformation rules were divided into 5 steps which must be carried out sequentially. Step 1 defines transformation rules from BPMN2 elements into SBVR general concepts. Step 2 defines transformation rules from BPMN2 elements or their pairs into SBVR verb concepts whereas Steps 3–5 define transformation rules from BPMN2 elements or their pairs into SBVR business rules. The transformation rules of Steps 3–5 were separated in order to distinguish the object or the initiator of the rule. There are 46 transformation rules in total. Examples of transformation are presented below.

BPMN2 Event → SBVR general concept

T_1: transform(BPM, event: Event) → SBVR General Concept$_1$, SBVR General Concept$_2$
e.g.: transform(BPM, 'car booking request is received ') → car_booking_request, received

BPMN2 Event → SBVR verb concept

T_{10}: transform(BPM, event: Event) $\xrightarrow{a*}$ SBVR Verb Concept$_1$, SBVR Verb Concept$_2$
e.g.: transform(BPM, 'rental contract is rejected ') $\xrightarrow{a*}$ rental_contract *is_rejected*, rental_contract *has_state* *rejected*

Activity$_1$ initiates activity$_2$

T_{28}: transform(BPM, pool|lane: Pool|Lane, activity$_1$: Activity$_1$, sequence_flow(activity$_1$, activity$_2$): SequenceFlow, activity$_2$: Activity$_2$) $\xrightarrow{a}$ SBVR Business Rule
e.g.: transform(BPM, 'branch', 'schedule pick up date time', sequence_flow('schedule pick up date time','schedule return date time'), 'schedule return date time') $\xrightarrow{a}$
It is obligatory that branch *schedule* return_date_time after branch *schedule* pick_up_date_time

4.3. BPMN2 business process model transformation into SBVR business vocabulary and business rules

The algorithm to transform BPMN2 BPM into SBVR BV&BR was divided into two separate parts. The first part of the algorithm defines SBVR BV extraction form BPMN2 BPM (Figure 4.1). A description of steps is presented in Table 4.1.

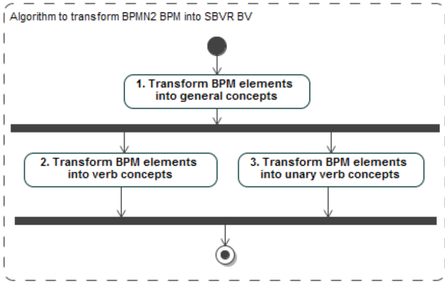

Figure 4.1. The algorithm of the transformation of BPMN2 BPM into SBVR BV

Table 4.1. Description of the steps of the algorithm of transforming BPMN2 BPM into SBVR BV

Step	Description
1	Transform BPMN2 BPM containers (Lane, Pool), noun phrases of events and activities (Event, Activity), data objects (DataObject), data stores (DataStore), messages (Message), data objects with states ((DataObject with state) into SBVR general concepts.
2	Transform BPMN BPM composite containers (Pool with Lane), activities (Activity) with containers (Lane, Pool), message flows (MessageFlow, MessageFlow with ref. Message), associations (Association) and data associations (DataAssociation) that are related to events that are related to message flows into SBVR verb concepts.
3	Transform BPMN2 BPM events (Event) into SBVR unary verb concepts.

The second part of the algorithm defines SBVR BR extraction from BPMN2 BPM (Figure 4.2 and Table 4.2).

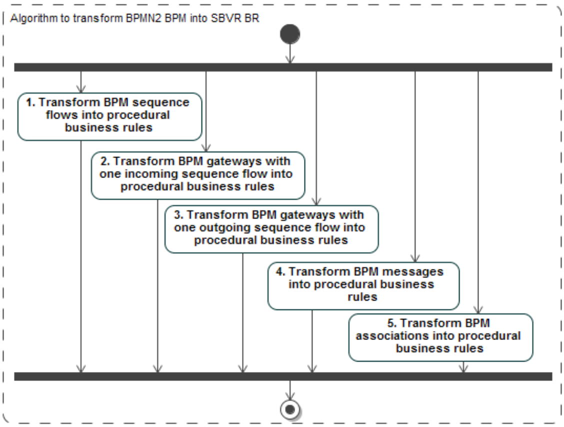

Figure 4.2. The algorithm of the transformation of BPMN2 BPM into SBVR BR

Table 4.2. Description of the steps of the algorithm transforming BPMN2 BPM into SBVR BR

Step	Description
1	Transform BPMN2 VPM sequence flows (SequenceFlow) into SBVR procedural business rules including conditions if they exist.
2	Transform BPMN2 VPM gateways (Gateway) with one incoming sequence flow into SBVR procedural business rules including conditions if they exist.
3	Transform BPMN2 VPM gateways (Gateway) with one outgoing sequence flow into SBVR procedural business rules.
4	Transform BPMN2 VPM message flows (MessageFlow, MessageFlow with ref. Message) into SBVR procedural business rules.
5	Transform BPMN2 VPM associations (Assotiation) from boundary compensation event (BoundaryCompensationEvent) into SBVR procedural business rules.

In addition to the main described transformation, other transformations were also analyzed and defined in this research: BPMN2 BPM into BPMN2 BPM V&R and their reverse transformations: SBVR BR&BV into BPMN2 BPM and BPMN2 BPM V&R into BPMN2 BPM.

Transformation algorithm of BPMN2 BPM into SBVR BV&BR is implemented as a plugin that can be used in the *MagicDraw CASE* tool. The transformation process is automatic and called over BPMN2 into SBVR conversation interface where the input is the BPMN2 business process model in the XML format whereas the result is SBVR business vocabulary and business rules in the XMI format. Transformation BPMN2 BPM into SBVR BV&BR is implemented by using the Eclipse environment tool with the QVT transformation language.

BPMN and SBVR profiles in the *MagicDraw CASE* tool enable these two models to be represented graphically except for the SBVR business rules which are presented in the textual format. The possibility of generating trace links between elements of BPMN2 and SBVR models is also provided. The SBVR profile (Skersys *et al.*, 2015) is based on the UML profile. The SBVR profile extending the BPMN2 profile was implemented in order to define BPMN2 business vocabulary where compatibility of SBVR and BPMN was ensured.

4.4. Requirements for BPMN2 BPM on which the quality of transformations depends

Two criteria have an influence on the transformation of BPMN2 BPM into SBVR BV&BR: 1) BPM element names (formats of element names e.g. for activities, events, etc.) also known as the good modeling practice and 2) the usage of certain elements in BPM.

1) In order to get semantically correct SBVR BV&BR after the transformation without linguistic analysis of the BPMN2 process model, it is necessary to follow the so-called ‘good modeling practice’. Based on this practice, BPMN2 element names have to be formed in accordance with

certain requirements described in this research.

2) It is necessary to use containers (Pools or Lanes) in BPM identifying responsibilities for specific operations (person, organization unit, etc.).

4.5. BPMN2 business process modeling method: application of the proposed solution

Two scenarios were identified for BPMN2 business process model development by using the proposed solution. The first scenario enables to create BPMN2 BPM and later transform it into SBVR BV&BR and BPMN2 BPM V&R (Figure 4.3).

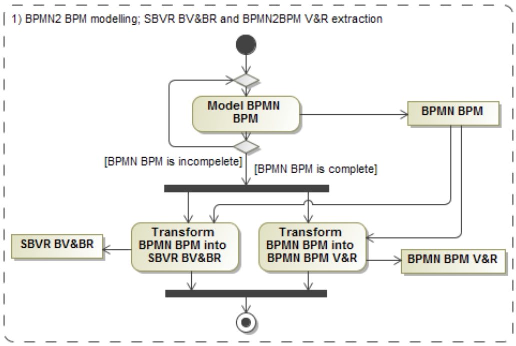

Figure 4.3. Application of the proposed solution. Scenario 1

The second scenario enables to create BPMN2 BPM and SBVR BV at the same time and later transform BPMN2 BPM into SBVR BV&BR and BPMN2 BPM V&R with an option of SBVR BV merging or overwriting (Figure 4.4).

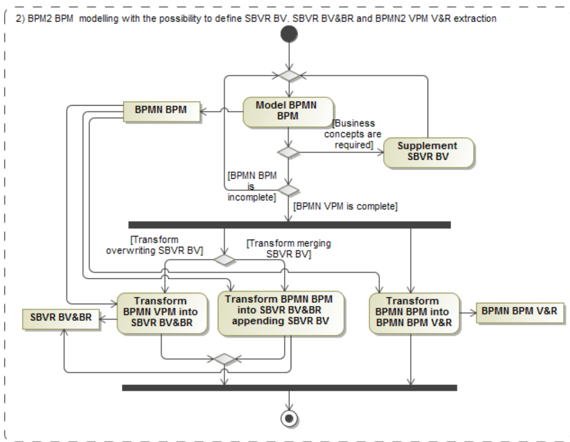

Figure 4.4. Application of the proposed solution. Scenario 2

5. Experiment of SBVR BV&BR Extraction from BPMN2 BPM

The experiment was carried out with BPMN2 models of three different domains. One of the models is the EU-Rent model which was created by SBVR specification. Other models were taken from the *MagicDraw CASE* tool example library: 1) library process and 2) ordering process. The two final models were analyzed in two ways: with and without the good modeling practice.

The goal of the experiment of transformation BPMN2 into SBVR was to evaluate the quality of the solution when using certain evaluation criteria. The experiment was evaluated by using the following quality criteria: precision (P), recall (R) and balanced F-score (F). Here, RE means the amount of SBVR elements which theoretically should be received; AE represents the amount of all SBVR elements; $RE \cap AE$ stand for the correct amount of SBVR elements. The summary of the experiment results is presented in Table 5.1 and Table 5.2.

Table 5.1. Summary of the experiment results (without using good modeling practice)

BPM	$\|RE \cap AE\|$	$\|AE\|$	$\|RE\|$	*P*	*R*	*F*
Library	55	131	127	0.42	0.43	0.42
Orders	45	88	127	0.51	0.35	0.41
			Average	0.47	0.39	0.42

Table 5.2. Summary of the experiment results (by using good modeling practice)

BPM	$\|RE \cap AE\|$	$\|AE\|$	$\|RE\|$	*P*	*R*	*F*
Library	127	127	127	1	1	1
Orders	127	127	127	1	1	1
EU-Rent	430	430	430	1	1	1

The experiment results showed that the application of the good modeling practice allows achieving 100% transformation accuracy and comprehensiveness in accordance to the defined transformation rules. The experiment results are dependent on the selected BPMN2 BPM. The experiment with other BPMN BPMs would give different results in comparison with the original models. The results from the adapted models will remain unchanged. Consequently, it can be concluded that the first part of the experiment (with the original models) depends on the BPMN2 BPM quality and on the satisfaction of requirements and it does not reduce the effectiveness of the solution if BPMN2 BPM meets all the defined requirements.

6. Conclusions

1. The abundance of the scholarly literature on modeling business processes and business rules shows that in order to model complex processes, one modeling method is not sufficient to convey different aspects of a process. Complex modeling standard evaluation has shown that BPMN and SBVR modeling languages are the most suitable ones. In addition, SBVR is expressed in a limited natural language understood by domain participants and can be processed by computer systems.
2. The analysis of existing solutions of business processes and business rules integration and transformation allowed to evaluate their advantages and disadvantages and also to define more complete mappings between BPMN and SBVR metamodels' elements and the transformation rules covering the full set of BPM elements.
3. The developed method provides an opportunity to form a comprehensive and consistent specification consisting of BPM and BV&BR. Depending on the cases in practice, the method can be used in two following specification scenarios:
   - 3.1. modeling graphical BPM based on BV&BR (supplement if necessary), and then transform it into the full set of BV&BR;
   - 3.2. modeling graphical BPM and then transform it into BV&BR.
4. The developed BPM into transformation BV&BR algorithm is based on the defined transformation rules and requirements for BPM which ensure the obtainment of BV&BR meeting the SBVR standard. The developed solution ensures:
   - 4.1. automatic BPM into BV&BR transformation without using linguistic text analysis;
   - 4.2. mutual compatibility between BPMN2 and SBVR models with the possibility of elements' traceability in one modeling environment;
   - 4.3. transformation result BV&BR compliance with the requirements under SBVR standard specification.
5. The created BPM into BV&BR transformation prototype in the CASE tool environment is based on the use of the UML profile mechanism enabling the extension of metamodels without changing them; consequently, the SBVR profile was used. The realization of the prototype showed that these transformations are possible and can be implemented in real life.
6. The experiment of BPM into BV&BR transformation confirmed the efficiency of the developed solution with the selected and adopted BPMs and showed that:

6.1. the results obtained by transforming the original VPM directly depend on the VPM itself, to what extent VPM meets the requirements for VPM defined in this work;
6.2. transformations can be applied for one business process but not for the process hierarchy, and that there is no possibility to distinguish among all the BPMN2 element (tasks, events, etc.) types. These issues can be solved by using two additional vocabularies: BPM V&T and BPMN2 concepts metavocabulary.

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1. **Mickevičiūtė, Eglė**; Nemuraitė, Lina; Butleris, Rimantas. Improving BPMN2 Business Process Model to SBVR Business Vocabulary and Business Rules Transformation with BPMN2 Event Naming Patterns // *Information Technology and Control, 45(4), IT&C 2016*. ISSN: 1392-124X, pp. 443–451.
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3. **Mickevičiūtė, Eglė**; Nemuraitė, Lina; Butleris, Rimantas. Applying SBVR Business Vocabulary and Business Rules for Creating BPMN Process Models // Business Information Systems Workshops: BIS 2014 International Workshops, Larnaca, Cyprus, May 22–23, 2014: Revised Papers / Editors: Abramowicz, Witold and Kokkinaki, Angelika. Cham: Springer International Publishing, 2014. (*Lecture Notes in Business Information Processing, 183,* ISSN 1865-1348), ISBN 9783319114590. pp. 105–116.
4. **Mickevičiūtė, Eglė**; Butleris, Rimantas. Towards the Combination of BPMN Process Models with SBVR Business Vocabularies and Rules // Information and Software Technologies: 19th International Conference, ICIST 2013, Kaunas, Lithuania, October 10–11, 2013: proceedings / [edited by] Skersys, Tomas; Butleris, Rimantas and Butkiene, Rita. Berlin, Heidelberg: Springer, 2013. (*Communications in Computer and Information Science*, Vol. 403, ISSN 1865-0929), ISBN 9783642419461. pp. 114–121.

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REZIUMĖ

VEIKLOS ŽODYNŲ IR VEIKLOS TAISYKLIŲ SEMANTIKA GRINDŽIAMAS VEIKLOS PROCESŲ VAIZDAVIMAS

Motyvacija

Informacinių sistemų kūrimas prasideda nuo veiklos procesų modeliavimo ir veiklos žodyno bei taisyklių identifikavimo. Daugeliu atvejų sunkumai atliekant reikalavimų analizę ir modeliuojant veiklos procesus kyla dėl nevisiškai išsiaiškintos veiklos logikos, kuri apibrėžiama veiklos taisyklėmis ir veiklos procesais (Andreescu, Mircea, 2014). Norint turėti pilną ir išsamią veiklos procesų modelio specifikaciją, tikslinga taikyti kelis veiklos modeliavimo standartus, kuriuose nagrinėjami skirtingi veiklos aspektai ir kartu suteikiama galimybė bet kuriam veiklos dalyviui pasirinkti tokį veiklos proceso vaizdavimo būdą, kuris yra jam priimtiniausias. Pasirinktas priimtinesnis proceso vaizdavimo būdas gali paspartinti bei pagerinti komunikaciją tarp veiklos dalyvių, padėti jiems išvengti nesusikalbėjimų dėl neteisingų interpretacijų ar terminų vartojimo; ypač tais atvejais, kai modelis yra didelis ir dėl to sunkiai skaitomas.

Veiklos procesų modeliavimas yra svarbus etapas informacinių sistemų kūrimo procese (Vasconcelos et al., 2001; Sinogas et al., 2001; Barjis, 2008; Kovalova, Turcok, 2014) ir būtinas norint suprasti, valdyti, optimizuoti veiklos procesus, įtraukti naujas arba atskirti esamas veiklos proceso veiklas ar jos dalis. Veiklos žodynas ir veiklos taisyklės yra kiekvieno veiklos procesų modelio dalis, kuri daro įtaką visoms jos sritims (Vasilecas, Lebedys, 2006), ir vargu ar egzistuoja nors viena veiklos sistema, kuri neturi tikslų, misijos bei veiklos taisyklių

(Lovrencic et al., 2006). Kadangi veiklos procesų modeliavimas ir veiklos taisyklių modeliavimas yra laikomi vienas kitą papildančiais metodais – atsiranda poreikis šiuos du modelius taikyti kartu. Veiklos žodyno ir veiklos taisyklių taikymas kuriant veiklos procesų modelius naudingas ir tuo, kad organizacija gali gauti vieningą veiklos žodyną, t. y. terminus, kurie vartojami žodine ar rašytine forma organizacijos veikloje ir yra priimti kaip veiklos konceptai. Toks žodynas suteikia galimybę pagerinti veiklos suvokimą ir išvengti nesusipratimų tarp dalykinės srities atstovų bei IT specialistų. Be to, būtent veiklos žodynas suteikia galimybę sujungti dinaminius (proceso elgsena) ir statinius (apribojimai, informaciniai srautai) proceso aspektus.

Palaikyti vientisumą tarp atskirai sumodeliuoto veiklos proceso ir atskirai aprašytų veiklos taisyklių nėra paprasta: nuolat kinta reikalavimai, atsiranda naujų kintamųjų, naujų sąvokų ar terminų – tokiu atveju papildant minėtus modelius naujomis žiniomis kyla rizika atsirasti prieštaravimams, nesutapimams ar kitoms spragoms. Norint veiklos procesų bei veiklos taisyklių modelius susieti tarpusavyje kyla sunkumų, kadangi veiklos procesams modeliuoti yra naudojamos grafinės notacijos, o žodynas ir veiklos taisyklės yra sudaromos naudojant ribotą natūralią kalbą.

Darbe yra siekiama integruoti veiklos procesų ir veiklos taisyklių modeliavimo standartus išsamiai bei darniai veiklos procesų specifikacijai gauti. Sprendimas pagrįstas BPMN2 ir SBVR modeliavimo standartais išsiaiškinus, kad kompleksinis jų taikymas leidžia geriausiai perteikti realaus pasaulio objektus bei procesus. Dviejų modelių suderinamumui užtikrinti realizuota galimybė transformuoti grafinius BPMN2 veiklos procesų modelius į SBVR veiklos žodynus ir veiklos taisykles su galimybe susieti jų elementus vieno *MagicDraw* CASE įrankio aplinkoje.

Tyrimo sritis ir objektas

Tyrimo sritis. Veiklos procesų ir veiklos taisyklių modeliai, vaizdavimo metodai, kalbos, įrankiai.

Tyrimo objektas. Veiklos procesų ir veiklos taisyklių specifikavimo, vaizdavimo ir susiejimo su taikomosios programinės įrangos modeliais procesas, apimantis visą veiklos procesų ir veiklos taisyklių gyvavimo ciklą.

Problema

Darbe yra sprendžiama veiklos procesų, veiklos žodynų bei veiklos taisyklių susiejimo ir dalykinės srities ekspertams suprantamo veiklos aprašymo, kuris atititiktų modelių formalius aprašymus, problema. Veiklos procesų modeliavimas ir veiklos taisyklių modeliavimas yra laikomi vienas kitą papildančiais metodais, jų taikymas kartu modeliuojant sudėtingus veiklos procesus leidžia apimti skirtingus veiklos aspektus (dinaminius, kurie nusako proceso elgseną, ir statinius, kurie parodo apribojimus bei informacijos srautus) ir įtraukti visus su veikla susijusius dalyvius. Atsiranda suderinamumo tarp modelių problema, nes veiklos procesai paprastai išreiškiami grafiniu būdu, o veiklos taisyklės – deklaratyviu būdu, todėl šių dviejų modeliavimo metodų taikymas kartu, jų suderinamumas, veiklos žodyno bei veiklos taisyklių išgavimas iš grafinių veiklos procesų modelių, norint įtraukti dalykinės srities ekspertus į projektavimo etapą, yra plačiai nagrinėjamos temos. Atsiranda poreikis turėti darnias, aiškias veiklos procesų ir veiklos taisyklių specifikacijas, kurios suteiktų galimybę suprasti bei patikrinti veiklos procesus ir veiklos taisykles, pagerintų veiklos dalyvių tarpusavio susikalbėjimą organizacijos ar kelių organizacijų mastu.

Tyrimas turi atsakyti į šiuos klausimus:

1. Ar įmanoma grafinius veiklos procesų modelius išreikšti deklaratyviu būdu, naudojant ribotą natūralią kalbą?
2. Ko reikia norint gauti veiklos žodynus bei veiklos taisykles iš grafinių veiklos procesų modelių netaikant lingvistinių metodų?
3. Kokios grafinių veiklos procesų modelių savybės gali padėti pagerinti veiklos žodynų bei veiklos taisyklių korektišką išgavimą?
4. Ko reikia norint atlikti abipusę transformaciją tarp veiklos procesų ir veiklos žodynų bei veiklos taisyklių modelių?
5. Ar galima realizuoti veiklos žodynų bei veiklos taisyklių išgavimą iš grafinių veiklos procesų modelių su galimybe susieti šių modelių elementus vienoje modeliavimo aplinkoje?

Tyrimo tikslas ir uždaviniai

Tyrimo tikslas. Sudaryti sąlygas kurti integruotus veiklos procesų ir taisyklių modelius veiklos dalyviams suprantama kalba, sukuriant metodą ir priemones, kurios leistų suformuoti išsamią bei darnią veiklos procesų specifikaciją (grafinį VPM ir VŽ&VT) vieno įrankio aplinkoje.

Uždaviniai:

1. Išanalizuoti literatūrą, susijusią su veiklos procesų, veiklos žodynų ir veiklos taisyklių modeliavimo būdais, kalbomis, metamodeliais, modeliavimo kalbų vertinimo metodikomis, integracija, transformacija bei esamais sprendimais.
2. Sukurti metodą, kuris leistų išreikšti grafinius procesų modelius veiklos žodyno konceptais bei veiklos taisyklėmis, ir tam aprašyti transformavimo taisykles bei algoritmus, taip pat įvertinant atvirkštinės transformacijos galimybes.
3. Realizuoti grafinių procesų modelių transformavimo į veiklos žodynus ir veiklos taisykles komponento prototipą CASE įrankio aplinkoje.
4. Atlikti eksperimentą tyrimo rezultatų tinkamumui įvertinti.

Tyrimų metodika

Išanalizuoti esami veiklos procesų, veiklos žodynų ir taisyklių sudarymo bei vaizdavimo metodai, kalbos, metamodeliai, modeliavimo įrankiai. Analizei atlikti pritaikyti informacijos paieškos, analizės, sisteminimo, lyginamosios analizės, struktūrinės analizės bei apibendrinimo metodai.

Veiklos žodyno ir veiklos taisyklių suderinamumui bei integracijai su veiklos procesų modeliu taikyti konceptualaus modeliavimo, sisteminės procesų analizės, sistemų procesų inžinerijos bei modeliavimo metodai. Veiklos procesų modelio transformacijai į veiklos žodyną ir veiklos taisykles taikytas konceptualus taisyklių sudarymo metodas taikant EBNF notaciją.

Eksperimentiniams tyrimams atlikti taikytas disertacijos tyrimams sukurtas prototipinis įrankis, transformuojantis veiklos procesus į veiklos žodyną ir veiklos taisykles pagal sukurtas transformavimo taisykles. Eksperimentinio tyrimo rezultatams gauti buvo taikomi kiekybinio vertinimo, ekspertinio vertinimo, apibendrinimo bei lyginamosios analizės metodai.

Tyrimas buvo vykdomas pagal „Design Science" metodą (Hevner et al., 2004): atlikta egzistuojančių sprendimų analizė, sukurti nauji artefaktai (nagrinėjamų modelių transformacijos taisyklės), atliktas eksperimentinis tyrimas su sukurtu prototipu, apibendrinti gauti rezultatai.

Ginamieji teiginiai

1. Aprašytas išsamus BPMN2 ir SBVR metamodelių elementų atitikimas leidžia sukurti VPM transformacijos į VŽ&VT taisykles, leidžiančias automatiškai išgauti VŽ&VT iš VPM.
2. Sukurtas metodas leidžia suformuoti išsamią bei darnią specifikaciją, susidedančią iš VPM ir VŽ&VT modelių pagal du skirtingus scenarijus.
3. Apibrėžti reikalavimai VPM elementams leidžia automatinės transformacijos metu netaikant lingvistinių metodų gauti semantiškai korektiškus bei SBVR standartą atitinkančius veiklos žodyną ir veiklos taisykles.
4. Transformavimo algoritmas leidžia automatiškai iš VPM išgauti VŽ&VT, tačiau atvirkštinės transformacijos vykdymui vien tik VŽ&VT nepakanka, būtina naudoti du papildomus žodynus BPMN2 modelio informacijai išsaugoti.

Darbo mokslinis naujumas

Disertacijoje pasiūlytas metodas suteikia galimybę automatiškai gauti vientisą, išsamų, tarpusavyje suderintą veiklos žodynų, veiklos taisyklių ir veiklos procesų modelio taisyklių aprašymą, susietą su grafiniu veiklos procesų modeliu tam netaikant jokių lingvistinių metodų. Tai pasiekiama naudojant aprašytą BPMN2 konceptų metažodyną, taikant sukurtas transformavimo taisykles bei algoritmus ir veiklos procesų modelių sudarymo reikalavimus.

Darbo rezultatų teorinė ir praktinė svarba

Sukurtas metodas, teikiantis galimybę kurti išsamesnius ir tikslesnius tarpusavyje suderintus veiklos procesų bei taisyklių modelius. Šiam metodui patikrinti sukurtas prototipinis įskiepis *MagicDraw* CASE įrankyje.

Teorinė svarba: ištirtos veiklos procesų, veiklos žodyno ir veiklos taisyklių integravimo bei transformavimo galimybės siekiant susieti veiklos procesų, veiklos žodyno ir taisyklių modelius vienoje modeliavimo aplinkoje; atskirtos veiklos taisyklės nuo veiklos procesų modelio taisyklių; apibrėžti reikalavimai veiklos procesų modelio elementų vardams; sukurtos transformavimo iš veiklos procesų modelio į veiklos žodyną bei veiklos taisykles taisyklės; teoriškai išnagrinėtos bei aprašytos atvirkštinės transformacijos iš SBVR veiklos žodyno ir veiklos taisyklių į BPMN2 veiklos procesų modelį, tam papildomai naudojant BPMN2 veiklos procesų modelio žodyną ir taisykles, kurios sudaromos naudojant BPMN2 konceptų metažodyną; sudarytos gerosios veiklos procesų modeliavimo gairės.

Praktinė svarba: galimybė automatiniu būdu transformuoti veiklos procesų modelį į veiklos žodyną bei veiklos taisykles ir gautą modelį pateikti veiklos dalyviams validuoti; galimybė papildomai automatinio transformavimo metu iš veiklos procesų modelio gauti veiklos procesų modelio žodyną ir taisykles atvirkštinės transformacijos galimybei įgyvendinti, kad būtų išsaugota visa veiklos procesų modelio informacija; galimybė turėti du modelius, pagal kuriuos nagrinėjami skirtingi veiklos aspektai, vienoje aplinkoje, ir kurių elementai yra tarpusavyje susieti, taip sumažinant neatitikimų galimybę; veiklos žodyno elementus panaudoti keičiant/papildant veiklos procesų modelį; suformuoti vieningą organizacijos veiklos žodyną. Tokių sprendimų iki šiol nėra realizuotų CASE įrankiuose.

Disertacijos rezultatų naudojimas projekte, autorinis indėlis

Disertacijos tematika atlikti integravimo bei transformavimo galimybių tyrimai ir kiti susiję su šiomis temomis darbai buvo atlikti vykdant projektą „Veiklos procesų ir veiklos taisyklių integravimas veiklos semantikos pagrindu“ (VP131V008F) 2013–2015 metais (kitaip dar vadinamas VEPSEM). SBVR profilis, transformacijos matricų, transformacijų taisyklių vaizdavimo formatai ir vartojamos notacijos bei atsekamumo ryšių kūrimo idėja yra perimta iš VEPSEM projekto.

Visų pateiktų transformacijų matricų turinys, aprašytos taisyklės, sudarytas BPMN2 konceptų metažodynas, modeliavimo metodas taikant šiame darbe sukurtą sprendimą, transformacijų iš BPMN2 veiklos procesų modelių į SBVR veiklos žodynus ir veiklos taisykles realizacija pritaikant aprašytą SBVR profilį bei sudaryta geroji VPM modeliavimo praktika yra laikomi autoriniais sprendimais.

Sukurtas sprendimas pritaikytas anglų kalbai, kadangi ji yra viena iš labiausiai paplitusių kalbų pasaulyje (įvertinant ir techninės literatūros paplitimą), be to, sprendimas realizuotas plačiai naudojamame *MagicDraw* CASE įrankyje, kadangi Lietuva panašių įrankių neturi. Sukurto sprendimo taikymas lietuvių kalbai susiaurintų jo pritaikomumą.

Išvados

1. Literatūros apie veiklos procesų ir veiklos taisyklių modeliavimą gausa rodo, kad norint modeliuoti sudėtingus procesus vieno modeliavimo būdo neužtenka norint perteikti skirtingus veiklos aspektus. Kompleksinis

modeliavimo standartų vertinimas parodė, kad tam tinkamiausios yra BPMN ir SBVR modeliavimo kalbos, be to, SBVR išreiškiama ribota natūralia kalba, suprantama visiems veiklos dalyviams bei gali būti apdorojama kompiuterinių sistemų.

2. Atlikta veiklos procesų ir veiklos taisyklių integravimo bei transformavimo sprendimų analizė leido įvertinti esamų sprendimų privalumus bei trūkumus ir apibrėžti išsamesnius BPMN2 ir SBVR metamodelių elementų tarpusavio atitikimus bei transformacijos taisykles, apimančias pilną VPM elementų aibę.
3. Sukurtas metodas suteikia galimybę turėti išsamią bei darnią veiklos procesų modelio specifikaciją, susidedančią iš VPM ir VŽ&VT. Atsižvelgiant į praktikoje pasitaikančius atvejus metodas įgyvendina šiuos specifikavimo scenarijus:
   3.1. formuoti grafinius VPM, remiantis VŽ&VT (papildant jei reikia), o vėliau VPT transformuoti į pilną VŽ&VT rinkinį;
   3.2. formuoti grafinius VPM ir vėliau VPT transformuoti į VŽ&VT.
4. Sukurtas algoritmas VPM į VŽ&VT transformuoti paremtas šiame darbe aprašytomis transformacijos taisyklėmis bei reikalavimais VPM, užtikrinančiais SBVR standartą atitinkančių VŽ&VT sudarymą. Sukurtas sprendimas užtikrina:
   4.1. automatinį VPM transformavimą į VŽ&VT netaikant lingvistinės teksto analizės;
   4.2. abipusį BPMN2 ir SBVR modelių suderinamumą bei susiejimą vienoje kūrimo aplinkoje su VŽ elementų atsekamumo galimybe;
   4.3. gauto transformacijos rezultato VŽ&VT atitikimą keliamiems reikalavimams pagal SBVR standarto specifikaciją.
5. Realizuotas VPM į VŽ&VT komponento prototipas CASE įrankio aplinkoje, kuris remiasi UML profilių mechanizmo panaudojimu, leidžiančiu išplėsti metamodelius jų nekeičiant, todėl realizacijai buvo panaudotas SBVR profilis. Įrankio prototipo, leidžiančio vykdyti VPM transformaciją į VŽ&VT, realizacija parodė, kad šios transformacijos yra įmanomos bei įgyvendinamos.
6. Atliktas VPM transformavimo į VŽ&VT eksperimentas patvirtino sukurto sprendimo efektyvumą su pasirinktais adaptuotais VPM bei parodė, kad:
   6.1. transformuojant pirminius VPM gauti rezultatai tiesiogiai priklauso nuo pačių VPM – kiek VPM tenkina šiame darbe apibrėžtus reikalavimus VPM;
   6.2. transformacijas galima taikyti vienam atskiram veiklos procesui, bet ne procesų hierarchijai, taip pat negalima atskirti visų BPMN2 elementų (užduočių, įvykių ir t. t.) tipų; todėl norint išsaugoti šią informaciją atvirkštinės transformacijos galimybei būtina papildomai naudoti VPM Ž&T ir BPMN2 konceptų metažodyną.

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