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A Meta-Meta-Model For Seven Business Process Modeling Languages

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***Abstract*— Many different business process modelling languages (BPMLs) have been designed in recent years. In cross-organizational business processes and heterogeneous organizations where multiple BPMLs are deployed there is a need for a unified view to ease communication and foster understandability. This paper proposes a language independent abstraction of seven mainstream BPMLs' concepts, in a unified meta-meta model based on an analysis of these modelling languages. Generic concepts are identified and a unified meta-model is developed. An ontological analysis of the representational capability of this meta-model is examined in relation to the Bunge-Wand-Weber ontology and applicability of the approach is demonstrated via an Example.**

Keywords*— *Business process; Business process modelling; Business process meta-meta model; Business process ontology; BWW ontology.

I. INTRODUCTION

Business Process Modelling (BPM) is currently not only of core importance for business process engineering, analysing and improving business processes but also in development of software systems to support the business processes [1]. A proliferation of business process modelling languages (BPMLs) currently exists [2] and is a notorious problem for business process management [3]. Standardization has been discussed for more than ten years, none of the proposals is commonly accepted as de facto standard in the industry [3].

Overcoming this problem, different authors propose different approaches mainly for bridging the gap between the design (i.e. conceptual modelling) and the implementation (i.e. executable specifications) phases of business process management. Hornung et al. [4] present an integration methodology used to integrate and consolidate heterogeneous BPM meta-models. They apply this methodology to the integration of XPDL 2.0 (as an interchange format for BPMN) and BPEL 2.0 (standards for process execution). Mendling et al. [3] introduce an interchange format for moving business process models between tools of different vendors. In a different approach van der Aalst [5] introduces workflow patterns framework as a collection of generic and recurring constructs.

Focusing on conceptual modelling of business processes (i.e. design phase), there are increasingly many situations (e.g. distributed projects) where a single BPML is neither practical nor feasible as project participants use different modelling languages. From a theoretical perspective, it is vital to have a clear understanding of the semantics of these approaches, their overlaps, differences and similarities. Only then does it become possible to systematically and objectively understand the potential contribution of each BPML.

Mendling et al. [3] realize the need for a reference model for BPM that unifies the different perspectives on modelling business processes. To this purpose, this paper proposes an abstraction that integrates seven mainstream BPMLs' concepts into a single and unified meta-model. Section 2 discusses the methodology used for development of the meta-meta-model. Section 3 presents the business process meta-model. Section 4 discusses an ontological analysis of the meta-model against the Bunge-Wand-Weber (BWW) [9] ontology as an upper ontology. Section 5 elaborates on application of the meta-meta-model. Section 6 presents a brief summary of the investigation of the related works. The paper concludes in Section 7 with a number of observations and suggestions for future work while highlighting the limitations of the research.

II. TOWARDS AUNIFIED META-MODEL

A meta-model is an explicit model of the constructs and rules needed to build specific models within a domain of interest. A valid meta-model is an ontology, as its constructs and rules represent entities in a domain. For the ontology introduced in this research, the domain is "business process modelling". An ontology makes knowledge explicit, expressing the concepts and relationships between them in a language close to the natural language, fostering an "understanding bridge" between business and IT experts [6]. Meta-modelling is classified as positivism in epistemology and realism in ontology. [7] In essence, a meta-modelling approach aims to be independent of an observer's appreciation of the modelling languages providing an intuitive way to specify modelling languages [8].

Meta-models are utilized to solve two fundamental types of task namely, design and integration [9]. Design involves the creation of meta-models for both the prescriptive definition of not yet existing as well as the descriptive modelling of already existing "subjects" of interest. Integration, on the other hand, denotes the application of meta-modelling for bringing together different existing

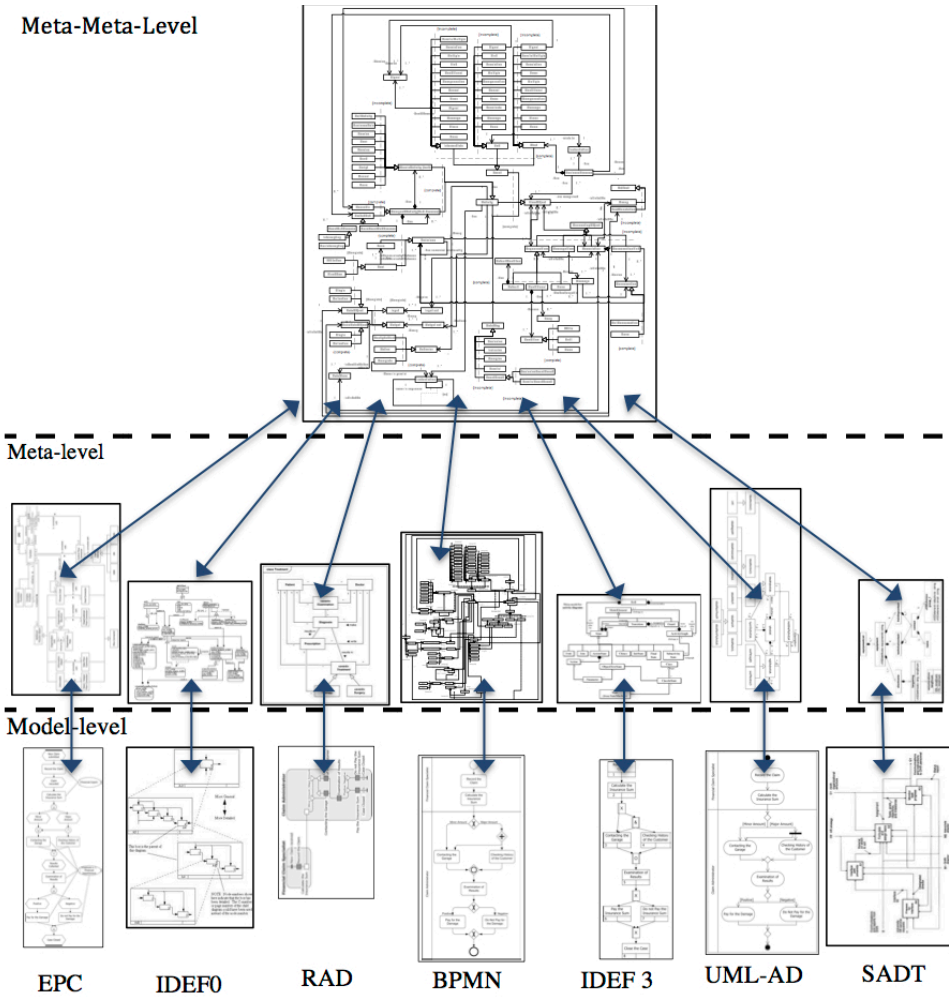

Fig 1. Integrating business process Modelling languages

"artefacts" of potentially various kinds generated using different meta-models.

The approach is to create a unified meta-meta-model for the purpose of "integration". The extensible unified business process meta-model proposed provides a language-independent business process ontology. The mainstream BPMLs on which it is based are: Business Process Modelling Notation (BPMN), Integrated Definition for Function Modelling (IDEF0 and IDEF3), Role Activity Diagram (RAD), Unified Modelling Language Activity Diagram (UML-AD), Structured Analysis and Design Technique (SADT), and Event-driven Process Chain (EPC). Each concept of these BPMLs is mapped onto only one concept in the unified business process meta-meta-model.

According to Karagiannis et al. to be able to define mapping relationships between different models (model-level) a common generic meta-meta-model is needed to which the concepts of the different meta-models correspond. This common meta-meta-model facilitates also the comparability of meta-model concepts with one another [9].

Fig.1 depicts the process of integration with 3 levels of models: model-level, meta-level and meta-meta level. Different representations of a single business process in the aforementioned BPMLs are shown at the lowest level of the abstraction, the model-level, together with their meta-level representations as the second level. An integrating meta-meta model is presented at the highest level. The BPM meta-meta model development process includes the steps of (1) generating the individual BPM meta-models, (2) concept mapping, and (3) concept integration.

The meta-models of the BPMLs are generated. Prerequisites for being able to establish a meaningful connection and mappings at the model-layer are corresponding links at the meta-level. Mapping implies the definition of concepts of different meta-models that are related [9]. The meta-models are heterogeneous, i.e semantically related concepts are captured by different meta-models in different ways, e.g. using different names or different structure. Concepts of these meta-models are analysed and the ones expressing similar aspects of reality are grouped together and mapped to a single concept in the meta-meta-level. The integrating meta-model is expected to be complete in capturing all concepts of the meta-models [4]. Integration means to find a logical correspondence between instances of the model-layer. The transformational aspect of the integration [9] allows for the next level of mapping, namely mapping the concepts representing the same aspects of reality to a single concept in meta-meta-level.

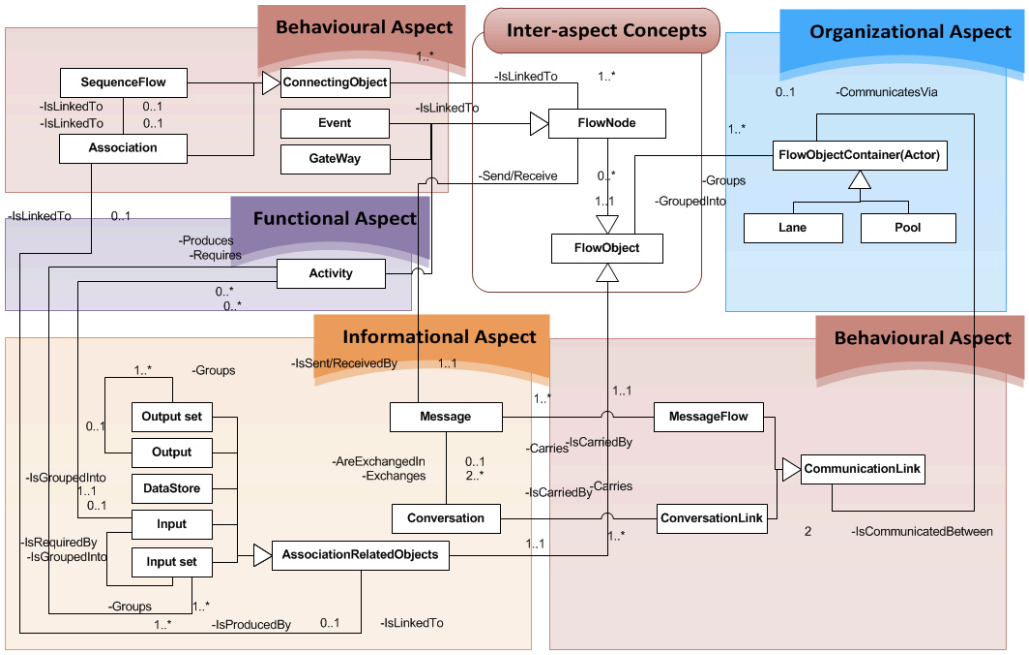

Fig 2. The overview of the business process meta-meta-model in relation to different aspects

The main assumption in the integration is that the languages (i.e. BPMLs) in a specific domain (i.e. BPM) express similar concepts. This makes it possible to create a common integrated meta-model. Conceptually, this integrating meta-model represents a union of all the concepts found in the BPMLs [2]. This paper argues the need to view modelling concepts through a lens that focuses on the ability to express different aspects of a business process rather than detailed semantics and syntax of the language used. Thus, interoperability mapping, with semantically identical concepts, is not subject of research. Concepts such as activity, action, unit of behaviour and task represent the executable concept of a business process.

III. THE META-META-MODEL FOR BPMLS

The concepts of the unified business process meta-model are categorized into different aspects of a business process namely: *functional*, *behavioural*, *organizational* and *informational* aspects.

Fig.2 depicts the business process meta-meta-model in terms of the main concepts and in relation to different aspects in a UML class diagram. Fig. 3 to 6 classify concepts of the meta-meta-model related to different business process aspects, in addition to inter-aspects relationships (concepts in grey). Concepts of Fig.2 (i.e. main concepts) occuring in Fig.3 to 6 are recognizable by their thicker borders.

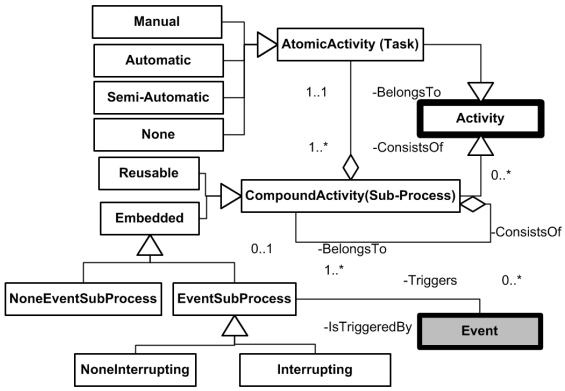

Fig 3. Business process meta-model: Functional aspect

Fig.3 depicts the concepts representing the functional aspect. These concepts are executable concepts of a business process. Fig.4 depicts the concepts representing the organizational aspect required to demonstrate executers (actors) of a business process. Fig.5 depict the concepts representing the behavioural aspect required to demonstrate coordination between different participants as well as the concepts that effect, trigger or control the flow in a business process. Fig.6 depicts the concepts representing the informational aspects required to demonstrate "inputs" and "outputs" of a business process as physical or data objects as well as "messages" or "conversations" exchanged between different executers. Mapping different concepts of the meta-model, and the BPMLs for different aspects are provided in Table 1. The terminology of the concepts at the meta-meta-level is freely chosen.

The proposed business process ontology represents an abstraction of the business process concepts, is universal and not dedicated to a single BPML. The business process ontology clarifies the exact relationships between the

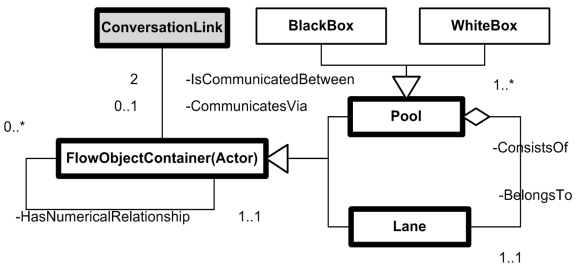

Fig 4. Business process meta-model: Organizational aspect

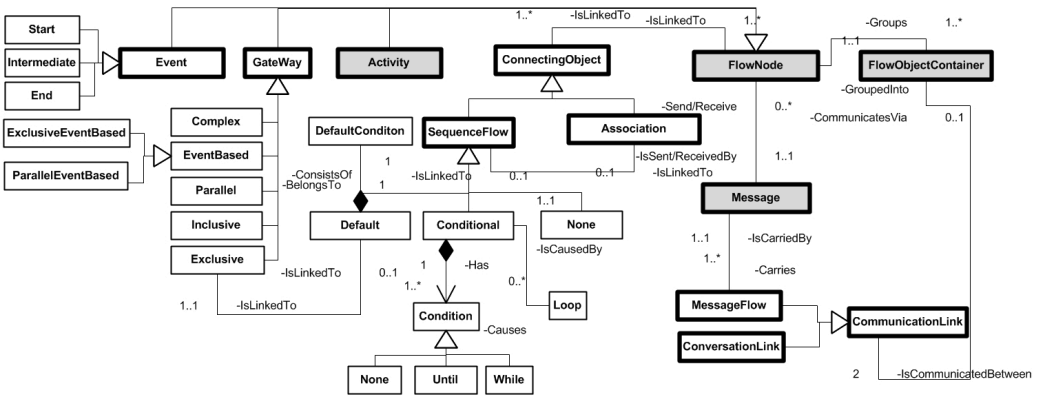

Fig 5. Business process meta-model: Behavioural aspect

concepts. Moreover, it provides an adequate semantic specification prohibiting invalid interpretations by experts in different domains. The ontology also provides an abstraction upon which elicitation, definition and documentation of requirements can happen.

This business process ontology -as a repository- can have several applications: (a) to represent models created via deploying any of the BPMLs as its instantiations, (b) to act as a reference between multiple BPMLs of the same project, (c) to provide the basis for developing a repository for managing emerging business process models irrespective of the language used, (d) to be extended to a knowledge base, (e) to facilitate direct implementation, and (f) to act as a reference model fostering incorporation of the stakeholders' requirements.

IV. Ontological Analysis of the Meta- Meta-Model

The ontological analysis is an established theoretical approach to evaluate modelling languages, in particular to evaluate their expressiveness (i.e. completeness). The ontological analysis requires a representation mapping of the ontological concepts to its corresponding meta-model concepts. This provides useful information for identifying the degree of clarity and completeness of the notation.

Following the justifications by Recker et al. [10], the BWW ontology [11] is chosen in this paper for the ontological analysis of the meta-model as: (a) it has specifically been derived with the information systems discipline in mind, (b) it serves as an upper ontology for modelling information systems, and its foundational character and comprehensive scope allow for wide range of applicability, and (c) there is an established track record of individual studies and a demonstrated usefulness of representational analyses of modelling languages using the representation model, which allows comparison of the results with other studies. The process of using the BWW model as a reference benchmark for the evaluation of the representational capabilities of a modelling language forms the core of the research method of representational analyses (e.g.[12]). Representational analyses can be used to make predictions of the modelling strengths and weaknesses of the language, viz., its capabilities to provide complete and clear descriptions of the domain [10]. The aim is to show how the meta-meta model is successful in expressing BWW concepts (Table 2).

Note that the unified meta-model does not include state-oriented concepts that are very situation specific [12]. The BWW ontology, in turn has limited concepts for expressing control concepts (e.g. Loop, gateway).

V. Demonstration of Applicability

This section demonstrates applicability of the business process ontology as a repository able to represent models by the BPMLs. The example "processing of automobile insurance claim" is adapted from [13]. The business process is modelled in BPMN, RAD, IDEF3, UML AD and EPC. Protégé is used to create valid instantiations. Due to space limitations, Protégé presentations of the models cannot be

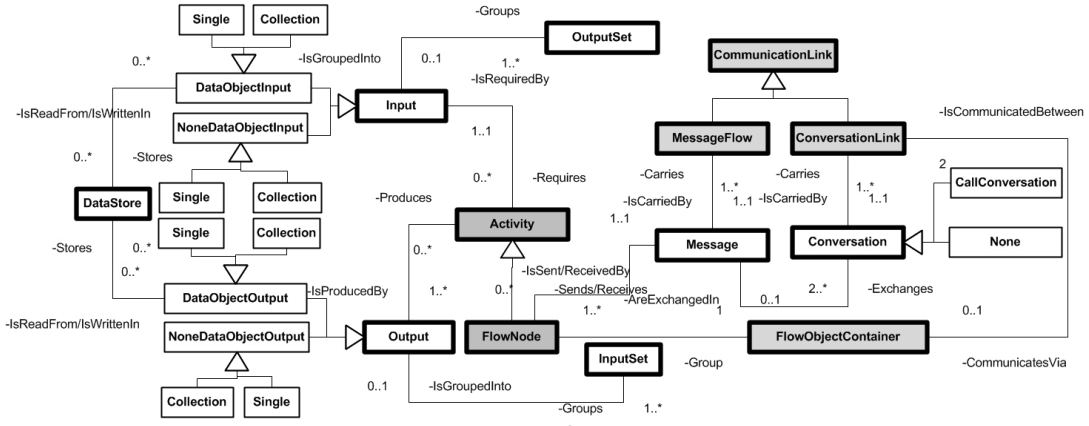

Fig 6. Business process meta-model: Informational aspect

TABLE I. META-MODEL AND THE BPMLS CONCEPTS MAPPING

	Meta-Model	BPMN	RAD	EPC	SADT	UML AD	IDEF0	IDEF 3
Functional	Activity	Activity	Activity	Function	----	Action	Function	Unit of behaviour
Organizational	Flow Object Container	Swimlane	Role	Organizational unit	----	Partition	-----	-----
Informational	Message	Message	----	----	----	Signal	----	----
	Conversation	Conversation	----	----	----		----	----
	Signal	-----	----	----	----		----	----
	Input	Data Input	----	Information/ material/ resource object	Input/ mechanism	Object node	Input/ mechanism	Object
	Output	Data Output	Output/role deliverable	----	Output	----	Output	----
	Data Store	Data Store	----	----	----	----	----	----
Behavioural	Event	Event	Event/ Triggering Condition	Event	Control	Initial/ Final node	Control	----
	Communication link	Conversation link/Message flow	Role Interaction	Information flow	----	Object flow	----	Object flow link
	Default condition	Default condition	Choice	----	----	Control	Control	----
	Connecting object	Sequence flow/Data association	State	Control flow	Control	Interaction-Control flow	Control	Precedent/ Relational link
	Condition	Condition	Choice	Action Constraint	Control		Control	-----
	Gateway	Gateway	Choice/ Part refinement	And/XOR/ OR	Control	Decision node/ join node	Control	And/XOR/ OR Junction

included.

Table 3 depicts the similarities between concepts with regard to different aspects: e.g. activity (BPMB, RAD), action (UML AD), function (EPC) and unit of behaviour (IDEF3). Not only does this approach show similarities but also gives a view of the differences. Note that some of the notations lack a distinctive concept for a particular purpose, e.g. executer in the organizational aspect represented by instances like "Financial Expert" is not covered by IDEF3 concepts, as there is no "concept" introduced with the purpose of demonstrating executers of an activity in IDEF3.

VI. RELATED WORK

The business process meta-models and ontology currently proposed in the literature are discussed below, focussing on:

A. Reference: What was the reference for creating the business process meta-model?
B. Language-dependency: Is the business process meta-model language-dependent?

In a claim of having a language independent approach, Axenath et al. [14] introduce an aspect-oriented meta model.

TABLE III. COMPARISON BETWEEN BPMLS AND META-MODEL CONCEPTS

No	Meta-Model	Aspect	BPMN	RAD	EPC	UML AD	IDEF 3
1	Message	Informational	Message	----	----	----	----
2	Message Start Event	Behavioural	Message Start Event	Event	Start	Initial Node	----
3	None Sequence Flow	Behavioural	None Sequence Flow	State	Control Flow	Control Flow	Precedence Link
4	Activity	Functional	Activity	Activity	Function	Action	Unit of Behaviour
7	Message Flow	Behavioural	Message Flow	Role Interaction	Information Flow	Object Flow	----
9	Exclusive Gateway	Behavioural	Exclusive Gateway	Choice	XOR Split	Decision Node	XOR Junction
10	Conditional Sequence Flow	Behavioural	Conditional Sequence Flow	----	----	----	Constraints Precedence Link
12	Condition	Behavioural	Condition	Choice	Event	----	Control
14	Parallel Gateway	Behavioural	Parallel Gateway	Part Refinement	And Join/Split	Fork/Join Node	AND Junction
21	Inclusive Gateway	Behavioural	Inclusive Gateway	----	XOR Join	Merge Node	XOR Junction
32	Terminate End Event	Behavioural	Terminate End Event	Event	End Event	Final Node	-----
33	White box Pool	Organizational	White box Pool	Role	Organizational Unit	Partition	----

TABLE II. REPRESENTATIONAL MAPPING OF BWW AND THE META-MODEL CONCEPTS

No	BWW	Meta-model	No	BWW	Meta-model
1	Things	Flow object container, input, output, signal, data store, message, conversation, condition	16	Coupling	Communication link
2	Properties	Attributes of the thing	17	System	Flow object container
3	Class	Association related object, flow node, flow object, flow object container, communication link, connecting object	18	System composition	----
4	Kind	Sub-types of mentioned classes	19	System environment	----
5	State	----	20	System Structure	----
6	Conceivable state space	----	21	Subsystem	Lane
7	Space law	----	22	System decomposition	----
8	Lawful state space	----	23	Level structure	----
9	Event	Event	24	External event	Event
10	Conceivable event space	----	25	Stable state	---
11	Transformation	Activity	26	Unstable state	
12	Lawful transformation	Sequence flow	27	Internal event	Event
13	Lawful event space	----	28	Well-defined event	End event
14	History	----	29	Poorly defined event	Start event, intermediate event
15	Acts on	Communication link			

The work is strongly inspired by workflow management literature and does not consider actual BPMLs' concepts.

An approach for transforming between different business process models is introduced in [2]. In doing so, the authors introduce an integrated language (IntL) via participating several languages namely, ADONIS, BPMN, EPC, and UML AD. The IntL is limited to 14 concepts.

Aldin's [15] business process ontology is based on the concepts identified in five business process definitions offered between 1992 and 1995. The author identifies six types of generalization and their use is demonstrated.

With the aim of improving the semantic completeness and expressiveness of business process models according to domain knowledge, Si-Said Cherfi et al. [16] introduce a meta-modelling approach to align business process models and domain knowledge. Their domain ontology represents business knowledge and rules of the underlying problem domain. Their meta-model represented in natural language, is based on the two definitions offered on business process.

An approach for classifying business processes is introduced in [17] with the aim of developing information systems via BPM. They introduce a business process meta-model and partition it into different views, namely: informational, functional, dynamic and organizational views. Their preferred approach for modelling business processes is object-oriented languages; however, they do not mention the bases for the formation of the meta-model.

A business process meta-model including main concepts of performer, task and transition is offered in [18]. The source of the meta-model is not clear, however, the authors introduced a mapping schema for mapping the notation dependent concepts (concepts from UML-AD and GRADE BM) to the notation-independent concepts (the business process meta-model concepts).

Jenz [6] introduces a business process ontology in order to represent the top-level ontology layer of the Business

Management Ontology. As a higher level of business management is considered, concepts like: business goal, business rule, community, country, currency, organizational chart, etc. are also included in the ontology. Some overlapping constructs and redundancies exist in the introduced business process ontology (e.g. person, pool, and organization unit).

Most approaches refer to business process definitions for creation of the ontology. Others define their ontology based on the concepts defined in BPMLs. Business process meta-models and ontologies differ with respect to language dependency: some are dedicated to a single BPML and others define a generic business process ontology/meta-model. The current research is based on the results of the related works and related works have encouraged this research and show that there is a need for language-independent and multi-BPMLs-source business process meta-meta-model to provide a comprehensive recognition of business process concepts.

VII. CONCLUSION AND FUTURE WORK

This paper proposes a language-independent business process meta-meta-model based on integration of seven mainstream BPMLs' concepts. Presentation of business process concepts in a meta-model supports interaction with and between non-technical business experts and information system experts in elicitation, definition and documentation of business processes. In the areas of requirement engineering and software engineering, the meta-model is the basis for realizing business process concepts and enriching them with requirements at the earliest stage of software and information systems development in a collaborative manner. Moreover, language-independency of the approach and extensive enrichment possibilities also allow for further application in many different areas such object-oriented system engineering.

The ontological analysis of the meta-meta-model against the BWW ontology for representational analysis is conducted in this research. This provided a view not only on consensus deficiencies of the BPMLs in representing a real world constructs but also on the concepts of the meta-meta-model that cannot be covered by BWW concepts.

There are limitations of this approach. First, it is based on mainstream BPMLs. Second, there is the issue of semantic loss when a BPML is mapped onto the unified meta-model. This semantic loss and the way to ameliorate any issues arising from this will also be a line of research in the future.

This work can be extended in several dimensions. A direction of future work will be an evaluation of correctness of the meta-meta-model. Considering the language-independency of the proposed meta-model, this meta-meta-model can be used as a reference model for comparative analysis of BPMLs. Moreover, the proposed meta-meta-model can also act as a basis for development of future BPMLs as well as enhancement of the existing ones. Developing an algorithm for transforming between different business process models is another direction for future work.

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