

Linking BPMN, ArchiMate, and BWW: Perfect Match for Complete and Lawful Business Process Models?

Ludmila Penicina

Institute of Applied Computer Systems, Riga Technical University,
1 Kalku, Riga, LV-1658, Latvia
ludmila.penicina@rtu.lv

Abstract. Enterprise architecture (EA) models are helpful for describing elements that are necessary for modelling business processes at different architectural layers of the enterprise. Business process models are used to describe detailed enterprise processes in order to analyse and improve them. Business process logic provided in the business layer of EA is very abstract comparing with business process models. Therefore EA models and business process models must be linked to address in detail both structural and behavioural aspects of the information system. However linked EA and business process models do not imply that the models provide complete and lawful descriptions of the information system. The paper uses a theoretical foundation of Bunge-Wand-Weber system's model and evaluates how industry standards BPMN and ArchiMate contribute to creation of complete and lawful business process models.

Keywords: Business process modelling, BPMN, ArchiMate, BWW.

1 Introduction

Nowadays organizations employ industry modelling standards like BPMN to understand and improve business processes. However, BPMN models are only one component of business modelling required for a holistic view of end-to-end business processes. More information is needed to build information systems supporting organizational business processes [1]. BPMN models mainly cover business process flow, but structural aspects such as actors, data objects, existing IT landscape, etc. are outside of BPMN scope. Enterprise Architecture (EA) models can reflect these aspects and are an essential component of creating accurate and complete business process models. Building complete and accurate business process models requires maintaining the relationships with EA models to add a structural context to processes (like actors, objects, etc.) and to refine business process models with an architectural layer perspective, namely, to depicting at what level each process is occurring – business, application, or infrastructure level. ArchiMate enterprise architecture modelling language has been developed in order to provide a uniform representation for diagrams that describe enterprise architectures [2]. In ArchiMate language the existence of business processes model is depicted. However, ArchiMate does not, prescribe to list the flow of activities in detail [2]. Linkage between business process

models and EA models would allow looking at the business processes at different layers of the enterprise in detail.

However besides the challenge of linking two modelling languages from different domains - BPMN and ArchiMate – there exists another challenge, namely, analysing completeness and lawfulness of business process models. By “completeness of process models” the author means that models must contain all necessary elements from information system’s point of view and by “lawfulness of process models” - compliance with laws related to the system. In this paper Bunge-Wand-Weber (BWW) model is used as a theoretical foundation to evaluate completeness and lawfulness of business process models. BWW model describes the necessary concepts for building an information system [3] and in this research is used to evaluate to what extent BPMN and ArchiMate support description of complete and lawful business process models. BWW model consists of constructs present in the real world that must be represented in information system.

The aim of this paper is to propose an approach towards creating complete and lawful business process models by linking BPMN models with ArchiMate models to add active and passive structure to flow aspect of BPMN and evaluate completeness and lawfulness of models using BWW model. The proposed approach requires a repository-based modelling tool that can accommodate all three modelling methods used, namely, BPMN, ArchiMate, and BWW.

The paper is structured as follows. In Section 2 related work is outlined. In Section 3 elements of BWW model are presented. In Section 4 the mapping of ArchiMate and BPMN is discussed. In Section 5 the evaluation of BPMN and ArchiMate using BWW model is discussed. In Section 6 algorithms for checking the completeness and lawfulness of business process models are discussed. Brief conclusions and future work are presented in Section 7.

2 Related Works

There exist a number of researches for linking ArchiMate and BPMN notations. The authors of [6] propose the approach of harmonizing BPMN, ArchiMate and UML notations. The authors of [7] analyse support of different kinds of active structure assignment in enterprise modelling techniques and frameworks, including ArchiMate, DODAF, and ARIS. Since these frameworks are be used in the description of an Enterprise Architecture in tandem with the detailed description of business processes, the authors also discuss the support for active structure allocation in processes modelling techniques, including XPDL, UML Activity Diagrams and BPMN in their analysis. The authors conclude that a complete integrated approach to the assignment of active structure and behaviour is yet to be incorporated into the languages and frameworks considered. However, the authors of the studies described do not propose to evaluate linked business process models and EA models for completeness and lawfulness.

The BWW model has been used in a number of studies for evaluation of modelling techniques. The authors of [5] report on the outcomes of an ontological analysis of BPMN and explore identified issues by reporting on interviews conducted with

BPMN users in Australia. As a result [5] defines few potential shortcomings in BPMN - such as existence of some ambiguous elements in its specification.

The authors of [8] examine how process modelling techniques have developed and compare modelling techniques using BWW model as a benchmark used for the analysis of grammars that purport to model, the real world, and the interactions within it. The authors of [9] propose an approach for developing a conceptual model that represents the structural, relational and behavioural elements of the computing systems based on the BWW model. The authors of [10] use of the BWW model to compare the representation capabilities of two business rule modelling languages.

This research is based on the results of related works and evaluates how the necessary elements for building an information system described by BWW model are represented by BPMN models linked with ArchiMate models.

3 BWW Model

The lack of consistent theoretical foundation for building information systems urged Wand and Weber [3] to build a set of models for the evaluation of modelling techniques. Wand and Weber have extended the systems ontology presented by Mario Bunge [4]. Wand and Weber developed a formal foundation called BWW model for modelling information systems [3] consisting of the constructs present in the real world that must be represented in information system. BWW model is a high-level ontology containing general concepts that are necessary for description of information systems [5]. Further in the text the elements of BWW model will be shown in italics. Due to the limitation of space the author has omitted the descriptions of BWW elements that can be found in [8].

The paper proposes to use BWW model as a theoretical foundation for evaluating BPMN and EA models for completeness and lawfulness. BPMN and ArchiMate models are standards with different abstraction levels, therefore gaps exist between these two standards. BPMN is used at the detailed process level, ArchiMate is used at EA level describing different layers of enterprise. BPMN and ArchiMate are complementary standards. Novelty of using BWW model as a theoretical foundation for linking BPMN and EA resides in the following:

1. Providing systems view of interlinked business processes and enterprise architecture. Interlinked ArchiMate 2.0 and BPMN 2.0 models describe elements that can be viewed and analysed as systems, e.g., application layer system, related subsystems and system environment.
2. Possibility to describe lawful states and events of systems – the evaluation of BPMN and ArchiMate using BWW shows that nor BPMN 2.0 nor ArchiMate 2.0 has the ability to describe lawful states and events of the systems at the different abstraction levels.
3. Emergent properties of systems - emergent properties describe properties possessed by a system and not by isolated elements. Emergent properties are specific properties of the system as a whole and this is added-value from BWW model.

4. Kind element of BWW model will provide the possibility to describe variations of business processes, e.g., Electronic submission process variation is Electronic submission of a journal paper or Electronic submission of a monograph.

4 Linking BPMN and ArchiMate

In an ArchiMate model, the existence of business processes is depicted [2]. It does not, however, list the flow of activities in detail [2]. The ArchiMate 2.0 specification [2] states: “During business process modelling, a business process can be expanded using a business process design language; e.g., BPMN.” However the specification itself does not define the relationship at the meta-model level. The author proposes to define the linkage between BPMN and ArchiMate at the meta-models levels, by extending the behavioural elements of ArchiMate with corresponding elements from BPMN 2.0 meta-models. In this section behavioural elements of ArchiMate business, application and technology layer are mapped to corresponding BPMN elements. The principle of linking BPMN with ArchiMate resides in the following, namely, high level descriptions of enterprise behaviour are extended with corresponding BPMN models. **Table 1** describes how each element is expanded by BPMN.

Table 1. Mapping ArchiMate and BPMN.

ArchiMate Business Layer Element	BPMN Element
Business Process	Business Process Diagram, Pools, Lanes
Function	Task, Sub-Process
Business Interaction	Collaboration Diagram
Business Event	Event
Business Object	Data Object
Business Role	Lane
ArchiMate Application Layer Element	BPMN Element
Application Function	Service Task, Script Task
Data Object	Data Object
ArchiMate Technology Layer Element	BPMN Element
Device	Data Store
Artefact	Data Objects

5 Evaluation of BPMN and ArchiMate Using BWW Model

Business Process Model and Notation (BPMN) [11] is the de-facto standard for representing in a very expressive graphical way the processes occurring in virtually every kind of organization [12]. However BPMN has its limitations when it comes to modelling other aspects of organization such as organizational structure and roles, data, business rules, technical systems, etc. [1]. The mapping of BWW into BPMN presented in [5] is taken as a basis and extended with statements that BPMN supports the BWW notions of the *State*, *Property* as well as *Stable* and *Unstable States*. In BPMN the *State* of the Data Object can be captured if the Data Object is attached to a

Sequence Flow that is an input of an Activity, and it comes out of the Activity with a different *State*. *Property* of a *Thing* can be defined using BPMN Attributes of elements, *Stable* and *Unstable States* can be described using BPMN Compensation Activities and Compensation Events. The *State* of a *Thing* does not describe the overall *State* of a *System*. One solution for detecting the *State* of a *System* is to define a set of all *States* of all *Things* present in the *System*. The second solution for detecting the *State* of a *System* is to look at *System's Emergent Properties* which based on BWW are defined as properties belonging only to the *System* and not to its components [8]. One more solution is included in BPMN modelling language. BPMN allows defining multiple end states of a process. In [2] author describes the state of the process as the state of the system. Business processes do not always end normally (as intended) and very often exceptions occur. BPMN allows defining separate end events to indicate distinct end states (“normal end state” and “exceptional end state”) [1]. Multiple end states of BPMN process can each correspond to *Stable* and *Unstable State* of a *System* or *Subsystem*. In BPMN the *State* of *System* can be described also with the *States* of all Data Objects that refers to a particular Pool that is considered to be a *System*. Exceptional end state should be linked with the *State* of the corresponding Data Object to reflect the *Unstable State* of a *System*. Figure 1 depicts a simple BPMN example with multiple End Events that might occur and define different end *States* of the process and system.

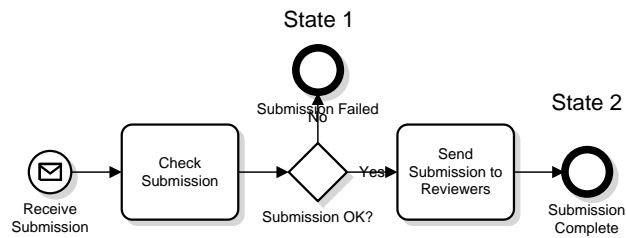


Fig. 1. Different end states of a process in BPMN.

There are 6 BWW model elements that are not supported by BPMN notation, namely, *State law*, *Conceivable State Space*, *Lawful State Space*, *History*, *Conceivable Event Space*, and *Lawful Event Space*. Since BWW model describes aspects that are important for building information systems [5], these six elements are to be taken into consideration to define a complete and consistent description of business processes.

To provide a uniform representation for diagrams that describe enterprise architectures, the ArchiMate enterprise architecture modelling language has been developed [2]. ArchiMate 2.0 language defines 3 layers of an enterprise architecture [2]:

1. Business layer offers products and services to external customers.
2. Application layer supports the business layer with application services.
3. Technology layer offers infrastructure services needed to run applications.

Table 2 shows the mapping of BWW to ArchiMate modelling language (only core elements of ArchiMate are considered. Use of extensions would provide more details concerning the *Environment* in BWW model).

Table 2. BWW elements mapped into ArchiMate elements.

BWW Elements	Corresponding ArchiMate Concepts
System	Enterprise architecture, Business layer, Application layer, Technology layer
System environment	Business layer (for Application and Technology layers), Application layer (for Technology and Business layers), Technology layer (for Business and Application layers)
System structure	Relationships
System composition	Structural concepts, Informational concepts
Level structure	Relationships between layers, Business layer, Application layer, Technology layer
Subsystem	Business layer, Application layer, Technology layer
System decomposition	Business layer, Application layer, Technology layer, Structural concepts, Informational concepts
Thing	Business actor, Business role, Business collaboration, Location, Business interface, Business object, Application component, Application collaboration, Application interface, Data object, Node, Device, System software, Infrastructure interface, Network, Communication path, Product, Contract, Artifact
Property	Meaning, Value, Representation
Class, Kind	Relationships
Event, External event, Internal event, Poorly-defined event	Business event
Transformation	Business service, Business process, Business function, Business interaction, Application function, Application interaction, Application service, Infrastructure function, Infrastructure service
Acts on, Coupling	Structural relationships
State, Conceivable state space, Lawful state space, State law, Stable state, Unstable state, History, Conceivable event space, Lawful event space, Well-defined event, Lawful transformation	<i>Not supported by ArchiMate</i>

From BWW point of view enterprise architecture is a *System* consisting of *Subsystems* – business, application and technology layers (while these sub-systems are not the only ones that can be identified in the EA). Business layer, application layer and technology layer are separate *Systems* consisting of structural and behavioural elements that are considered to be BWW *Things*. Structural and informational concepts form *System Composition* and ArchiMate Relationships between these concepts form *System Structure*. BWW element *Thing* is supported by

ArchiMate active and passive structural elements. BWW element *Property* is supported by ArchiMate element *Meaning*, since *Meaning* is related to ArchiMate Business object element and thus is as a *Property* of a *Thing*. According to BWW model *Property* maps the thing into some *Value*. According to ArchiMate Value is the relative worth, utility, or importance of a business service or product – hence it is mapped to the *Property* element of BWW model. Representation is the property of a Business Object, hence, it is mapped to the *Property* element of BWW model. BWW model elements *Class* and *Kind* are supported with ArchiMate Relationships (grouping, composite, aggregate). ArchiMate does not provide a straightforward mapping to BWW *State* element. However, if ArchiMate models are related to BPMN models, notion *State* is supported by different *States* of BPMN Data Objects and multiple End Events of the process. Since BWW model element *Transformation* is defined as a mapping from one *State* to another *State*, it is supported by all ArchiMate behavioural concepts. BWW elements *Acts* on and *Coupling* are mapped into ArchiMate structural relationships between ArchiMate concepts that are mapped into BWW *Things*. Altogether the ArchiMate modelling language does not support the description of 11 BWW model constructs comparing to 6 BWW elements missing in BPMN. Nevertheless, ArchiMate allows defining structural components of an information system at all three levels of the enterprise architecture in much greater detail than BPMN.

6 Towards Analysing Completeness and Lawfulness of Business Process Models

Business process modelling requires a meta-structure (background knowledge) that maintains the relationships between all the different models linked to business process models. When creating business process models linked with the set of enterprise models, it is necessary to achieve that all aspects of business process are stored and can be accessed and reused afterwards. Assuming that BWW model can be used as a meta-structure for analysing the completeness and lawfulness of the business process models it is necessary to identify which elements from BWW model are supported by BPMN and ArchiMate models. BWW model defines elements of the information system that are supported by BPMN and ArchiMate standards as well as a set of elements that are not supported by these standards. It indicates that complementary to BPMN and ArchiMate models it is necessary to address these missing elements in order to build the information system that conforms with a functioning system described by BWW model [3]. Mappings presented in the previous sections show that majority of BPMN and ArchiMate core elements can be mapped to BWW constructs. However, still, there exist six elements that cannot be represented using these two modelling languages, namely, *State Law (SL)*, *Conceivable State Space (CSS)*, *Lawful State Space (LSS)*, *History (H)*, *Conceivable Event Space (CES)*, and *Lawful Event Space (LES)*. These missing BWW model elements have to be added to interlinked BPMN and ArchiMate models in order to include all BWW model's elements required for building an information system.

The proposed approach requires a repository-based modelling tool that:

1. Accommodate all three modelling methods used, namely, BPMN, ArchiMate, and BWW. Meaning that the modelling tool supports the meta-models and visual representations of BPMN, ArchiMate, and BWW.
2. Possibility to add to the BPMN, ArchiMate meta-model the missing elements from BWW model.
3. Allows defining algorithms, mechanisms, and queries to execute the completeness and lawfulness analysis on the business process models. E.g., analysing if all BWW elements are present in the business process models, analysing lawful event space – lawfulness analysis showing what are the lawful events in the business process models, analysing the lawful state space - lawfulness analysis showing what are the lawful states in the business process models, analysing whether unconceivable states and events are present in the model – lawfulness analysis showing if models are realistic.

Let's review an illustrative example. Figure 2 depicts a fragment of business process of Electronic paper submission process and ArchiMate 2.0 model that shows Business level and Application level, however does not show detailed process. The business process in the ArchiMate model called Electronic submission process is extended with BPMN business process model containing 2 lanes. Further the ArchiMate business process Receive Submission is linked with BPMN lane Editor that contains activities that Editor is responsible for. The ArchiMate business process Review Process is linked with the BPMN lane Reviewer that contains the activities the Reviewer is responsible for. The ArchiMate business role Editor is linked with the BPMN lane Editor and the business role Reviewer is linked with the lane Reviewer. Nevertheless ArchiMate model supplements BPMN model with layers and active and passive structure, still these models does not include descriptions of (the added value of BWW):

1. *State Law* - a set of all properties that are lawful to a *Submission*.
2. *Conceivable State Space* and *Lawful State Space* - to indicate what states of a data objects (e.g., *Submission*) and systems (e.g., *Application components system*) are lawful and what are conceivable. For example, *Submission* can have *Incomplete* or *Not conforming with the Template* or *Accepted* states, from which only *Accepted* is a lawful state.
3. *History* of states - for business process monitoring purposes it is necessary to maintain a log of previous states of a *Submission*, such as *Submitted*, *Reviewed*, *Accepted*, etc.
4. *Conceivable Event Space* and *Lawful Event Space* - it is necessary to indicate what events described in BPMN model are lawful, e.g., *New Submission* is a lawful event in the system, but events like *System's error* are unlawful.
5. Emergent properties of a system - one of the emergent property of Electronic submission system is faster and more efficient management of submissions.
6. Business process variations - using *Kind* element it is possible to describe different variations of the business process, e.g., Electronic submission of a monograph.

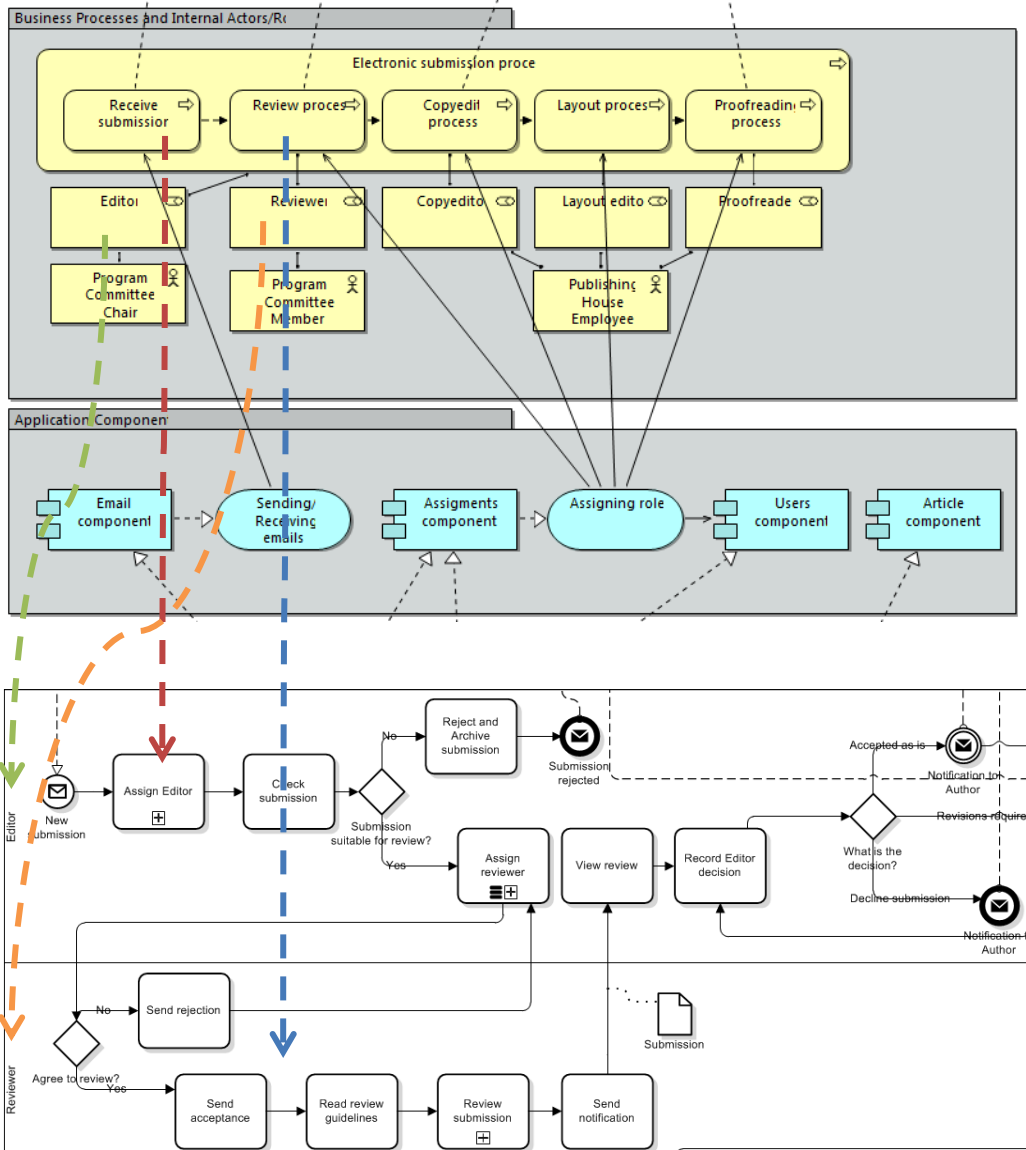


Fig. 2. Relationships between BPMN and ArchiMate.

7 Conclusions

In this paper a step towards evaluating completeness and lawfulness of business process models using BWW system's model is discussed. It was concluded that to implement the approach for completeness and lawfulness analysis the repository-based modelling tool is required. The modelling tool must allow accommodating BPMN, ArchiMate and BWW meta-models and defining algorithms, mechanisms and queries for lawfulness and completeness checking. Another essential feature is supplementing the BPMN and ArchiMate meta-models with elements from BWW model that are missing, namely, *State Law (SL)*, *Conceivable State Space (CSS)*, *Lawful State Space (LSS)*, *History (H)*, *Conceivable Event Space (CES)*, and *Lawful Event Space (LES)*, because the lack of these elements hinder lawfulness and completeness of business process models. Analysing business process models using the BWW system's model will allow analysing what necessary elements for information system developing are missing in the models. The further work will include implementing the prototype of the described repository-based modelling tool and described algorithms and queries using the ADOxx platform [13] because this platform allows creating customized modelling languages and defining algorithms, mechanisms and queries for analysing the models.

References

1. Silver, B.: BPMN Method and Style with Implementer's Guide. Cody-Cassidy Press (2011).
2. The Open Group: ArchiMate 2.0 Specification, <http://goo.gl/7gC5B>.
3. Wand, Y., Weber, R.: On the ontological expressiveness of information systems analysis and design grammars. *Information Systems Journal*. 3, 217–237 (1993).
4. Bunge, M.: *Treatise on Basic Philosophy: Vol. 4: Ontology II: A World of Systems*. (1979).
5. Recker, J., Indulska, M., Rosemann, M., Green, P.: Do Process Modelling Techniques Get Better? A Comparative Ontological Analysis of BPMN. Campbell, Bruce, Underwood, Jim, & Bunker, Deborah (Eds.) 16th Australasian Conference on Information Systems. (2005).
6. Berg, M. Van Den: ArchiMate, BPMN and UML: An approach to harmonizing the notations. Orbus software white paper. (2012).
7. Arpini, R.H., Almeida, J.P. a.: On the support for the assignment of active structure and behavior in enterprise modeling approaches. *Proceedings of the 27th Annual ACM Symposium on Applied Computing - SAC '12*. p. 1686. ACM Press, New York, New York, USA (2012).
8. Rosemann, M., Recker, J.: A study of the evolution of the representational capabilities of process modeling grammars. *Advanced Information Systems Engineering*. 447–461 (2006).
9. Goumopoulos, C., Kameas, A.: *Theory and Applications of Ontology: Computer Applications*. Springer Netherlands, Dordrecht (2010).
10. Muehlen, M. zur, Indulska, M., Kamp, G.: Business Process and Business Rule Modeling: A Representational Analysis. 2007 Eleventh International IEEE EDOC Conference Workshop. pp. 189–196. IEEE (2007).
11. OMG: Business Process Model and Notation 2.0, www.bpmn.org.
12. Chinosi, M., Trombetta, A.: BPMN: An introduction to the standard. *Computer Standards & Interfaces*. 34, 124–134 (2012).
13. BOC GROUP: ADOxx.org.