Towards Simulation of Business Processes
Transforming BPMN Models to Enterprise Dynamics Models

Ralf Schepers, Tobias Minning, Yannik Moog and Ingo J. Timm
Business Informatics I, University of Trier, Trier, Germany
{*ralf.schepers, s4tominn, s4yamoog, ingo.timm*}*@uni-trier.de*

Keywords: Business Process Simulation, Material Flow Simulation, Enterprise Dynamics (ED), BPMN.

Abstract: Due to the ISO 9001 certification and process oriented-organization, many business process models are available at enterprises and public institutions. They are e.g. used for documentation or for introducing processes to new employees. As a de-facto standard notation BPMN "Business Process Model and Notation" is widely used. These process models can support static analyses of business processes. Dynamic analysis, e.g., by simulation is beneficial for in-depth analysis and optimization. However, only few approaches are available to perform simulation on basis of BPMN. In the production engineering domain, process simulation for analysis and optimization is a de-facto standard. In this domain, material flow simulation is a valid method of analysis, planning and construction.

In this paper, we discuss the potentials and shortcomings of transforming BPMN models to a material flow simulation model. On the basis of an analysis of BPMN and material flow simulation, we identified requirements for transforming. Four levels of transformation complexity are defined. Furthermore we developed matching relation from BPMN elements to material flow elements. As proof of concept, we implemented the transformation process using Enterprise Dynamics and evaluated its outcome. The benefits and limitations of this approach are discussed in the paper in front of evaluation and related work.

1 INTRODUCTION

The ISO 9001 certification represents an authoritative reference of quality management. Since 2009, Switzerland's public institutions have to be complied with ISO 9001(eCH eGov, 2013). One requirement of this certification is the documentation of business processes. BPMN 2.0 (Business Process Model and Notation) is a common standard for process notation(Freund and Ruecker, 2012), which has been chosen by Switzerland. In consequence, for each certified institution (in Switzerland), the business processes are available in BPMN. Those are used, e.g., for documentation and analysis matters. The modeling and maintenance of business process documents is resource intensive. So an additional value should be added. On basis of the process models, static analysis are enabled, however, as underlying research question of this paper, the question occurs, if it is possible to derive a standard process for dynamic analysis of business processes.

There exists already the approach to simulate business processes by business process simulation. But it lacks on a low leeway in decision-making (Shannon, 1998) and missing standards(Januszczak and Hook, 2011). To re-use existing models in simulation, a transformation approach into executable models is necessary. To improve support of decision-making, the method of material flow simulation will be used, because simulation is a well-defined process method for analysis in engineering. Due to the relevance of BPMN standards and the possibility of the conversion within the standards, the transformation from BPMN models to executable simulation models will be analyzed. As a first step, our objective is to study the transfer of BPMN into an existing simulation environment. This will be evaluated by the implementation of the transformation function in a simulation system i.e. Incontrol Enterprise Dynamics.

2 FUNDAMENTALS

Due to our research objective, BPMN and the mean of material flow simulation will be introduced in the following sections.

Schepers R., Minning T., Moog Y. and Timm I.
Towards Simulation of Business ProcessesTransforming BPMN Models to Enterprise Dynamics Models.
DOI: 10.5220/0005425501590165
In *Proceedings of the Fourth International Symposium on Business Modeling and Software Design (BMSD 2014)*, pages 159-165
ISBN: 978-989-758-032-1

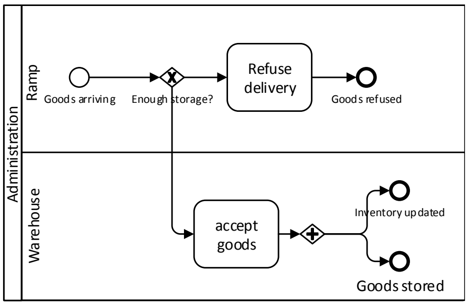

Figure 1: Example BPMN process.

2.1 BPMN

The BPMN 2.0 standard is defined by the OMG Object Management Group(Chinosi and Trombetta, 2012). It includes seven groups of elements. There are activities, gateways, events, swim lanes, data, choreographies and conversation(Chinosi and Trombetta, 2012). Thus, the BPMN elements can be aggregated to a sequence flow. An additional layer can be constructed by message links between the elements. An example of business process can be found in figure 1 and will be used as illustration within this paper.

Although syntax of BPMN is clearly defined, semantics is not. The underlying logic can be annotated or it can implicit. However, the logic have to be extractable. In our example (figure 1) the gateway is annotated with ”enough storage”. Alternatively, it could be annotated with ”insufficient storage”. Also the definition is implicit, which storage is meant. Since 2008 the OMG tries to solve this problem by the definition of ”Semantics of Business Vocabulary and Business Rules” (SBVR)(OMG, 2008). This provides the ability to map the context to a machine-interpretable operands. It is also used to derive processes from textual descriptions(Bajwa et al., 2011). However the problem of implicitly can only be solved by improving the modeling process.

Beside the semantics, the general transformation and simulation potential of BPMN must be analyzed. For this purpose, the technical basis of transformation will be considered. In order to recondition BPMN diagram information in a machine-interpretable way, the OMG defines the ”BPMN Diagram Interchange” schema. BPMN DI is part of the BPMN 2.0 standard. The DI scheme includes all structural information of the model. Meta-information, such as the element type, its name or edge type, and the execution semantics are included in the ”BPMN Execution Semantics Schema” (BPMN-ES)(OMG, 2011). A BPMN model consists of the Diagram Interchange and the Execution Semantics Information. It can be stored by a XML file. This forms a reasonable technical basis, which includes the information needed to transfer and display BPMN processes between different modeling platforms.

2.2 Material Flow Simulation

In a simulation, a model of a real world system, will be run under experimental conditions (Shannon, 1998). The objective is to understand the behavior of the system to find improvements, which can be evaluated through experiments (Shannon, 1998). A simulation project consists of analysis, modeling, experiment and interpretation of results(Lattner et al., 2011). Each simulation run is performed several time due to its probabilistic parameters (Lattner et al., 2011). Material flow simulation is one kind of simulation with focus on production and logistic. An abstract view on material flow simulation is given by (Rittgen, 1998). A process consists of elements which are atomic in nature. The process is define by its elements. Each element can perform an action, which is hidden, only the effect of a process can be seen. But this view is too abstract to be used as a transformation basis.

The mean of material flow simulation is based on experience and efforts of engineers, who are the main user of those systems. Different commercial simulation software, e.g. “Plant Simulation” by Siemens[1], “Enterprise Dynamics” (ED) by Incontrol Simulation Solution[2], and “Arena” by Rockwell Automation[3] are available. There notations are based on graph models, however different elements are obtainable. As an example of different elements, Arena offers a “decide” module comparable to a BPMN gateway. This function has to be implemented in ED and in Plant Simulation due to elements properties or adapted elements. As a representative of a material flow simulation software, we will further use ED. It will be exemplarily introduced.

ED offers an atomic library of elements. Each element is represented by an instance of an atom, with its own variables and logic. So, ED combines both an object orientation and an event implementation. As a result, the atoms can be defined, reused and derived (object-orientation). The logic, however, is implemented inside the instance of an atom (event-based). The tokens (e.g. products or orders) are created by a source and leave the process via a sink. The status of the atoms and global variables, like the set of tokens within the model or the content of a queue, are

[1] www.plant-simulation.de
[2] www.incontrolsim.com
[3] www.arenasimulation.com

representing the state of the model. After creation, the tokens are then processed according to the model pattern.

2.3 Discussion

From a methodological point of view, business processes are similar to material flow models witch respect to its graph structure as well as its atomic elements. However its perspective can be different. Business processes, which are modelled for documentation matters, should map all relevant elements of its business objectives. In contrast a material flow model, is a problem-oriented homomorphous mapping of a real world system. This could be congruent to business processes, but it is not compulsorily. In case of the usage of an existing BPMN model, the focus of the model possibly have to changed in order to meet the underlying question of the analysis.

3 REQUIREMENTS ON SIMULATION SOFTWARE

The simulation environment must be defined, before raises the possibility of a transformation, the overall requirements to.

1. Availability of basic concepts of nodes and edges
2. Decision functions within nodes
3. Model import via XML format
4. Graphical representation of BPMN model
5. Interface for input/ output data
6. Validated random generator

Starting with the sixth requirement, a validated random generator is necessary to receive statistically valid results(L'Ecuyer, 1997). Random values are used as an abstraction of variance of the real world to a model. A validated random generator should be included in a commercial and established simulation software. The basis of an analysis in simulation lies in the analysis of data. However, it is not a typical job to a business process modeler. In contrast, data handling, is a core task of the method of material flow simulation. Well studied solutions for data analysis are available, e.g. by (Bogon et al., 2012).

In the case of transforming existing models into a material flow simulation software, a graphical representation, close to BPMN would reduce training. The graphical representation leads to an increased acceptance of the method of simulation, because the participants understand the model. This is a crucial point in simulation projects(Wenzel et al., 2007). To perform simulation experiments, the gateways have to be negotiable. So there is a need of decision functions inside the available nodes. Close related to the graphical representation, is the ability of the model import. This is not yet possible to the above mentioned software solutions.

The first four requirements could be covered by common BPMN simulators such as Signavio[4]. However, the last requirements, necessitate the use of more extensive simulation environments, such as material flow simulation software solutions. The use of material flow simulations demands a high variance in modeling, due to corresponding production. Therefore it provides expandability of the used elements. Manufacturing processes models follows similar to BPMN models, the pattern of change between puffer, processing and transportation.

4 CONCEPT

At a high level of abstraction, the generation of a transfer process of business process to material flow simulation model, can be seen in figure 2. At the beginning the business model has to be readable, e.g. via a XML file. Subsequently transfer rules from a meta-model of business process or specific a meta model (e.g. BPMN meta-model) to a meta-model of material flow simulation have to be defined[5]. Afterwards, the rules can be deployed on the business process model. As a proof of concept, whether a transformation is possible, direct transformation rules will be specified in the following. The abstraction steps will be avoided.

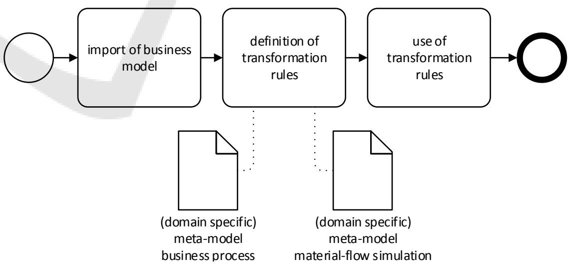

Figure 2: Generation of a transformation process.

4.1 Matching Concept

As mentioned in section 2.2, there are differences be-

[4] www.signavio.com

[5] So far no meta-model of material flow simulation is known to the authors.

Table 1: ED atom overview.

Atom	Function	Input / Output	Attribute
source	source of product	product / n	inter-arrival time
sink	leaving of product	1 / -	-
server	cycle time	n / n	cycle time,in- & output strategy
splitter	sequence flow split	1 / n	cycle time & quantity matrix
assembler	sequence flow merge	n / 1	cycle time & quantity matrix
composition container	element group	- / -	-

tween available simulation solutions, and there exists no consensus of notation. To prove the transferability, a direct transformation to ED will be discussed. In the following, destination elements in ED will be searched, to map BPMN elements. Thus standard properties and behaviors according to the BPMN standards could be defined in advance. Alternatively, the properties of existing ED elements can be used.

To model the production process flow-logic and the presentation of the processing activities, ED provides six basic elements (atoms): source, sink, server, assembler, transport, and composition container. The products are distributed via directed channels, connected by in- and output channels. An overview of atoms, their functions, and their properties can be seen in table 1. The processing is provided by the server, the assembler and the splitting atoms. Here, the choice of the output channel (send to), as well as the processing time can be fixed by stochastic distribution or by an absolute term. An example of processing atoms, are packing and unpacking activities. The split atoms or the assembler atoms are able to split or to join the process flow. A splitter atom can be entered via one input channel and n output channels. Vice versa to the assembler atom. The determined in- and output ratio of products can be set by a table. Also a processing time can be set.

For visual grouping of the atoms, ED uses a composition container atom. It could be also used for a logical grouping. The atom provides a rectangle that is drawn around atoms. According to the association of data objects, ED uses an ActiveX or a database connection. Thus, the simulation can be based for example on an Excel spreadsheet, containing input data. Of course data elements in the BPMN perspective, like standard forms are not needed for simulation.

The prescribed ED atomic structure potentially offers both the modeling options to map the BPMN flow elements, as well as the possibility to represent the process. A mapping of BPMN to ED elements can be seen in table 2. On this basis a transformation possibility can be derived to infer the suitability of ED as a target simulation environment. In addition, a logic detection is needed. In the following, four different levels of complexity of transformation can be differentiated.

4.2 1st Degree: Straight Mapping

The straight mapping includes presentation of the basic elements, shown in table 2. A 1:1 transfer of elements to ED takes place. Simple tasks can be mapped to server atom with appropriate properties. From the group of gateways, the parallel and the exclusive gateways can be transferred. The parallel gateway can be matched to the splitter atom. The process flow can be merged by an assembler atom. In case of an exclusive gateway, a server atom with specific “sent to” ratio will be set. This can be set by conditions, as well as a percent ratio. The merging gateway can be set to a server atom. Such takes the product from any input channel and supplies it to one output channel. Informations about average processing time of tasks is not given by a BPMN model. Consequently it would have to be inserted while the transformation process. To get plausible simulation results, data have to be collected. By default, this follows a negative

Table 2: Mapping complexity degrees.

BPMN	Enterprise Dynamics
1^{st} degree	
start-event	source
end-event	sink
timer-events	time based release
parallel gateway	splitter/ assembler
exclusive gateway	output strategy server
sequence flow	relations
task	server
(swim) lane	composition atom
2^{nd} degree	
start message event	adapted source
message event	adapted atom
message task	adapted token
sub process	composition atom
3^{rd} degree	
looping task	adapted server
event based gateway	adapted server

exponential function, set by ED.

4.3 2nd Degree: Local Logic Detection

The 2^{nd} complexity degree requires to implement the rules based on the local recognition of logic. It is based on the defined elements to represent the atoms. In this case, these rules primarily support message events. This requires the adaption of ED atoms, because communication actions are not a part of the material flow simulation method yet. There are possibility to send messages like parameters, but a deliberation is not yet possible. We did some work, to implement communication actions according to FIPA standard(Bellifemine et al., 1999).

4.4 3rd Degree: Global Recognition

In order to map more complex control structures like anonymous processes and pools, a composition of ED atoms is required. Also sub processes and black boxes can be represented. For this purpose, incoming and outgoing messages as well as sequence flows of containers have to be identified and grouped. They could lead to a source or a sink atom in a composition container.

For this level of complexity, pattern recognition is necessary. It should check the kind of parent and son element. The event- based gateways can be viewed in a global context with their downstream events. The event gateway can be mapped to a server with its own processing strategy. This can be influenced by specifying a script in the ED scripting language 4DSCRIPT. The in- and output channels of the group are then aggregated into a server atom. Likewise, the mapping of loop tasks can be classified under this level of complexity.

4.5 4th Degree: SBVR Logic and Complex Mapping

The 4^{th} level includes the mapping of the remaining elements. Although these affect the process flow, the underlying logic implemented is difficult to recognize, and consequently more difficult for a machine due to lack of semantic interpretability. The implementation requires an extended semantic context, such as it is used for example in the SBVR research. To implement the logic correctly, additional recognition of complex patterns as well as dynamic transfer rules will be necessary.

5 EVALUATION

Starting to evaluate this approach, a transformation application based on 1^{st} degree, has been implemented. The transformation fulfills the requirements three, by acting as an interface between a BPMN model and ED. It includes importing of the BPMN XML documents, as well as conversion and storage in the file format used by ED. Due to the application, ED is able to fully implement all transferable elements. As shown in figure 1, the application were able to transform all elements. The atom properties, like cycle time were predefined. In comparison to figure 1, which were used as origin, requirements one (availability of basic concepts of nodes and edges) as well as the “graphical representation of BPMN model” can be proven. Due to the predefined parameters, output data could be generated by ED (requirements five) but there were no further transformation as 1^{st} degree complexity. In addition, no data collections were made to set parameters. Those were set random. As a result, generated data are not valid. For each control structure of the 1^{st} and 2^{nd} complexity degrees a mapping could be found. In addition, a corresponding control structure has been developed to map the 3^{rd} level of complexity. For a transformation of higher degree than 1^{st} degree, a pattern and logic recognition is necessary. However, the author belief, that the information base should be adequate up to 3^{rd} degree, but a composition of atoms is required. The mapping of further elements and control structures of the 4^{th} degree of complexity underlie the mentioned problems. They cannot be transpose without an extension of the information base. The requirement for a correct representation of the process flow logic is given only for the first three levels of complexity.

6 RELATED WORK

An approach to transform BPMN to a simulation environment was proposed by (Cetinkaya et al., 2012). They developed an executable meta-model of the BPMN standard. But they weren’t able to establish an executable model. In addition, no reproduce of the diagrams was possible. Another possibility to simulate business processes are proposed by (Mueller, 2012). They are proposing to use EPC (event-driven process chain) notation to model simulation models. Those models were then compiled to an executable program. This forms an advantage in contrast of our approach, because no standard notation or software are used to run the process model. However shortcoming were identified due to EPC extension for simulation like

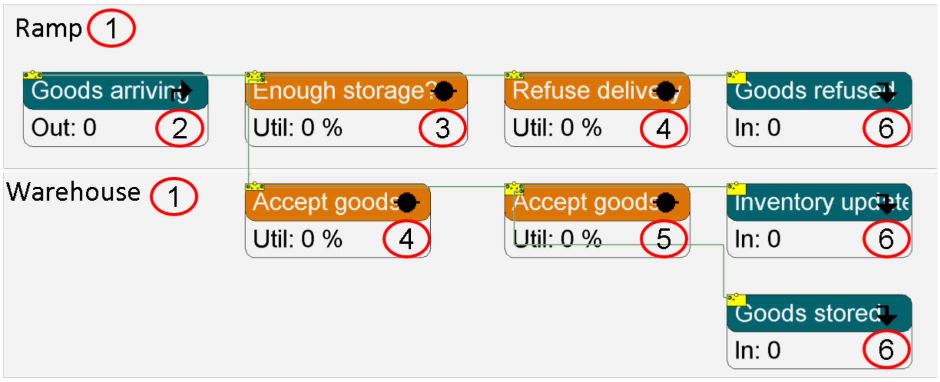

Figure 3: Process in ED: 1 swim lane, 2 start-event, 3 parallel gateway, 4 task, 5 exclusive gateway, 6 end-event.

data. Also simulation experts should be necessary. In case the use of our approach, also simulation specific data are needed. The advantage of our approach lies in the reuse of existing models as well as the use of material flow simulation software. In contrast to generated code, adjustment can be done with respect to modeling and configuration actions. This can be done and understood by BPMN modeler too after training.

(Januszczak and Hook, 2011) discuss a simulation standard for business process managements in general. In this approach, also the usage of a standard notation (e.g. BPMN) is proposed to reduce the needed training for simulation. The discussion remained at a meta-level and proposed no transformation but an extension of business process modeling notations. In consequence, BPMS (business process management suite) can be used for simulation. In our approach, the use of material flow simulation software is proposed, to use existing method(s), as well as existing software solutions.

Another approach is represented by (Dijkman et al., 2008). They map BPMN to petri net. In difference to material flow simulation and BPMN, petri net have got a well-studied formal language as well as "efficient static analysis techniques"(Dijkman et al., 2008). As already mentioned, semantics are identified as a challenge by (Dijkman et al., 2008). A similar approach is presented by (Raedts et al., 2007). A lot of BPMN primitives are successfully mapped into a petri net. The subjacent question was to be able to find specification inconsistency located within the BPMN diagrams like deadlocks or loops.

In summary, the tendency to generate an additional advantage of the models gets obvious. Also the ability to convert between the notation and methods are met. In case of transformation, the problem of machine-interpretability demand of an ontology for business process(Cabral et al., 2009).

7 CONCLUSION

BPMN as a modeling language is well established in business. One benefit of this approach is, to improve the communication between the principal and agent due to a joint basis of communication in a simulation project. Thus, as an additional application of our approach, BPMN models could be specified in workshops between customers and service providers of simulation technology. Doing so, a first scratch, i.e., a first simulation model could be derived from these models. As a missing link, semantics, especially the quantitative information of the models, are required for sophisticated simulation. Here more research is needed to identify the best point of time, when to acquire these information in the simulation process. Depending on this result the acquisition should extend the BPMN or the material flow model.

As there is an extensive usage of BPMN models in companies, adding additional value to these process models is of high relevance. In this paper we analyzed, how BPMN process can be transferred into ED material flow simulation to enable a dynamic analysis of the underlying process structure. The feasibility of transferring a BPMN process model into a simulation model of commercial material flow simulation software has been shown at a defined (low) level. At higher level, the relevant tasks have been discussed. As a result of the analysis, there is a high coverage of concepts in BPMN and in material flow simulation.

We proposed a general transformation process (see fig. 2), by which a transformation will be run through a meta-level. By the employment of BPMN meta-model or the Business Process Definition Meta-Model, a transformation to a meta-model of simulation is needed. In contrast, the presented approach discuss a direct transformation. Based on section 2.2 argumentation, that different simulation software have got different natured, but similar notations, the presented approach is limited to following aspects:

1. static specific rules (BPMN to ED)
2. portability of approach to other material flow simulation is not ensured
3. portability of approach to other business process modeling notations like EPC is not ensured

The negotiability to other material flow simulation software systems as well as other modeling notations is disputable. Difference between modeling methods (e.g. focus) of other software and notations, lead to different used elements. As a result, there is no standardized meta-model of material flow simulation. However, relevant tasks, e.g. logic detection remain relevant to other modeling notations as wells as to other material flow simulation software. Further research steps will include the analysis of common material flow simulation software. In comparison to BPMN notation, an ontology based approach will be developed. Goal is the interoperability of BPMN to material flow simulation software.

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