Using BPMN for Modeling Manufacturing Processes

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Abstract

Value Stream Mapping (VSM) is an established technique to model, analyze and optimize material and information flows in a manufacturing company. VSM does supply a graphical notation, however, it does not provide an automatic execution model. As a result, the flows modeled in VSM need to be mapped to executable IT-Systems manually. This paper proposes an approach to enable automatic execution of VSM flows which is achieved by mapping the VSM language to an established business process modeling language such as the Business Process Modeling Notation (BPMN). Processes modeled in BPMN can be automatically translated into executable processes. This enables executing both, the manufacturing processes and the business processes of a company in the same IT environment. Thus, interoperability is enabled between shop floor and office area.

Keywords:

Process, Modeling, BPMN

1 INTRODUCTION

Today's manufacturing companies are operating under turbulent market circumstances. They are facing fast changing technologies, globalization and the fluctuation of supply and demand. Next generation factories are expected to manage their business within such a turbulent environment by being adaptive, versatile, high-performing and intelligent [1]. Manufacturing companies need to become more flexible and agile as business models change. Their ability to adapt quickly to a changing business environment mainly depends on the agility of their corporate cultures, flexibility of their business processes and interoperability of their IT systems. Unfortunately, many manufacturing companies today use IT systems that are inflexible [2], heterogeneous and are difficult and expensive to enhance,

maintain and support [3]. In order to solve this problem there are a number of data-driven approaches that enable interoperability among manufacturing IT systems [4].

However, these integration solutions are not flexible enough to quickly adapt to changes in the processes of a manufacturing company. One architecture paradigm that is used in the business domain to solve the problem of flexibility and reuse is the Service Oriented Architecture (SOA). In a SOA, the IT system's functionality is encapsulated in reusable services that expose a clearly defined interface. These services, and thus the functionality of the IT-system, can then be composed into business processes that realize higher-level functionality. One set of technologies that are commonly used in business applications to realize a SOA is the Web Service stack [5]. Using Web service technology, business processes can be described using the Business Process Execution Language (BPEL). BPEL processes are executed using BPEL execution engines that are available from major vendors or as open source products [6, 7].

The business process modeling notation (BPMN) is a well-established standard to graphically model business processes [8]. BPMN creates a standardized bridge for the gap between the business process design and the process implementation [9, 10, 11]. Several work exists that provides a (partial) mapping of BPMN to BPEL and thus allows to execute business processes modeled in BPMN on a BPEL engine.

In the manufacturing domain Value Stream mapping (VSM) [12] is an established paper and pencil practice that allows modeling of the material flows and information as products make their way through the value stream and therefore offers a better understanding of production processes. Flow diagrams support the visualization of value streams. However, VSM Flow diagrams serve documentation purposes only and cannot be executed directly by IT systems. The objective of this work is therefore to make VSM executable by describing a mapping of VSM to BPMN. Processes modeled in BPMN can then be mapped to BPEL and executed by BPEL engines. This paper identifies which elements BPMN 2.0 lacks in terms of representing manufacturing processes and suggests suitable extensions.

Another result of the mapping of VSM to BPMN 2.0 is that business processes as well as manufacturing processes are modeled in the same language. Thus, making the communication between back-office, IT and the shop floor becomes more seamless and efficient.

2 TERMS AND BACKGROUND

A **business process** is a collection of activities to produce a product or provide a service. A process model describes the structure of a business process in the real world. It defines all possible paths through the business process, including the rules that define which paths should be taken and all actions that need to be performed. This model is a template from which *process instances* are instantiated [14]. Several standards to model business processes exist, the most widely accepted one is the Business Process Modeling Notation (BPMN). It has been developed to enable

business users to design readily understandable graphical representations of business processes. In addition, BPMN is supplemented by appropriate graphical object properties that enable the generation of executable BPEL [10]. In general, BPMN is used to model business processes such as in travel agencies or in insurance companies.

A **manufacturing process** is a transformation process in which employees use machines, energy and information to transform material into products [15]. Within the production flow, the movement of material through the factory is the most prominent type of flow that usually comes to mind. However, the information flow that tells each manufacturing process what to do next has to be considered as well [12].

The manufacturing processes are the core processes and the main objective of any manufacturing company. In this sense, information flows can be characterized as auxiliary flows and business processes such as purchasing or logistics basically support and manage the manufacturing processes.

A **value stream** comprises all the actions (both value added and non-value added) currently required to bring a product through the production from raw material to the customer [12]. **Value Stream mapping** is a technique that helps to model and understand the flow of material and information in a manufacturing company and the linkages between them. In VSM a product's production path from supplier to customer is followed, and a visual representation of every process in the material and information flow is drawn. Then the map can be analyzed and a "future state" map of how value should flow can be drawn [12].

3 EXPRESSING VSM FLOWS IN BPMN

Rother and Shook [12] provide a graphical notation to visualize their information and material flows. They group these VSM symbols into three categories: material flow, information flow and general symbols [12]. In this section it is explored how symbols of these different categories can be mapped to business processes modeled in BPMN. This is done by mapping the different VSM symbols to BPMN constructs with similar semantics. To best of knowledge there exists no mapping from VSM to a business process language.

3.1 Mapping the VSM Symbols to BPMN

Considering the elements of the VSM notation, a classification under the following aspects seems reasonable: (i) suppliers and customers, (ii) material inventory, (iii) access to material, (iv) transfer of material, (v) manufacturing processes and settings, (vi) the corresponding information flows and (vii) the symbols dealing with material and information flows.

Suppliers and Customers

Suppliers and customers are business partners of a manufacturing company. In VSM, the business partners are represented by a single icon named *customer/supplier*. They demonstrate a kind of self-contained unit dealing with the manufacturing company. In BPMN, *pools* have the same semantics. They represent a self-contained unit dealing with other units.

Thus, the icon *customer/supplier* of VSM corresponds to *pools* in BPMN. Figure 3 (b) shows how a supplier, a customer and a manufacturing company are modeled as BPMN *pools*. The manufacturing company itself has no explicit representation in VSM because the whole map refers to a single company. In BPMN, it is plausible to depict the manufacturing company as another *pool*.

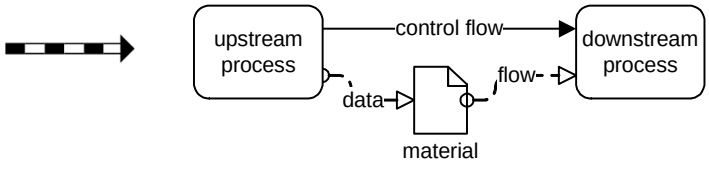
Material Inventory

In VSM, the inventory of material is represented by the symbols *inventory*, *supermarket* and *safety stock*. Analog to *suppliers*/*customers* they are mapped to *pools* in BPMN. The types of inventory differ in how the material within can be accessed and therefore require no extension of *pools* semantics.

Access to Material

Material can be accessed in two ways: It is either pushed or pulled. *Inventory* uses the push system. *Supermarket* and *safety stock* use the pull system.

In a push system, a process produces and moves something regardless of the immediate needs of the downstream manufacturing process [12]. This *push arrow* (Figure 1 (a)) is mapped to a BPMN *data flow* between two *tasks,* which represent manufacturing processes. See Figure 1 (b). Mapping the manufacturing processes to BPMN is explained later on in Section “Manufacturing Processes and Settings”.



(a) (b)

Figure 1: Material push in BPMN.

In a pull system, the actual demand of the downstream process controls the production of the upstream process. See Figure 2 (a). The purpose of placing a pull system to transfer material between two manufacturing processes is to have a means of giving accurate production instructions to the upstream process, without trying to predict downstream demand and scheduling the upstream process [12]. In BPMN, this pull system requires the combination of multiple existing BPMN constructs. The self-regulating production is demonstrated in Figure 2 (b). As can be seen, the downstream process sends a *message event* (representing a kanban) to the *supermarket*. The *supermarket* supplies the demanded material and sends a *message* to the upstream process to trigger the production of new material.

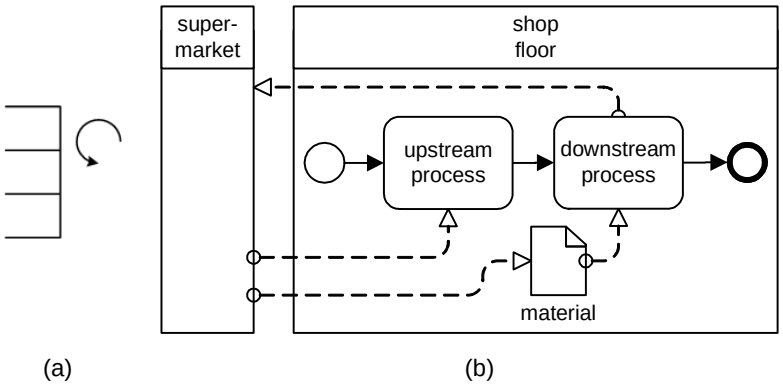


Figure 2: Material pull in BPMN.

Transfer of Material

The transfer of material is visualized in VSM with the symbols *Shipment*, *External Shipment* and *FIFO transfer*.

Shipment (Figure 3 (a)) represents the movement of either raw material from the supplier to the receiving dock of the factory or finished goods from the shipping dock of the factory to the customer. *External Shipment* indicates that external transportation is used and the frequency of shipments is specified as text under the icon. In BPMN, the representation of both *shipment* and *external shipment* of materials can be implemented as a *data flow* with a *data object* representing the material. See Figure 3 (b).

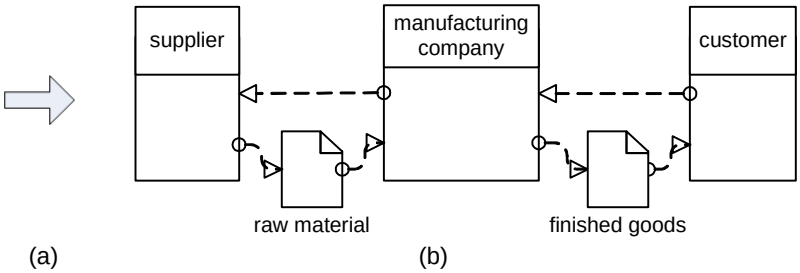


Figure 3: Shipment/External shipment in BPMN.

The *FIFO* icon represents a queued transfer of material between processes in a first-in-first-out sequence (Figure 4 (a)). It is labeled with the maximum capacity of the queue. This transfer follows the push principle as described in “Access to material”. The *FIFO* construct cannot be represented with the BPMN syntax. Therefore, a new data flow association is introduced that allows specifying the capacity by label or *Text Annotation*. Figure 4 (b) shows an example of this new type of data flow association.

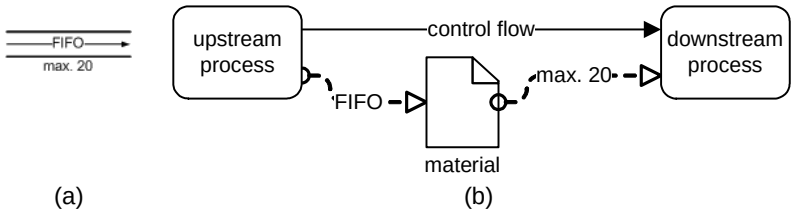


Figure 4: FIFO transfer in BPMN.

Manufacturing Processes and Settings

A manufacturing process is defined as *process* in VSM. This icon is also used for representing departments, such as production control. A process in VSM corresponds to a *task* in BPMN. In contrast to the general manufacturing process, the production control "process" exchanges information only with customers, suppliers and the shop floor where the manufacturing processes are executed. A production control "process" therefore deals only with information flows. There are two ways of mapping production control "processes" to BPMN. They can be mapped either to a single *task* such as a usual manufacturing process or to a *lane*. Mapping the production control to a BPMN *lane*, the organizational structure of the company could become a part of the model which better reflects the real world structure of a manufacturing company.

Settings concerning the manufacturing process such as cycle time or changeover time are specified in VSM in a *Data Box* located under the *process* symbol. The *Data Box* is mapped to a *Data Object* construct in BPMN. Currently, the *Data Object* construct in BPMN only represents information flowing through the process, such as business documents, e-mails, or letters. However, there is no possibility of specifying variables. Recording information such as machine uptime requires such a possibility. Therefore, the *Data Object* needs a customizable structure that allows information to be specified as options.

Information Flow

Information that flows between the central production control and suppliers, customers and the manufacturing processes are specified in VSM with the help of *Manual Information flow*, *Electronic Information flow*, *Information* and several kanban types. *Manual Information flow* or *Electronic Information flow* also indicate organizational information such as daily orders. The VSM information flow is conceptually equal to the BPMN *data flow.* Thus, information flow is mapped to *data flow*.

Pulling material requires information which is specified in VSM using various kanban types: *Production Kanban*, *Withdrawal Kanban* and *Signal Kanban*. A *Production Kanban* triggers the production of parts, while a *Withdrawal Kanban* is a shopping list that instructs the material handler to get and transfer parts. *Signal Kanban* is used when a reorder point is reached and another batch needs to be produced [12]. All these kanban constructs are mapped to BPMN *message events* which indicate the receiving and the sending of messages along with the type of kanban.

Other Symbols

Kanbans are collected in a place named *Kanban Post*. The representation of a *Kanban Post* is realized with a *Data Store* in BPMN. This construct provides a specific place where a process can read or write data.

The *Go See* icon in VSM means adjusting the schedules based on checking inventory levels. Scheduling refers to *manual information* in VSM. This means human involvement and can be expressed by a *Manual Task*/*User Task* in BPMN. As an alternative, a new task type can be introduced with a label *Go See*.

The *Kaizen Burst* highlights improvement needs at specific processes that are critical to achieving the value-stream vision. To map this to BPMN, a normal *Text Annotation* construct can be used.

The *Operator* icon shows the number of operators required to support a manufacturing process at a particular workstation. This case requires a construct which indicates human labor. In BPMN, *operators* can be represented by using the *Manual Task*/*User Task* in which it can be specified how many operators are needed.

Load Leveling is a tool to intercept batches of kanban and level the volume and mix them over a period of time. This may be represented by introducing a new task type “Scheduling Task” in BPMN.

4 CONCLUSION AND OUTLOOK

This paper has shown how SOA and BPM technologies such as BPMN can be used to help today’s manufacturing companies to become more flexible and can adapt more quickly to fast changing business environments. The idea presented showed how VSM symbols that are used to model production flows are translated in BPMN that are used in a SOA environment to model and execute processes. Thus, a work on mapping VSM symbols to BPMN has been made.

Several aspects of mapping VSM symbols to BPMN are still unsolved because there is need for further investigations. For example, introducing a new type of data flow which represents the material flow instead of using the actual data flow in BPMN has to be discussed. Also, the icon *Sequenced-Pull Ball* is not yet mapped to BPMN because it impacts the execution time. Another example is the dependency between *Data Box* and the corresponding manufacturing *process* which is not yet modeled. Primarily, the main objective was the mapping of single VSM icons. The guidelines in VSM for designing an optimized future value stream map and their meaning and impact on BPMN process models have not been examined in this work.

Altogether, the presented mapping is a manual work and must be formalized. After this, it needs to be supported by of a mapping tool which allows the modeling of a value stream map and the automatic generation of a BPMN model.

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