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A Comparison of BPMN 2.0 with Other Notations for Manufacturing Processes

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Abstract. In order to study their current practices and improve on them, manufacturing firms need to view their processes from several viewpoints at various abstraction levels. Several notations have been developed for this purpose, such as Value Stream Mappings or IDEF models. More recently, the BPMN 2.0 standard from the Object Management Group has been proposed for modeling business processes. A process organizes several activities (manual or automatic) into a single higher-level entity, which can be reused elsewhere in the organization. Its potential for standardizing business interactions is well-known, but there is little work on using BPMN 2.0 to model manufacturing processes. In this work some of the previous notations are outlined and BPMN 2.0 is positioned among them after discussing it in more depth. Some guidelines on using BPMN 2.0 for manufacturing are offered, and its advantages and disadvantages in comparison with the other notations are presented.

Keywords: manufacturing process, modeling, IDEF, BPMN.
PACS: 07.05.Bx, 64.60.aq, 89.20.Ff, 89.20.Hh.

INTRODUCTION

In order to study their current practices and improve on them, manufacturing firms need to view their processes from several viewpoints at various abstraction levels. Several notations have been used for this purpose, such as IDEF3 or Value Stream Mappings. More recently, the BPMN 2.0 standard from the Object Management Group has been proposed for modeling business processes, using three kinds of views: collaborations, processes and choreographies. BPMN is intended as a bridge between business process design and process implementation [1]. It has gained considerable momentum in the recent years, with over 73 implementations by various vendors. However, there is little work on comparing BPMN with previous notations.

In this work some of the existing notations are outlined and BPMN 2.0 is positioned among them after discussing it in more depth. Some guidelines on using BPMN 2.0 for manufacturing are offered, and its advantages and disadvantages in comparison with the other notations are presented.

The rest of this work is structured as follows: after a brief introduction of IDEF3 and VSM, BPMN 2.0 is described in further depth. The notations are compared using

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a case study based on a textual description of a manufacturing process. This work concludes by inferring general observations on the selected notations, and suggesting a specific use case for each of them.

SELECTED NOTATIONS

In this section, two of the notations previous to the inception of BPMN 2.0 will be described: IDEF3 and VSM. The authors believe that these notations are a representative sample of the existing notations, as they cover graphical notations for process specification, process reengineering and reasoning about processes. However, many other notations exist. The survey by Aguilar-Savén in [2] covers an extensive range of flow-based notations, but it predates BPMN 2.0. Zor et al. have described a limited manual mapping from VSM to BPMN models in [3]: our approach will focus on the relative strengths of the two notations, instead.

Integrated Definition for Process Description Capture Method (IDEF3)

According to the original report, IDEF3 "was created specifically to capture descriptions of sequences of activities" [4]. IDEF3 uses two kinds of models: *process schematics* and *object schematics*. Process schematics describe the valid sequences of the *Units of Behavior* (UOBs) in the process. Object schematics describe the kinds of objects present in the system, their relationships and their state transitions. Node and link shapes for IDEF3 process and object schematics are shown in Figure 1.

Process schematics represent UOBs as boxes with textual labels and unique identifiers. Precedence links specify valid sequences of UOB activations. A *simple* precedence link from A to B only indicates that whenever A and B both happen, A must happen before B. *Constrained* precedence links can further limit the valid possibilities. Finally, *junctions* can split or join paths. *AND* junctions activate or join all related paths, *OR* junctions only some, and *XOR* junctions exactly one.

Object schematics represent the possible *states* for each object in the system. Links relate different objects, represent their state transitions or classify them. A state transition from A to B means that object *b* can only be in state B after object *a* has been in state A. Object *a* may be the same as object *b* or not. Users set conditions on transitions or states by linking them to UOBs.

Value Stream Mapping (VSM)

Lean manufacturing strives to reduce costs and increase flexibility by removing waste (*muda*) from the manufacturing process. VSM is a tool for identifying issues and creating improvement plans to reduce waste. A "value stream" contains all the actions required to bring a product to the customer. This section will refer to the VSM workbook from the Lean Enterprise Institute, focused on the production flow [5]. The graphical icons to be used are listed in Figure 2.

Factory icons represent external plants. Shipments use a *truck* icon with a broad arrow. The manufacturing process is divided into *process boxes*: sequences of steps in which materials flow continuously. Elements may be connected by information flows or material flows. Material flows indicate how inventory is handled.

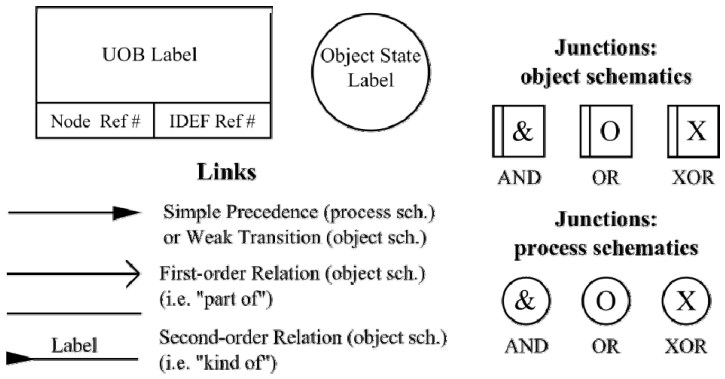

FIGURE 1. Selected subset of the IDEF3 notation.

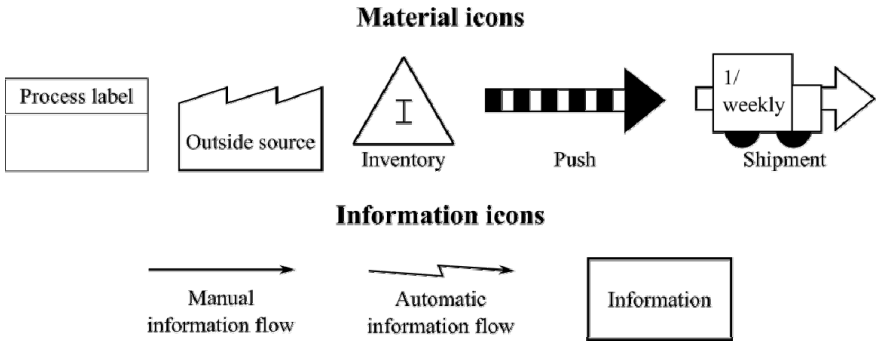

FIGURE 2. Selected subset of the Value Stream Mapping notation.

BUSINESS PROCESS MODELING NOTATION 2.0 (BPMN 2.0)

In the recent years, interest in modeling business processes for reengineering, simulation and execution has steadily increased. The proliferation of low-level notations for process execution motivated the creation of BPMN as a high-level notation which could be used by both business analysts and software developers. BPMN 2.0 has added formal execution semantics based on Petri networks and several file formats to the specification, making it usable both for process design and process enactment [1]. Part of the notation is shown in Figure 3.

Activities represent units of work in the process. Activities may have sub-processes describing them in more detail. Some of these sub-processes may be started in response to an event. Activities performed by different stakeholders will be usually placed in different *pools*, which may be further divided into *lanes*. The type of a task is noted by decorating it with an icon in the upper left corner.

Events are situations to which the BPMN process reacts. Events are drawn as circles: the line style of the circle indicates if it is a start event, an intermediate event or a finish event. Inner icons indicate what kind of event is handled.

Finally, activities and events are connected through *flows* and *gateways*. *Message* flows model information exchanges between participants, and *sequence* flows control the execution of the activities and may converge or diverge through gateways.

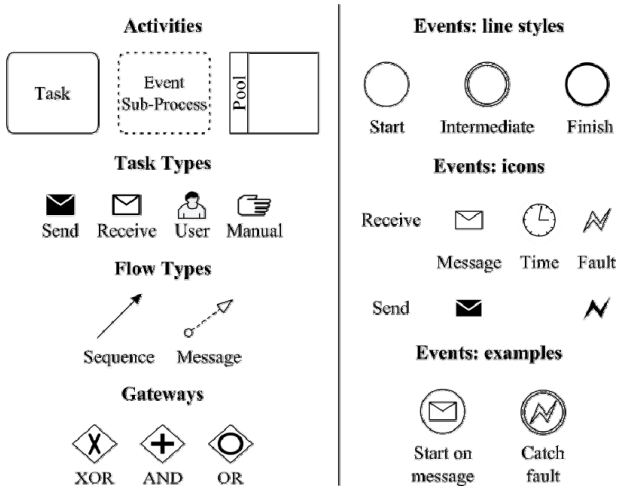

FIGURE 3. Selected subset of the BPMN 2.0 notation.

CASE STUDY

In the previous sections, IDEF3, VSM and BPMN 2.0 were presented. This section uses each notation to model a hypothetical manufacturing process described in natural language. In the next section, the models will be used to compare the notations.

Textual description

The company under study ("Company A") receives tobacco and cellulose acetate and produces cigarettes. Tobacco preprocessing consists of several steps and slightly varies from product family to product family. 180-200kg boxes of raw tobacco are regularly received from external suppliers. First, the moisture in the raw tobacco is increased and casings are added. Next, tobacco is blended, cut, compressed and packaged. Optionally, the tobacco may be "expanded" to produce the "light" variants.

Cigarette filters are produced from cellulose acetate tows, separating the fibers before adding a plasticizer and cutting the filter rods into individual filters. After letting the filters harden on trays, they are sent to the cigarette making machine. Filters and processed tobacco are received by another department, which wraps the tobacco and adds the filters, joining the cigarette with the filter using tipping paper. These cigarettes are then packed, bought by distributors and finally sold by retailers.

It is important to note that Company A recently joined a larger group and needs to synchronize its in-house information system with the SAP R/3 installation in use

within the group. This includes inventory levels, manufacturing reports and production forecasts. Shipments are handled by an external company, part of the same group.

IDEF3 model

Figure 4 is the IDEF3 object schematic for the manufacturing process. Objects represent intermediate products, from raw materials up to packaged goods. The UOB boxes have a slightly different notation, as they refer to UOBs in the omitted process schematic. They describe the process steps required for each state transition. There are two types of processed tobacco (regular and expanded), and therefore two types of cigarettes (regular and "light"). Most UOBs have a single digit: their contents have not been expanded. However, as an example, the "Make filters" UOB (#2) has been expanded into four nested UOBs, with identifiers from 2.1.1 to 2.1.4. Additionally, the "Filters" object node has a different line style and is decorated with a "C", indicating there are several types of filters not shown in the diagram.

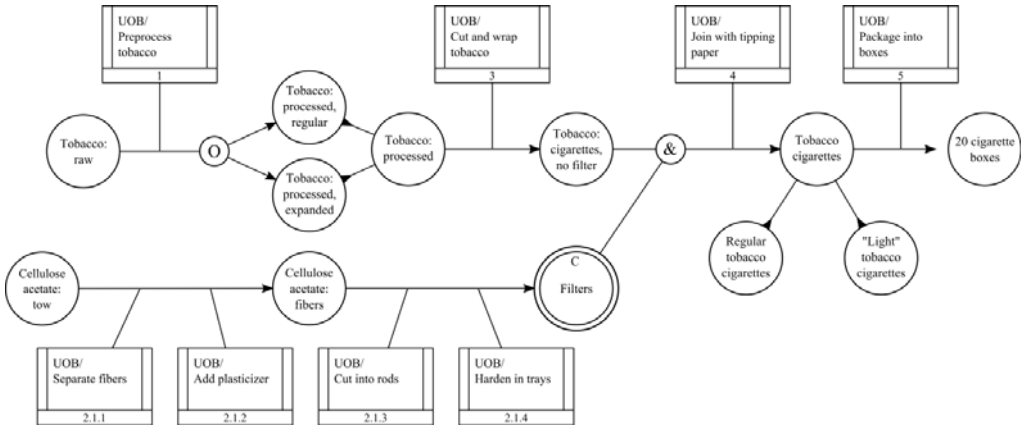

FIGURE 4. *IDEF3 model for the case study*

VSM model

Figure 5 presents a VSM schematic describing the different material and information flows in the plant. Suppliers provide the required tobacco and cellulose acetate tows once a week and these are pushed through the process, which performs 2 weekly shipments of cigarette boxes. There are two information systems communicating with the plant: an in-house system sends daily orders to the tobacco preprocessing area and weekly orders to the filter manufacturing area, and receives regular notifications about the shipments. The SAP/R3 system from the parent company sends weekly manufacturing schedules and receives periodic status reports.

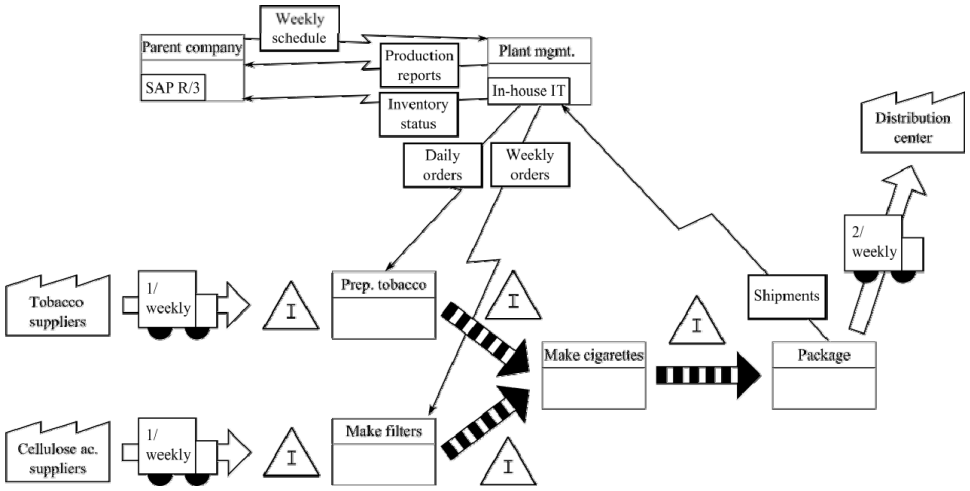

FIGURE 5. VSM model for the case study.

BPMN 2.0 model

Figure 6 is a BPMN 2.0 model of the manufacturing process. The model is divided into several lanes: one for each participant in the process. Lanes do not need to represent every action taken by a participant: for instance, this diagram only shows the activities from the parent company and in-house IT directly related to this manufacturing process. The lane for the logistics company is completely empty: all the model shows is that the plant sends shipment requests to it after a batch is done.

The model indicates that the plant receives every day the batches to be produced, and repeats the basic manufacturing process for each of them. Repetition in BPMN 2.0 is modelled by marking the repeated activity ("Produce batch") with a small circle-shaped arrow. The contents of "Produce batch" are very similar to the IDEF3 process schematic in Figure 4. The BPMN model adds the capability to model the messages sent to the other participants. An event-based subprocess (marked with a dashed rectangle with rounded corners) indicates that when there is a fault, a message is sent to the in-house IT system.

RESULTS AND DISCUSSION

In the previous section, the same manufacturing process has been described from several viewpoints, using IDEF3, VSM and BPMN 2.0. This section will compare the expressive capabilities of these notations for several important aspects in manufacturing processes. Table 1 summarizes these results.

All the notations allow for defining valid sequences for the tasks in the manufacturing process. VSM uses very high-level tasks, dividing the process only where continuous flow is interrupted. IDEF3 and BPMN 2.0 model sequences of activities, which can diverge into different paths or converge into one path using junctions (IDEF3) or gateways (BPMN). BPMN can also describe what to do if something goes wrong, how to undo changes and how to respond to signals. IDEF3

and VSM do not explicitly model timing constraints: they can only be emulated through textual descriptions. BPMN 2.0 allow for setting alarms at certain times, frequencies or delays, as shown in the models.

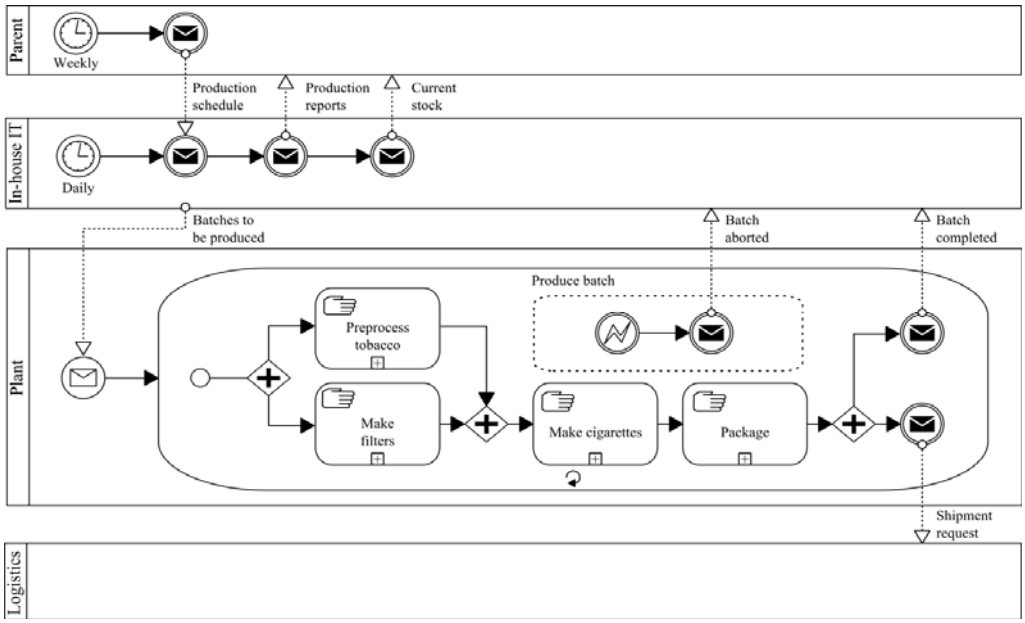

FIGURE 6. *BPMN 2.0 model for the case study*

TABLE 1. Summary of the comparison results.

	IDEF3	**VSM**	**BPMN 2.0**
Activity sequences	Fine-grained (control flows)	Coarse (material flows)	Fine-grained (control flows, events)
Timing constraints	Implicit (text)	Implicit (text)	Explicit (alarms)
Machine/operator assignments	Implicit (objects)	Implicit (data boxes)	Implicit (pools)
Material flows	Implicit (object transitions)	Explicit	Implicit (messages)
Information flows	Needs IDEF0/IDEF1X	Explicit, no internal structure	Explicit, relies on extensions for internal structure

Machine/operator assignments can be emulated in IDEF3, relating the object node with the machine to the object node. VSM does not model assignments and only includes the parameters of the process which affect material flow, such as changeover or cycle time. BPMN does not explicitly model machine/operator assignments, but they can be emulated using pools and lanes if desired.

Material flows can be emulated in IDEF3 using state transitions between object nodes, as in Figure 4. BPMN cannot accurately model continuous material flows, but

can emulate material flow in discrete manufacturing through messages with the part information. Material flows can be explicitly modeled in VSM.

Information flows cannot be described with a single IDEF3 model: supporting IDEF0 and IDEF1X models will be usually required. VSM models information flows directly, but does not provide any formal mechanisms to describe their internal structure. BPMN explicitly models the messages exchanged between each of the participants, but relies on extensions to describe the structure of the messages.

CONCLUSIONS AND FUTURE WORK

The aim of this work was to position BPMN 2.0 among the existing notations. IDEF3 was selected as a graph-based notation for modeling the expected behavior of a process and VSM as a graph-based notation for the material and information flows in a manufacturing process. After introducing the notations, a case study modeling a tobacco manufacturing process was presented. Using the obtained models, the expressive power of each of these notations was compared.

BPMN 2.0 can be seen as a superset of IDEF3 process schematics, adding explicit support for modeling the participants in the process, event handlers and message exchanges. However, BPMN cannot model the existing objects and their transitions, like IDEF3 object schematics can. VSM is a much simpler notation than BPMN and only provides a very high-level picture of the process, focusing on the material and information flows rather than the exact sequence of operations. For this reason, VSM complements BPMN: the former is a quick pen-and-paper tool for iterative process improvement, and the latter is for detailed process design and enactment.

As it is, the authors would recommend BPMN 2.0 in two areas: describing the information-intensive activities which support the manufacturing process, and describing repetitive manufacturing processes with few variations.

ACKNOWLEDGEMENTS

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