Business Process Modelling and Simulation: Hybrid Method for Concurrency Aspect Modelling

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Abstract. BPMN is successfully used for business process visualization and it has the ability to represent an aspect of a workflow. A workflow is defined as a set of activities that coordinate people and/or software. Moreover, a workflow is not equal to a business process, as a business process covers more aspects than a workflow. Therefore, the use of BPMN models generates several difficulties in business process modelling and particularly in simulation, e.g. in task modelling, BPMN does not support a capability to consider limited resources and time perspective that are essential for business process simulation. Consecutively, when a business process has a limitation of resources or a parallel task execution, then an aspect of concurrency must be represented. A concurrency can be found in business process simulation and execution, and appears, when several jobs are executing simultaneously (in concurrency manner), potentially interacting with each other when using the same resources. Concurrencies can be found in business process simulation and execution. The paper discusses workflow and concurrency aspects in business process modelling and simulation, and proposes a hybrid approach for modelling and simulation of business processes with limited resources.

Keywords: Business process simulation, BPMN, workflow, concurrency.

1. Introduction

Business process models are usually designed using Unified Modelling Language (UML) activity diagrams or Business Process Modelling and Notation (BPMN). UML is designed for the field of software engineering. There are attempts to use UML on a business system level (Eriksson and Magnus, 2000, Ko et al., 2009), but it is not expressive enough for business modelling and simulation purposes and the using UML Activity Diagrams for business process are increasingly losing favour with practitioners (Ko et al., 2009, Koskela and Haajanen, 2007). BPMN is devoted to business systems specification. One of the purposes of BPMN is to provide a notation that is understandable by business people. BPMN is usually used for workflows modelling, business requirements specification and modelling of business functionality. Moreover, BPMN models can be used for business process simulations. There exist several tools (Januszczak , 2011) that adapt BPMN for simulation, but these tools are suitable only for simplified business process simulations.

The BPMN language proposed by Business Process Management Initiative (BPMI) has some weaknesses, e.g. BPMN does not allow to define parameters such as activity duration, resources, etc., which are necessary for execution of a simulation. It also cannot represent all possible situations like modelling executions of business process instances. It can lead to significant limitations when developing business process simulation models. Also, BPMN provides only weak support for representing routine work and resources. When resources of a business process are limited, then queues usually must be defined. Queues are especially topical to business process simulation and optimization. In many cases, queues are topical to business people, because queues can show where the problems of business are. So it is necessary to include the queues in a business process model. Business process modellers may have to handle complex queuing situations (Lanner Group Limited, a). Otherwise, in many simulation languages, the creator of the process model must include queues where transactions or entities wait before acquiring resources or messages (Clark and Enstone, 2006; Mathew and Mansharamani, 2012).

Also, queues are encountered in a concurrency of activities that takes place in many situations because of parallel processing. Queues and concurrencies are applicable in real time systems. Another standardized general-purpose modelling language UML also does not have a notation to queue modelling. However, UML has a Real Time UML (RT-UML) profile for modelling real time systems. Moore, Cooling (2000) and Lanner Group approaches propose to model queues using a concurrency diagram that is an extension of a collaboration diagram, where activities and jobs compete with each other. Many BPMN simulation tools deal with queues using First In, First Out (FIFO), Last In, First Out (LIFO) methods, but that is not always a suitable idea. Some jobs that wait in a queue need to be processed first according to some business rules and not according to default methods.

Traditionally, business process modelling languages emphasize the behavioural aspect or the control flow between activities. However, BPMN is not enough to simulate a process and to model complex business processes that have limited resources and parallel jobs of different instances of the process, for example, when one instance of the process competes with another instance of the same process. Therefore, the aim of this paper is to introduce an addition for extension of a BPMN model to visualize concurrency aspects of a process.

The remainder of this paper is organized as follows. In section 2, we discuss business process aspects and BPMN capability to represent concurrency. Section 3 discusses aspects in modelling and simulation and also about information and material flow. Section 3 represents a proposed approach for concurrency modelling. Section 5 contains a case study. Finally, in section 6, we present conclusions.

2.   Related Works

A business process (BP) is a collection of activities necessary to produce a product or provide a service. A business process model is a more or less formal and detailed description of, first of all, people and artefacts involved in the execution of a particular business process and its activities, second, the rules governing this execution (Axenath et al., 2007). During the execution of a business process model, a business process is called

an instance (Axenath et al., 2007). Each business process model captures aspects of a real business process. One process might have several models or parts of models that differ at the level of details or have different goals. Therefore, it is necessary to model a process in different aspects.

The literature distinguishes several approaches to the aspects of the business process. The paper by Vondrik (2007) describes three aspects of business process modelling. One of the aspects is a functional model. It characterizes identification of BP architecture and this aspect can give an answer to the question what processes exist in an organization and what their structure is. An object model identifies a static structure of a business process. A coordination model is based on object-oriented and functional models, and its goal is to show how the process will be enacted. The coordination aspect (Vondrik, 2007) is the most significant because it enables to define the order in which all activities are executed and conditions for their potential concurrency.

Axenath et al. (2007) also distinguishes three important aspects, which are an organizational aspect, a behavioural aspect and an informational aspect. The organizational aspect describes the structure of an organization, the resources and agents, and the ways in which they are used in a business process (Axenath & Rubin, 2005) (Axenath et al., 2007). The informational aspect describes the information that is used in a business process, the way it is represented and spread among various activities. The control aspect describes the order in which different activities are executed or, in other words, the workflow. The behavioural aspect is the same as the control aspect described by Axenath et al. (2007). However, in addition, this aspect by Axenath et al. (2005) defines the order in which the tasks of a business process are instantiated, and in which the corresponding activities are executed. Besides these aspects, authors distinguish more aspects of modelling: structuring, assignment, security, transaction and authorization.

Table 1 Aspects of modelling and simulation

Aspect	BPM	Simulation
Logical (Rule)	+/-	+
Functional (Process)/ Control-flow/ workflow	+	+
Informational (Object)	+/-	+
Structural (Data)	+/-	+
Behavioural (Event)	+	+
Infrastructure (Resource)	+/-	+
Coordination/concurrency	-	+
Visualization/animation	-	+
Optimization	-	+
Analytical	-	+
Capacity	-	+
Workload	-	+

The Zachman framework (Zachman and Sowa, 1992) includes six perspectives, i.e. data (What), function (How), network (Where), people (Who), time (When) and motivation (Why). However, business process simulation needs many other aspects. The aspects of simulation depend on the purpose of simulation. Process visualization and

animation are important when a business process analyst wants to show the picture of the process. However, when capacity or workload of the process is investigated, visualization is not significant. The relevant aspects of business processes following this literature review are identified in Table 1.

The aspects are introduced in the first column of the Table 1. The ability of Business process modelling language BPMN to represent aspects is shown in the second column. The "+" means that the language has the capability to represent the aspect; the "+/-" means that the aspect can be represented with some limitations, and the "-" means that there is no capability to represent the aspect. The third column shows the aspects that are necessary for simulation. Further in this article, we examine the control and concurrency aspects.

Business process simulation helps to understand, analyse and design business processes (Jansen-Vullers and Netjes, 2006). Business process simulation often overlaps with discrete event simulation (Jansen-Vullers and Netjes, 2006). Discrete event simulation uses a mathematical or a logical model of a real system that represents the model state change at a precise point in simulated time (Richar, 1993). The simulation is driven by, first of all, a sequence of discrete events that occurs when activities are completed and, secondly, the entity movement that occurs as a consequence of these events (Mathew and Mansharamani, 2012).

A BPMN diagram suggests that this is quite similar to Discrete Event Simulation (DES), but instead of transactions or entities moving between blocks, there are tokens moving between symbols (Mathew and Mansharamani, 2012). A BPMN token explains the logic of a sequence flow in a process diagram. At a time when the business process starts, a start event creates a token which then moves through the process, until it reaches the end event (Allweyer, 2010). A BPMN token animation is not a business process simulation.

Academic people prefer languages like process algebras and Petri nets because these languages have proper formal semantics (Lohmann et al., 2009). Petri nets are a graphical and mathematical tool that provides a uniform environment for modelling, formal analysis, and design of discrete event systems. Petri net can be used to model properties such as process synchronization, asynchronous events, concurrent operations and conflicts or resources sharing (Shih et al., 2001). Krumnow et al. (2010) propose an approach to transform a BPMN model to a Petri net and to simulate it using a Petri net engine. However, Petri nets have some limitations.

YAWL (Yet Another Workflow Language) is based on Petri nets and extends the latter with constructs allowing additional features. YAWL extends Petri nets with constructs to address the multiple instances, advanced synchronization, and cancellation patterns (Aalst and Hofstede, 2005).

Although the AnyLogic[1] language has good capabilities for process simulation, this tool does not provide BPMN support. This is a disadvantage because the BPMN is de facto standard for business process modelling. The model in AnyLogic language can visualize the process, but it does not provide a capability to create an understandable workflow of a process.

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[1] http://www.anylogic.com

3. Aspects in modelling and simulation

In this section, we examine the workflow and the concurrency aspects, their usage and modelling of an informational and a material flow.

3.1. Workflow aspect

Abilities of BPMN to represent common control-flow modelling requirements that occur in business process models are described by Wohed et al. (2006). The workflow aspect reflects the intended sequence flow in a defined business process. When a business process is viewed from the aspect of a workflow, the time, the lack of resources and the queues are irrelevant. The predefined plan telling us how such business process must be carried out is to be found in a so-called process definition. The workflow or control-flow aspects are supported by BPMN and UML Activity diagrams. The workflow logic may be specified using business rules, and business rules should be separated from the program code, as this would allow to immediately react to the changes on the market by changing existing business rules (Smaizys et al., 2009). This approach would also allow to make quick changes to a workflow in business process simulation.

3.2. Concurrency aspect and concurrency in modelling languages

In theoretical computer science concurrency concerns modelling two or more things happening in parallel (Stevens, 2003). Another definition of concurrency concerns modelling two or more things happening in parallel. A concurrency is a property of systems in which several computations are executing simultaneously, and potentially interacting with each other (Gu et al., 2009).

Most UML descriptions are focused upon architectural, or static, aspects of design. Where dynamic or concurrent behaviour is described, it is usually done in terms of representative instances of interaction; no attempt is made to present models that characterize every possible sequence of interaction (in terms of the set of actions and events defined in the model).

The Object Management Group (OMG) has defined UML. UML is becoming the de facto standard support for object-oriented analysis and design. UML is lacking for the quantifiable notion of time and resources (Cambronero et al., 2007). Real-time UML (RT-UML) is UML profile for modelling Real Time Systems and embedded domains, but RT-UML can also be used in other domains, e.g. to describe Web Services Orchestration with time constraints (Cambronero et al., 2007).

The UML has no direct model for specifying the implementation of the inter-task communications (Moore and Cooling, 2000). Artisan software tools extend a UML collaboration diagram to model inter-object communication and for dealing with multitasking.

Using BPMN, it is difficult to represent a queue, so the queue can be modelled using pools. The paper by G. Wagner (2009) proposes how to model a service queue system with the help of a BPMN activity. S. Zor et al. (2010) proposes a new approach to enable automatic execution of Value Stream Mapping flows, which is achieved by mapping the Value Stream Mapping language to BPMN, and introduces a new data flow association, that allows specifying the capacity by label or Text Annotation.

However, the activity may have attributes specifying its additional behaviour, such as looping, parallel and sequential multiple instances. The parallel Multi-Instance Activity maintains three vertical lines, and the sequential multi-instance activity uses three horizontal lines. The parallel multi-instance activity constructs reflect the programming construct 'For Each' (Dijkman et al., 2008). The key point is that the activity does not cycle around; each activity performance is distinct from the other one (White and Miers, 2008).

3.3. The use of aspects

The goals of a business process model indicate the selection of the business process modelling language and the level of abstraction or detail for business process modelling. The purpose of the model also indicates the relevant aspects of business process. For example, if we only need to model for better understanding of the business process and to graphically represent it, then the capabilities of BPMN are enough. However, if we need to have a more detailed business process model, then it is necessary to model the business process in different aspects.

In this paper, we review two aspects of business processes. Workflow aspects can be used to:

- Create a graphical notation of a business process;
- Describe behaviour directly in business terms;
- Separate behaviour from scheduling;
- Capture existing processes by structurally representing their activities and related elements;
- Describe the workflow logic of a business process.

Concurrency aspects can solve or can be used for these tasks:

- Simulation;
- Simulation when cost calculation is needed;
- Modelling a business process involving limited resources;
- Planning and scheduling;
- Representing new processes in order to evaluate their performance;
- Business process optimization;
- Multitasking design for a system with parallel processing of jobs;
- Operational decision support;
- Long term planning and strategic decision making.

Business process management suites or business process management systems (BPMS) are used for BP modelling and execution. Several BPMS offer possibilities to simulate a business process. Most business process management systems focus on the workflow or control aspect of business process.

BonitaSoft[2] is a BPMS that does not allow representing queues in the business process model. However, it allows adding some parameters that allow simulating the business process model. The result of the simulation is a report where the queues that

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[2] http://www.bonitasoft.com/

exist in a business process can be found. However, when a person analyses the business process, it is better to have queues in a BP model, as this leads to a better understanding of a BP model. Therefore, BonitaSoft is only able to represent a workflow aspect of the process. Bonita Studio does not allow executing multiple instances of the process at the same time. Also, Bonita Studio does not allow representing how the instances of the processes compete for resources.

3.4. Modelling of material and informational flows

Material and informational flows are important for business processes. Both flows are especially significant for business process simulation and improvement of the process because these flows often have a relationship. The material flow can be associated with the movement of material through the factory. Usually, a modeller of the manufacturing process focuses on the material flow, but in manufacturing, the informational flow tells each process what to do next (Rother and Shook 2003). Therefore, an informational flow must be treated as a material flow. The informational flow can be a supporter for other task or it can be an enabler for the whole process. It depends on the design of a business process.

Nonetheless, business process modellers using BPMN usually concentrate on informational flow modelling and ignore the material flow. Developers use BPMN models for development of the information systems and informational processes of automation.

Data flow diagram (DFD) is a diagrammatic model representing the flow of data or information within a system (Aguilar-Saven, 2004). DFD allows specifying a process at the logical level. It describes how information enters and leaves the system or the process, how it flows in the system, what changes the information, and where the information is stored. However, nowadays the DFD are rarely used.

Many UML diagrams do not have the ability to represent the data or informational flow, because the UML is used in object-oriented software design. The most similar diagram is a UML activity diagram. However, the transitions between activities do not represent the data flow. These transitions describe the sequence of activities or decisions. An activity diagram has a data store element, input and output pins, but the model with a lot of these elements becomes complicated and is difficult to understand.

## 4. Hybrid modelling Approach for Business Process Simulation Design

The section presents a hybrid approach for business process modelling and simulation with resource limitation. A higher level (business system) model represents the process workflow aspect modelled using BPMN. The lower level is modelled using a collaboration diagram of RT-UML with a concurrency diagram extension.

4.1. Description of the model

Firstly, we describe the dependencies of models that are presented in Figure 1. We do not analyse other aspects of a business process in this paper; thereby other columns of

aspects are not shown. The business process (BP) model presents a workflow or a control aspect of a business process. The BP model consists from tasks and resources. Resources are presented in the resources model. The tasks of a business process can be composite, and those are presented in the concurrency model. After that, all models are transformed into the simulation model, and some parameters for the simulation are added.

We propose a hybrid approach for business process modelling and simulation. The approach can be used for informational and manual tasks. Also, the method can be used for modelling of a manufacturing process. For a high-level (business system) business process model, we use BPMN, as it is understandable for business people and developers of information systems. We argue that concurrency modelling is significant for business process simulation. The BP model allows a graphical representation of a business process and verification of the workflow logic. The BP has tasks that are modelled with a concurrency model. The concurrency model is a low level model with details that are not relevant at the business system level. Nonetheless, this model is important for
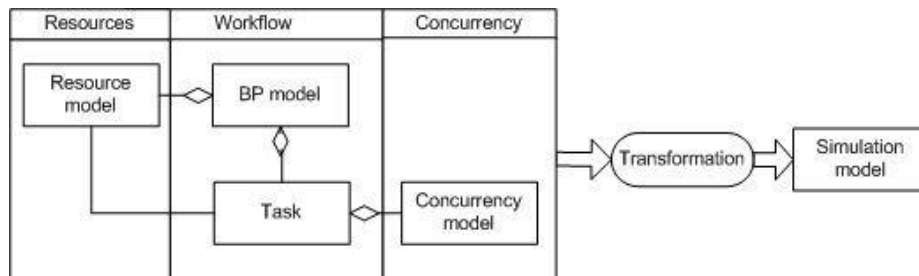
Fig. 1. Modelling aspects of simulation

information systems developers and creators of a simulation model. An important aspect of the resource model of a business process is that we model using a class diagram. All these models are transformed to an executable simulation model.
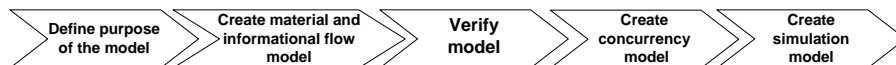
Fig. 2. Basic steps of the method

Secondly, we describe basic steps of the proposed method that are presented in Figure 2. First of all, we need to define the purpose of the model. Models and simulations are developed for a specific purpose. This purpose affects the examined areas and business process granularity. Next, we create a business process model that is at a high level of abstraction. We use BPMN language, because it is understandable for business people. We accept that high level business process models should be as simple as possible for business people to understand them easily. Material and informational flows are often separated from each other. We believe that the material flow influences the informational flow, and vice versa. Consequently, we offer to model both flows in

one business process model. The model should not be overloaded with details. However, the essence of the process should be conveyed.

Next step is the verification of the model. In other words, it means verifying workflow logic of a business process. If the workflow logic is incorrect, the model must be corrected. Next step needed after verifying workflow logic of the business process is identification of concurrency aspects in the business process. It is necessary to examine each activity of the process and to identify activities that are sharing limited resources. We propose to use a RT-UML collaboration diagram with extensions for concurrency for modelling these activities or tasks. The notation was presented above. The low-level models including all necessary details should be more complex than high-level models. Finally, we create a simulation model. We use AnyLogic Simulation software in experiments, because these tools have a queue notation that can represent a concurrency in some way, however, like it was mentioned, it does not have a BPMN representation. Also, AnyLogic is more frequently used for animation and visualization of various processes, but not for simulation of processes with a material and an informational flow.

Often a business process model is created only with an informational flow to show how informational flows in and out of activities (Cousins, Stewart 2002). However, for business process simulation and optimization, it is not enough to have only an informational flow model. It is equally important to include the material flow of the process. The purpose of the method is to create a full process model with material and informational flows, to represent aspects of a business process and the use of this model for simulation. Finally, the model and simulation results yield recommendations for improvement of business processes.

This method can be used for situations where a business process is designed not only for information processing. This is important because business processes include tasks that cannot be realized in information systems, as these tasks are important for further business process improvement.

The method is oriented to business process that cannot be fully automated and requires a human work or some inventory. The approach can be used in areas where parallel work, multitasking and concurrent tasks exist. This business process can be in manufacturing, logistics, various human works and etc.

4.2. A detailed view of material and informational flow modelling

In this paper, we describe the material and informational flow model of a business process in more detail. We propose to model informational and material flows in one model, i.e. not to separate these into different models, as informational and material flows are often related to each other.

The basic steps are:
- Identify activities that are needed to the process to create a process output (produce the product);
- Identify the material flow;
- Create a draft model of the material flow;
- Identify information needed to execute activities of the process;

- Identify all documents that are created during the execution of the process. Also, there is a need to identify the entire informational flow that includes printed documents, e-mails, invoices, faxes and etc.;
- Identify all participants who are involved in the process;
- Identify all resources used to create the process output;
- Identify or calculate average duration needed to process activities. This duration can be pulled out from different systems logs, such as database logs, fax log and etc.;
- Identify queues and activities that compete for resources in the process ;
- Create a high level business process model using BPMN.

5. Case Study

In this section, we examine a business process with information and a material flow. These flows are dependent on each other. That means that if the activity of information processing is not ended, then the next material or information processing activity cannot start. The case study has activities that compete for resources.

5.1. Analysis and modelling using BPMN

One of the steps of the method is the analysis of a business process and creating a model. We analyse a business process of a company that unloads goods from wagons, stores them and then loads the goods onto ships. The business process was analysed before (Rima et al, 2012), and problems were identified. Therefore, one of the business processes is discharging products from wagons. It is significant to mention that the arriving wagons always compete for processing (unloading).
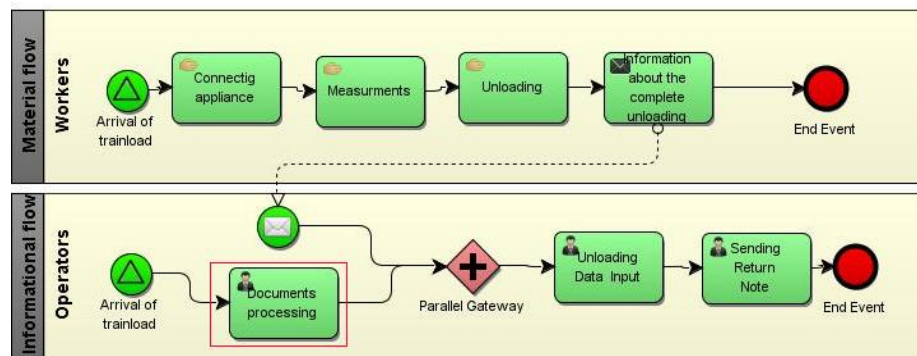

Fig. 3. The business process model in BPMN

A BPMN diagram of the process is shown in the Figure 3. The marked activity (Documents processing) is detailed in the second section. The business process begins from the arrival of trainload. After that, the workers connect the appliance and the operators begin to process documents. After all train unloading, the workers send the
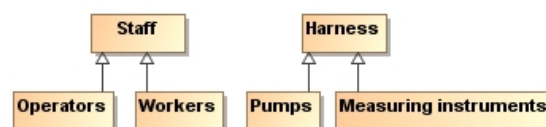

Fig. 4. The resource model

operators a message informing that wagons are unloaded and including wagon measurement data. After that, operators process the unloading and send a return note to the station. Many tasks of this process have queues, and the jobs of the process compete with each other.

Figure 4 presents the basic resources used during the process. The resources are staff and equipment. The operator performs tasks related to the processing of information. Workers perform manual work and use equipment.

5.2. Modelling concurrency and creating simulation model

The goal is to present the concurrency at the time when the process simulation is running. The simulation and business process models when used in the ordinary way ignore a concurrency aspect. In such a case, the task is executing without allowing for concurrency and resources can blocked for a long time. Figure 5 shows the timing diagram of simulation with and without concurrency. The Y axis shows the number of business process instances. The X axis shows the time needed for execution. The solid lines show that the tasks are executing and using the resource. When simulation is running without concurrency manner, the resource can work with each task in a exclusive manner until the task is completed. When tasks are executed with concurrency support, multitasking of the resource can be applied and the tasks of the process do not block resources for a longest time. For example, human tries to perform two jobs simultaneously and switch himself from one job to another. This situation is naturally, but cannot be modelled and simulated with usual business process modelling and simulation tools.
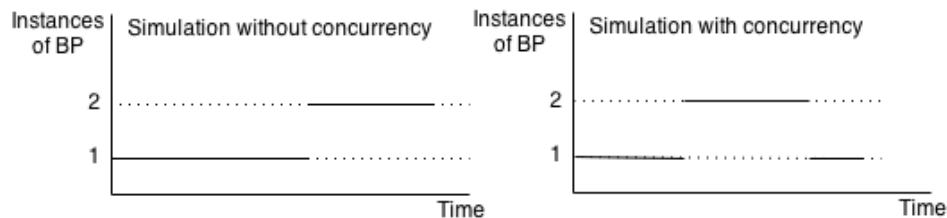

Fig. 5. Simulation without and with concurrency

We examine the document processing task of the informational flow in detail. The model is presented in Figure 6. This model is done manually and consistency check is done also manually. The model in some way can be presented in AnyLogic format (Figure 7). This is done manually to show ability to simulate the task.

Fig. 6. Informational flow of document processing task

A ModelMaker[3] tool extends the collaboration diagram of RT-UML that has a queue symbol. Also, it has other symbols like a timer, an event flag, and a mail box and we added the resource symbol. The notation is presented in Table 2. This diagram with additional notation shows some aspects of the process and allows focusing on multitasking issues and to present inter-task communications that are usually handled by the execution (simulation) of the model. The model with communication mechanism and resources notation is better to understand and represent concurrency aspect.

Table 2 A concurrency diagram notation adapted from ModelMaker Tools (WEB, a)

	Operation - an action resulting from a single instruction.
	Event Flag
	Queue - a line of waiting jobs.
	Mail Box - a storage
	Timer - a switch that causes a mechanism to operate at a specific time or predetermined intervals
	Resource

This model helps to better understand the activity. Different instances of the process have different collections of documents. The activity 'Document Sorting' involves people to sort documents, and this activity has a limited number of people (resources). This activity takes some time, so before the activity, there is a queue of the collections of documents (jobs), so when documents arrive, they are placed in the queue 'UnprocessedDocuments'. When the collection of the documents is sorted and prepared to input, they move to the next in the queue.

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[3] http://www.modelmakertools.com/

AnyLogic has a library of rails and trains, but it is not designed for our purpose, because the library is for visualization of railways, and not for modelling both flows.
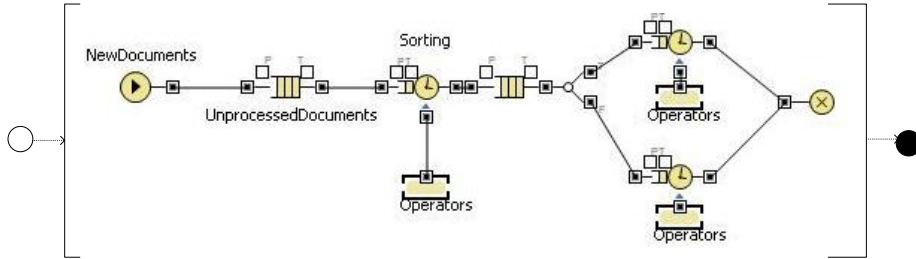

Fig. 7. An AnyLogic model

5.3. Multiple instance tasks in BPMN

In this section, we describe the existing possibility to model parallel or sequential processing using BPMN and its difference from our approach. The activity element of BPMN has two multi-instance markers. A multi-instance marker for parallel instances should be used (three vertical lines). If the work is performed only sequentially, a multi-instance marker for sequential instances should be used (three horizontal lines). These markers can also be used for data objects in BPMN.
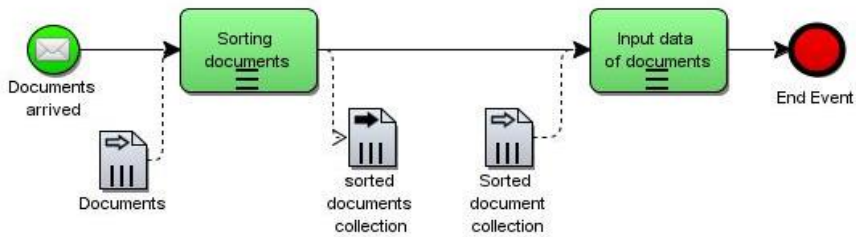

Fig. 8. A multi-instance task and multi-instance objects

Figure 8 presents an example described in the Case Study section (Section 5). The tasks ('Sorting documents' and 'Input data of documents') have a sequential processing parameter, because the task handles the documents sequentially and processes only the documents of the instance. This approach does not represent the concurrency aspect, because there is only sequential or parallel processing and the tasks do not compete for resources. However, the main difference from our approach is that the multiple instance tasks execute several instances of tasks for one instance of a process. Also, BPMN multi-instance marker does not deal with several instances of a business process.

6. Conclusions

The paper has shown that the aspect of concurrency is significant for business process modelling and simulation. The control-flow or workflow aspect representation in existing modelling languages is insufficient in case of modelling processes with limited resources. Diagrams of most popular business process modelling language BPMN represent only a sequence of tasks and message flows and are not suitable enough for representation of complex business processes with queues resulting from limited availability of resources that determines delays. This type of business processes is one of the main focuses in simulation based business process analysis. The proposed extension of a business process model with a detailed concurrency specification allows business process simulation with regards to the resource and concurrency aspects.

The proposed approach contributes a concurrency aspect model at the information system level to support the workflow aspect of a process model realized in BPMN at the business system level. This enables to maintain business processes understandable for business people and allows representation of the concurrence for resources which are needed to accomplish material and informational tasks of the process. The novelty of our approach lies in our focus on queues and delays in business process models used for the further development and improvement of business process simulations.

We will focus our future work on further improvement of the proposed approach, on analysis and involvement of the business process infrastructure capacity aspect and automation of transformations of all the involved models into executable simulation models.

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