# A Resource-aware Simulation Tool for Business Processes

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Abstract: The deep knowledge of internal and external business processes, along with the capability of governing them, are a key requirement for enterprises to survive. In the dynamic and unpredictable worldwide market, the achievement of business goals depends on the ability of enterprises to adapt to new market conditions by promptly re-engineering their processes. The cost for process re-engineering may be not negligible, if we consider that it may require several refinement steps and that tuning processes on-the-job may impair regular business activities. To this end, there is a growing interest towards tools that allow to simulate process modifications before actually enforcing such changes. In this paper we propose a tool for business process simulation which makes use of modeling specifications such as the Business Process Model and Notation (BPMN) and exploits the rigor of the Colored Petri Nets (CPNets) formalism. With respect to other approaches proposed in the literature, the one presented here defines a detailed model of enterprise's resources (both human and non-human) and cost allocation inspired to the Activity Based Costing (ABC) accounting principles. A case study test was conducted on a prototype implementation and related results are presented.

## 1 INTRODUCTION

Many organizations are recognizing the value of Business Process Management (BPM) as a strategic business tool. BPM combines established management methods with information technology to measure performance, identify bottlenecks and improve business processes more quickly and easily (Weske, 2012). It enables business managers to make better-informed decisions and to look at the enterprise "as-a-whole" when facing new market changes and challenges. Beyond process modeling, the analysis phase plays a key role in the BPM discipline. Business process analysis is a term used with a rather broad meaning, including a range of different tactics such as simulation and diagnosis, verification, and performance analysis of processes (Vergidis et al., 2008).

In this paper we focus our attention on simulation. Simulation provides dynamic analysis of business processes, going beyond static diagrams and averaged numerical process verification. Processes involving variability, disruptions and interaction complexity are ideal for simulation. Other (static) techniques for measuring processes, such as spread sheets and flow diagrams, often ignore or treat these factors as averages, with important consequences (Jansen-vullers and Netjes, 2006). Simulation tools provide a structured environment in which business managers can understand, analyze, and improve business processes. With such tools it is possible to evaluate the performance of the existing process model (*as-is* model) and to compare it with its modified versions (*to-be* models) in order to verify the improvement of key performance indicators (KPIs).

In this paper we present the design of a simulation tool that relies on the standard Business Process Model and Notation (BPMN) (OMG, 2011) and exploits the formalism of Colored Petri Nets (Jensen, 1996) for which efficient and consolidated analysis techniques are available. One of the main contribution of our work with respect to existing tools is the definition and the integration of an enterprise's resource model within the simulation framework. In particular, we introduce a cost-oriented characterization of resources which is inspired to the Activity Based Costing (ABC) accounting principles. Business process models typically abstract away from the resource perspective or provide a simplistic view of resource participating in a task. As it will be shown later, our framework allows to model and simulate complex interactions between activities (tasks) and resources (both human and non-human).

The rest of the paper is organized as follows. In Section 2 an overview of related work in the field of business process simulation is provided. In Section 3 an ABC-centric view of the enterprise's process

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model is described. Section 4 provides the main design principles of our simulator. In Section 4.1 technical details on the the main component performing the mapping from the BPMN model to the CPNet model are discussed. Section 5 presents a practical and explicative use case and Section 6 concludes the work.

## 2 LITERATURE REVIEW AND MOTIVATION

Business Process Simulators are acknowledged as one of the must-have tools which business managers should use to analyze enterprise's business processes and to keep the business goals under strict control over time.

Process Simulation is one of the key features of both commercial Business Process Management Suites (BPMS) and research prototypes of business process tools. Many commercial actors such as ARIS, Oracle, iGrafx and IBM have developed very powerful simulation tools, which unfortunately are embedded in their respective BPMS, and though open process notation formats like the BPMN (OMG, 2011) are supported, the full set of offered simulation features can be exploited only if the proprietary notation format is used. An interesting analysis on the limits shown by the approach adopted by the majority of commercial simulation tools can be found in (Van der Aalst et al., 2008).

Within business process management, simulation can be readily used for both process design and ongoing process improvement. In (Januszczak and Hook, 2011) authors argue that in most cases simulation is more effective (in terms of costs and practical benefits) if applied after processes have already been automated. In that case, in fact, processes' output data may be collected and used as input for the simulation model. Further, they propose to adopt a standard format to represent both the processes' gathered data and the parameters of simulation scenarios in order to improve the accuracy of simulation results.

In the literature some works have appeared which focus on the need of integrating security and risk aspects in the management of business processes, and propose risk-aware simulation models(Tjoa et al., 2011; Betz et al., 2011). Most of literature approaches, though, deal with economic aspects: processes, activities and involved resources are regarded in the perspective of the costs they produce. Further, most of the proposed simulation tools rely on Petri Nets (and their derivatives) as modeling languages to describe processes and process interactions.

In (Koizumi and Koyama, 2007) authors try to estimate the process execution time by using a Timed Petri Net model. Protos2CPN tool (Gottschalk et al., 2008)'s strategy is to transform a Protos model into Colored Petri Nets (Jensen, 1996), and simulate it in standard CPN tools. In (Van der Aalst et al., 2008) focus is on the correct modeling of resources. The YAWL language (Van der Aalst and Ter Hofstede, 2005) is used to capture and model resource features within the process dynamics. Colored Petri Nets are also adopted in the simulation step.

The simulative approach we propose in this paper is very much focused on **resources** involved in the business process execution and on the determination of **analytical costs** incurred to execute processes. The objective is to build a simulation tool capable of providing the business analyst with as much detailed as possible costs to best support the ABC analysis. We argue that the BPMN is the best candidate to capture all the dynamics of processes at any management level (from top level to production chain). Thanks to the high flexibility shown by the modeling language, processes can be modelled at any degree of detail, and the more processes get detailed, the more analytic will be the incurred costs. The advantage of using BPMN is that all kind of enterprise's processes can be modelled. Even the so called *support processes* (Porter, 1985) (e.g., Human resource management, supply management), which produce overhead costs (indirect costs), may be modelled in BPMN and integrated in our simulation environment. Eventually, our approach enables for overhead costs to be directly allocated over the enterprise's products/services, thus facilitating the job of the cost analyst.

Our proposal recalls the Protos2CPN's in that the business process model is transformed into a Colored Petri Net, but unlike Protos2CPN the starting process model is a standard BPMN model (and not a proprietary one). As for the Petri Net simulator we integrated the Renew simulation engine (Kummer et al., 2004), which provides a flexible Java-based high-level Petri net simulator. To sum up, our strategy combines the high flexibility of BPMN used to capture the process dynamics at all enterprise's management levels with the formalism and rigor of Petri Nets used to simulate business process executions. Finally, regarding the definition of simulation scenario parameters, the guidelines presented in (Januszczak and Hook, 2011) where followed.

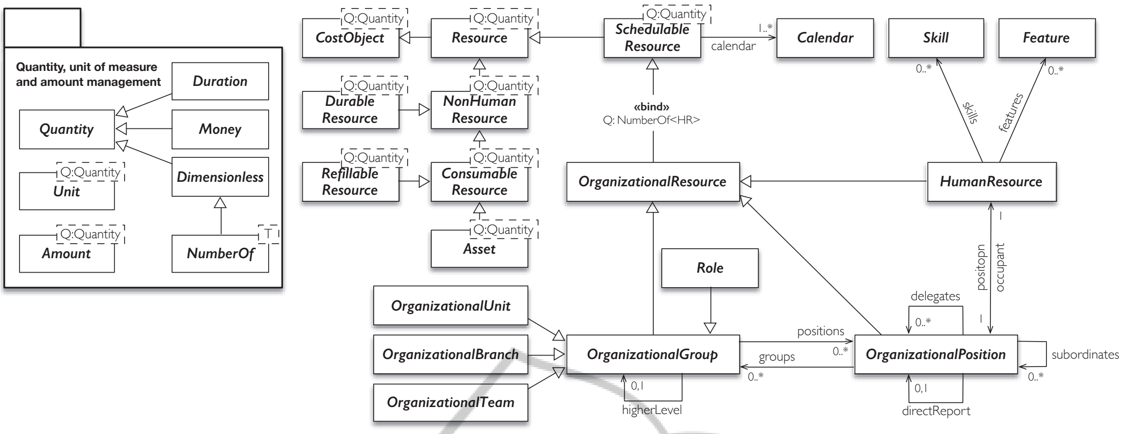


Figure 1: Class diagram representation of the Resource Model.

## 3 AN ABC-CENTRIC INFORMATION MODEL

In order to design an accurate simulator a fine-grained characterization of business processes must be first carried out. To characterize and analyze at best business processes (BPs) several kinds of information are needed. Put in a simple way, BPs interact to each other's and involve multiple activities, which in their turn have to be fed with many data in order to complete successfully. Current BP's modeling notation such as XPDL (Coalition, 2012), EPC, BPMN (OMG, 2011) and YAWL (Van der Aalst and Ter Hofstede, 2005) help the process designer to model processes according to the process flows' specification. Still, a process model may not be said to be exhaustive unless it is complemented by the information which is necessary for the processes' implementation within its execution environment. In the study conducted in (Vara and Sánchez, 2009), authors point out that classic BP modeling tools are not able to elicit all functional requirements needed to integrate the process implementation to the enterprise's information system. According to that study, a single BP is characterized, among others, by some pre/-post conditions (conditions which must be fulfilled before/after the process is executed), the *data object* consumed/produced by the process flows, the business rules to be enforced in strategic points of the process branches, and the set of actions that both human beings and the system carry out during the normal execution of the process.

We argue that the design of a simulator of business process executions must account for the discussed set of requirements. In the proposed approach, such requirements will form the basis of an *Information Model* ($I_{mod}$) which the simulator will rely on. In our design the $I_{mod}$ breaks down in three sections: Business Process Model, Resource Model and Bridge Data Model.

The *Business Process Model* ($BP_{mod}$) represents the definition of processes and their control flows. There is a lot of well-known and largely acknowledged specifications which can be used to model processes. This work does not address the definition of a new business process modeling specification. But, since a business process model is required for the project's purposes, we decided to adopt the well known Business Process Model and Notation (BPMN) standard to model processes, subprocesses, tasks and control elements of BPs (OMG, 2011).

Differently from what other approaches have proposed, the work presented here focuses on the definition of an enterprise's *Resource Model* ($R_{mod}$) and on its strong integration with the business process model. The $R_{mod}$ aims at capturing and representing information regarding any kind of "resource" that need to be consumed by each process task, be it a human or a non-human resource, and more specifically puts the basis for an Activity Based Costing (ABC) analysis of processes. We believe that an accurate representation of all resources potentially exploitable by the enterprise, along with the specification of a tight integration of such resources to the enterprise's BPs, will help the process designer to contextualize the process model and, thus, to better estimate the KPIs' fulfillment.

The *Bridge Data Model* ($BD_{mod}$) was designed to embed information regarding a) the integration of processes' workflow elements with the resources available in the enterprise and b) other functional requirements which are useful to contextualize the BPs in their real runtime environment. As for a), information can be found, for instance, on the type and quantity of a given resource $R$ (defined in the $R_{mod}$) associated to a specific process task $T$ (defined in the $BP_{mod}$). With respect to point b), the document collects data related to the processes' runtime execution, i.e., specific functional requirements regarding the enterprise's IT context where processes are going to be deployed. This section of the document is used to model the behavior of BP elements (like business rules, gateways) which may require input data coming from the enterprise's information system. Such behaviors may be modeled either through statistical functions or through data objects attributes evaluation, and of course it is up to the designer to search for the most appropriate function and fine-tune its parameters.

While the $BP_{mod}$ is well defined by the BPMN specifications, the need for integrating it with an enterprise-level resource model and all parameters related to the simulation scenario lead us to the design and implementation of the $R_{mod}$ and the $BD_{mod}$.

The starting point is suggested by the approach used in ABC analytical accounting systems (Cooper and Kaplan, 1992). We assume that all enterprise costs are generated whenever an activity consumes a resource. The strength of ABC is that all costs generated by resource consumptions are directly allocated to the activities by means of the appropriate resource drivers, in other words, all costs (including overhead costs produced by supporting activities) may be viewed as direct costs. Given the full activity cost configuration it is afterward possible to allocate this cost to every cost object through well suited activity drivers that define how a cost object "consumes" each activity.

The $R_{mod}$ targets at modeling an enterprise resource pool, and defines the resource concept as a cost object extension. Figure 1 presents its relevant UML classes and their relationships. Each resource, as well as each cost object, is defined by its unit of measure and its unit cost. As measures and unit framework, a JSR-275 standard implementation has been used[1].

The *NonHumanResource* class allows the definition of resources like goods and services. *ConsumableResource* extends it by introducing the concept of "residual amount" and it is suited for available-if-in-stock resources. *SchedulableResource* represents a generic resource whose availability is defined by one or more calendars; the most common calendar based resource is the *HumanResource* who occupies an *OrganizationalPosition* within an *OrganizationalGroup* or an *OrganizationalUnit* structure (organizational chart).

[1]http://jscience.org

The base class for *Resource* and *Activity* is the *CostObject* class. Each cost object can rely on a set of other cost object requirements (see figure 2), enabling hierarchical cost object modeling and cost aggregation providing a generic chart of cost objects accounts. The $BD_{mod}$ uses this feature to map the ABC resource driver concept into the activity resource requirements.

Figure 2 shows how the *Activity* class implements the bridge between the $BP_{mod}$ and the $R_{mod}$, given that the activity is both a cost object and a process flow element.

In standard ABC accounting, activity drivers are generally defined by the ratio between the number of activity instances related to the given cost object and the total number of activity instances or, in case of activities that work on a mix of different cost objects of the same class, by the ratio of time spent by the activity working on the given cost object and the total work time of the activity. The second approach is well justified when low levels of information about the inner structure of the activity are available, so that it is not possible to exploit the trace of the elementary tasks composing the entire activity in a simple way.

Under the business process management view, it is possible to assert that the latter event should never occur. Given the fundamental approach of BPMN modeling and implementation phases, that imposes a full breakdown of all processes up to their task levels in conformity with each data-object lifecycle, it can be safely assumed that $BP_{mod}$ enables a full resource-activity-cost object mapping given the fact that resources are consumed by tasks that generally work on a single and well defined cost object set. The only exception may arise in case of high-level non-executable process models. It should be responsibility of the designer to detail the $BP_{mod}$ up to the required level.

# 4 DESIGN OF A BUSINESS PROCESS SIMULATOR

In this section the design of a Business Process Simulator is presented. Simulation of business processes is a technique which may be used to analyze the impact of some important choices that are to be taken at process (re)design time, right before (re)implementing the processes. Through simulation designers are able to estimate the fulfillment of the enterprise's key performance indicators (KPIs). The more accurate the simulator, the narrower the gap between the estimated KPIs and the actual KPIs that will be achieved at process execution time.

The simulator was designed to be "fed" with data

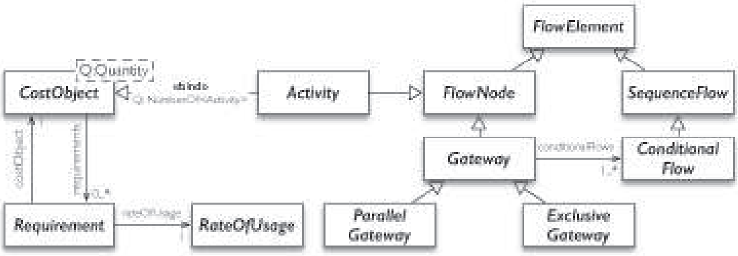


Figure 2: Class diagram representation of the Bridge Data Model.

organized according to what is specified in the $I_{mod}$ structure. The data organization is a manual task committed to the designer, who will have to gather all processes' requirements and give them the structure recommended by the $I_{mod}$. In particular, the designer is responsible for the definition of the $BP_{mod}$, the $R_{mod}$ and the $BD_{mod}$ respectively. In the definition of the $BP_{mod}$ they will be guided by the requirements on the enterprise's business workflows. Then, they will take care of mapping enterprise's resource requirements onto the resource categories specified in the $R_{mod}$ (see section 3). Last designer's responsibility is the elaboration of the $BD_{mod}$, which represents the bridge element integrating the BPs and the enterprises' information system.

The simulator can be called into action after the completion of the modeling task. The objective of the simulation is to estimate the values of some predefined process KPIs. Results from the simulation are used to refine the process design and, if the case, rerun the simulation. This step may be iterated until the estimated KPIs get close to those established by the business objectives. We did not implement a new simulation engine, rather, we searched for well known techniques and robust solutions which might grant the achievement of our objectives. In particular, the main requirement the simulator ought to fulfill was the capability of simulating "annotated" business processes, i.e., business processes to which supplementary information is associated. We ended up choosing a tool based on the Colored Petri Nets (CPNet) (Jensen, 1996). The approach of simulating business processes defined in the BPMN notation through Petri Nets is not new in the literature (Dijkman et al., 2008). What instead may be considered a novelty in our approach is the integration of the BPMN with additional models and the mapping of the integrated models on a CPNet.

In Figure 3 the overall architecture of the discussed system is depicted. In order to be able to feed a CPNet simulator with well structured data, we had to design an ad-hoc component called **Model Mapper** which parses the $BP_{mod}$, $R_{mod}$ and $BD_{mod}$, and maps the parsed data onto *Petri Net Markup Language (pnml)* structured data, which is a data format

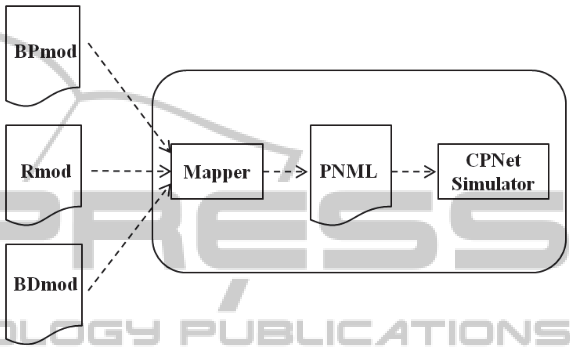


Figure 3: System architecture.

ready to be submitted to a timed CPNet. For the purpose of this work, the Renew tool (Kummer et al., 2004) was used as a simulation environment. Such a tool supports the development and execution of Petri Nets and enables a seamless integration with the Java Runtime Environment. This last feature allowed us to run resource-aware simulations of business processes.

### 4.1 Model Mapper

This section discusses some technical details of the mapping process carried out by the Model Mapper component. The Mapper is charged of parsing the $BP_{mod}$, iterating on each BPMN element, enriching it with information retrieved from the $R_{mod}$ and the $BD_{mod}$, and finally creating the corresponding CPNet network. Such network is the configuration file to be passed to the Renew tool (Kummer et al., 2004) for actual simulation. For space reason, in this paper we can not describe the mapping of all BPMN elements, therefore we are going to focus on just two (yet representative) of them: the **Send Task** and the **Exclusive Gateway**.

In Figure 4 the mapping of a very simple example of a *send* task has been depicted.

In the uppermost part of the figure, the three instances of $BP_{mod}$, $R_{mod}$ and $BD_{mod}$ are reported. At the bottom of the figure, the result of the mapping procedure is shown. As the reader may notice from the

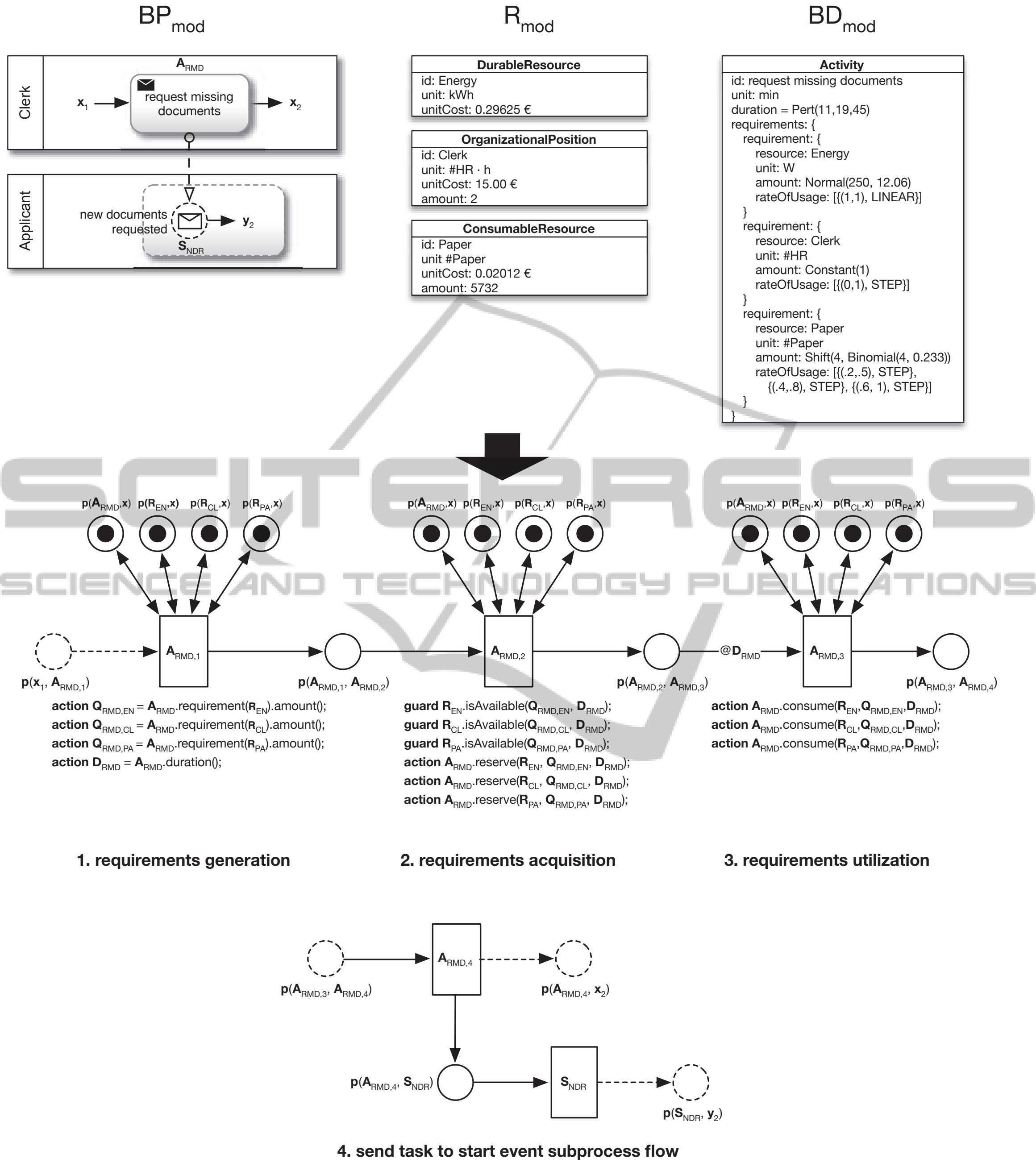


Figure 4: Mapping of a “send” task.

$BP_{mod}$, two actors are involved in two different processes, of which one is an internal enterprise's process, the other is not. The *Clerk* owns the internal process and is committed the task of sending a request for some documents. Let us notice that the Clerk is also a resource which is exploited by the task. Other resources which are consumed by the task, and thus are listed in the $R_{mod}$, are *Energy*, *Paper*, *Letter*, *Stamp*, *Printer* (which carries its depreciation cost) and *Office* (which carries its rent cost). In the figure, for space reason only Clerk, Energy and Paper have been reported. Finally, the $BD_{mod}$ specifies some requirements regarding the association of the task and the cited resources. For example, the first listed requirement states that for Energy is required an amount of watts described by a Normal distribu-

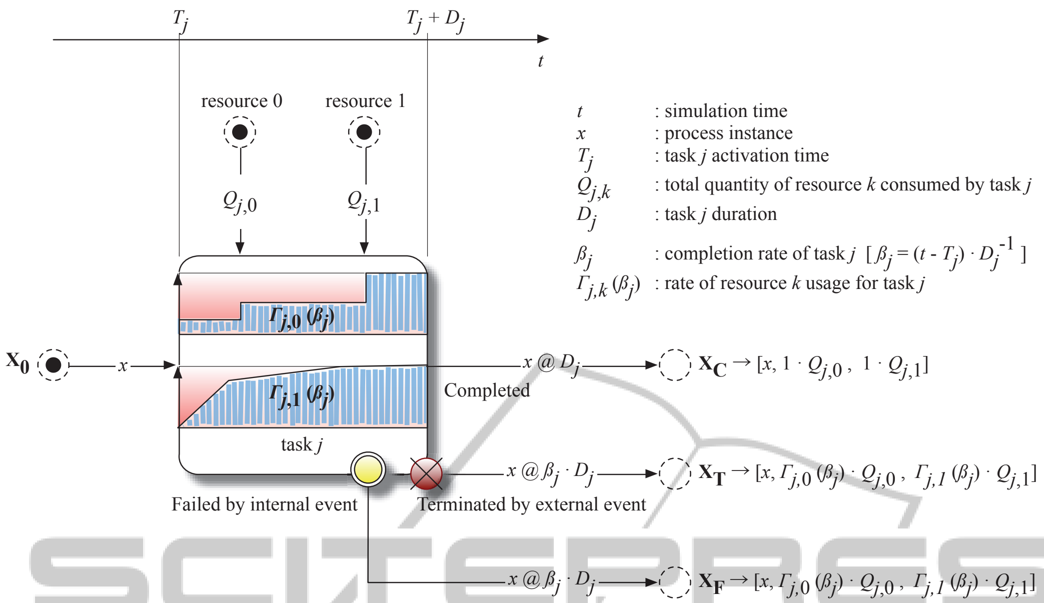


Figure 5: Representation of two resources' rates of usage.



tion with ($\mu = 250, \sigma = 12.06$). For Clerk, just one unit is required.

The *rateOfUsage* parameter appears in all requirements and defines the law of consumption for the pair task-resource being considered. In practice, if the task is successfully completed, the resource is considered to be consumed as a whole with respect to the expressed amount; if instead the task is preempted or fails for any reason, then the rateOfUsage states what is the rate of the resource that must be considered consumed. The reader may refer to Figure 5 for details about the rateOfUsage concept.

The task operational logic consists of a sequence of three phases that are responsible for processing the given resources:

1. requirements generation;
2. requirements acquisition;
3. requirements utilization.

Every process instance token that reaches a task needs to pass through these phases for the task to complete successfully.

The Mapper translates these three phases in a sequence of three transitions. Depending on the number of task's incoming and/or outgoing sequence/message flows, one more transition is put before (phase 0) and/or after (phase 4) these three to perform the corresponding workflow logic.

In the simulation initialization phase, a number of $BD_{mod}$'s classes are instantiated and fed to the CPN as tokens, each one located in its own place. These places are shared between multiple transitions and

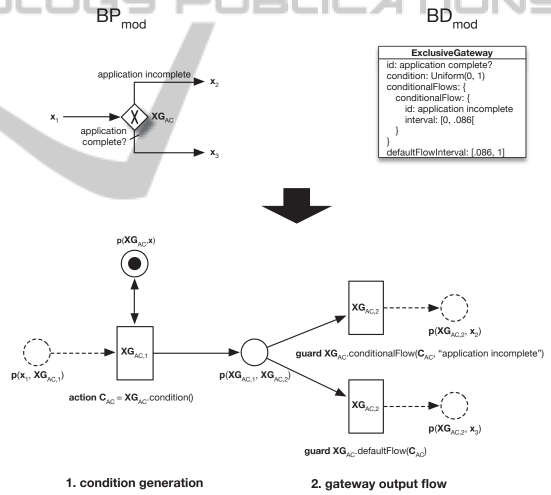


Figure 6: Mapping of an "exclusive gateway".

connected by reserve arcs, so that when such transitions fire, a series of actions can be performed on the $BD_{mod}$'s instances. On the transition input side, the Renew tool permits to control its firing by equipping it with guard inscriptions. Guard inscriptions are expressions that are prefixed with the reserved word **guard**. A transition may only fire if all of its guard inscriptions evaluate to true. On the transition output side, the tool allows the execution of a certain number of expressions at its firing time by equipping it with action inscriptions. Action inscriptions are expressions preceded with the keyword **action** and are guaranteed to be evaluated exactly once during the firing of a transition.

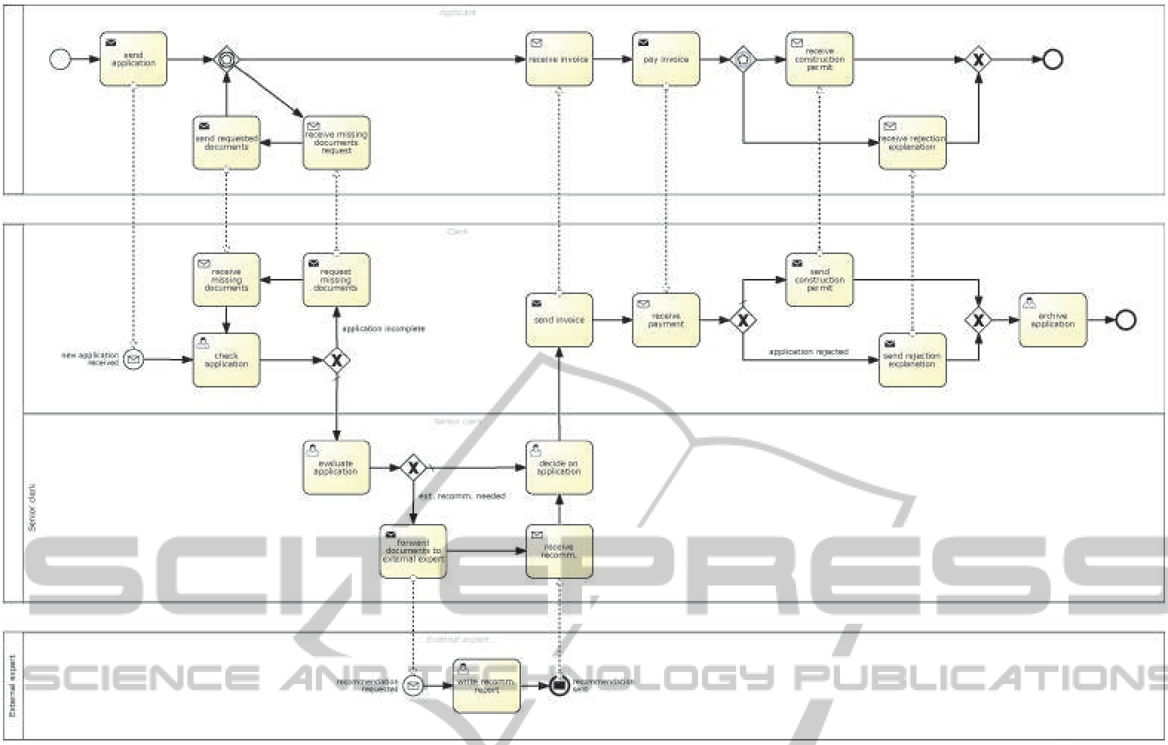


Figure 7: BPMN model of the example process.



With reference to Figure 4, before the send task performs its workflow logic (phase 4), the three operational transitions need to be fired. Each of these transitions is connected through reserve arcs to a series of places containing the needed $BD_{mod}$'s instances tokens. As shown, these three transitions acquire the bridge data from:

1. the place containing the particular $BD_{mod}$'s activity instance $\mathbf{A}_j$ (in the sense of Java class instance, not to be confused with the BPMN concept of activity instance);
2. all the places containing the $BD_{mod}$'s resource instances $\mathbf{R}_k$ required by the activity.

During phase 1, the activity work requirements are generated. When transition $\mathbf{A}_{j,1}$ fires, activity $\mathbf{A}_j$ requirements are generated as quantity $\mathbf{Q}_{j,k}$ of resource $\mathbf{R}_k$ needs. Also, the activity duration $\mathbf{D}_j$ is generated in this step by applying the modeled probability distribution. The generated requirements are then queued into the execution token to grant their availability in the next transitions. In particular, $\mathbf{D}_j$ is also used as a delay inscription in the transition $\mathbf{A}_{j,3}$ input arc.

Phase 2 concerns the requirements acquisition, that is, the transition $\mathbf{A}_{j,2}$ fires only when all activity requirements are available, eventually reducing their resource's residual amount by each quantity taken (reserved).

In phase 3, only after the time $\mathbf{D}_j$ has elapsed, the work completes successfully with the firing of transition $\mathbf{A}_{j,3}$, in which the activity instance consumes the allocated resources and internally augments its cost by $\sum_{k=1}^{K} \mathbf{R}_k.\text{getCost}(\mathbf{Q}_{j,k}, \mathbf{D}_j)$.

The model allows activity interruption from an interrupting boundary catch intermediate event or a parent activity terminate throw end event. These events are handled by other transitions that absorb the token that might be in place $\mathbf{p}(\mathbf{A}_{j,1}, \mathbf{A}_{j,2})$ or $\mathbf{p}(\mathbf{A}_{j,2}, \mathbf{A}_{j,3})$. Transition $\mathbf{A}_{j,4}$ gets fired only if the activity successfully completes. The pattern (1, 2, 3) is used for every task, while 4 depends on the particular task type.

In Figure 6 a simple example of an *exclusive gateway* has been depicted. In the $BD_{mod}$, the choice of which branch is to be followed is determined by a uniformly distributed probability in the [0,1] range. For the particular case, the “application incomplete” branch is chosen if the randomly generated number is less than 0.086. The token in place $\mathbf{b}(\mathbf{XG}_j, \mathbf{x})$ is the $BD_{mod}$'s exclusive gateway instance and is used by transition $\mathbf{XG}_{j,1}$ for randomly determining which branch has to be taken.

## 5 USE CASE EXAMPLE

The designed simulator tool has been tested on a simple yet not trivial use case. In this Section results

Scenario 1

resources

| resource | type | unit | units | usage cost | unit cost | time unit cost |
|---|---|---|---|---|---|---|
| Clerk | orgPosition | #HR | 2 | | | 10 €/#HR/h |
| Senior Clerk | orgPosition | #HR | 1 | | | 20 €/#HR/h |
| External Expert | durable | #EX | inf | | | 30 €/#EX/h |
| Energy | durable | kW | inf | | | 0,3 €/kWh |
| stamp | consumable | #stamp | 1,00E+09 | | 0,8 €/#stamp | |
| paper | consumable | #paper | 1,00E+09 | | 0,1 €/#paper | |

requirements

| cost objects | shift | frequency |
|---|---|---|
| Maintenance | 0 | Exponential(48) h |
| Building Renovation | 0 | Exponential(240) h |
| Preservation & Restoration | 0 | Exponential(1440) h |
| Urban Restructuring | 0 | Exponential(1960) h |

| task | start quantity | completion quantity | loop type | loop count generator | duration generator | failure generator | completion rate generator | Energy | paper | stamp | Clerk | Senior Clerk | External Expert |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| archive application | 1 | 1 | NONE | - | Pert(.4,.5,.6) h | Bernoulli(0) | default | | | | 1 #HR | | |
| check application | 1 | 1 | NONE | - | Pert(.5,1,2) h | Bernoulli(0) | default | 500 W | | | 1 #HR | | |
| decide on application | 1 | 1 | NONE | - | Const(10) min | Bernoulli(0) | default | | | | | 1 #HR | |
| evaluate application | 1 | 1 | NONE | - | Pert(2,2.25,4.8) d | Bernoulli(0) | default | 200 W | | | | 1 #HR | |
| forward documents to external expert | 1 | 1 | NONE | - | Pert(1.2,2,4) min | Bernoulli(0) | default | 500 W | | | | 1 #HR | |
| pay invoice | 1 | 1 | NONE | - | Pert(30,60,120) h | Bernoulli(0) | default | | | | | | |
| receive construction permit | 1 | 1 | NONE | - | Const(0) h | Bernoulli(0) | default | | | | | | |
| receive invoice | 1 | 1 | NONE | - | Const(0) h | Bernoulli(0) | default | | | | | | |
| receive missing documents | 1 | 1 | NONE | - | Pert(.1,.15,.2) h | Bernoulli(0) | default | | | | 1 #HR | | |
| receive missing documents request | 1 | 1 | NONE | - | Const(0) h | Bernoulli(0) | default | | | | | | |
| receive payment | 1 | 1 | NONE | - | Pert(.1,.15,.2) h | Bernoulli(0) | default | | | | 1 #HR | | |
| receive recommendation | 1 | 1 | NONE | - | Pert(1.2,1.5,1.8) min | Bernoulli(0) | default | 500 W | | | | 1 #HR | |
| receive rejection explanation | 1 | 1 | NONE | - | Const(0) h | Bernoulli(0) | default | | | | | | |
| request missing documents | 1 | 1 | NONE | - | Pert(.5,.75,1) h | Bernoulli(0) | default | 500 W | 2 #paper | 4 #stamp | 1 #HR | | |
| send application | 1 | 1 | NONE | - | Const(0) h | Bernoulli(0) | default | | | | | | |
| send construction permit | 1 | 1 | NONE | - | Pert(.2,.3,.5) h | Bernoulli(0) | default | 500 W | 2 #paper | 10 #stamp | 1 #HR | | |
| send invoice | 1 | 1 | NONE | - | Pert(.2,.3,.5) h | Bernoulli(0) | default | 500 W | 1 #paper | 2 #stamp | 1 #HR | | |
| send rejection explanation | 1 | 1 | NONE | - | Pert(.2,.5,1) h | Bernoulli(0) | default | 500 W | 2 #paper | 4 #stamp | 1 #HR | | |
| send requested documents | 1 | 1 | NONE | - | Pert(48,72,120) h | Bernoulli(0) | default | | | | | | |
| write recommendation report | 1 | 1 | NONE | - | Pert(20,30,40) h | Bernoulli(0) | default | | | | | | 1 #EX |

| gateway | generators | goto | if | goto | if |
|---|---|---|---|---|---|
| Exclusive (XOR) | x=Uniform(0,1) | request missing documents | x<20% | evaluate application | default |
| Exclusive (XOR) | x=Uniform(0,1) e=entity.type | forward documents to external expert | x<25% OR e IS "Preservation &Restoration" | decide on application | default |
| Exclusive (XOR) | x=Uniform(0,1) | send rejection explanation | x<10% | send constructio n permit | default |

Scenario 2

resources

| resource | type | unit | units | usage cost | unit cost | time unit cost |
|---|---|---|---|---|---|---|
| Clerk | orgPosition | #HR | 1 | | | 10 €/#HR/h |
| Senior Clerk | orgPosition | #HR | 2 | | | 20 €/#HR/h |
| External Expert | durable | #EX | inf | | | 30 €/#EX/h |
| Energy | durable | kW | inf | | | 0,3 €/kWh |
| stamp | consumable | #stamp | 1,00E+09 | | 0,8 €/#stamp | |
| paper | consumable | #paper | 1,00E+09 | | 0,1 €/#paper | |

Figure 8: Simulation parameters.



from the simulation are reported and discussed. The BPMN model of the considered use case is shown in Figure 7. It represents the process of releasing a construction permit by a Building Authority of a city.

The whole process involves different actors who interacts to each other exchanging information and/or documents (represented in the model as specific messages). The involved actors are:

- **Applicant:** it is the private citizen/company who needs to obtain the building permit and triggers the whole process;
- **Clerk:** it is the front-office employee of the Building Authority who receives the Application and is in charge of a) checking the documentation of the application, b) interacting with the applicant in order to obtain required documents and c) sending back the result of the application;
- **Senior Clerk:** it is the back-office employee of the Building Authority who evaluates and decides on the application;
- **Expert:** it is an external expert who may be called upon by the Senior Clerk whenever specific technical issues arise and the final decision may not be autonomously taken.

The business process spans four swimlanes, one for each actor. Both the Applicant and the Expert are external entities, i.e., are not part of the enterprise's business process dynamics. While there was no reason to represent the Applicant in the resource model, the Expert was modeled as a *DurableResource* (paid by the hour). The Clerk and the Senior Clerk were modeled as *OrganizationalPosition*. Other con-

Scenario 1

resource-activity cost report [€]

| resource \ activity | archive application | check application | decide on application | evaluate application | forward documents to external expert | receive missing documents | receive payment | receive recomm. | request missing documents | send construction permit | send invoice | send rejection explanation | write recomm. report | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clerk | 698,66 | 1.860,23 | | | | 46,52 | 211,50 | | 234,11 | 405,84 | 439,13 | 68,06 | | **3.964,04** |
| Senior Clerk | | | 466,76 | 180.804,62 | 29,79 | | | 20,78 | | | | | | **181.321,95** |
| External Expert | | | | | | | | | | | | | 37.568,34 | **37.568,34** |
| Energy | | 55,81 | | 2.712,07 | 0,45 | | | 0,31 | 7,02 | 12,18 | 13,17 | 2,04 | | **2.803,05** |
| stamp | | | | | | | | | 49,60 | 201,60 | 112,00 | 22,40 | | **385,60** |
| paper | | | | | | | | | 12,40 | 126,00 | 28,00 | 5,60 | | **172,00** |
| **TOTAL** | **698,66** | **1.916,03** | **466,76** | **183.516,69** | **30,24** | **46,52** | **211,50** | **21,09** | **303,13** | **745,61** | **592,31** | **98,10** | **37.568,34** | **226.214,97** |

activity-object cost report [€]

| activity \ object | units | Maintenance | Building Renovation | Preservation & Restoration | Urban Restructuring | TOTAL |
|---|---|---|---|---|---|---|
| archive application | 140 | 512,71 | 150,05 | 16,07 | 19,83 | **698,66** |
| check application | 342 | 1.421,51 | 427,93 | 28,10 | 38,50 | **1.916,03** |
| decide on application | 140 | 343,40 | 100,02 | 10,00 | 13,34 | **466,76** |
| evaluate application | 280 | 135.855,84 | 39.313,37 | 3.704,71 | 4.642,78 | **183.516,69** |
| forward documents to external expert | 82 | 21,36 | 4,68 | 2,03 | 2,17 | **30,24** |
| receive missing documents | 31 | 31,12 | 15,40 | | | **46,52** |
| receive payment | 140 | 155,11 | 45,43 | 4,44 | 6,53 | **211,50** |
| receive recommendation | 82 | 15,02 | 3,04 | 1,47 | 1,56 | **21,09** |
| request missing documents | 62 | 203,14 | 99,99 | | | **303,13** |
| send construction permit | 252 | 557,81 | 147,40 | 17,70 | 22,69 | **745,61** |
| send invoice | 280 | 435,75 | 127,11 | 11,99 | 17,46 | **592,31** |
| send rejection explanation | 28 | 62,71 | 35,39 | | | **98,10** |
| write recommendation report | 41 | 26.142,37 | 5.571,93 | 2.979,96 | 2.874,08 | **37.568,34** |
| **TOTAL** | **1.900** | **165.757,86** | **46.041,73** | **6.776,46** | **7.638,93** | **226.214,97** |

activity-object queue time report [h]

| activity \ object | units | Maintenance | Building Renovation | Preservation & Restoration | Urban Restructuring | TOTAL |
|---|---|---|---|---|---|---|
| archive application | 1 | 0,19 | | | | **0,19** |
| check application | | | | | | |
| decide on application | 135 | 19.185,37 | 37.973,37 | 644,18 | 551,84 | **58.354,75** |
| evaluate application | 276 | 16.396,76 | 6.171,42 | 336,47 | 387,47 | **23.292,12** |
| forward documents to external expert | 82 | 3.226,89 | 5.347,15 | 894,31 | 2.578,80 | **12.047,15** |
| receive missing documents | | | | | | |
| receive payment | | | | | | |
| receive recommendation | 76 | 3.959,44 | 755,26 | 1.718,45 | 5.853,40 | **12.286,55** |
| request missing documents | | | | | | |
| send construction permit | 14 | | 0,38 | | | **0,38** |
| send invoice | 8 | 0,88 | 0,43 | | 0,24 | **1,55** |
| send rejection explanation | | | | | | |
| write recommendation report | | | | | | |
| **TOTAL** | **592** | **42.769,53** | **50.248,02** | **3.593,41** | **9.371,74** | **105.982,69** |

Figure 9: Scenario 1 costs and times report.

Scenario 2

resource-activity cost report [€]

| resource \ activity | archive application | check application | decide on application | evaluate application | forward documents to external expert | receive missing documents | receive payment | receive recomm. | request missing documents | send construction permit | send invoice | send rejection explanation | write recomm. report | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clerk | 771,98 | 1.920,82 | | | | 38,37 | 232,84 | | 196,70 | 450,55 | 486,57 | 67,45 | | **4.165,29** |
| Senior Clerk | | | 513,44 | 199.897,60 | 25,17 | | | 17,03 | | | | | | **200.453,24** |
| External Expert | | | | | | | | | | | | | 30.388,55 | **30.388,55** |
| Energy | | 57,62 | | 2.998,46 | 0,38 | | | 0,26 | 5,90 | 13,52 | 14,60 | 2,02 | | **3.092,76** |
| stamp | | | | | | | | | 41,60 | 228,80 | 123,20 | 17,60 | | **411,20** |
| paper | | | | | | | | | 10,40 | 143,00 | 30,80 | 4,40 | | **188,60** |
| **TOTAL** | **771,98** | **1.978,44** | **513,44** | **202.896,06** | **25,55** | **38,37** | **232,84** | **17,29** | **254,60** | **835,86** | **655,17** | **91,47** | **30.388,55** | **238.699,64** |

activity-object cost report [€]

| activity \ object | units | Maintenance | Building Renovation | Preservation & Restoration | Urban Restructuring | TOTAL |
|---|---|---|---|---|---|---|
| archive application | 154 | 630,37 | 110,81 | 26,29 | 4,50 | **771,98** |
| check application | 360 | 1.621,93 | 291,80 | 56,31 | 8,40 | **1.978,44** |
| decide on application | 154 | 420,08 | 73,35 | 16,67 | 3,33 | **513,44** |
| evaluate application | 308 | 165.351,98 | 29.146,71 | 7.011,25 | 1.386,12 | **202.896,06** |
| forward documents to external expert | 68 | 17,35 | 4,15 | 4,05 | | **25,55** |
| receive missing documents | 26 | 29,78 | 8,59 | | | **38,37** |
| receive payment | 154 | 190,59 | 32,72 | 7,96 | 1,57 | **232,84** |
| receive recommendation | 68 | 12,29 | 2,57 | 2,43 | | **17,29** |
| request missing documents | 52 | 194,42 | 60,18 | | | **254,60** |
| send construction permit | 286 | 703,21 | 109,86 | 17,50 | 5,30 | **835,86** |
| send invoice | 308 | 537,25 | 92,15 | 21,34 | 4,43 | **655,17** |
| send rejection explanation | 22 | 47,27 | 26,44 | 17,76 | | **91,47** |
| write recommendation report | 34 | 21.475,54 | 4.462,73 | 4.450,28 | | **30.388,55** |
| **TOTAL** | **1.994** | **191.232,07** | **34.422,07** | **11.631,84** | **1.413,66** | **238.699,64** |

activity-object queue time report [h]

| activity \ object | units | Maintenance | Building Renovation | Preservation & Restoration | Urban Restructuring | TOTAL |
|---|---|---|---|---|---|---|
| archive application | 12 | 3,8 | | | | **3,84** |
| check application | 18 | 3,8 | 2,0 | | | **5,75** |
| decide on application | 132 | 11.765,5 | 261,4 | 654,3 | 85,6 | **12.766,93** |
| evaluate application | 254 | 11.863,4 | 1.271,2 | 166,0 | 17,7 | **13.318,30** |
| forward documents to external expert | 62 | 232,8 | 23,2 | 389,1 | | **645,04** |
| receive missing documents | | | | | | |
| receive payment | 13 | 2,9 | 1,6 | | | **4,46** |
| receive recommendation | 58 | 1.578,8 | 42,3 | 21,5 | | **1.642,57** |
| request missing documents | | | | | | |
| send construction permit | 98 | 3,5 | 0,5 | | | **4,04** |
| send invoice | 37 | 16,8 | 4,1 | 1,7 | 0,2 | **22,90** |
| send rejection explanation | 8 | 0,2 | | | | **0,17** |
| write recommendation report | | | | | | |
| **TOTAL** | **692** | **25.471,5** | **1.606,3** | **1.232,7** | **103,5** | **28.413,99** |

Figure 10: Scenario 2 costs and times report.

sidered resources in the scenario are energy, modeled as *DurableResource*, paper and stamps, both modeled as *ConsumableResource*.

As for the simulation scenario, four types of permits (representing the "cost objects" in the ABC terminology) were considered: Maintenance, Building Renovation, Preservation&Restoration and Urban Restructuring. The Expert's advice is always requested for applications requiring permits of type Preservation&Restoration; for other types of application the Expert is called upon with a likelihood which follows a Uniform distribution (typically, 25% of times the Expert is involved). In Figure 8 the complete set of simulation parameters, modeled according to the specification of the $R_{mod}$ and $BP_{mod}$ discussed in the Section 3, are depicted.

We ran two simulations for two different scenarios. The scenarios differs for just the number of units of employed internal human resources. In the scenario n.1 two Clerks and one Senior Clerk were employed, while in scenario n.2 one Clerk and two Senior Clerks were employed. For each scenario the measures taken into account were *monetary costs*, *work times* and *queue times* respectively. Figures 9 and 10 depict reports of analytical costs and queue times computed for the two scenarios. In particular, costs incurred for the allocation of resources to activities are reported in the section "resource-activity cost" of the report; activity costs absorbed by the four cost objects are instead shown in the section "activity-object cost" of the same report. As for the times, those spent by object costs waiting for activities to start have been reported.

The reader may notice that scenario n.1 shows a very unproductive usage of the two Clerk resources, given that the total cost over the three years period adds up to about €4.000,00 and, also, no queue time is found for their own activities (*archive application*, *check application*, *receive missing documents*, *receive payment*, *request missing documents* and *send rejection explanation*), which can be interpreted as an over-availability of the resource. On the other side, Senior Clerk seems to be overloaded, as their average queue time is about 180 hours per application. By reducing the Clerk units to just one and adding a new Senior Clerk position, Scenario n.2 introduces a slight increment of 5.5% in overall costs but succeeds in recovering 73,2% of time globally spent in queue (wait) by construction permit requests, thus gaining a better resource (just human resource in this simple case) allocation configuration.

## 6 CONCLUSIONS

In the past decade there has been a growing interest of enterprises towards the Business Process Management's methodology and techniques. Field experts agree that one of the most critical step in the management of business processes is process analysis and modeling. Simulation tools may help designers to tune the process model before actually implementing and deploying processes in their execution environments. Most of existing tools lack the capability of integrating process characteristics and the enterprise's resources which are directly involved in the process execution. This paper presented a proposal of a simulator of business processes which integrates a resource model designed according to the ABC accounting principles. The simulator leverages the functionality provided by a CPNet tool to run simulations of processes which are modeled through BPMN and have been "enriched" with information regarding types and quantity of involved resources. Main technical features of the simulator have been discussed throughout the paper and some explicative examples of how the whole framework works have been provided. A concrete enterprise's use case was also simulated and the obtained results have been discussed.

## REFERENCES


Betz, S., Hickl, S., and Oberweis, A. (2011). Risk-aware business process modeling and simulation using XML nets. In *Proceedings - 13th IEEE International Conference on Commerce and Enterprise Computing, CEC 2011*, pages 349–356.

Coalition, W. M. (2012). XPDL: XML process definition language (Version 2.2). http://www.xpdl.org.

Cooper, R. and Kaplan, R. S. (1992). Activity-based systems: Measuring the costs of resource usage. In *Accounting Horizons*, volume 6, pages 1–12.

Dijkman, R. M., Dumas, M., and Ouyang, C. (2008). Semantics and analysis of business process models in BPMN. *Information and Software Technology*, 50(12):1281–1294.

Gottschalk, F., van der Aalst, W., Jansen-Vullers, M., and Verbeek, H. (2008). Protos2CPN: Using colored Petri nets for configuring and testing business processes. *International Journal on Software Tools for Technology Transfer*, 10(1):95–110.

Jansen-vullers, M. H. and Netjes, M. (2006). Business process simulation a tool survey. In *In Workshop and Tutorial on Practical Use of Coloured Petri Nets and the CPN*.

Januszczak, J. and Hook, G. (2011). Simulation standard for business process management. In *Proceedings - Winter Simulation Conference*, pages 741–751.

Jensen, K. (1996). *Coloured Petri Nets: Basic Concepts, Analysis Methods and Practical Use*. Springer-Verlag, London, UK.

Koizumi, S. and Koyama, K. (2007). Workload-aware business process simulation with statistical service analysis and Timed Petri Net. In *Proceedings - 2007 IEEE International Conference on Web Services, ICWS 2007*, pages 70–77.

Kummer, O., Wienberg, P., Duvigneau, M., Schumacher, J., Khler, M., Moldt, D., Rlke, H., and Valk, R. (2004). An extensible editor and simulation engine for petri nets: RENEW. *Lecture Notes in Computer Science*, 3099:484–493.

OMG (2011). Business Process Model and Notation (BPMN 2.0). http://www.omg.org/spec/BPMN/2.0/.

Porter, M. E. (1985). *Competitive advantage: Creating and sustaining superior performance*. Free Press.

Tjoa, S., Jakoubi, S., Goluch, G., Kitzler, G., Goluch, S., and Quirchmayr, G. (2011). A formal approach enabling risk-aware business process modeling and simulation. *Services Computing, IEEE Transactions on*, 4(2):153–166.

Van der Aalst, W. M. P., Nakatumba, J., Rozinat, A., and Russell, N. (2008). Business process simulation: How to get it right. In *International Handbook on Business Process Management*. Springer-Verlag.

Van der Aalst, W. M. P. and Ter Hofstede, A. H. M. (2005). YAWL: Yet Another Workflow Language. *Information Systems*, 30(4):245–275.

Vara, J. L. and Sánchez, J. (2009). Bpmn-based specification of task descriptions: Approach and lessons learnt. In *Proceedings of the 15th International Working Conference on Requirements Engineering: Foundation for Software Quality*, pages 124–138. Springer-Verlag.

Vergidis, K., Tiwari, A., and Majeed, B. (2008). Business Process Analysis and Optimization: Beyond Reengineering. *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on*, 38(1):69–82.

Weske, M. (2012). *Business Process Management: Concepts, Languages, Architectures (2nd ed.)*. Springer-Verlag.