A Cost-centric Model for Context-aware Simulations of Business Processes

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Abstract: Business process modeling is recognized as being one of the most crucial step in the management of the Business Process life cycle. Models which either are incorrect or do not accurately represent the desired process dynamics may seriously impair the achievement of an enterprise's business goals. There is a growing interest towards simulative tools that take in input a process model and provide an estimate of the costs incurred by an hypothetical process execution. It is then of paramount importance that the input model be as accurate as possible, otherwise actual process execution costs may dramatically diverge from the estimates. In this paper we propose the definition of a comprehensive Business Process Model which inspires to the basic principles of the Activity Based Costing (ABC) analysis to provide a cost-centric perspective of the Business Processes to be executed. Emphasis is put on the need to represent the process Context, i.e., the resources processes need to consume and the environment where processes will execute. The introduced process context model is proposed as an extension to the BPMN standard. Further, we implemented a Business Process Simulator capable of simulating business processes defined according to the newly proposed model. A case study example was simulated and results are presented in the paper.

1 INTRODUCTION

In a globalised market the capability of an enterprise to keep or acquire new market shares is strongly related to its ability to adapt its business strategy to accommodate the new or the ever changing demand. Often the change of a strategy imposes a prompt reorganization and restructuring of all or a subset of the enterprise business processes. In order for that reorganization to be effective, process designers need to know in advance what its impact would be in terms of gained performance and incurred costs. Simulating business processes via software is the technique used to produce estimates on their performance and costs. Simulation provides useful information that help process analysts and designers to fine-tune process models before processes are actually executed. Of course, the reliability of the estimate provided by the simulation depends on how good and accurate the process model adopted for the simulation is.

There are many well-established specifications which can be used to model business processes. The OMG's BPMN (OMG, 2011) is the specification recognised by the majority of researchers and practitioners as the reference standard in the field of process modeling. Though by many it is considered a powerful notation to represent the process workflow's dynamics, still it lacks the support for the characterization of some process' key features such as the resources involved by the process activities and many other factors that impact on the process at execution time. In the paper, we are going to refer to such features as *process context*. As for the *cost* aspect, we argue that the Activity Based Costing (ABC) methodology (Cooper and Kaplan, 1992) offers a framework where the BPMN, if adequately integrated with the support to model the process context, may find a perfect collocation. The *activity* concept, which is central to both the BPMN and the ABC, is the base of this "marriage".

The purpose of the work presented in this paper is to define a novel *Business Process Model*, capable of representing all the main aspects of business processes and of their runtime context under a *cost-sensitive* perspective. In order to build that view, our approach leverages and integrates the BPMN specification and the ABC methodology. Further, we developed a business process simulator to simulate

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business processes defined according to the proposed model. A simple but well structured business process was also designed and used to test the simulator. Process' incurred costs and execution times are gathered from the simulation run and presented to the process analyst.

The paper is structured in the following way. In Section 2 related literature is reviewed. In Section 3 a novel cost-sensitive process model is introduced. In Section 4 we present the definition of a use-case process and discuss the result obtained from simulating the process. Concluding remarks can be found in Section 5.

2 LITERATURE REVIEW

Process simulation plays an important role in the context of the Business Process Management. The purpose of simulation is to give business analysts a clue on what the performance and the cost of processes could be according to the actual process design, and to provide hints on the corrective actions to take in order to improve the overall process performance.

Process simulation is a key features provided by many commercial Business Process Management Suites (BPMS). Most BPMS offer process analysts a tool to simulate process workflows and to customize the process context scenario. A simulation tool's strategy and implementation is specific to the suite it is embedded in. In particular, it is tightly coupled with the process modeling approach and language (be it proprietary or open) adopted by the BPMS. ARIS Simulation is an extension of the well known ARIS Architect suite[1]; it is based on the L-SIM simulation engine and allows to simulate process modeled by using Event-driven Process Chain notation (Scheer and Nüttgens, 2000). Recently the BPMN support has been added. iGrafx Process[2] is a process analysis and simulation tool enabling dynamic "what-if" process analysis. It may be used as a standalone tool or within the iGrafx suite of process modeling and analysis. Oracle BPM Suite[3] has a simulation module too, which allows to define simulation scenarios with various configurable parameters. Besides full fledged BPMS suites, specialized simulation products exist, such as SimProcess[4]. It is a hierarchical modeling tool that combines process mapping, discrete-event simulation, and the ABC; it allows users to carry on powerful analysis such as "what-if" scenarios, but it does not use any standard notation for modeling processes. An interesting survey on some commercial simulation tools is proposed in (Jansen-vullers and Netjes, 2006).

The majority of literature works addressing the business process simulation calls on Petri Nets. Petri Nets are preferred to other modeling techniques because of their rigorous and clear formalism. Also, there are many easily available and freely accessible tools which analyse Petri Nets and evaluate their "soundness"(Kherbouche et al., 2013), i.e., whether the model is free of potential deadlocks and livelocks. The basic approach adopted by researchers is to transform the business process model (usually defined in the BPMN language) into its "equivalent" Petri Net model and to feed the model to a simulator engine (Dijkman et al., 2008; Koizumi and Koyama, 2007). The Protos2CPN tool's strategy (Gottschalk et al., 2008) is to transform a Protos model into a Colored Petri Net (CPNet), and simulate it in standard CPNet tools. CPNets (Jensen, 1996) is a very powerful discrete-event modeling language combining the capabilities of Petri Nets with the capabilities of a high-level programming language.

Petri Nets are rather a good technique which is proved to be particularly effective in the simulation of workflows. In (Van der Aalst, 2010) authors discuss the limitations of traditional simulation approaches and identify three specific perspectives that need to be defined in order to simulate business processes in a structured and effective manner: the control flow, the data/rules and the resource/organisation. Focus is put on modeling at the right abstraction level the business data influencing the process dynamics and the resources to be allocated to process activities. Similarly, authors in (Van der Aalst et al., 2008) argue that a business processes simulator can not disregard the *environment* where processes are executed and the *resources* required to carry on the process activities. They also propose to use an ad-hoc workflow language – YAWL (Van der Aalst and Ter Hofstede, 2005) – to model resources involved in the process dynamics.

The idea proposed in this paper differs from the mentioned works in that it melts two consolidated and broadly adopted techniques to build an integrated business process perspective. The basic principles of ABC and the expressiveness of the BPMN are combined to devise a *cost-sensitive* business process model that can be used to characterize both the workflow and the execution context of a process.

[1] www.softwareag.com

[2] www.igrafx.com/products/process-modeling-analysis/process

[3] www.oracle.com/us/technologies/bpm

[4] www.simprocess.com

3 A COST-CENTRIC BUSINESS PROCESS MODEL

In this section we propose the definition of a novel Business Process (BP) model. The purpose of the model is to enable process designers to represent both the (static) structural features of BPs and all external entities and factors that may potentially affect the dynamics of BPs at execution time. For what concerns the structure of a BP, the model will have to support the representation of process' activities and tasks and their control flow, or in a word, the representation of the *process workflow*. Instead, we will refer to the "Context" of a process as the set of factors, external to the process logic, yet capable of influencing the process behaviour and performance at execution time. This set includes, for instance, the human resources responsible for carrying out process tasks, the non-human resources consumed by process tasks (such as goods and services), the business rules enforced on decisor elements, and in general any impromptu event that may occurr at process execution time.

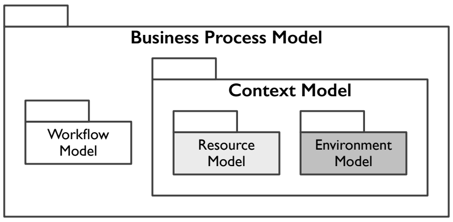

Figure 1: Business Process Model.

In our design, the process *Context Model* is defined to be the union of the *Resource Model*, that can be used to characterize both human and non-human resources, and the *Environment Model*, used to represent the rest of external factors that build up the process environment. In Figure 1 a package-view of the overall process model is depicted. In the remainder of the section, first some key concepts of the Activity Based Costing methodology are briefly recalled. Then we discuss in details the Resource Model, the integration of the Resource Model with a well known process workflow specification, and the Environment Model.

3.1 Basic ABC concepts

An accurate tracking of costs (and revenues) is one of the most fundamental internal procedures an organization can utilize. "Analytical accounting" is an umbrella term for the financial component of business management. It relies on financial data to make determinations about how, when and why a business spends (and receives) money.

For the sake of cost-flow tracking we draw inspiration from the approach used in the ABC analytical accounting system (Cooper and Kaplan, 1992). The basic assumption of ABC is that any enterprise cost is generated whenever an activity consumes a resource. The strength of ABC is that all costs generated in the system from the consumption of resources by activities may be directly allocated to these activities by means of appropriate *resource drivers*; in other words, all costs – including overhead costs produced by enterprise's support activities (Porter, 1985) – are treated as *direct costs* when allocated to activities that are indeed precise *costs carriers*.

Given the full activity cost configuration, it is afterward possible to allocate these costs to the *final cost-object*s through their *activity drivers* that define how each activity is "consumed" by the final cost-object. By "final cost-object" we refer to every business entity whose cost has to be computed for the analysis, such as products, customers or channels.

The ABC model depicted in Figure 2 defines the *CostObject* as the base entity for all subsequent cost-oriented concepts. Each *CostObject* has an unit of measure and can be "driven" by a set of *Driver*s that defines its requirements as the amounts of different cost-objects demanded for one unit of it. In addition, every *CostObject* can target in the run a set of other cost-objects through *Allocation*s of its quantities to them over different dimensions such as cost, units and time.

An implementation of the Java Units of Measurement API[5], namely JSR-363 which is currently under review for approval, has been used as measures and units framework (package *Measures and Units* in Figure 2).

3.2 Resource Model

We focus on the definition of a cost-oriented Resource Model capable of capturing the resource categories that BPs may need. The Resource Model aims at capturing and representing costs and other process related information regarding any kind of "resource" that has to be "consumed" by a process task, be it a *human* or a *non-human* resource, and more specifically puts the basis for an ABC analysis of processes.

The **Resource Model** defines the resource concept as a cost-object extension itself. Figure 3 presents its relevant classes and their relationships in the UML notation (OMG, 2005). A Resource, no matter the

[5]http://www.unitsofmeasurement.org

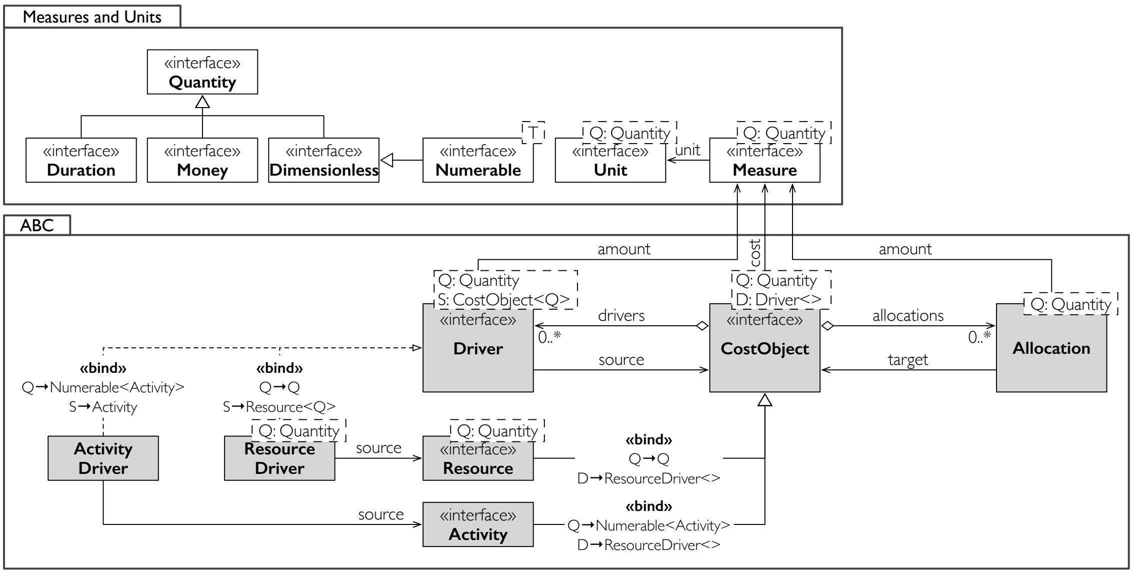

Figure 2: Activity-based-costing accounting system model.

kind, produces a cost whenever it is allocated and actually consumed by some business operation. As better explained in the Section 3.3, the CostObject concept depicted in the diagram represents the element that, in our proposed view, bridges the domain of resources and the domain of all the business operations that actually make use of resources.

The *NonHumanResource* class may be used to definie resources such as 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 where each *Calendar* represents a set of time intervals in which the resource is available to the whole system; the most common calendar based resource is the *HumanResource* (HR) which represents the physical person who, in turn, occupies an *OrganizationalPosition* within an *OrganizationalGroup* structure such as an *OrganizationalUnit* structure (organizational chart).

Each *OrganizationalPosition* can be occupied by one HR at a time and is related to other organizational positions through the *directReport* and the *delegates* relations. The *directReport* relation points to the HR which is accountable for the position (usually a manager) whereas the *delegates* relation allows the **Resource Model** to identify a set of alternative HRs when the requested one is not readily available.

3.3 Integrating the Resource Model with BPMN

There is a lot of specifications available to define BP models. Some provide features to represent basic activities and the control flow (UML's activity diagrams), others integrate the representation of *Events* that trigger activities and/or that are triggered by activities (Scheer and Nüttgens, 2000). To our knowledge there is no open specification capable of representing all the features of the Business Process model that have been so far discussed. The well known OMG's Business Process Model and Notation (BPMN) (OMG, 2011) standard was though a good candidate for our purpose.

Our choice is in part motivated by the fact that BPMN has reached a good level of maturity, and is adopted and continuously supported by many vendors. Besides new semantic elements, such as callable elements and event-triggered sub-processes, the 2.0 version of BPMN introduced the complete Collaboration, Process and Choreography meta-models, the BPMN Diagram Interchange meta-model, the BPMN Execution Semantics, the Basic and Extended Mapping of BPMN Models to WS-BPEL and the BPMN Exchange Formats with its XMI and the XSD files for XML serialization. Most important, the BPMN 2.0 "*... introduces an extensibility mechanism that allows the extension of standard BPMN elements with additional attributes. It can be used by modelers and modeling tools to add non-standard elements or artifacts to satisfy specific needs, such as the unique requirements of a vertical domain, and still have valid*

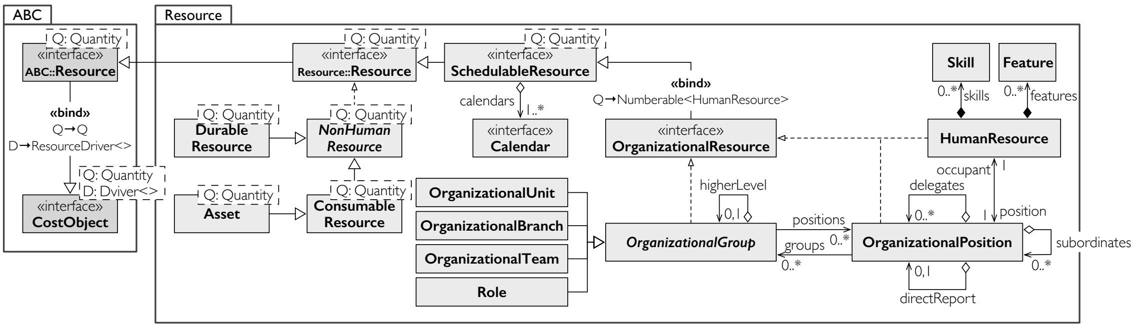

Figure 3: Resource Model.

BPMN Core." This appealing features drove us to choose the BPMN as the specification on which to groud our modeling needs.

The BPMN provides for a comprehensive notation that allows to represent many features of a business process. Basically, in BPMN it is possible to define a process workflow articulated in sub-processes, call activities, tasks, and to also model the control flow of activities. Various type of external and internal events may also be defined. Further, the organization units responsible for a given process, a sub-process or even a single task may be modeled by means of concepts like pools and lanes. Like other specifications, though, BPMN lacks of notation to model the "contextualization" of a process into its execution environment. We intend to tackle this deficiency by integrating the discussed *Context model* to the process model defined in the BPMN specification.

On the left of the class diagram in Figure 4 relevant BPMN elements have been reported (white boxes), while on the right end the Resource Model package is depicted (light gray boxes). In order to integrate the two models, it is of primary importance to bring the elements of the BPMN domain under a *cost-sensitive* perspective. The bridge between the two models is realized by the ABC package, whose basic concepts are depicted in dark gray boxes.

The BPMN model is integrated into the cost perspective by means of the *BPMN::Activity* class. This class implements the behaviour of the *ABC::Activity* interface, which represents the Activity concept in the ABC sense. Basically, we let the *Task*, the *SubProcess* and the *Process* behave like an *ABC::Activity*.

According to this representation, the BPMN entities in Figure 4 are cost objects as well. Further, their classes are bound to the Resource class (which again, is a cost object) by means of the *ResourceDriver*. This is to model that, at the lowest level, a *Task* is an elementary business operation that basically needs to consume Resources for its execution: the cost produced by the task execution is exactly the aggregated cost of the consumed resources. Further, *Participant*, *Process*, *LaneSet*, *Lane* and *SubProcess* are *ABC::Activity* as well, but in this perspective they act as cost aggregators. It is easy to build a cost "chain" where a Process aggregates the costs of it's Lanes, which in turn aggregate the costs produced by their Tasks, which in turn aggregate the costs produced for consumption of their associated Resources. The aggregation is realized by means of an Allocation scheme that sums up the measures (costs, number of instances and times) to the higher level elements in a bottom-up fashion, starting from tasks.

In Figure 4 both the Resource and the business operations (process, sub-process, task) are CostObjects; but with the slight difference that Resources are *cost generators*, whilst the business operations are *cost aggregators*.

The granularity of the business elements provided by the BPMN standard well matches the ABC philosophy. By associating costs to the most atomic business element (the resource), by means of direct-cost allocation it is easy to derive the costs of every operation at any level in the hierarchy of business operations, from the simplest *task* to the most complex *process*.

3.4 Environment Model

We discuss the factors that are external to the process logic but that are anyway capable of affecting the process execution. In the literature, researchers (Van der Aalst, 2010) have identified numerous aspects that designers either tend to neglect or are not able to account for at design time, and that have a negative impact when the process executes. Some of those are the employment of oversimplified (or even incorrect) models, the discontinuous availability of data and resources, the inhomogeneous skill of the employed human resources (which leads to non deterministic human tasks' duration), the lack of knowledge about the exact arrival time of process' external stimuli, and so

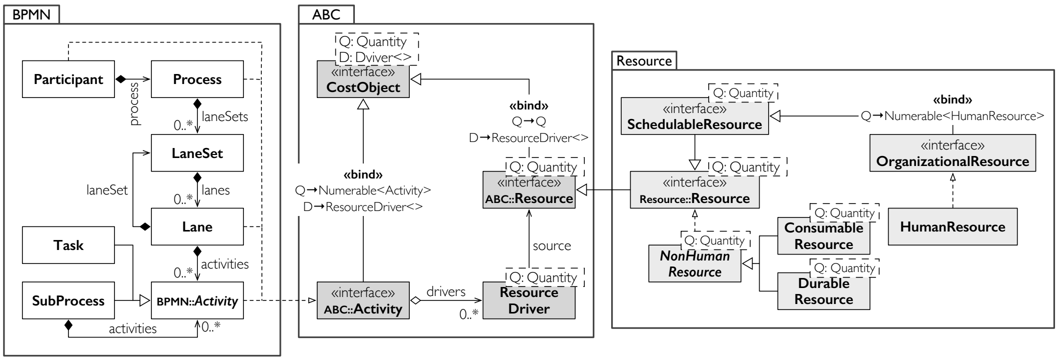

Figure 4: Integration between the BPMN and the Resource model.

on.

Our objective is to provide the process designers with a tool to simulate the effects that external factors may have on the process dynamics and performance. Basically, we introduce a model which provides for the representation of non-deterministic behaviours of the process elements. The proposed model is an extension of the one proposed in an earlier work (Cartelli et al., 2014). Figure 5 shows the BPMN elements which have been associated a statistical behaviour, and the categories of statistical behaviours that have been modeled.

StatisticalBehavior is the root class representing a generic behaviour which is affected by non-deterministic deviations. It includes several probability distribution models (uniform, normal, binomial to cite a few) that can be used and adequately combined to build specific behaviours.

Duration models the temporal length a certain event is expected to last. This concept will be used to specify the expected duration of the following BPMN elements: *tasks*, *sequence flows* and *message flows*. Tasks, in fact, may have a variable duration in respect, for instance, to the skills of the specific person in charge of it or, in the case of a non-human task, to the capability of a machine to work it out. A sequence flow may have a variable duration too. It is not rare, in fact, that time may pass since the end of a preceding task to the beginning of the next one (think about a very simple case when documents need to be moved from one desk to another desk in a different room). Finally, message flows fall in this category too since they are not “instant” messages, and the time to reach the destination may vary from case to case.

ResourceConsumption models the uncertainty regarding the unpredictability of the consumption of a *Resource* by a given *Task*. The implemented statistical behavior concerns the *amount* of a given resource type that can be consumed by a task. For instance, in the case of human type of resource, it is possible to model a task consuming a discrete number of resource units which is computed by a statistical function; whereas in the case of a non-human resource type, it will be possible to specify the statistical amount of the resource expressed in its unit of measure (kilowatts, kilograms, meters, liters, etc.).

LoopIteration models the uncertainty of the number of iterations for a specific looped activity. This is the case of both BPMN’s *standard loop* and *multi-instance loop activities*, i.e., tasks or sub-processes that have to be executed a certain number of times which either is prefixed or depends on a condition.

ConditionalFlowSet models the uncertainty introduced by the conditional gateways (both inclusive and exclusive). It will be used to select which of the gateway’s available output flow(s) are to be taken.

The *Instantiation* concept models the rate at which a specific event responsible for instantiating a process may occur. In particular, it will be used to model the behaviour of the BPMN’s *Start Event* elements that are not triggered by the flow.

The *Occurrence* models the delay after which an event attached to an activity may occur. The event is triggered exactly when the activity flow-time exceeds the delay.

4 CASE STUDY EXAMPLE

The objective of this work was to devise a business process model that process designers may use to define processes and characterize its context features; next step was to implement a simulator capable of running lon-term, context-aware simulations of those processes and producing cost-sensitive results useful for ABC analysis. In an earlier work (Cartelli et al., 2014) the design and implementation of a preliminary version of the simulator was presented. It was compatible with an earlier version of the business process model. The reader may refer to that work for details

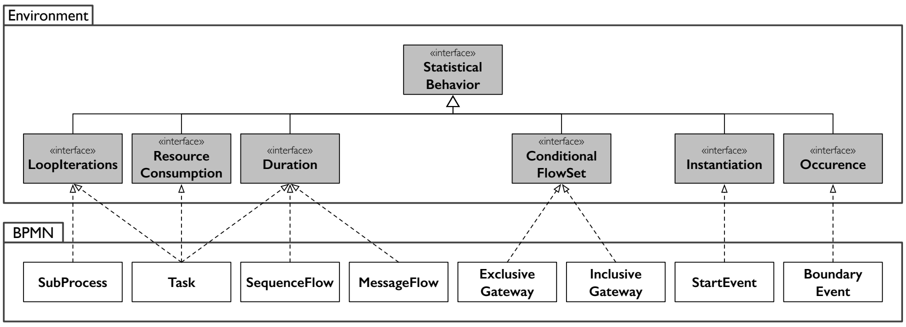

Figure 5: Process Environment model.

on the simulator design. The simulator code has now been refactored to support the enhanced model introduced in this paper. Despite the significant changes, the basic simulator strategy remained the same: process models taken in input are first transformed into equivalent Colored Petri Nets (Jensen, 1996) and then simulated through a third party CPNet simulation engine[6].

Designers wishing to use the simulator must supply a *Business Process Definition* (BPD) file, which is an instance of their process model embedding all the specific features of the process in terms of workflow and execution context respectively. A BPD is an XML file that is structured according to a schema that we are going to briefly describe. In order to define the process workflow, plain BPMN standard in its XML serialised form will be used. The standard envisions some points of extensions (OMG, 2011) that, instead, we are going to exploit to represent the process context features. In the end, the BPD file is still compliant to the BPMN standard.

The basic schema for the overall process representation, then, is that of the BPMN standard. The BPMN *extensionsElements* tag identifies a section that can be used to *"...attach additional attributes and elements to standard and existing BPMN elements"* (OMG, 2011). There it is where we are going to provide extra information concerning the process context. In particular, using that tag we can add the environmental features discussed in Section 3.4 to *Subprocess*, *Task*, *SequenceFlow*, *MessageFlow*, *ExclusiveGateway*, *InclusiveGateway*, *StartEvent* and *BoundaryEvent* respectively. Moreover, being the BPMN *resource* an extension of the *tRootElement*, which in turn extends the *tBaseElement*, extra information concerning the newly introduced Resource::Resource concept (Fig. 3 in Section 3.2) can be added through that extension point. In Listing 1 the schema excerpt describing the Resource::Resource element has been reported.

[6]For our purpose the engine of the Renew tool was used: www.renew.de

Listing 1: XSD excerpt of the BPSIM resource.

```
<xsd:schema
     xmlns="http://www.unict.it/bpmn/bpsim/2.0"
     ...>

<xsd:element name="resource" type="Resource" />
<xsd:complexType name="Resource">
 <xsd:sequence>
  <xsd:element name="unit" type="Unit"
       minOccurs="1" maxOccurs="1" />
  <xsd:element name="timeUnit" type="TimeUnit"
       minOccurs="1" maxOccurs="1" />
  <xsd:element name="moneyUnit" type="MoneyUnit"
       minOccurs="1" maxOccurs="1" />
  <xsd:element name="usage" minOccurs="1"
       maxOccurs="unbounded">
   <xsd:complexType>
    <xsd:sequence>
     <xsd:element name="availability"
          type="Amount" maxOccurs="1" />
     <xsd:element name="usageCost" type="Amount"
          minOccurs="0" maxOccurs="unbounded" />
     <xsd:element name="unitCost"
          type="TimeableAmount" minOccurs="0"
          maxOccurs="unbounded" />
    </xsd:sequence>
    <xsd:attribute name="scenarioRef"
         type="xsd:IDREF" use="required" />
   </xsd:complexType>
  </xsd:element>
 </xsd:sequence>
 <xsd:attribute name="type" type="xsd:string" />
</xsd:complexType>
```

Finally, the standard *category* tag is another element of the BPMN schema that we are going to use to supply other specific information regarding the definition of the simulation scenarios, the calendars and the cost objects.

In the following we provide an example of how to define a BPD file for a case study process. A BPMN description of the investigated case study process is shown in Figure 6. It represents the process of **releasing a construction permit** by the Building Authority of a Municipality. 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*, the private citizen/company who needs to obtain the building permit and triggers the whole process; *Clerk*, 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*, the back-office employee of the Building Authority who evaluates and decides on the application; *Expert*, 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 considered resources in the scenario are energy, modeled as *DurableResource*, paper and stamps, both modeled as *ConsumableResource*.

The BPMN diagram depicted in Figure 6, which represents just the process workflow, has an equivalent *Xml* representation that we are not going to show for space reason. Instead, we deem interesting to report what the *Xml* representation of the process context will look like. Suppose we want to set up a context scenario (say *scenario1*) for which we intend to employ all the above mentioned resources. Also, we need a calendar (*official-calendar*) to state that for human resources the working days are Monday through Friday and the working hours follow the pattern [8:00AM to 12:00AM, 1:00PM to 5:00PM]. We then specify four different types of application ("cost object", in the ABC terminology) that potential applicants may submit. Further, in the specific scenario we require 1 unit of the Clerk resource type and 2 units of Senior Clerk resource type, whose hourly costs are 10€and 20€respectively. Listing 2 reports an Xml excerpt of the definition of the scenario, the cost objects and the Clerk. Note that all the new elements describing the process context, and that are out of the BPMN standard, have been assigned a *bpsim* prefix, while BPMN elements shows no prefix.

Listing 2: XML excerpt defining the scenario, the cost objects and the Senior Clerk resource.

```
<definitions id="sid-6cc2411a-..."
      xmlns="http://www.omg.org/spec/BPMN/20100524/MODEL">
    <xmlns:bpsim="http://www.unict.it/bpmn/bpsim/2.0" ...>
<import location="BPSIM20.xsd"
      namespace="http://www.unict.it/bpmn/bpsim/2.0"
      importType="http://www.w3.org/2001/XMLSchema" />
<extension definition="bpsim:BPMNExtension"
      mustUnderstand="true" />
<category id="bpsim-scenarios" name="BpSim␣Scenarios">
 <categoryValue id="scenario1" value="Scenario␣1">
  <extensionElements>
   <bpsim:scenario default="true">
    <bpsim:timeUnit>month</bpsim:timeUnit>
    <bpsim:moneyUnit>EUR</bpsim:moneyUnit>
    <bpsim:maxInstances>1000000</bpsim:maxInstances>
    <bpsim:startInstant>2015-01-01T00:00:00.000
    </bpsim:startInstant>
    <bpsim:endInstant>2018-01-01T00:00:00.000
    </bpsim:endInstant>
   </bpsim:scenario>
  </extensionElements>
 </categoryValue>
</category>
<category id="bpsim-cost-objects" name="BpSim␣Cost␣
      Objects">
 <categoryValue id="application" value="Application">
  <extensionElements>
   <bpsim:costObjectType id="application-maintenance"
        name="Maintenance" />
   <bpsim:costObjectType
        id="application-building-renovation"
        name="Building␣Renovation" />
   <bpsim:costObjectType
        id="application-preservation-and-restoration"
       name="Preservation␣and␣Restoration" />
   <bpsim:costObjectType
        id="application-urban-restructuring"
       name="Urban␣Restructuring" />
  </extensionElements>
 </categoryValue>
</category>
<resource id="senior-clerk" name="Senior␣Clerk">
 <extensionElements>
  <bpsim:resource type="OrganizationalPosition">
   <bpsim:unit>#HR</bpsim:unit>
   <bpsim:timeUnit>h</bpsim:timeUnit>
   <bpsim:moneyUnit>EUR</bpsim:moneyUnit>
   <bpsim:usage scenarioRef="scenario1">
    <bpsim:availability calendarRef="official-calendar">2
    </bpsim:availability> <!-- 2 #HR -->
    <bpsim:unitCost timeBound="true">20.00
    </bpsim:unitCost> <!-- 20 EUR/h/#HR -->
   </bpsim:usage>
  </bpsim:resource>
 </extensionElements>
</resource>
```

In Listing 3 we show how to assign resources to a specific task. The *bpsim:resourceConsumption* tag models the statistical behaviour "ResourceConsumption" of Figure 5 discussed in Section 3.4. Specifically, the *send invoice* task is assigned exactly one Clerk, an amount of energy that is dis-

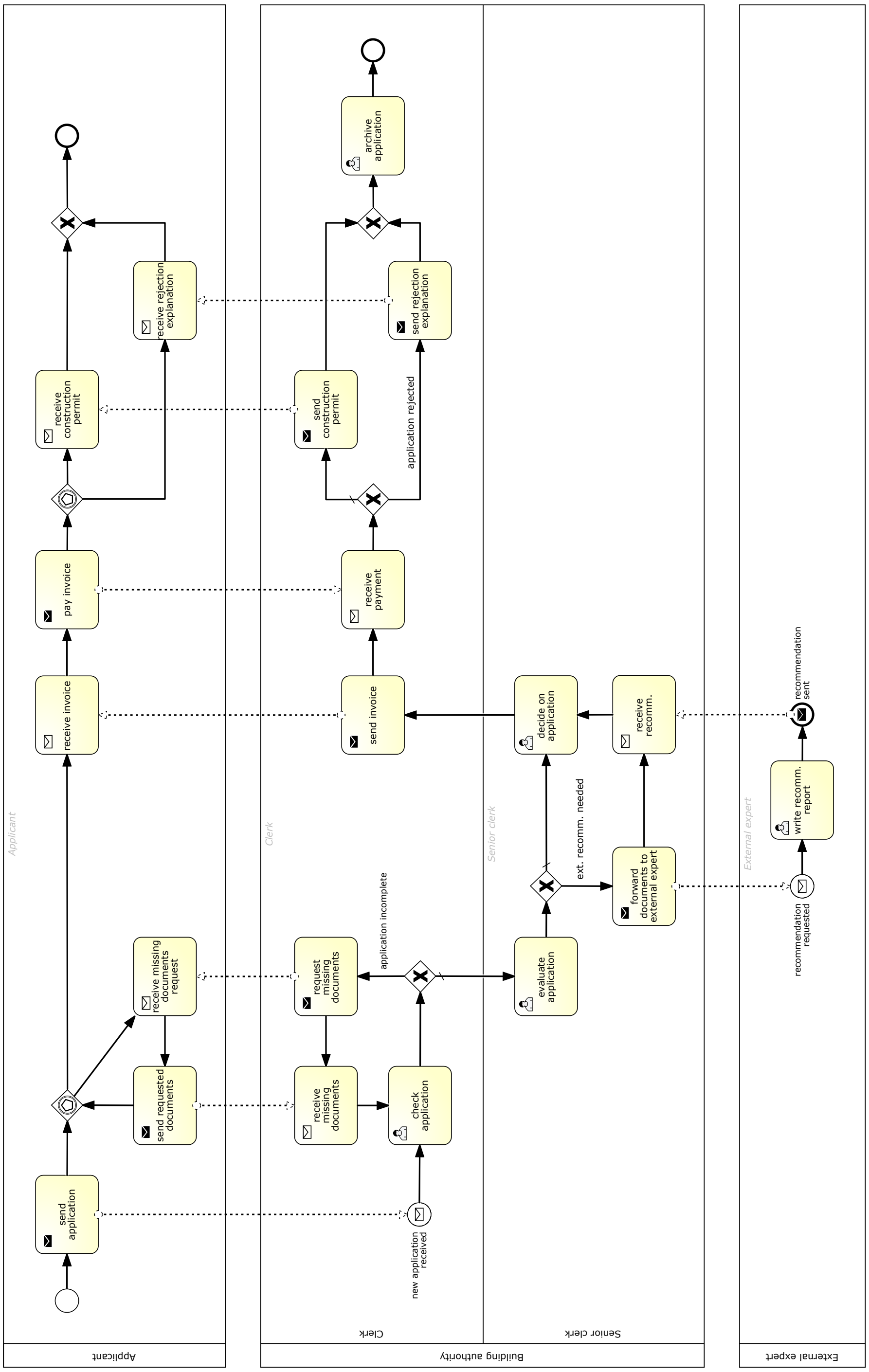

Figure 6: BPMN model of the example process.

tributed according to the Normal law, a number of paper sheets that is Bernoulli distributed and exactly 2 stamps. Further, the duration of *send invoice* task (which models the statistical behaviour "Duration" of Figure 3) has a Beta (PERT parametrized) distribution (*bpsim:duration* section). Finally, the excerpt reports the parameters of the *autonomous decision* gateway. In particular, it is stated that in the case that at the input flow arrives a cost object of type *application-maintenance*, *application-building-renovation* or *application-urban-restructuring*, one of the outgoing flow has 20% probability of be-resource/activity report

resources			costs [€] – Building Authority – Clerk: check application	send invoice	receive payment	send construction permit	archive application	request missing documents	receive missing documents	send rejection explanation	Senior Clerk: evaluate application	decide on application	forward documents to external expert	receive recommendation	External Expert: write recommendation report	TOTAL
Building Authority	Organizational	Clerk	3.025,72	676,42	312,73	611,59	1.062,48	466,82	99,67	104,88						**6.360,32**
		Senior Clerk									267.660,75	706,67	49,10	34,24		**268.450,76**
	Durable	Energy	27,23	6,09		5,50		4,20		0,94	481,79		0,22	0,15		**526,13**
	Consumable	Paper		2,12		3,84		1,28		0,40						**7,64**
		Stamp		339,20		1.536,00		204,80		64,00						**2.144,00**
		TOTAL	**3.052,96**	**1.023,83**	**312,73**	**2.156,94**	**1.062,48**	**677,10**	**99,67**	**170,22**	**268.142,54**	**706,67**	**49,32**	**34,40**		**277.488,85**
		per time unit [€/h]	10,09	15,14	10,00	35,27	10,00	14,50	10,00	16,23	20,04	20,00	20,09	20,09		**19,74**
		per unit [€/#activity]	11,06	4,83	1,48	11,23	5,01	10,58	1,56	8,51	1.264,82	3,33	0,73	0,51		**153,14**
External Expert	Durable	External Expert													61.771,13	**61.771,13**
		TOTAL													**61.771,13**	**61.771,13**
		per time unit [€/h]													30,00	**30,00**
		per unit [€/#activity]													908,40	**908,40**

activity/cost-object report

activities			costs [€] – cost-objects: Maintenance	Building Renovation	Preservation & Restoration	Urban Restructuring	TOTAL	work times [h] – cost-objects: Maintenance	Building Renovation	Preservation & Restoration	Urban Restructuring	TOTAL	queue times [h] – cost-objects: Maintenance	Building Renovation	Preservation & Restoration	Urban Restructuring	TOTAL
Building Authority	Clerk	check application	2.444,56	371,33	214,46	22,60	**3.052,96**	242,3	36,8	21,3	2,2	**302,6**	3,8	2,0			**5,8**
		send invoice	818,94	148,31	46,55	10,03	**1.023,83**	54,0	9,9	3,0	0,7	**67,6**	16,8	4,1	1,7	0,2	**22,9**
		receive payment	250,95	43,72	14,75	3,30	**312,73**	25,1	4,4	1,5	0,3	**31,3**	3.384,9	242,5	371,0		**3.998,3**
		send constr. permit	1.718,95	304,58	110,64	22,77	**2.156,94**	48,8	8,7	3,0	0,7	**61,2**	3,5	0,5			**4,0**
		archive application	848,09	152,69	52,06	9,65	**1.062,48**	84,8	15,3	5,2	1,0	**106,2**	3,8				**3,8**
		request missing documents	557,08	42,33	77,69		**677,10**	38,3	2,9	5,5		**46,7**					
		receive missing documents	82,33	6,41	10,93		**99,67**	8,2	0,6	1,1		**10,0**	12.870,4	2.262,9	772,8	140,6	**16.046,7**
		send rejection explanation	145,18	25,04			**170,22**	9,0	1,5			**10,5**	0,2				**0,2**
	Senior Clerk	evaluate application	214.532,66	37.760,23	13.413,99	2.435,66	**268.142,54**	10.707,4	1.884,6	669,5	121,6	**13.383,0**	11.863,4	1.271,2	166,0	17,7	**13.318,3**
		decide on application	566,67	100,00	33,33	6,67	**706,67**	28,3	5,0	1,7	0,3	**35,3**	11.765,5	261,4	654,3	85,6	**12.766,9**
		forward docs to ext. expert	36,88	5,33	7,11		**49,32**	1,8	0,3	0,4		**2,5**	232,8	23,2	389,1		**645,0**
		receive recomm.	25,75	3,53	5,12		**34,40**	1,3	0,2	0,3		**1,7**	1.578,8	42,3	21,5		**1.642,6**
		TOTAL	**222.028,06**	**38.963,48**	**13.986,64**	**2.510,68**	**277.488,85**	**11.249,3**	**1.970,2**	**712,3**	**126,8**	**14.058,6**	**41.724,0**	**4.110,0**	**2.376,4**	**244,2**	**48.454,6**
		per time unit [*/h]	17,34	17,80	14,00	19,80	**17,22**	100%	100%	100%	100%	**100%**	371%	209%	334%	193%	**345%**
		per unit [*/#cost-objects]	1.306,05	1.298,78	1.398,66	1.255,34	**1.308,91**	66,2	65,7	71,2	63,4	**66,3**	245,4	137,0	237,6	122,1	**228,6**
External Expert		write rec. report	46.625,99	6.550,08	8.595,05		**61.771,13**	1.554,2	218,3	286,5		**2.059,0**					
		TOTAL	**46.625,99**	**6.550,08**	**8.595,05**		**61.771,13**	**1.554,2**	**218,3**	**286,5**		**2.059,0**					
		per time unit [*/h]	30,00	30,00	30,00		**30,00**	100%	100%	100%		**100%**					
		per unit [*/#cost-objects]	274,27	218,34	859,51		**291,37**	9,1	7,3	28,7		**9,7**					

Figure 7: Overall report for scenario1.

ing selected, the other takes the remaining 80%; instead, in the case that an *application-preservation-and-restoration* cost object arrives, a specific output flow is alway selected. In our cost-based view, Gateways are one of the many elements where the type of the processed cost object affects the workflow.

Listing 3: XML excerpt defining the "send invoice" task's resource assignement and the exclusive gateway statistical behaviour.

```
<sendTask completionQuantity="1"
    id="sid-7B9D15A6-..."
    implementation="##WebService"
    isForCompensation="false" name="send␣invoice"
  startQuantity="1">
  <extensionElements>
    <bpsim:task scenarioRef="scenario1">
      <bpsim:resourceConsumption resourceRef="clerk"
          unit="#HR">
        <bpsim:numerable type="Constant">
          <bpsim:parameter
              name="value">1</bpsim:parameter>
        </bpsim:numerable>
      </bpsim:resourceConsumption>
      <bpsim:resourceConsumption
          resourceRef="energy" unit="W">
        <bpsim:fractional type="Normal">
          <bpsim:parameter
              name="mu">500</bpsim:parameter>
          <bpsim:parameter
              name="sigma">3.33</bpsim:parameter>
        </bpsim:fractional>
      </bpsim:resourceConsumption>
      <bpsim:resourceConsumption resourceRef="paper"
          unit="#paper">
        <bpsim:numerable type="Bernoulli" shift="4">
          <bpsim:parameter
              name="p">0.12</bpsim:parameter>
        </bpsim:numerable>
      </bpsim:resourceConsumption>
      <bpsim:resourceConsumption resourceRef="stamp"
          unit="#stamp">
        <bpsim:numerable type="Constant">
          <bpsim:parameter
              name="value">2</bpsim:parameter>
        </bpsim:numerable>
      </bpsim:resourceConsumption>
      <bpsim:duration unit="h" type="Pert">
        <bpsim:parameter name="a">10</bpsim:parameter>
```

```
    <bpsim:parameter name="m">15</bpsim:parameter>
    <bpsim:parameter name="b">30</bpsim:parameter>
   </bpsim:duration>
  </bpsim:task>
 </extensionElements>
 ...
</sendTask>

<exclusiveGateway id="sid-4A21D4F4-..."
    default="sid-59595B8C-..."
    gatewayDirection="Diverging" name="autonomous␣
    decision?">
 <extensionElements>
  <bpsim:exclusiveGateway scenarioRef="scenario1">
   <bpsim:conditionalFlowSet
       flowRef="sid-A1FD99EE-...">
    <bpsim:probabilities>
     <bpsim:probability costObjectTypeRef=
         "application-maintenance">0.2
     </bpsim:probability>
     <bpsim:probability costObjectTypeRef=
         "application-building-renovation">0.2
     </bpsim:probability>
     <bpsim:probability costObjectTypeRef=
         "application-preservation-and-␣
             restoration">1.0
     </bpsim:probability>
     <bpsim:probability costObjectTypeRef=
         "application-urban-restructuring">0.2
     </bpsim:probability>
    </bpsim:probabilities>
   </bpsim:conditionalFlowSet>
  </bpsim:exclusiveGateway>
 </extensionElements>
 ...
</exclusiveGateway>
```

The cost-sensitive approach adopted to design the Business Process Model eventually allowed us to gather data produced by the simulation and easily put them in a form that facilitates ABC analysis. Focus is put on the application. As explained earlier, each submitted application is a *cost-object*, in the sense that it accumulates the costs produced by every activity that is going to process the application itself. Also, when traversing the activities an application is also capable of recording both the time spent in every activity's queue and the time for being processed.

Three simple process KPIs are going to be assessed through the simulation: the *monetary costs* incurred by the Building Authority to serve the requests, the *work times* spent by the activities to process applications and the *queue times* applications had to wait before being processed by the activities. Figure 7 depicts a report of analytical costs and times computed for the scenario. In particular, costs incurred for the allocation of resources to activities are reported in the section "resource/activity report"; activity costs and times absorbed by the four types of application are instead shown in the section "activity/cost-object report". The resource pools are spliced into internal resources (Building Authority) and external resources (External Expert) and further classified by type; the activity pools coincide with those of the BPMN model.

The obtained data provide a picture of the performance of the process in terms of costs and times. Process designers may use those data to ground their analysis, and guess which part of the process (workflow, resource assignments) is susceptible of improvements. In the "activity/cost-object" section, if we focus on the intersection between the "costs [€]" macro-column and the "per unit [*/#cost-objects]" row of the *Building Authority* pool we can observe the unit cost of each application type (*Maintenance*, *Building Renovation*, ...). So, for instance, the unit cost of the *Maintenance* application is 1.306,05 €/#cost-object, i.e., every *Maintenance* application has an average cost of 1.306,05 €. Similarly, if we look at the "per time unit [*/h]" row, the hourly cost of the *Maintenance* application is 17,34€/h, i.e., every work hour on the *Maintenance* application has an average cost of 17,34€.

5 CONCLUSION

Business process practitioners 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 fine-tune the process model before the process is actually implemented and executed. Most of existing commercial tools use proprietary or hybrid technique to represent all process features and the resources involved in the process execution. This paper presented a proposal of a novel process context model, which grounds on the BPMN and leverages on the ABC accounting principles. The model allows process designers to represent process features under a cost-sensitive perspective. In order to test the model viability, an example process was modeled and fed to a business process simulator. Result of the simulation were presented in the paper. In the future, the management of resource preemption and priority will be integrated with the model. The exploitation of the BPMN choreography model's features will be object of investigation too.

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