Defining and Analysing Resource-Aware Process Performance Indicators*

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Abstract. A key aspect to identify improvement points of the business processes (BP) of an organisation is to conduct performance management, which involves defining appropriate PPIs (Process Performance Indicators). Up to date, existing approaches to define and analyse PPIs usually focus on time and control flow aspects, leaving disregarded the organisational perspective. In this paper we extend PPINOT, a PPI metamodel, to support the definition of resource-aware PPIs in BPs enriched with resource information. Furthermore, leveraging the formal foundation of PPINOT, we introduce automated operations that relate PPIs to the people that may have an influence on them.

Keywords: Performance Management, Key Performance Indicator, Process Performance Indicator, Resource Aware Business Process.

1 Introduction

Companies today spend effort, money and time improving and optimising their BPs. Process performance measurement tools and techniques applied to enterprise environments are essential for this continuous improvement. A key part of performance measurement is the definition of PPIs, which are quantifiable metrics that can be measured directly by data generated within the process flow and are aimed at the process controlling and continuous optimisation [1,2].

Existing approaches to manage PPIs tend to focus on control flow or time aspects such as the number of times certain activity is executed, while they stray their attention from the organisational perspective. However, the participation of people in BPs is of utmost importance, both to supervise the execution of automatic activities and to carry out software-aided and/or manual activities. Therefore, their influence in BP performance should be considered by means of resource-aware PPIs. They are PPIs that measure aspects related to the resources[1] involved in activities of a BP like the time certain resource spends on a given activity or the resources involved in its execution.

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[1] From now on, we will use resource to refer to human resources uniquely.

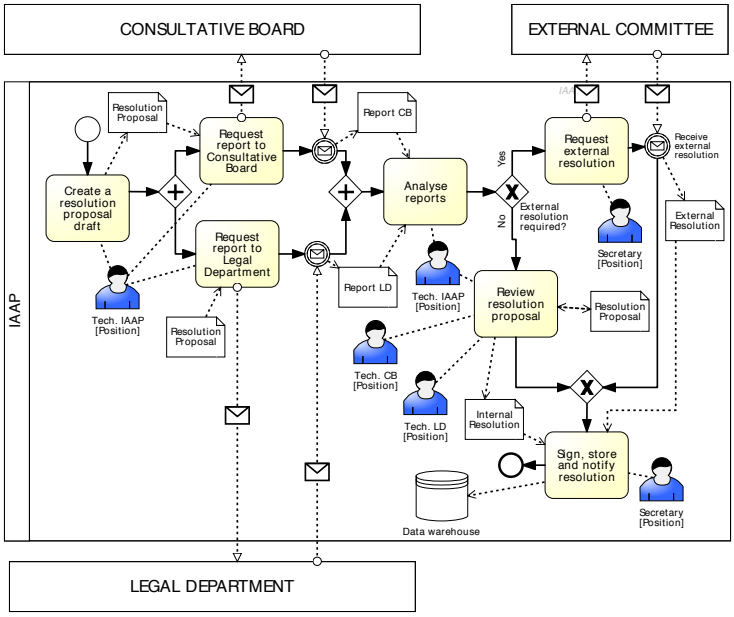


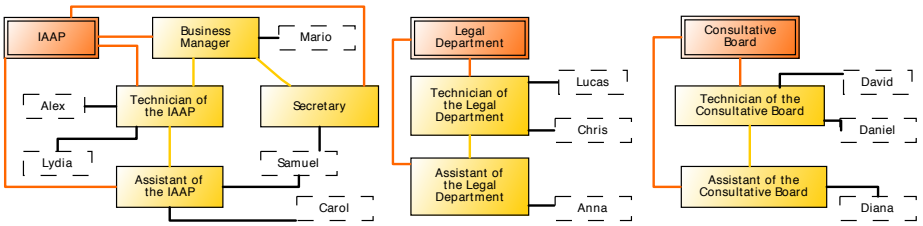
Fig. 1: Excerpt of the process to create and process a resource resolution proposal

Unfortunately, to the best of our knowledge, no proposal is able to define them, probably because the organisational perspective in BPs has been much less addressed in literature than others like, for instance, control flow.

In this paper, we address this issue as follows. On the one hand, we extend PPINOT, a metamodel to define PPIs described in [3] (cf. Section 3), to allow the definition of resource-aware PPIs (Cf. Section 4) in BPs enriched with resource information modelled with RAL (Resource Assignment Language) [4]. On the other hand, we leverage the formal foundation of both PPINOT and RAL to introduce two automated operations that relate PPIs to the people that may have an influence on them (Cf. Section 5). The final result is a holistic approach that provides insight, not only on the control-flow performance or the resources, but the combinations and interrelations between them.

2 Use Case

The process depicted in Figure 1 takes place in the Andalusian Institute of Public Administration (IAAP) and represents the procedure to create and process a resource resolution proposal (RRP) for hiring people. Since we focus on resource-aware PPIs, the BP must also contain information regarding the resource assignments to its activities. Note that assigning several resources to an activity means any of them can execute it, e.g. activity *Review resolution proposal* can be done by a Technician of the IAAP, a Technician of the Consultative Board or a Technician of the Legal Department. These



Position	Role
Business Manager	Accountable
	Process responsible
Technician of the IAAP	Technician Analyst
Technician of the Legal Department	
Technician of the Consultative Board	

Position	Position
Assistant of the IAAP	Technical assistant Document writer
Assistant of the Legal Department	
Assistant of the Consultative Board	
Secretary	Document signer

Fig. 2: Excerpt of the organizational model of the IAAP. Orange rectangles are organisational units, yellow rectangles are positions, and dashed-line rectangles are resources

positions are defined in the organisational model of the IAAP regarding Administrative Resource Management depicted in Figure 2.

To evaluate the performance of this process, the following PPIs can be defined:

- PPI1: Average time of report analysis
- PPI2: RRPs that required external resolution out of resolved RRPs
- PPI3: Number of RRPs under review
- PPI4: Number of RRPs created per technician
- PPI5: Resources that review an RRP
- PPI6: Average lifetime of an RRP

Note that PPI4 and PPI5 are resource-aware PPIs since they are related to the resources involved in activities *Create a resolution proposal draft* and *Review resolution proposal*, respectively.

3 Background on RAL and PPINOT

As detailed in the introduction, the approach we follow to define resource-aware PPIs and to relate PPIs with the people that may have an influence on them are supported by a language to define resource assignments and a PPIs metamodel called RAL and PPINOT, respectively.

RAL is an expressive DSL that allows defining the conditions that the members of the organisation must fulfill in order to be assigned to the BP activities [4]. Specifically, RAL expressions use the following concepts:

- The organisational model of the company, which in the case of RAL is based on the organisational metamodel described in [5]. This involves selecting people with a certain capability (`HAS CAPABILITY Degree`); belonging to a given group resource[2] (`HAS POSITION Secretary`); having a group resource in common with

[2] The term *group resource* refers to concepts that represent group of persons, i.e., positions, roles or organisational units.

another person (`SHARES SOME ROLE WITH Samuel`); or people that report or can delegate work to a given position (`REPORTS TO Technician of the IAAP`).
- The data and resource BP perspectives, e.g. to select the person responsible for another activity (`IS RESPONSIBLE FOR ACTIVITY Analyse Reports`) or someone specified in a data object (`IS PERSON IN DATA FIELD RP.Analyser`). Furthermore, RAL is aware of the different duties that may be involved in a single activity. In particular, it considers the five so-called RASCI roles [6], namely: responsible, i.e., the person who performs the work; accountable, i.e., the person who approves the work; support, i.e., the people who may assist in completing the activity; consulted, i.e., the people whose opinion is sought while performing the work; and informed, i.e., the people that are kept up-to-date about the results of the work.

RAL expressions can be composed (`AND`/`OR`) and negated (`NOT`). For instance, according to Figure 1, which only represents assignments for task duty *responsible*, the RAL expression for activity *Review resolution proposal* is `((HAS POSITION Tech. IAAP) OR (HAS POSITION Tech. CB.)) OR (HAS POSITION Tech. LD).`

PPINOT is a metamodel that has been created to allow the modelling of PPIs in a way that is unambiguous and complete, understandable by technical and non-technical users, traceable with the BP elements and amenable to automated analysis [3]. Figure 3 depicts an excerpt of PPINOT showing the main elements of a PPI definition and the types of measure that can be used to define a PPI. These types are: Base, Derived and Aggregated. A **Base Measure** is obtained directly from a single process instance and does not require any other measure to be computed. It can be subdivided into four classes: *Time Measure*, for the time duration between two time instants; *Count Measure*, for the number of times something happens; *Condition Measure*, for the fulfillment of certain condition referred to either a BPElement state (*StateConditionMeasure*) or a DataObject restriction(*DataPropertyConditionMeasure*), in both running or finished process instances; and *Data Measure* for the value of a certain part of a DataObject. A **Derived Measure** is defined as a mathematical function over one or more measure definitions, that can be single- (*DerivedSingleInstanceMeasure*) or multi-instance measures (*DerivedMultiInstanceMeasure*). An **Aggregated Measure** aggregates one single-instance measure in several process instances using an aggregation function (*e.g.* sum or average). They can also be grouped by the content of a DataObject. For further detail, we refer the reader to [3].

4 Definition of Resource-Aware PPIs

There are two different types of resource-aware PPIs. Next, we describe how the PPINOT metamodel can be extended to support them (cf. Figure 3).

Resource Measure. It measures the resources that perform certain task duty associated to an activity. For instance: *PPI5: Resources that review an RRP.* This is modelled by means of attribute `measuresResource` that selects the resource that is performer of a task duty (attribute `taskDuty`) associated to an activity. As established above, five

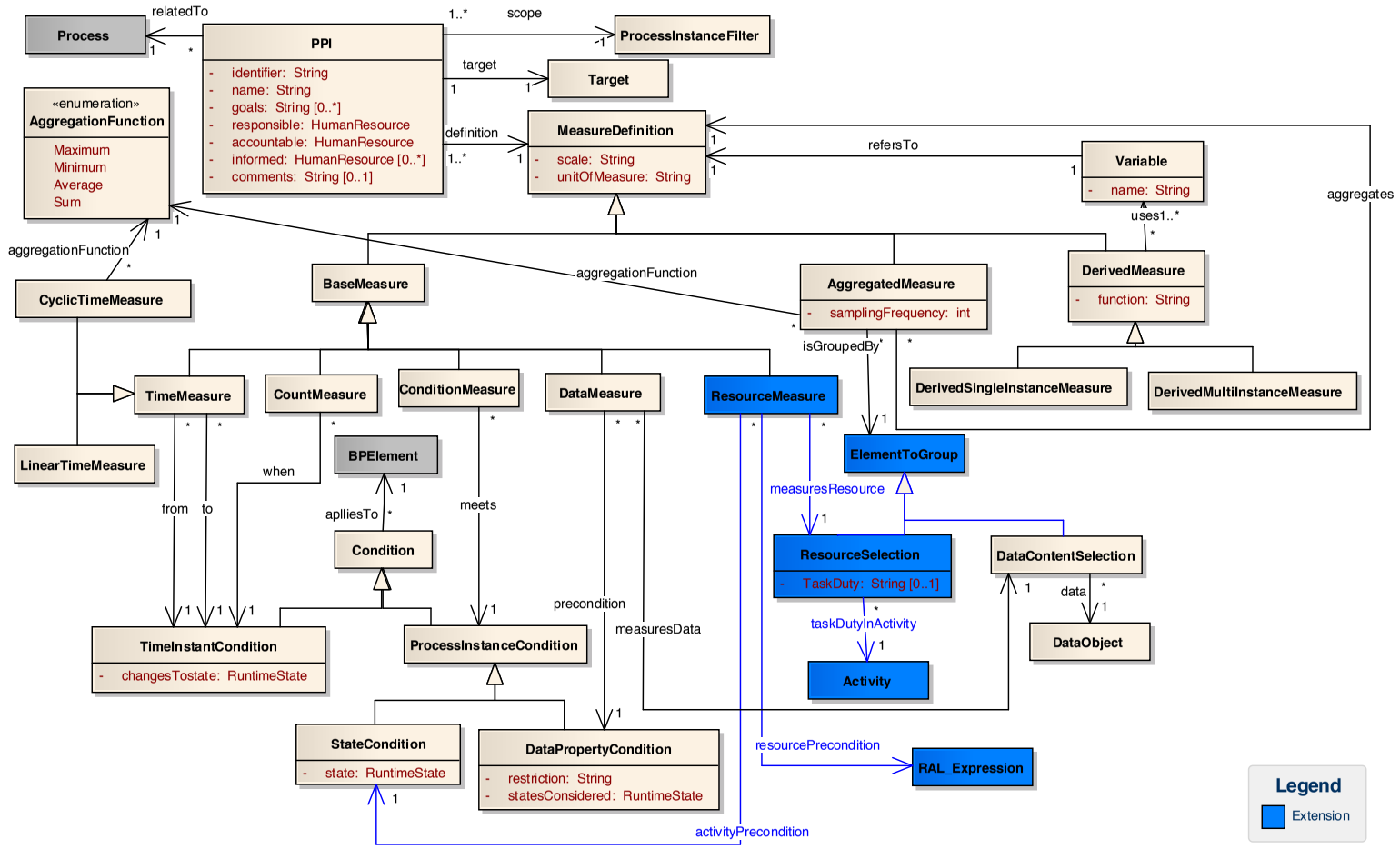


Fig. 3: Excerpt of PPINOT Metamodel (extended to take into account human resources)

Measure type	BP elements involved
Time	(1) The elements that are executed between the start and the end of the time measure and (2) the elements at the start or at the end if some of the time of their execution is included in the time measure.
Count	(1) The element that is being counted and (2) the XOR gateways that have taken the execution path to that element.
Condition	(1) The element used in the condition and (2) if the condition involves a data object, the activities that can write in it.
Data	(1) The data object whose value is measured and (2) the activities that can modify the data object.
Resource	The activity referred by the resource selection associated to the measure.
Aggregated	(1) The elements involved in the measure that it aggregates and (2) if it groups results by some value, the data object that provides it.
Derived	The elements involved in the measures used by the mathematical function that calculates the value of the measure.

Table 1: Elements involved in a PPI as defined in [3] extended with resource measures

possible task duties can be assigned: responsible, accountable, supported, consulted and informed. In the case of PPI5, the task duty is *responsible* since we are considering the person that actually does the review, not those that support her or approve it. Furthermore, attribute `activityPrecondition` allows one to specify a state condition that the activity must fulfill when the measure is taken (e.g., to be active), while attribute `resourcePrecondition` allows the specification of further constraints on the resource assignment of that activity (for instance, `HAS ROLE Analyst`) . In addition, for aggregated measures that aggregate resource measures, the aggregation function *countDifferent* should be used. It allows us to measure the different persons that performed certain task duty associated to an activity, in several process instances.

Group by Resources. The other type of resource-aware PPI is based on grouping aggregated measures by certain resource selection, e.g. *PPI4: Number of RRPs created per technician*. For doing so attribute `isGroupedBy` of aggregated measures can be defined by means of a `ResourceSelection` (the user must ensure that the activity whose task duty is used to group coincides with the activity to which the PPI is applied).

5 Automated Resource-Aware Analysis of PPIs

The automated analysis of PPIs is introduced in [3] as a means to investigate properties of PPI specifications and their relationships with other models. In particular, [3] focus on a relationship between PPIs and activities called *involved in*. An activity is *involved in* a PPI when it has an influence in the value of the PPI [3]. The automated analysis of this relationship is based on the idea that, although the activities involved in a PPI cannot always be directly inferred without run-time information, it is possible to leverage the definition of the PPI and the control flow of the BP to make a design-time estimation of the BP elements that may have an influence on the PPI (cf. Table 1).

In this paper, we build on this idea to define a new relationship called *influenced by* that relates PPIs and resources. A PPI is potentially[3] *influenced by* a person when she is potentially responsible of an activity involved in that PPI, except for PPIs defined on resource measures. In that case, the resources potentially influencing the PPI value are those that perform the specified *taskDuty* in the activity specified by the measure definition. For instance the resources potentially influencing the *average lifetime of an RRP* (PPI6) are all the people that may perform duty *responsible* in the activities whose duration make the average lifetime longer or shorter, i.e. activities *Create RRP draft*, *Request report to CB*, *Request report to LD*, *Analyse report*, *Request external resolution*, *Review RRP*, *Sign, store & notify resolution*.

On the basis of relationship *influenced by*, two analysis operations can be defined:

Resources potentially influencing a set of PPI(s) It takes a set of PPIs and the corresponding resource-aware BP model as input and returns the set of resources potentially influencing those PPIs.

PPIs potentially influenced by a set of Resources It takes a set of resources (that can be only one resource), the corresponding reource-aware BP model and the PPIs model defined for that BP as input and returns the set of PPIs that are potentially influenced by those resources. This operation is the opposite of the previous one,

The former operation is useful to find out which the resources whose performance have an influence in more PPIs are, or to identify those resources that are not being taken into consideration by the current set of PPIs, i.e. those that are not influencing any PPI. The latter operation can assist during the evolution of BPs. For instance, if part of the organisational model evolves and is modified (e.g., a person is fired), this operation allows one to identify which PPIs could be affected.

These two operations can be automated using off-the-shelf DL reasoners by leveraging the formal foundation based on description logics (DL) of both PPINOT and RAL. On the one hand, in [3], the relationship *involved in* is formalised as a DL role inv in which $inv(e, md)$ means that the BP element e is involved in the measure definition md. On the other hand, in [4], for each activity A of the BP that has resources assigned, a DL concept $AssignmentA$ is defined. This concept represents the people assigned to A and is obtained from the RAL expression assigned to it.

On the basis of these two elements, a new role inf can be defined for each measure definition md as follows:

- If md is a resource measure or aggregates a resource measure, then:

$$\begin{aligned}\exists inf.\{md\} \equiv\ & \exists isPotentialResponsible(\exists inv.\{md\}) \sqcap \\ & \exists resourcePrecondition^{-}.\{md\}\end{aligned}$$

- Otherwise: $\exists inf.\{md\} \equiv \exists isPotentialResponsible(\exists inv.\{md\})$

Where $isPotentialResponsible(p, a)$ means that $Person\ p$ can be responsible for $Activity\ a$ (i.e., $\exists isPotentialResponsible.\{a\} \equiv AssignmentA$).

[3] We perform design-time analysis and before execution the actual activities' performers are unknown.

Given inf, the relationship ***influenced by*** can be formalised as $definition \circ inf^{-} \sqsubseteq influencedBy$, where $definition(p, md)$ represents the relationship between a PPI p and its measure definition md.

Finally, role $influencedBy$ allows expressing the aforementioned analysis operations in terms of the DL reasoning operation $individuals(C)$, which finds all individuals that are instances of concept C. In particular:

- Finding the influencing resources of a set of PPIs PPI is the same as solving

$$individuals(\exists influencedBy^{-}.PPI)$$

  where $influencedBy^{-}$ is the inverse role of $influencedBy$.
- Similarly, the influenced PPIs of a set of persons P is the same as solving:

$$individuals(\exists influencedBy.P)$$

6 Conclusions and Future Work

This paper presents an approach to support the definition and automated design-time analysis of resource-aware PPIs. Its main benefit is the holistic view that provides to performance evaluation, not only considering the resource-related information, but relating it also to control-flow, time or data information.We build our approach on top of two proposals vastly validated: PPINOT [3] and RAL [8].

As future work, we plan to validate this approach by applying it to real scenarios. Furthermore, the integration of these results into the existing software tools PPINOT and CRISTAL is also part of our future work in this line.

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