Temporal, Semantic and Structural Aspects-based Transformation Rules for Refactoring BPMN Model

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Abstract: Refactoring a business process model (BPM) may improve its usability (understandability, modifiability) performance, and/or ease its maintainability. So-far proposed refactoring approaches have used either refactoring which focuses on structural aspects and/or semantic information. Nevertheless, these aspects provide a partial view of the model. As we show in this paper, combining the semantic and structural aspects with the temporal aspect decreases further the complexity of a business process modelled in BPMN and enhances its performance. Our method uses a set of transformation rules. We illustrate their efficiency through well-established performance measures (temporal and cost) and structural measures (complexity).

1 INTRODUCTION

A business process (BP) is a series of activities occurring within a company that lead to the production of a product or a service (ISO/IEC 19510, 2013). It allows organizations to keep or even increase their competitiveness. For this reason, companies manage business processes with the adequate quality degree, i.e., without faults that influence understandabiliy, modifiability or performance of the BP among others features. Indeed, understandability, modifiability and performance have proved to be three of the most important features to accomplish business processes with appropriate quality degrees (Lanz et al., 2016).

For instance, to show the improvements of the undestandabilty and modifiability, several researches apply a set of well-known structural measures expressing the complexity of the BP (Cardoso, 2006) (Gruhn and Laue, 2006) such as the number of sequence flows, tasks and connectors, connectivity, density, average/maximum connector degree, control flow complexity, etc. In addition, for organizations seeking continuous improvements, the recent literature on the BP performance measures (Lanz et al., 2016) (Kis et al., 2017) has shown three trends of approaches: those based on time, those centered on cost and those combining the two aspects. For instance, (Lanz et al., 2016) define the measure "Activity Duration" to determine the necessary time to perform an activity.

Furthermore, refactoring techniques are required for a potential and promising solution in order to improve understandability, modifiability and performance of BP models. In this context, current approaches focusing on refactoring are classified into structure-based works, semantic-based works, and works which combine the semantic and structural aspects (Khlif et al., 2017).

The first type of refactoring approaches is based on refactoring operations and social network rediscovery-based methods (Oinas-Kukkonen et al., 2010). The former defines a set of refactoring operators and algorithms to change the internal structure of BPM without altering its external behavior (La Rosa et al., 2011). The latter considers that social relationships (ie. structural relations) and collaborative behaviors among people within an enterprise affect the overall process performance (Boulmakoul, and Besri, 2013).

The second type of these approaches relies on social network discovery-based methods which explore the human perspectives (performers and their roles) to discover knowledge expressing the relationships among performers in a BPM (Kim et al., 2014).

The third type of approaches (Khlif et al., 2017) shows how to apply the correlated structural (i.e., functional and organizational) and semantic aspects to restructure BPM specified in the Business Process

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Modelling Notation (BPMN) (ISO/IEC19510, 2013).

Our literature review reveals that the so-far proposed refactoring techniques have been based on the structural and or semantic aspects while neglecting the temporal aspect that can also affect the refactoring quality. More specifically, in this paper, we propose to reuse the proposed strategy in (Khlif et al., 2017) to define transformation rules related to all perspectives. The authors browse the fragments based on the defined top down approach (Khlif et al., 2017). These transformation rules use the BPMN model structure and the business context that describe semantic information related to BPMN elements such as the description of the activities, the information about the performers associated to each activity, etc.

Toward this end, we tackle the limits presented in the literature by enhancing the EVARES approach (Khlif et al., 2017) with : 1) a way to annotate a BPMN model by using the business context as a means to encapsulate temporal information related to the actor and to all BPMN elements. These information are pertinent to the business logic and organizational aspect; 2) a set of new temporal and cost measures to improve the performance of a BP; and 3) BPMN transformation rules that encapsulates also the temporal constraints. To show the improvements gained by applying the transformation rules and their influence on the complexity and performance dimensions of a model, we use a set of well-known structural and performance measures.

The remainder of the paper is organized as follows: Section 2 summarizes related work. Section 3, introduces concepts related to the quality of a BPM. In section 4, we propose temporal and cost measures to evaluate the performance of a BPM. Section 5 presents the definition of the business context in BPMN model. In section 6, we illustrate a subset of our transformation rules. Section 7 illustrate our transformation rules through an example. Finally, section 8 summarizes the presented work and outlines its extensions.

2 RELATED WORK

The works in this section are overviewed not only on structural and performance measures but also on refactoring methods which aim at optimizing the model.

2.1 Structural and Performance Measures

In the area of business process, a wide variety of business quality measures has been developed. These measures are classified into two categories: structural measures and performance measures.

2.1.1 Structural Measures

Structural measures fall basically into three types: *complexity*, *coupling* and *cohesion* (Cardoso, 2006). In this paper, we focus on the complexity measures such as the size measures (Rolón et al., 2006) that calculates the number of each BPMN element (ie. Number of Sequence flows (NSF), Number of Lanes (NL), Total Number of Gateways (TNG), Total Number of Events (TNE), Number of Activities (NOA), Number Of Activities, Joins and Splits in the process (NOAJS)). In addition, (Mendling, 2006) identifies the Density (Den) measure.

Others complexity measures are defined in (Cardoso, 2006) such as the Control Flow Complexity (CFC); and Coefficient of Connectivity (CNC). (Gruhn and Laue, 2006) present the Cognitive Weight (CW) measure which reveals the effort required for comprehending a given model.

2.1.2 Performance Measures

In this section, we overview works on the BP performance based on measures. These works are organized in three categories: time based-performance measures, cost based-performance measures and integrating time and cost to measure the BP performance.

In the first category, (Lanz et al., 2016) identify 10 different time patterns which constitute solutions for representing temporal constraints. They are classified into 4 distinct groups: 1) Durations and Time Lags. 2) Restricting Execution Times. 3) Variability. 4) Recurrent Process Elements. Based on time patterns, (Lanz et al., 2016) define for instance the Activity Duration (AD) belongs to TP2.

(Del-Río-Ortega et al., 2013) propose the PPINOT metamodel that has been created to allow the modelling of Process Performance Indicators (PPIs). PPINOT shows the main elements of a PPI definition and the types of measures (Base, Derived and Aggregated) that can be used to define a PPI. PPINOT defines also two types of resource-aware PPIs: *Resource Measure* and *Group by Resources*. For instance, the authors present the measure Total Number of Actors that perform Tasks in a period of time (TNAT(period)).

In the second category, (Sampathkumaran and Wirsing, 2013) propose a methodology for cost calculation by dividing a business process into patterns. For example, the cost of n tasks in a sequential order represents the total cost of all the tasks in a sequential order.

In the third category, Kis et al., 2017) propose a framework on how the four dimensions of the devil's quadrangle (time, cost, quality and flexibility) can be measured. In this context, (Kis et al., 2017) define the measure Lead Time of the Activity which is calculated as the sum of the duration of each activity and the wait time.

In summary, the majority of the presented measures in literature are related to the activity and event elements, or resources measures. However, the authors neglect the gateway, sequence flow and lane/pool elements which have an impact on evaluating BP performance. In addition, the authors don't use these measures to refactor the BPM and improve their performance. Besides, there is no works that combine the cost and temporal measures of all BPMN elements with the actor's measures.

2.2 Works on Business Process Refactoring

The recent literature on business process refactoring has shown three trends of approaches:

- those which are structure-based: these works focus on refactoring operations and social network rediscovery-based methods;
- those which are semantic-based: they represent social network discovery-based methods;
- those which combine the semantic and structural aspects (Khlif et al., 2017).

2.2.1 Structure-based Refactoring

Refactoring has been used in literature for improving the quality of a BPM. For example, (Fernández-Ropero et al., 2013) provide a mechanism to detect the sub-set of refactoring operators which structurally transform a model while preserving its behavior if the pre-conditions are satisfying. (La Rosa et al., 2011) identify twelve patterns which determine structural fragments subject to reorganization. (Corradini et al., 2018) optimize the understandability of the BPM during refactoring.

In addition, several works are based on social network, especially, on rediscovery-based methods (Boulmakoul and Besri, 2013) (Kajan et al., 2014) in order to recognize processes from execution event logs and identify the structural relations among the performers or organizational units. Adopting this type of approach, (Kajan et al., 2014) propose a method using a set of social relations that connect tasks, persons and machines together to develop specialized networks that capture the interactions during BP execution. (Boulmakoul and Besri, 2013) propose methods for assessment of organizational structure based on structural analysis.

2.2.2 Semantic-based Refactoring

Besides the structure based, other approaches focus on discovering social network knowledge. More specifically, (Battsetseg et al., 2013) propose an algorithm to discover an activity-performer affiliation network model from an Information Control Net (ICN) based workflow model. (Kim et al., 2014) visualize the workflow performer-role affiliation networking knowledge from an ICN based workflow model.

2.2.3 Refactoring based on Combining Semantic and Structural Aspects

In (Khlif et al., 2017), the authors propose a method called EVARES Quality (EVAluation and Quality Restructuring) to refactor and evaluate the quality of BP models. The authors defined twenty-eight transformation rules that consider the semantic and structural information. These rules are related to the behavioral and organizational perspectives. The behavioral rules exploit only the structural aspect. The organizational rules rely on the structural and semantic (business context) information.

In summary, the majority of refactoring approaches, presented in literature, use the semantic and/or structural. However, there is no works that take into account the temporal aspect. Evidently, neglecting this aspect reduces the amount of information that can be extracted and, therefore, may reduce the scope for potential improvement solutions. Our proposed method build on our preliminary work in (Khlif et al., 2017) and combines structural, semantic and *temporal* aspects in order to improve the BP performance (ie. reduce the time, cost) and the understandability and modifiability of the BP.

3 BACKGROUND

(ISO/IEC 25010, 2011) provides a guide for the use of the international standard called Evaluation and Requirements Software Quality Requirements and Evaluation (SQuaRE). SQuaRE is composed of five divisions. This paper focuses on the quality model division which proposes eight quality characteristics of the models (products): functional suitability, reliability, performance efficiency, usability, operability, security, compatibility, maintainability and transferability.

Each characteristic is composed of a set of sub characteristics. For example, according to this classification, understandability, modifiability and reusability are sub-characteristics, respectively, of usability and maintainability. In addition, performance efficiency is shown by the sub characteristics time behaviour and resource utilization. Reliability is revealed by the sub characteristics maturity and fault tolerance.

The understandability is expressed by the sub-characteristics (appropriateness, recognisability). It is defined as the clarity degree of the objectives of a system for the evaluator (Azim et al., 2008).

Modifiability is defined by the easy modification of a process model (Azim et al., 2008) while re-usability allows to reuse BP fragments.

Time behaviour and Resource utilization are the sub characteristics of the performance efficiency that is defined by the capability of the BPMN element to provide a performance relative to the resources and the time used (Heinrich and Paech, 2010).
Time behaviour is defined as the appropriate transport time between different BPMN elements and processing times when executed; while Resource utilization represents the capability of the BPMN element to use appropriate amounts and the types of resources when executed under stated conditions.

Maturity and fault tolerance are the sub characteristics of the reliability which is determined by the capability of the activity to maintain its performance (Heinrich and Paech, 2010). Maturity is the capability of the activity to avoid failure in the activity. Fault tolerance is the capability of the activity to maintain its performance in cases of faults.

To evaluate the presented characteristics, we use measures that are shown in sections 2.1.1 and 2.1.2 and we propose also a set of performance measures that cover all BPMN concepts and the social aspect (actor) which affect the performance of a BP.

4 MEASURES FOR BUSINESS PROCEESS PERFORMANCE

Before proposing a set of new measures, we define in this section the availability and suitability characteristics that are related to the actor. Availability is the capability of the actor to be able to perform the activity in the required unit of time. Suitability focuses on actor skills that cover his qualification, expertise, social competence, skills, motivation and performance ability.

In addition, we propose the characteristic cost which is expressed as a price or monetary value associated to BPMN element and to actor in a period of time.

Next, we propose measures that will be classified according to the presented characteristics.

4.1 Measures to Assess the Suitability and Availability of the Actor

In this sub-section, we propose the following measures related to the Actor suitability:

- *Shift Time of an Actor to perform an Activity* ($ShT_{Act}(A)$): a period where an actor is scheduled (planified) to perform an Activity.
- *Actor's BReaks when he performs an Activity* ($BR_{Act}(A)$) : unproductive time where the actor is scheduled not to work**.** A scheduled time when workers stop working for a brief period.
- *Ideal Cycle Time of an Actor to perform an Activity (ICTAct(A))* : Theoretical minimum time to perform an activity by an actor.
- *Stop Time of an Actor when he performs an Activity* ($ST_{Act}(A)$) : the time where the actor was intended to work but was not due to unplanned stops (breakdowns) or planned stops (changeovers).
- *Planned Production time of an Actor* to *perform an Activity* ($PPT_{Act}(A)$): the total time that an actor is expected to produce.
- *Working Time spent by an Actor* to perform an Activity ($WT_{Act}(A)$): It corresponds to the run time which is simply calculated by the difference between the Planned Production Time and Stop Time.
- *Percentage of an Actor Time Contribution in a Lane per day* ($PTC_{Act}(L)$): it represents the proportion of the working time spent per day by an actor in a lane (L) and the total working time of the same actor in all the process P.
- *Performance of an Actor per Day* ($PerDay_{Act}$): It expresses how fast the actor's work ? In addition, it represents all elements that causes the process to operate at less than the maximum possible speed, when running. It compares the working Time spent by an actor per day to the Ideal Cycle Time.
- *Ratio of Defected Activities by an Actor per day* (RDA_{Act}): is calculated by the Total Number of Defected Activities performed by an actor divided by the Total number of Activities performed by the same actor.

- *Ratio of Good Activities performed by an Actor* (RGA_{Act}): is calculated by the Total Number of Good Activities realized by an actor in a day divided by the Total number of Activities performed by the same actor in one day.
- *Availability of an Actor in a Day* ($AVDay_{Act}$): represents the capability of the actor to be able to perform the activity in the required unit of time. It is calculated as the ratio of Working Time spent by an actor on a day to Planned Production Time.

4.2 Measures to Assess the Cost of the Actor

In this sub-section, we propose cost measures related to actor.

- *Cost of an actor in a Lane per Day* ($CosDay_{act}(L)$): is calculated by the product of the total working time spent by an Actor in a Lane per Day ($TWTDay_{Act}(L)$) and its actual Labour Costs per Hour (LCH_{Act}).

4.3 Measures to Assess the Time of the BPMN Elements

In this sub-section, we propose performance measures related to BPMN elements (gateway, sequence flow and lane/Pool).

- *Lane Duration* (LD): the sum of the needed time to carry out all BPMN elements in a lane.
- *Pool Duration* (PD): It is calculated by the sum of lanes duration in the process.
- *Gateway Duration* (GD (Gateway): represents the duration of a gateway.
- *Sequence Flow Duration* (SeqFD): represents the transfer time between BPMN elements (activity, gateway and event).

We note that the sequence flow duration expresses also the time lag (difference) between the start of an element i+1 and the end of an element i.

4.4 Measures to Assess the Cost of the BPMN Elements

In this sub-section, we propose cost measures related to BPMN elements (gateway, activity and lane/Pool).

- *Cost of an Activity realized by an actor* (CA_{Act}): is calculated by the product of the actor's actual Labour Costs per Hour and the working time spent by an Actor to perform an Activity.
- *Cost of a Lane per Day* (CosDay(L)): determines the cost of all BPMN elements in a Lane per Day. It includes the cost of transfer time between them.
- *Cost of a Sequence Flow* ($CosSeqF_{Act}$ (BPMN el_{i+1}, BPMN el_i)): the product of the Sequence Flow Duration (SeqFD) and the actor's actual Labour Costs per Hour (LCH_{Act}).

5 BPM BUSINESS CONTEXT

The business *context* allows to classify the semantic and temporal information according to five business process perspectives: organizational, functional, informational, behavioural and temporal.

The organizational perspective focuses on the social context. It denotes "Where" and by "whom" the activities are performed. "Pool" and "Lane" are the main BPMN concepts in the organizational perspective (Curtis et al., 1992). In particular, lane and pool elements are described with the following information: Unique identifier of the lane (ID_L)/pool ($ID_{p)}$, their labels, the list of actors affiliated with the lane, their permissions and their role assignments, and the relation between the actors that can be hierarchical roles (Khlif et al., 2017). Recall that hierarchical roles indicate partial ordering on roles. Roles are partially ordered to reflect the organizational hierarchy. Therefore, for two roles *r* and *r', r* $\rightarrow$*r'* implies that permissions that exist within *r'* are subsumed into those in *r* (Khlif et al., 2017). We extend the between actors by cooperation roles and actors having the same position.We note that the cooperation roles imply that the actors have the same permissions and different roles; while the same position indicates that the actors have the same roles and permissions.

We extend the business context in the organizational perspective by the semantic information representing the social aspect related to the actor and the corresponding temporal constraints: the *availability* of an actor expressing his capability to perform an activity in the required unit of time, his *suitability* representing his capability to perform the activity well, his *performance* expressing how fast his work is and *working time* expressing how long an actor performs an activity.

In the functional and temporal perspectives, activity node represents the main concept which is documented with the following context information: the unique activity identifier (ID), its lane, the ID of the actor responsible for performing it, the IDs of the activities on which it directly depends (before and after), the dependency type (authorization, coordination or resource dependency), and its required objects which can be either shared or private (Khlif et al., 2017). We extend this annotation by the following temporal and semantic information: *Performance duration* that denotes the starting and finishing time of an activity, its cost, its state which can be defected (*IsDefected*) or good (*IsGood)* and the time lags between two activities expressing the transfer time between them.

In addition, we define in the informational and temporal perspectives, the business context associated to the events. We suppose that the event in a BPM is documented with the following context information: Time date that specifies a fixed date when trigger will be fired, its duration, its cost that represents the cost of sending/receiving an event and the time lags between event and other elements.

The behavioural and temporal perspectives focus on the business context associated to the gateway and sequence flow elements. We suppose that the gateway and sequence flow nodes in a business process model are documented with the following context information: Unique identifier of the gateway (ID_G)/sequence flow (ID_{SeqF}), their labels, their duration and costs. Note that the gateway can be also expressed by the time lags between it and other BPMN elements (gateway, activity and event) expressing the transfer time between them.

6 TRANSFORMATION RULES

In this section, we use the proposed strategy in (khlif et al., 2017) to define six transformation rules related to all perspectives: functional, behavioural, organizational, informational and temporal. In fact, to apply a transformation rule, we browse the fragments based on the defined top down approach (Khlif et al., 2017). We note that the transformation rules preserve the semantics of the transformed fragment. To prove this property, we have compared the behavioral profiles (Weidlich et al., 2011) of pattern fragments before and after each transformation rule, and we have verified that they effectively satisfy the behavior preserving property; that is, both models have equivalent trace sets.

In order to propose the organizational and temporal rules, we studied the possible cases that may be included in a model well-formed according to the BPMN meta-model. Our method considers the sequential tasks in the same lane (R1) and in different lanes (R2) where the availability and the suitability of the actors are an important factor for the transformation rules. The same factors are considered to delete a department (R3). In addition, R4 and R5 are represented by parallel fragments containing duplicate tasks in different lanes where all the tasks or the set of tasks are *defected*. In this case, R4 replaces a parallel fragment by a sequential one and R5 removes department containing only defected tasks. Finally, R6 presents conditions that allow duplicating an activity.

R1: Merge directly connected activities performed by two actors in the same lane and associate the resulting activity with the actor who is the most suitable and available to perform the original activities.

			Task 1	Task 2	Task 3
Semantic and temporal information for actor	**Actor name**		Ali	Salah	Salah
	Relation	**Ali**	Ali is the leader of Salah		
		Salah	Salah is under the hierarchy of Ali		
	Role	**Ali**	Task 1		
		Salah	Task 2 Task3		
	Permission	**Ali**	Task 1 Task 2 Task 3		
		Salah	Task 2 Task 3		
	Availability	**Ali**	Monday at 08:00	Since Monday at 10:00	
		Salah	-	Monday at 14:00	Monday at 14:45
	Suitability: level	**Skills**	1	2	2
	Labor cost		20 euro	17 euro	17 euro
Semantic and temporal information for task	**Start Time**		Monday 08:00	Monday 14:00	Monday 14:45
	End Time		Monday 09:45	Monday 14:30	Monday 15:45
	Time lags	**Task 1**	-	10 min	-
		Task 2	-	-	15 min
		Task 3	-	-	-
	Activity cost		35 euro	8.5 euro	17 euro
	Is defected		0	0	0
	Affiliation		Lane 1	Lane 1	Lane1

Figure 1: Organizational and temporal annotations to illustrate rule **R1**.

Figure 1 shows the semantic and temporal information for annotating tasks and assigning actors expressing the organizational and temporal aspect. Since "Ali" is the leader of "Salah", the permission attributed to "Salah" is also attributed to "Ali". The leader has been available since Monday at 10:00 to perform "Task2" and "Task3", and "Salah" can be available on Monday at 14:00. In this case, we affect "Task2" and "Task3" to "Ali" who has the higher skills comparing to "Salah". In addition, when "Ali" performs the tasks assigned to "Salah", he can reduce the transfer time and even eliminate it. In fact, "Ali" can perform these tasks with less time than "Salah". We propose to merge the three tasks in one activity: "SP1-2-3". Figure 2 illustrates the application example for rule R1.

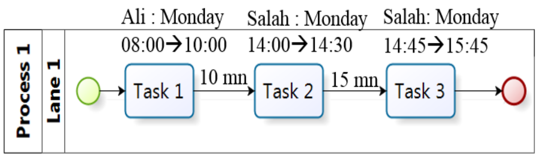


Figure 2: Application example for **R1**.

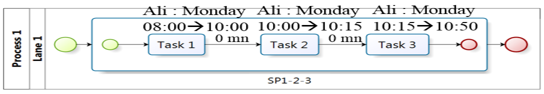


Figure 2: Application example for **R1** (cont.).

- *Measure for its detection*
  - *Structural measures*: CW, NSF, NOAJS, NOA, TNT.
  - *Temporal measures*: LD , PD, AD(Task2), AD(Task3), SeqFD(Task3$_{Salah}$, Task2$_{Salah}$), TNAT(Monday), PerDay$_{Ali}$, AVDay$_{Ali}$, SeqFD(Task2$_{Salah}$,Task1$_{Ali}$),PTC$_{Ali}$(Lane1).
  - *Cost measures*: CA$_{Salah}$(Task3), CosSeqFD(Task2$_{Salah}$,Task1$_{Ali}$), CA$_{Salah}$ (Task2), CosDay$_{Salah}$(Lane1), CosSeqFD (Task3$_{Salah}$,Task2$_{Salah}$), CosDay (Lane1).
- *Improvements after refactoring*: increase the understandability, modifiability and reusability of the model. Decrease time behaviour, cost and increase the availability and suitability of the actor.

R2: Merge directly activities related and performed by two actors with hierarchical roles in two different lanes. Associate the resulting activity with the actor who is available to carry out the original activities and who has skills to save time.

			Task 1	Task 2	Task 3	Task 4
Semantic and temporal information for actor	Actor name		Ali	Ali	Salah	Sami
	Relation	Ali	Ali is the leader of Salah			
		Salah	Salah is under the hierarchy of Ali			
		Sami	Sami is not under the hierarchy of Ali			
	Role	Ali	Task 1 Task 2			
		Salah	Task 3			
		Sami	Task 4			
	Permission	Ali	Task 1 Task 2 Task 3			
		Salah	Task 3			
		Sami	Task 4			
	Availability	Ali	Tuesday at 08:00	Tuesday at 08:47	Tuesday at 10:00	-
		Salah	-	-	Tuesday at 11:00	-
		Sami	-	-	-	Tuesday at 08:00
	Suitability: Skills level		1	1	3	1
	Labor cost		20 euro	20 euro	17 euro	19 euro
Semantic and temporal information for task	Start Time		Tuesday 08:00	Tuesday 08:47	Tuesday 11:00	Tuesday 12:12
	End Time		Tuesday 08:45	Tuesday 10:00	Tuesday 12:00	Tuesday 13:00
	Time lags	Task 1	-	2 min	-	-
		Task 2	-	-	16 min	-
		Task 3	-	-	-	12 min
		Task 4	-	-	-	-
	Activity cost		15 euro	24.3 euro	17 euro	15.2 euro
	Is defected		0	0	0	0
	Affiliation		Lane 1	Lane 1	Lane 2	Lane 2

Figure 3: Organizational and temporal annotations to illustrate rule **R2.**

Figure 3 presents the information about the tasks and the actors that perform each task. In this case, since "Salah" is under the hierarchy of "Ali", the permission attributed to "Salah" is also attributed to "Ali". In addition, we note that "Ali" can be available before Salah. In fact, we assign "Task3" to "Ali" who can start performing this task on Tuesday since 10:00. R2 affects "Task1", "Task2" and "Task3", to "Ali" who has the skills to perform them in "Lane1". This rule is illustrated in Figure 4.

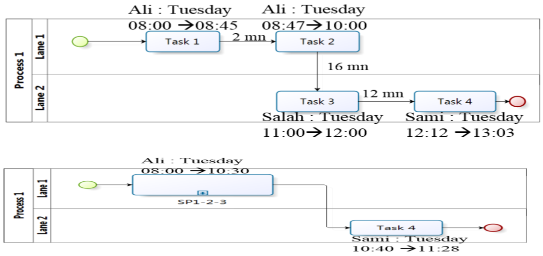


Figure 4: Application example for **R2**.

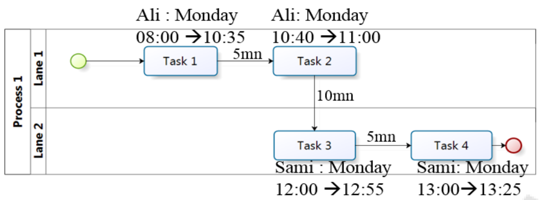
- *Measure for its detection*
  - *Structural measures:* CW, NSF, NOAJS, NOA, TNT.
  - *Temporal measures*: AD(Task3), LD, PD, SeqFD(Task2$_{Ali}$,Task1$_{Ali}$), SeqFD (Task3$_{Salah}$, Task2$_{Ali}$), SeqFD (Task4$_{Sami}$, Task3$_{Salah}$), AVDay$_{Ali}$, PTC$_{Ali}$(Lane1), PerDay$_{Ali}$, TNAT(Tuesday).
  - *Cost measures*: CosDay$_{Salah}$(Lane2), CosSeqFD (Task2$_{Ali}$,Task1$_{Ali}$), CosSeqFD (Task3$_{Salah}$,Task2$_{Ali}$),CosSeqFD(Task4$_{Sami}$,Task3$_{Salah}$),CA$_{Salah}$(Task3), CosDay(Lane2).
- *Improvements after refactoring*: Increase the understandability, modifiability and reusability of the BP. Decrease time behaviour, cost and increase the availability and suitability of the actor.

R3: Delete a lane containing only activities that are sequentially linked to other activities in another lane and which are performed by actors related by a hierarchical role. Then affect the resulting activity to the actor who is *available* and has the *most appropriate skills (suitability)* to perform the original activities.

			Task 1	Task 2	Task 3	Task 4
Semantic and temporal information for actor	Actor name		Ali	Ali	Sami	Sami
	Relation	Ali	Ali is the leader of Sami			
		Sami	Sami is under the hierarchy of Ali			
	Role	Ali	Task 1 Task 2			
		Sami	Task 3 Task 4			
	Permission	Ali	Task 1 Task 2 Task 3 Task 4			
		Sami	Task 3 Task 4			
	Availability	Ali	Monday at 08:00	Monday at 10:40	Monday at 11:00	
		Sami	-	-	Monday at 12:00	Monday at 13:00
	Suitability: Skills level		1	1	2	2
	Labor cost		20 euro	20 euro	18 euro	18 euro
Semantic and temporal information for task	Start Time		Monday 08:00	Monday 10:40	Monday 12:00	Monday 13:00
	End Time		Monday 10:35	Monday 11:00	Monday 12:55	Monday 13:25
	Time lags	Task 1	-	5 min	-	-
		Task 2	-	-	10 min	-
		Task 3	-	-	-	5 min
		Task 4	-	-	-	-
	Activity cost		51.6 euro	6.6 euro	16.5 euro	7.5 euro
	Is defected		0	0	0	0
	Affiliation		Lane 1	Lane 1	Lane 2	Lane 2

Figure 5: Organizational and temporal annotations to illustrate rule **R3**.

Figures 5 and 6 show an example where rule R3 can be applied. Since "Sami" is under the hierarchy of "Ali", the permission attributed to "Sami" is also granted to "Ali". In addition, the leader has been available since Monday at 11:00 to perform "Task3" and "Task4" within "Lane1". However, "Sami" can be available on Monday at 12:00. In this case, we affect "Task3" and "Task4" to "Ali" who has the higher skills comparing to "Sami". We note that the more the suitability value is minimal, the more the actor is suitable to perform the tasks. R3 proposes to merge "Task1", "Task2", "Task3" and "Task 4" into one process: "SP1-2-3-4" and grant it to "Ali".



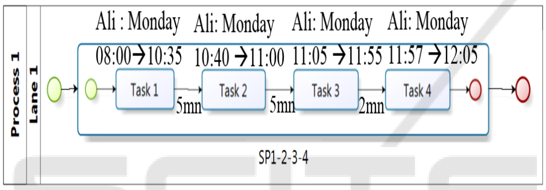


Figure 6: Application example for **R3**.

- *Measure for its detection*
  - *Structural measures:* CW, NSF, NOAJS, NOA, NL, TNT.
  - *Temporal measures*: AD(Task3), LD, PD AD(Task4), SeqFD($Task3_{Sami}$,$Task2_{Ali}$), SeqFD ($Task4_{Sami}$, $Task3_{Sami}$), $PerDay_{Ali}$, $AVDay_{Ali}$, PTC_{Ali}(Lane1), TNAT(Monday).
  - *Cost measures*: CA_{Sami}(Task3), CA_{Sami}(Task4), CosDay(Lane2), CosSeqFD ($Task3_{Sami}$, $Task2_{Ali}$), $CosDay_{Sami}$(Lane2), CosSeqFD ($Task4_{Sami}$,$Task3_{Sami}$).
- *Improvements after refactoring*: Increase the understandability, modifiability and reusability of the model. Improve performance by decreasing time behaviour, cost and optimize the availability and suitability of the actor.

R4: Replace a parallel fragment containing the same or a subset of *defected* activities that belong to different lanes by a sequence fragment, if the activities are performed by actors affiliated to different lanes and having cooperation relation. Associate then the obtained sequential fragment to skilled actor who can perform activities and terminate them *correctly*.

				Task 1	*Task 2*	*Task 3*	*Task 1*	*Task 2*
Semantic and temporal information for actor	Actor name			Sami	Sami	Sami	Ali	Ali
	Relation	Sami		Sami has cooperation relation with Ali				
		Ali		Ali has cooperation relation with Sami				
	Role	Sami		**Lane 1 :** Task 1, Task 2, Task 3				
		Ali		**Lane 2 :** Task 1, Task 2				
	Permission	Sami		**Lane 1 :** Task 1, Task 2, Task 3		**Lane 2 :** Task 1, Task 2		
		Ali		**Lane 1 :** Task 1, Task 2, Task 3		**Lane 2 :** Task 1, Task 2		
	Availability	Sami		Monday at 08:05	Monday at 09:00	Monday at 10:55	-	-
		Ali		-	-	-	Monday at 08:10	Monday at 08:40
	Suitability: Skills level			2	1	1	1	2
	Labor cost			17 euro	17 euro	20 euro	20 euro	20 euro
Semantic and temporal information for task	Start Time			Monday 08:10	Monday 09:00	Monday 09:40	Monday 08:10	Monday 08:40
	End Time			Monday 08:55	Monday 09:30	Monday 10:00	Monday 08:35	Monday 09:30
	Time lags	Lane 1	*Task 1*	-	5 min	-	-	-
			Task 2	-	-	10 min	-	-
			Task 3	-	-	-	-	-
		Lane 2	Task 1	-	-	-	-	5 min
			Task 2	-	-	-	-	-
	Activity cost			14.1 euro	29.7 euro	11.6 euro	8.3 euro	16.6 euro
	Is defected			1	0	0	0	0
	Affiliation			Lane 1	Lane 1	Lane 1	Lane 2	Lane 2

Figure 7: Organizational and temporal annotations to illustrate rule **R4**.

Figure 7 represents semantic and temporal information used to annotate tasks and actors. Since "Sami" and "Ali" have cooperation relation, the permission granted to "Sami" is also attributed to "Ali". "Ali" can perform "Task1" correctly, while "Sami" produces "Task1" in "Lane1" which represents failure due to internal errors. In this case, we assign "Task1" to "Ali" and delete the corresponding one associated to "Sami" in "Lane1". However, "Sami" has more skills than "Ali" to perform "Task2". R4 delete then "Task2" in "Lane2" and give it to "Sami". This rule is illustrated in Figure 8.

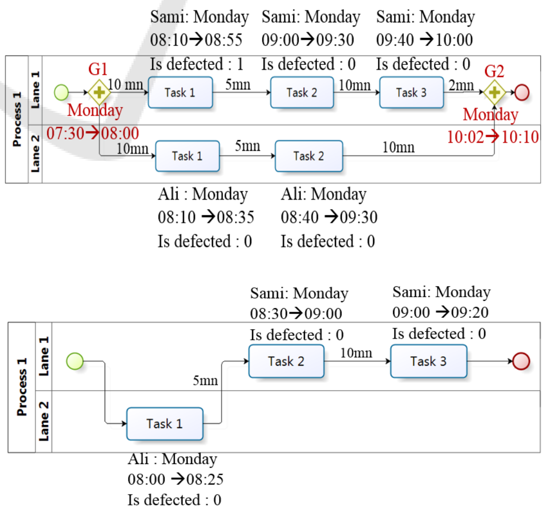


Figure 8: Application example for **R4.**

- *Measure for its detection*
  - *Structural measures*: CW, NSF, NOAJS, NOA, TNT, TNG, NL.

– *Temporal measures*: LD, PD, TDADay$_{Sami}$, TADay$_{Sami}$, RDA$_{Sami}$, SeqFD(Task1$_{Ali}$, G1), SeqFD(G2, Task3$_{Sami}$), SeqFD(G2, Task2$_{Ali}$), SeqFD(Task2$_{Ali}$,Task1$_{Ali}$), SeqFD (Task1$_{Sami}$, G1), SeqFD(Task2$_{Sami}$, Task1$_{Sami}$), PerDay$_{Sami}$, AVDay$_{Sami}$, PTC$_{Sami}$(Lane1), GD(G1),GD(G2), TNAT (Monday).
– *Cost measures*: CA$_{Sami}$(Task1), CA$_{Sami}$(Task2), CosDay(Lane1), CosDay (Lane2), CosSeqFD(Task1$_{Ali}$, G1), CosSeqFD (Task2$_{Ali}$, Task1$_{Ali}$), CosSeqFD (Task2$_{Sami}$,Task1$_{Sami}$), CosDay$_{Ali}$ (Lane2), CosSeqFD(G2, Task2$_{Ali}$), CosGat(G1), CosDay$_{Sami}$(Lane1), CosSeqFD(Task1$_{Sami}$, G1),CosSeqFD(G2, Task3$_{Sami}$), CosGat(G2).

- *Improvements after refactoring*: Increase the understandability, modifiability and reusability of the model. Increase performance since the cost and the time are reduced, improve reliability and fault tolerance and optimize the availability and suitability of the actor.

R5: If a parallel fragment contains the same or a subset of activities belonging to different lanes and if one lane has only *defected* tasks that can be performed by an actor who is related to other actors in another lane by hierarchical roles or by having the relation cooperation or the same position, then apply in order: *R4, R3*.

				Task 1	Task 2	Task 1	Task 2
Semantic and temporal information for actor	Actor name			Sami	Sami	Ali	Ali
	Relation	Sami		Sami has the same position of Ali			
		Ali		Ali has the same position of Sami			
	Role	Sami		Lane 1 : Task 1 Task 2			
		Ali		Lane 2 : Task 1 Task 2			
	Permission	Sami		Lane 1 : Task 1 Task 2			
		Ali		Lane 2 : Task 1 Task 2			
	Availability	Sami		Monday at 10:00	Monday at 10:45	-	-
		Ali		-	-	Monday at 10:00	Monday at 10:25
	Suitability: Skills level			2	2	1	1
	Labor cost			17 euro	17 euro	20 euro	20 euro
Semantic and temporal information for task	Start Time			Monday 10:00	Monday 10:45	Monday 10:00	Monday 10:25
	End Time			Monday 10:35	Monday 11:15	Monday 10:20	Monday 10:45
	Time lags	Lane 1	*Task 1*	-	5 min	-	-
			Task 2	-	-	-	-
		Lane 2	*Task 1*	-	-	-	5 min
			Task 2	-	-	-	-
	Activity cost			9.9 euro	8.5 euro	6.6 euro	6.6 euro
	Is defected			1	1	0	0
	Affiliation			Lane 1	Lane 1	Lane 2	Lane 2

Figure 9: Organizational and temporal annotations to illustrate rule **R5**.

Figure 9 and 10 show an example where R5 can be applied: "Lane2" contains only "Task1" and "Task2" all of which are performed by "Ali". Since "Ali" and "Sami" have the same position (Figure 9), then rule R5 suggests to replace the parallel fragment by a sequence fragment, to remove "Lane1" and to associate "Task1" and "Task2" with "Ali" who is allowed to perform them and can therefore do them correctly.

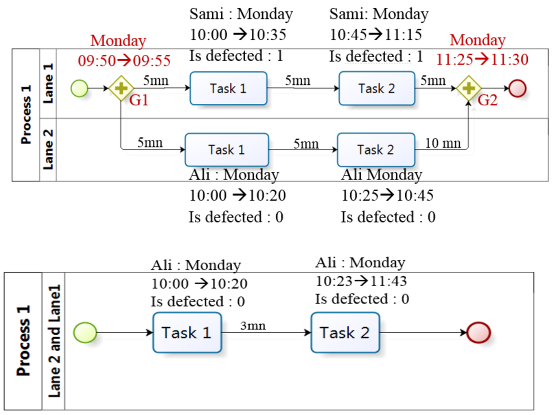


Figure 10: Application example for **R5.**

- *Measure for its detection*
  – *Structural measures*: CW, NSF, NOAJS, NOA, TNT, TNG, NL.
  – *Temporal measures*: LD, PD, TDADay$_{Sami}$, TADay$_{Sami}$, RDA$_{Sami}$, SeqFD(Task1$_{Ali}$, G1), SeqFD(Task2$_{Ali}$,Task1$_{Ali}$),PTC$_{Sami}$(Lane 1), GD(G1),GD(G2), SeqFD(Task1$_{Sami}$, G1), SeqFD(G2, Task2$_{Ali}$), SeqFD(Task2$_{Sami}$, Task1$_{Sami}$), SeqFD(G2, Task2$_{Sami}$), PerDay$_{Ali}$, AVDay$_{Ali}$, TNAT(Monday).
  – *Cost measures*: CA$_{Sami}$(Task1), CA$_{Sami}$(Task2), CosGat(G2), CosGat (G1), CosDay(Lane1), CosSeqFD (Task1$_{Ali}$, G1), CosSeqFD(Task1$_{Sami}$,G1),CosSeqFD(Task2$_{Ali}$, Task1$_{Ali}$), CosSeqFD (G2,Task2$_{Ali}$), CosSeqFD(G2,Task2$_{Sami}$),CosSeqFD(Task2$_{Sami}$,Task1$_{Sami}$), CosDay$_{Sami}$(Lane1).
- *Improvements after refactoring*: Increase the understandability, modifiability and reusability of the BP. Increase performance by decreasing time behaviour, cost. Improve reliability and fault tolerance and optimize the availability and suitability of the actor.

R6: Duplicate a defected activity in a lane that doesn't belong to *them*, if it is followed and/or preceded by a parallel fragment(s) which is performed by an actor in another lane and who is available and suitable to perform the original activity correctly.

Figure 11 shows the semantic and temporal information for annotating tasks and assigning actors expressing the organizational and temporal aspects.

			Task 1	Task 3	Task 7	SP 4-5
Semantic and temporal information for actor	Actor name		Ali	Ali	Salah	Sami
	Relation	Ali	Ali is the leader of Sami			
		Salah	Salah is the leader of Sami			
		Sami	Sami Is under the hierarchy of Ali and Salah			
	Role	Ali	Task 1 Task 3			
		Sami	SP4-5			
		Salah	Task 7			
	Permission	Ali	Task 1 Task 3 SP4-5			
		Sami	SP4-5			
		Salah	Task 7 SP4-5			
	Availability	Ali	Monday at 08:00	Monday at 09:35	-	Monday at 10:15
		Salah	-	-	Monday at 09:35	Monday at 10:05
		Sami	-	-	-	Monday at 10:25
	Suitability: Skills level	Ali	1	1	-	2
		Salah	-	-	1	1
		Sami	-	-	-	3
	Labor cost		17 euro	17 euro	17 euro	14 euro
Semantic and temporal information for task	Start Time		Monday 08:00	Monday 09:35	Monday 09:35	Monday 10:25
	End Time		Monday 09:15	Monday 10:10	Monday 10:00	Monday 11:45
	Time lag	Task 1	-	-	-	-
		Task 3	-	-	-	-
		Task 7	-	-	-	-
		SP 4-5	-	-	-	-
	Activity cost		21.2 euro	9.9 euro	7 euro	20 euro
	Is defected		0	0	0	1
	Affiliation		Lane 1	Lane 1	Lane 3	Lane 2

Figure 11: Organizational and temporal annotations to illustrate rule **R6**.

Figure 11 illustrates that "Sami" performs a defected sub process "SP4-5" in "Lane2". In addition, we note that "Sami" is under the hierarchy of "Ali" and "Salah". So, the permission attributed to "Sami" is also attributed to "Ali" and "Salah". Since "Salah" is available before "Ali" and has more skills (skills level =1) than him (skills level =2), he performs "SP4-5". R6 assigns "SP4-5" to "Salah" who terminates "SP4-5" correctly before "Ali". Figure 12 illustrates this rule.

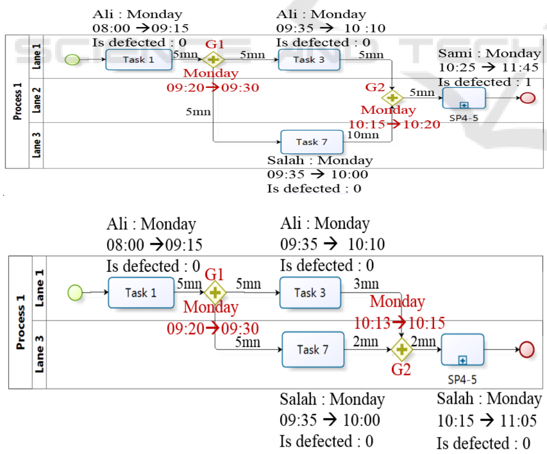


Figure 12: Application example for **R6**.

- *Measure for its detection*
  - *Structural measures*: CW, CFC, NSF, TNG, NOAJS, NOA, NL, TNT, CNC, Den.
  - *Temporal measures*: GD(G2), $\text{TADay}_{\text{Sami}}$, $\text{TDADay}_{\text{Sami}}$, TNAT(Monday), RDA_{Sami}, SeqFD(G2, $\text{Task7}_{\text{Salah}}$), SeqFD($\text{SP4-5}_{\text{Sami}}$, G2), $\text{AVDay}_{\text{Salah}}$, PD, LD, $\text{PTC}_{\text{Salah}}$(Lane3), $\text{PerDay}_{\text{Salah}}$.
  - *Cost measures*: $\text{CosDay}_{\text{Salah}}$(Lane2), CA_{Sami}(SP4-5), CosSeqFD(G2, $\text{Task7}_{\text{Salah}}$), CosDay(Lane2),CosSeqFD($\text{SP4-5}_{\text{Sami}}$, G2), CosGat(G2).
- *Improvements after refactoring*: Increase the understandability, modifiability and reusability of the model. Decrease time behaviour and cost which allow to improve the performance of the actor and therefore that of the BP. Improve reliability and fault tolerance.

In summary, some of the proposed transformation rules have negative aspects. For instance, *R3* leads to the deletion of "Lane2" that represents a department of a company. This induce loss of some information which might be necessary to better understand the entire process. To preserve the semantic of the fragments before and after the application of R3, the designer should rename the remaining lane "Lane 1-2" since it will contains also "Task 3" and "Task 4". In addition, R5 propose to merge two identical parallel process streams into one stream. This might be feasible for a make-to-stock process where the output is not that important. However, this type of refactoring can be problematic for make-to-order process types since the merge of two parallel process streams into one stream with the reduction of the workforce in this process results in a decreased output. To verify that fragments in *R5* satisfy the behavior preserving property before and after transformation, we eliminate only the actor who is not suitable in "Lane1" and who produced defected activities. In this case, we preserve the quantity of the produced output since the actor in "Lane2" performs the corresponding tasks very well.

7 APPLICATIVE EXAMPLE

In order to illustrate the transformation rules, we use the "Sales management of items" example modelled with BPMN in Figure 14. The model is annotated by temporal constraints and semantic information (cost and organizational aspects) that help designer to refactor the BPMN model. Figure 13 shows the semantic and temporal information for annotating tasks and assigning actors expressing the organizational and temporal aspect. The transformation of the "Sales management of items" example is illustrated in Figure 15.

For instance, we suppose that two actors ("Salah" and "Hedi") have a hierarchical relation in the "Payment" lane. Since "Salah" is the leader of "Hedi", the permission attributed to "Hedi" is also attributed to "Salah". The leader is available since Monday at

08:40 to perform "T4: Deliver bill", and "Hedi" is available on Monday at 09:00. In this case, we affect "T4: Deliver bill" to "Salah" who has the higher skills (skills level =1) comparing to "Hedi" (skills level =2). In addition, when "Salah" performs the task assigned to "Hedi", he can reduce the transfer time and even eliminate it. In fact, "Salah" can perform this task with less time than "Hedi". He terminates this task at 08:45. After that, *R1* merges "T3: Establish payment" and "T4: Deliver bill" in one activity: "SP2: Pay bill".

			T1	T2	T3	T4	SP1
Semantic and temporal information for actors	Actor name		Sami	Sami	Salah	Hedi	Ali
	Relation	Sami	Sami is the leader of Ali				
		Salah	Salah is the leader of Ali and Hedi				
		Hedi	Hedi Is under the hierarchy of Salah				
		Ali	Ali Is under the hierarchy of Salah and Sami				
	Role	Sami	T1 and T2				
		Salah	T3				
		Hedi	T4				
		Ali	SP1				
	Permission	Sami	T1, T2 and SP1				
		Salah	T3, T4 and SP1				
		Hedi	T4				
		Ali	SP1				
	Availability	Sami	Monday at 08:05	Monday at 08:35	-	-	Monday at 08:50
		Salah	-	-	Monday at 08:35	Monday at 08:40	
		Hedi	-	-	-	Monday at 09:00	-
		Ali	-	-	-	-	Monday at 09:25
	Suitability: Skills level	Sami	1	1	-	-	2
		Salah	-	-	1	1	1
		Hedi	-	-	-	2	-
		Ali	-	-	-	-	3
Semantic and temporal information for	Start Time		Monday at 08:05	Monday at 08:35	Monday at 08:35	Monday at 09:00	Monday at 09:25
	End Time		Monday at 08:15	Monday at 08:50	Monday at 08:40	Monday at 09:10	Monday at 09:53
	Time lag	T1	-	-	-	-	-
		T2	-	-	-	-	-
		T3	-	-	-	5min	-
		T4	-	-	-	-	-
		SP1	-	-	-	-	-
	Is defected		0	0	0	0	1

Figure 13: Organizational and temporal annotations to illustrate the "Sales management of items" example.

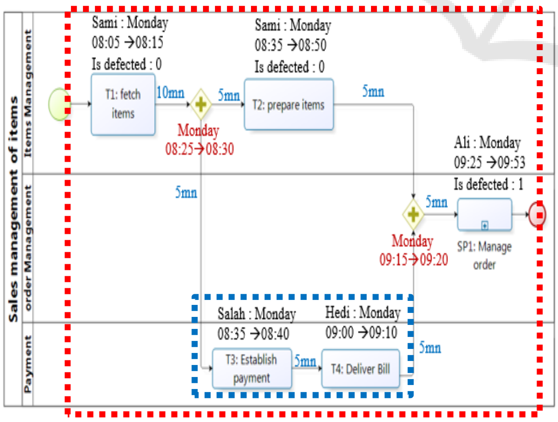


Figure 14: "Sales management of items" example before the transformation.

Furthermore, "Ali" performs a defected sub process "SP1: Manage order" in the "Order management" lane. We note that "Ali" is under the hierarchy of "Sami" and "Salah". So, the permission attributed to "Ali" is also attributed to "Sami" and "Salah". Since "Salah" is available before "Sami" and has more skills (skills level=1) than him (skills level=2), he performs "SP1: Manage order". Consequently, R6 assigns "SP1: Manage order" to "Salah" who terminates it correctly before "Sami". To preserve the semantic of the fragments before and after the application of *R6*, the designer should rename the remaining lane "Order management and payment" since it will contains also "SP1: Manage order".

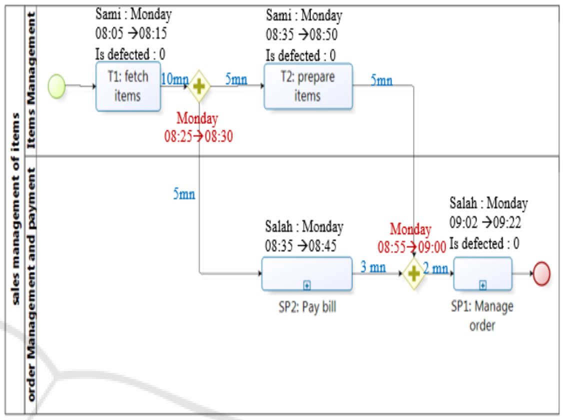


Figure 15: "Sales management of items" example after the transformation.

8 CONCLUSION

In this paper, we focused on improving the quality of BPMN models in term of their complexity and performance. To end this purpose, we first enriched the existing measures by proposing a set of cost and temporal ones related to BPMN elements and actors. These measures are based on business context.

In addition, we proposed a set of transformation rules that consider the semantic, structural and temporal information to refactor a BPM. The structural aspect describes the connections between the BP elements. The semantic aspect is derived from the context-enriched nodes in BPMN, and the temporal aspect represents the temporal constraint related to BPMN elements and to the actor.

Our future work will focus on defining an algorithm to decide on the application order of the transformations to produce the best performance of a BPM. Then, we will study the impact of their application to a well-structured model. In addition, we are going to focus on analysing the correlations among the transformation rules in order to ensure the production of an optimal restructured BPMN.

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