A Framework for Evaluating Business Process Performance

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Abstract: Measuring the performance of business processes is an essential task that enables an organization to achieve effective and efficient results. It is by measuring processes that data on their performance is provided, thus showing the evolution of the organization in terms of its strategic objectives. To be efficient in such task, organizations need a set of measures, thereby enabling them to support planning, inducing control and making it possible to diagnose the current situation. Indeed, several researchers have defined specific measures for assessing the business process (BP) performance. Our approach proposes new *tempora*l and *cost* measures to assess the performance of business process models. The aim of this paper is to classify the performance measures proposed so far within a framework defined in terms of characteristics, design and temporal perspectives, and to evaluate the performance of business process models. This framework uses business and social contexts to improve particular measures. It helps the designer to select a subset of measures corresponding to each perspective and to calculate and interpret their values in order to improve the performance of their model.

1 INTRODUCTION

Performance is one of the major topics for organizations seeking continuous improvements. Evidently, evaluating the performance of business process model is a necessary step to reduce time, cost and to indicate whether the company goals are successfully achieved or not. Obviously, the business process performance is highly influenced by decisions taken during the modelling phase. This justifies the motivation of several researchers to invest in finding solutions to define, manage and evaluate the performance of a business process model. The recent literature on the BP performance measurement shows three trends of approaches: those based on time, those centered on cost and those combining the two aspects.

The first type of appraoches is based on indicators and time patterns. Works that collect and analyze performance related to Key Performance Indicators (KPIs) are crucial to ensure consistent and continuous process optimization (Del-Río-Ortega et al., 2016), (Mendes and Santos, 2016), (Van der Aa et al., 2017), (El Hadj Amor and Ghannouchi, 2017), (Hompes et al., 2018). KPIs can be defined as quantifiable measures that an organisation uses to measure the performance in terms of meeting its strategic and operational objectives.

In addition, several works are based on temporal patterns (Kluza et al., 2016), (Lanz et al., 2016) to evaluate the BP performance. It is by measuring temporal aspect of processes that data on their performance is provided (D'Ambrogio et al., 2016).

The second type of approaches use the cost factor, (Wynn et al., 2013), (Kaplan and Cooper, 1988). Certainly, all aspects of the business process that have a monetary component are made part of the overall cost structure. The allocation of costs with different products or services lead the manager to a decision based on false information (Wynn et al., 2013).

The third type integrate the cost and time aspects to evaluate the performance of business process (Araújo et al., 2016), (Kis et al., 2017). In this approach type, time and cost are fully inter-related. Naturally, the amount of time required to perform activities will be directly related to the amount of resources allocated to the business process (cost).

However, the so-far proposed approaches neglect the organizational aspects of a business process model, expressed by social relationships, collaborative behaviors among actors and their

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features such as availability and suitability which affect the overall process performance.

We recall that an actor can be represented as a performers or business role who realizes a business activity.

In addition, they neglect temporal and cost aspects related to BPMN elements such as gateway, sequence flow, lane, Pool). The lack of these information may reduce the scope of possible analyses that can be made.

Our objective in this paper, is to show how to apply the correlated temporal (*i.e.*, time lag between two activities, etc.), cost and organizational aspects (*ie.* Performance, availability, suitability of an actor, relation type with other actors, etc.), to evaluate the business process performance models specified in the Business Process Model and Notation (BPMN).

To end this purpose, we propose new performance measures representing cost and temporal aspects. Since the diversity of measures, we propose a framework for classifying them. Our measure classification is based on business process model perspectives (*e.g.,* informational, functional, organizational, behavioral and *temporal*), and the elements (activity, event …) involved in computing the measures.

One advantage of our classification is that it provides for a better usage of the perfomance measures: 1) Depending on his/her perspective, a designer would be examining only a subset of performance measures pertinent to his/her point of view. In addition, the measures are defined in terms of BPMN elements and social context (ie., actor) that he/she is interested in. 2) Based on the obtained measures values, the desiginer decision is made. He knows the impact of his decision on other measures dealing with other perspectives; the business process model elements involved in the examined measure provides for traceability among the various perspectives.

A second advantge of our classfication, is the genericity of the framework since it is expressed in the BPMN standard notation.

The rest of this paper is organized as follows: Section 2 presents an overview of the business process performance measurement. Section 3, proposes temporal and cost measures to evaluate the performance of a business process model. These measures are related to the social aspect (actors) and the BPMN elements. Section 4 presents our classification framework and illustrate it through an example annotated by semantic and temporal information that can provided by an expert or a business designer. Finally, we conclude this paper with a summary of the presented work and an outline of its extensions.

2 RELATED WORK

In this section, we overview works on the measurement of the BP performance. These works are divided into three categories: Time based-performance measurement, cost based-performance measurement and works combining time and cost.

2.1 Time Based-performance Measurement

The first category is classified in two work types: Indicators based-performance measurement and Patterns based-performance measurement.

2.1.1 Indicators Based-performance Measurement

(Del-Río-Ortega et al., 2016) propose the Process Performance Indicators meta-model (PPINOT) to allow the modelling of the Process Performance Indicators (PPIs). PPINOT support two different types of resource-aware PPIs and shows the main elements and the types of measure (Base, Derived and Aggregated) that can be used to define a PPI. Table 2, in Section 4.2.2, illustrates the performance measures.

In (Van der Aa et al., 2017), the authors translate the natural language PPI descriptions into Process Performance Indicators (PPIs) according to a structured notation.

(Mendes and Santos, 2016) identified the model used for evaluating the performance of BP which best fits the evaluation of the business processes, with a view to a greater alignment between the indicators of the process and the strategic objectives.

(Hompes et al., 2018) introduced a generic approach to process performance analysis from event data. Using event data, the authors compute the basic performance measures defined on the states and transitions of the artifact lifecycle models.

D'Ambrogio et al., (D'Ambrogio et al., 2016) expressed how the model-driven techniques can be applied to manage the performance properties. They introduce the Performability-oriented BPMN (PyBPMN), which can be used to annotate the BPMN models with: i) the performance requirements, ii) the results provided by the BP simulation-based analysis, and iii) the measures taken at execution time, so as to include in a single BPMN model all the data associated to the performance properties.

To measure the performance of a business process, (El Hadj Amor and Ghannouchi, 2017) used an ontology based on a real business process to create the semantic relationships between all key Performance indicators (KPI), represented as qualitative and quantitative indicators. After that, they were based on data mining technique to extract information from data measurement. In addition, (Peral et al., 2017), analyzed the candidate KPIs through data mining techniques to ensure that they reflect the relationships identified during the business strategy modeling.

In summary, all performance indicators defined in (Del-Río-Ortega et al., 2016), (Hompes et al., 2018) (El Hadj Amor and Ghannouchi, 2017) rely on the remaining aspects related to the BPMN elements. These works investigate the performance of the business process based on techniques, template and linguistic patterns. However, they don't illustrate the BP performance by using measures.

2.1.2 Time Patterns Based-performance Measurement

Time Patterns are crucial for any enterprise to know the temporal properties of its business processes. These properties strongly affects the performance of the business process execution. For example, Lanz et al., (Lanz et al., 2016), identified 10 different time patterns to support the selection of the appropriate process-aware information systems (PAISs). They are classified on 4 distinct categories: 1) Durations and Time Lags, 2) Restricting Execution Times, 3) Variability and 4) Recurrent Process Elements.

The first pattern category and time lags contains three time patterns expressing the durations for different kinds of process granularities: TP1: Time lags between two activities, TP2: Duration and TP3: Time lags between two arbitrary events.

The second category "Restricting Execution Times" is composed of the following four patterns that consist in restricting the execution times of an activity or process (e.g., earliest start or latest completion time): TP4: Fixed Date Element to properly time the execution of activities and process instances, TP5: Schedule Restricted Element to bind the execution of an activity or process to an external schedule, TP6: Time-based Restrictions to limit the number of executions of an activity (process) within a particular time frame and TP7: Validity Period to restrict the lifetime of an activity or process.

The third pattern Variability is based on TP8: Time-dependent Variability pattern which provides the different control flow, depending on time aspects.

The fourth pattern Category Recurrent Process Elements comprises TP9: Cyclicity elements pattern and TP10: Periodicity.

Kluza et al., (Kluza et al., 2016), provide a short overview of the selected temporal logics that specify the time patterns in business process models.

Based on time patterns, we extract a set of measures presented in Table 2. These measures focus mainly on the temporal constraints related to the following BPMN elements: activity and event. However, they neglect gateway that is considered important decision-making element, sequence flow and lane/pool elements which have an impact on assessing the business process performance.

2.2 Cost Based-performance Measurement

(Wynn et al., 2013) propose a framework to support management accounting decisions on cost control by automatically incorporating cost information, from annotation of event logs for monitoring, predicting and reporting process-related costs. The cost information is related to the employee and activity element.

(Sampathkumaran and Wirsing, 2013) propose a methodology for cost calculation by dividing a business process into patterns. A cost and reliability factor for each of these patterns is calculated based on the cost of the BPMN elements.

(Kaplan and Cooper, 1988) proposed an activity-based-costing (ABC) which emphasises on the per (activity) unit cost of all possible activities. However, the ABC technique requires a substantial effort to implement and to be kept up-to-date.

(Gupta and Galloway, 2003) defined a conceptual proposal for the use of ABC and its variation ABM (Activity-Based Management), in order to improve the decision-making operations. ABM is the way in which an entity can drive, measure and control the aim to improve their performance.

Nevertheless, there is no work that combines the cost of all BPMN elements with the actors.

2.3 Cost and Time Aspects Based-performance Measurement

Cost represents the expenses of a business process required for its execution. For example, (Korherr 2007) presented a metamodel with its extension to integrate the business process goals and the performance measures into BPMN modelling language. The extension offers the goals a business process must achieve, as well as an incorporation of the performance measures time cost, and quality.

(Araújo et al., 2016) calculate the cost of idleness and implementation of the TDABC (Time-Driven Activity-Based Costing) to support the development of a costing system for public universities.

Kis et al., (Kis et al., 2017) provided a framework on how the four dimensions of the devil's quadrangle (time, cost, quality and flexibility) can be measured by using log data generated by a process engine.

The presented works ignore the organizational aspects of a business process model expressed by social relationships, collaborative behaviors among actors and their features determined in terms of availability, suitability, etc. Our proposed method combines both aspects to cover all BPMN concepts, the organizational and the social aspects in order to improve the performance of a business process model.

3 MEASURES FOR BUSINESS PROCESS PERFORMANCE

In this section, we propose performance measures related to actors and to BPMN elements (gateway, activity, sequence flows and lane/Pool). We note that an actor represents the performers or organizational units. These measures are classified into temporal and cost measures.

3.1 Measures for Actor

We propose the following measures related to the actor element. They express the cost and the temporal aspects.

- *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.
- *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).
- *Ideal Cycle Time of an Actor to Perform an Activity* ($ICT_{Act}(A)$): Theoretical minimum time to perform an activity by an actor.
- *Total Number of Good Activities Performed by an Actor per Day* ($TGADay_{Act}$): expresses the number of performed activities by an actor that terminate correctly in a day.

$$TGADay_{act} = \sum_{i=1}^{m} GA_i \quad (1)$$

Where m is the number of good activities (GA_i) produced by an actor.

A high number of good activities performed by an actor expresses a high suitability and availability, which depends on its capacity because an actor is available if he is able to provide the needed capacity at the required unit of time.

- *Total Number of Defected Activities Performed by an Actor per Day* ($TDADay_{Act}$): determines the number of activities performed by an actor (Act) in a day and that represent the failures due to internal errors or wrong user input in a specific period of time, detected faults, etc.

$$TDADay_{Act} = \sum_{j=1}^{n} DA_i \quad (2)$$

Where n is the number of defected activities (DA_j) produced by an actor.

The more defected activities registered for a specific period of time, the worse the process performed in terms of technical quality. This increases the fault tolerance and decreases the performance of an actor, his availability, and suitability.

- *Total Number of Activities Processed by an Actor per Day* ($TADay_{Act}$): includes the well performed activities and the defected ones.

$$TADay_{Act} = TGADay_{Act} + TDADay_{Act} \quad (3)$$

- *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.

$$RDA_{Act} = \frac{TDADay_{Act}}{TADay_{Act}} \quad (4)$$

- *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.

$$RGA_{Act} = \frac{TGADay_{Act}}{TADay_{Act}} \quad (5)$$

A high ratio value of good activities performed by an actor expresses a high actor's suitability and availability. This reduces the cost and reflects a good reliability of the activity.

- *Planned Production Time of an Actor* to *Perform an Activity* ($PPT_{Act}(A)$): the total time that an actor is expected to produce. It is calculated by subtracting the schedule loss from all time. So first, exclude any Shift Time where there is no intention of running production (typically Breaks).

$$PPT_{Act}(A) = ShT_{Act}(A) - BR_{Act}(A) \quad (6)$$

- *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.

$$WT_{Act}(A) = PPT_{Act}(A) - ST_{Act}(A) \quad (7)$$

- *Total Working Time Spent by an Actor in a Lane per Day* ($TWTDay_{Act}(L)$): the sum of working time spent, in a day, by an actor in the corresponding lane.

$$TWTDay_{Act}(L) = \sum_{p=1}^{f} WT_{Act}(A_p) \quad (8)$$

Where *f* is the number of activities in a lane performed by an actor.

- *Total Working Time Spent by an Actor in the whole Process per Day* ($TWTDay_{Act}(P)$) : the sum of working time spent by an actor in all lanes in the process.

$$TWTDay_{Act}(P) = \sum_{k=1}^{q} TWTDay_{Act}(L_k) \quad (9)$$

Where *k* is the number of lanes in the process.

- *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.

$$PTC_{Act}(L) = \frac{TWTDay_{Act}(L)}{TWTDay_{Act}(P)} * 100 \quad (10)$$

A high percentage value of an actor time contribution represents that the actor is suitable and available to accomplish his work. This increases his performance.

- *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.

$$AVDay_{Act} = \frac{TWTDay_{Act}}{PPTDay_{Act}} \quad (11)$$

A high value of AVDay indicates that the production of an actor is important and he is able to provide the needed capacity at the required time. This increases his suitability and the performance per day.

- *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.

$$Per\,Day_{Act} = \frac{TWT\,Day_{Act}}{ICT\,Day_{Act}} \quad (12)$$

The best value of the performance is equal to 1. It indicates that the actor has a high speed of production, that is always available and that he is suitable to perform the assigned tasks.

- *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 ($TbWTDay_{Act}(L)$) and its actual Labour Costs per Hour (LCH_{Act}).

$$CosDay_{Act}(L) = TWTDay_{Act}(L) * LCH_{Act} \quad (13)$$

- *Percentage of the actor's Cost in a Lane per day* ($PCos_{Act}(L)$): represents the proportion of the actor cost in a Lane per Day and the lane cost per Day.

$$PCos_{Act}(L) = \frac{Cos\,Day_{Act}(L)}{Cos\,Day(L)} * 100 \quad (14)$$

A high cost percentage of the actor expresses that he is very expensive for the organization. This can be due to the fact that the actor is not suitable to accomplish tasks.

As the same, Formula 13 and 14 can be applied to the pool.

3.2 Measures for the Activity Element

We propose to complete the temporal measures related to the activity presented in the literature (Lanz et al., 2016) (e.g., Activity Duration (AD)) by those focusing on the cost and the activity reliability.

- *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.

$$CA_{Act} = LCH_{Act} * WT_{Act}(A) \quad (15)$$

It is important to note that an increase of the activity cost has an impact on the lane cost and the entire organization.

- *Ideal Cost of an Activity realized by an actor* (ICA_{Act}): is calculated by the product of the actor’s actual Labour Costs per Hour and Ideal Cycle Time of an Actor to perform an Activity.

$$ICA_{Act} = LCH_{Act} * ICT_{Act}(A) \tag{16}$$

- Difference between Cost of an Activity realized by an actor and Ideal Cost of an Activity realized by an actor ($DCIC_{Act}$).

$$DCIC_{Act} = CA_{Act} - ICA_{Act} \tag{17}$$

The high difference expresses that the actor cost is expensive and the required time to accomplish the activity is high. In fact, the actor is not the most appropriate one to perform the activity.

- Number of Detected Faults in an activity performed by an actor in a period of time ($NDFA_{Act}$).

A high number of detected faults has a negative impact on the reliability of the activity. Besides, it reflects that the actor has not the skills to perform this activity.

- Number of Error Event (NEE) that can appear in an activity in a period of time.

We note that, the low number of errors minimizes the necessary time to accomplish an activity and consequently, reduces the cost of an activity.

3.3 Performance Measures for Gateway/Sequence Flow Elements

Table 1: Performance measures related to the gateway and sequence flow elements.

	Pattern category	Time patterns		Measures
Temporal measures	Duration and time lags	TP2 : Duration	Sequence Flow	SeqFD: Sequence Flow Duration represents the transfer time between BPMN elements (activity, gateway and event). SeqFD= ST(BPMN element$_{i+1}$)– ET(BPMN element$_i$) where ST: Start Time ET End Time
				SeqFSD : Sequence Flow Set Duration $SeqFSD = \sum_{u=1}^{w} SeqFD_u$ where w: the total number of sequence flows and $SeqFD_u$ is the duration of a sequence flow u
			Gateway	GD: Gateway Duration GD=ETG-STG Where: ETG: End Time of a Gateway STG: Start Time of a Gateway
				GSD : Gateways Set Duration $GSD = \sum_{i=1}^{y} GD_i$ where y: the total number of gateways and GD_i is the duration of a gateway i
		TP : Time lags	Time lags between two gateways	DSTG : Difference between Start Time of different Gateways DSTG = STG(G1)-STG(G2)
				DETG : Difference between End Time of different Gateways DETG= ETG(G1)-ETG(G2)
			Time lags between a gateway and an activity	DSTASTG : Difference between Start Time of an Activity (STA) and Start Time of a Gateway DSTGSTA = STA-STG
				DETAETG : Difference between End Time of an Activity (ETA) and End Time of a Gateway DETGETA = ETA-ETG
			Time lags between a gateway and an event	DETGETE : Difference between End Time of a Gateway and End Time of an Event (ETE) DETGETE = ETG-ETE
				DSTGSTE : Difference between Start Time of a Gateway and Start Time of an Event DSTGSTE = STG-STE
	Restricting Execution Times for a gateway	TP4: Fixed Date Elements		FDG : Fixed Date of a Gateway
		TP6 : Time based restriction		NGTP : Number of Gateways executed per Time Period
		TP7 : Validity period		MinTVG : Minimal Time Validity of a Gateway
				MaxTVG : Maximal Time Validity of a Gateway
				VPG : Validity Period of a Gateway VPG = MaxTVG – MinTVG
Cost measures	Gateway			Cost of a Gateway ($CosGat_{Act}$): the product of the gateway duration and the actor’s actual Labour Costs per Hour (LCH_{Act}). $CosGat_{Act} = GD * LCH_{Act}$
	Sequence flow			Cost of a sequence flow: ($CosSeqF_{Act}$): the product of the Sequence Flow Duration (SeqFD) and the actor’s actual Labour Costs per Hour (LCH_{Act}). $CosSeqF_{Act} = LCH_{Act} * SeqFD$

Table 1 presents the proposed measures for gateway and sequence flow elements that concern the temporal and the cost aspects. Temporal measures related to the gateway and sequence flows are classified, based on the time patterns presented in Lanz et al., (Lanz et al., 2016). We note that splitting gateways usually do no take time because represents a decision. On the other hand, merging gateways may took time for example when we are dealing with parallel join gateway since previous activities must end to the process continues. Sequence flow duration represents also the time lags (difference) between the start of an element i+1 and the end of an element i. Cost measures reflects the cost needed to perform the gateway and sequence flow elements.

A high value of the time lags between a gateway and a BPMN element (activity, event, and gateway) increases the transfer time. This has a negative impact on the duration of the whole process.

Besides, a high duration of a gateway or sequence flow makes its cost more expensive and increases the cost of the process.

3.4 Performance Measures for Lane/Pool Element

This section presents the measures for Lane/Pool elements. They aim to evaluate the time and the cost of the whole process.

- *Lane Duration* (LD): the sum of the needed time to carry out all BPMN elements in a lane.

$$LD = \sum_{a}^{b} AD + \sum_{h=1}^{g} SeqFD + \sum_{o=1}^{p} GD + \sum_{d=1}^{e} ED \quad (18)$$

  Where b is the number of activities, g is the number of sequence flows, p is the number of gateways and e is the number of events in a lane.

- *Pool Duration* (PD): It is calculated by the sum of lanes duration in the process.

$$PD = \sum_{l=1}^{v} LD_l \quad (19)$$

Where l is the number of lanes in a process.

A high duration has a negative impact on the time behavior and leads to an expensive cost of the whole process.

- *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.

$$CosDay(L) = \sum_{w=1}^{y} CA + \sum_{x=1}^{t} CosSeqF_{Act} + \sum_{e=1}^{c} CosGat_{Act} + \sum_{i=1}^{r} CosEv \quad (20)$$

Where y is the number of activities, t is the number of sequence flows, c is the number of gateways and r is the number of events in a lane.

The shorter is the BPMN elements duration, the more the cost of a lane is reduced. Formula 20 can be also applied to the pool.

4 A PERFORMANCE FRAMEWORK FOR BPMN MODEL

In our previous work, we annotated a BPMN model by using the *context concept* (Khlif et al., 2017) as a means to encapsulate the semantic information pertinent to the business logic and the organizational aspect. (Khlif et al., 2017) defined the context by assimilating a business process P to an undirected graph $G_P = (V, E)$ where V is the non-empty set of nodes representing elements of P such as pools, lanes, activities, gateways and events, etc. $E \subseteq V \times V$ is the set of edges linking the nodes V. Let F_V be the set of features describing each node individually. A context C_P is defined as the set of all instances derived from the set F_v. From this generic definition, the authors derive two instances of context: social context and business context. The social context CS_P of a process P instantiates the C_P context where V is the set of actors and F_v expresses their characteristics. The business context of a business process places the social context in the organizational aspect and completes it with semantic information related to organizational, functional and informational perspectives (Khlif et al., 2017).

To define our framework and since the presented definition neglect the temporal constraints, the temporal perspective and the cost that are useful to annotate our BPMN model, we propose in this paper to enrich as follows the context definitions of a business process:

4.1 Enriched Context Definitions of a Business Process

We extend the social context by additional properties related to actor that can improve the performance of a business process such as his availability (AV_{act}), his SuiTability (ST_{act}), his performance to realize activities, etc. Furthermore, we extend the business context using semantic information related to the behavioral and temporal perspectives. The temporal perspective includes the temporal constraints related to the social aspect (Actors), and associated to different BPMN elements (activities, lanes, pools, gateway, etc.). More precisely, the business context of a business process P covers the following semantic information:

4.1.1 Semantics of Organizational and Temporal Perspectives

The organizational perspective which places the social context within the enterprise represents "Where" and by "whom" the business process activities are performed. The main BPMN concepts that reflect the organizational perspective are "Pool" and "Lane". In particular, the context is associated to the lane and pool elements. It describes the following information: Lane ID and label, pool ID and label, the list of actors affiliated with the lane, permission and role assignments, and the hierarchical roles among the actors (Khlif et al., 2017). Recall that a 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 by those in r (Khlif et al., 2017).

We extend the business context in the organizational perspective by the following information that integrate also the temporal perspective:

- *Cooperation Roles*: expresses that the actors have the same position (the same roles and permissions).
- *Actor's Availability*: is the capability of the actor to perform an activity in the required unit of time.
- *Actor's Suitability*: represents the capability of the actor to perform the activity well.
- *Shift Time of an Actor*: a period of time where an actor is scheduled to perform a task.
- *Actor's Break*: a scheduled time when the actor stop working for a brief period.
- *Stop Time of an Actor*: a passage of time where the actor stops temporarily since unplanned stops (breakdowns) or planned stops (changeovers).
- *Ideal Cycle Time of an Actor*: the minimum period when an actor performs the activity.
- *Planned Production Time of an Actor*: a period of time that an actor is expected to perform an activity.
- *Working Time Spent by an Actor*: represents the duration that an actor performs an activity.
- *Performance of an Actor*: represents the percentage of all elements that permit the process to operate at less than the maximum possible speed, when the actor performs the activity.
- *Contribution of an Actor in a Lane*: indicates how the working time spent by an actor in a lane affects total working time of the same actor in all the process.
- *Actor Cost*: Cost of an actor when he perform an activity.

4.1.2 Semantics based on Functional and Temporal Perspectives

Activity node is the main concept in the functional perspective. It is documented with the following context information: the unique activity identifier (ID), its lane, the ID of the actor responsible of performing it, the IDs of the activities on which it directly depends (before and after), the dependency type (authorization, coordination, or resource dependency), and his 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*: is a pair (Start Time, End Time) that denotes respectively the starting and finishing time of an activity.
- *Time Lags between Activities*: it expresses the transfer time between activities.
- *Validity Period of an Activity*: Allows to restrict the lifetime of an activity or a process.
- *Activity Cost*: Cost needed to accomplish an activity
- *IsDefected*: verifies if the activity is defected
- *IsGood*: verifies is the activity that is well performed.

4.1.3 Semantics based on Informational and Temporal Perspectives

Since the informational perspective is represented in terms of data and events, the resources needed by an activity express the semantic information that related to this perspective (Khlif et al., 2017). We extend the business context in the informational perspective, by those expressing temporal and cost information:

- *Time Date of an Event*: specifies a fixed date when trigger will be fired.
- *Time Duration of an Event*: specifies how long the timer should run before it is fired.
- *Time Lags between Two Events*: specifies the time lags between two arbitrary events.
- *Event Cost*: the cost of sending/receiving an event.

4.1.4 Semantics based on Behavioural and Temporal Perspectives

We define 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 element (gateway, activity and event) expressing the transfer time between them.

4.2 Classification Framework

Due to the fact that no consensual classification exists for the multiple measures proposed, this complicates their exploitation. Thus, in this section, we propose a classification framework for performance measures to facilitate their use in the evaluation of the business process performance. It should be noted that the existing measures in the literature and those we have proposed adhere to this classification.

4.2.1 Framework Architecture

The measure classification framework is given in Figure 1. A "BPMN model" is represented as a "Graph" which is composed of "Nodes" and "Arcs".

The "Graph" has an "Abstract Context". Both "Business Context" and "Social Context" are viewed as an instantiation of the context concept. "Business Context" is related to the "Flow Element" and "Social Context" concerns the "Actor" node.

Our classification framework is organized in three levels. The first level expresses that a measure can be temporal or representing the cost. They concerns the following nodes: flow element(s) and actor.

In order to determine the scope of each temporal (respectively cost) measure, we introduced the "FlowElement" class whose instances are the BPMN concepts (*i.e.,* gateway, event, lane, activity and sequence flow). The association "concerns" establishes a link between the "Temporal Measures related to BPMN elements" (respectively "Cost measures related to BPMN elements") and "FlowElement". The latter provides an indication of the BPMN elements involved in the measurement. For example, the measure AD (Activity Duration) and CA_{Act} (Cost of an Activity realized by an Actor) have as scope the basic element "Activity".

In addition, we introduce the "Actor" class. The links "Associated to" and "Concerns" relate the latter to respectively "Temporal Measures related to Actor" and "Cost Measures related to Actor" classes. These links provide indications about the temporal and cost features involved in the measurement. We note that "Actor" and "FlowElement" classes have temporal constraints. The association between these classes, and the "Temporal Constraint" class indicates temporal dependencies.

The second level associates for each category a set of measures that are classified into perspectives: functional, organizational, behavioral, informational, and temporal.

The association between the "Measures" class and the "Perspective" class, presented in Figure 1, establishes a link between each measure and the perspective(s) in which it can be calculated. From a perspective, a set of the related measures represents a quantitative view of this perspective. Using this classification, our framework helps the designer to select an appropriate subset of measures associated to the corresponding perspective.

We classify at the last level the temporal and cost measures on base, derived and aggregated. A measure is characterized by its name, calculation formula and a "type" attribute that indicates whether the measure is base, derived and aggregated. A base measure provides a direct idea on the temporal or cost aspects of one BPMN element or an actor, and on the interpretation of the measure value, while a derived measure is defined as a mathematical function over one or more measure. An aggregated measure aggregates one single measure using an aggregation function (*i.e.,* sum or average).

Each characteristic is composed of a set of sub characteristics. Based on our classification, the association "informs about" links the class "Measure" to the class "Characteristic". It states that each Measure is associated to one or more (sub) quality characteristics (Bocciarelli et al., 2014), (D'Ambrogio et al., 2016) on reliability, performance efficiency and cost characteristics.

In (Heinrich and Paech, 2010), the first characteristic performance efficiency is defined by the capability of the BPMN element to provide an appropriate performance, relative to the amount of resources and the time used, under stated conditions. It is shown by the sub characteristics time behavior and resource utilization.

Time behavior is defined as the appropriate transport time between different BPMN elements and processing times when executed. For instance, we associate Time Lags between two start activities (STASTA: Start Time of the first Activity and Start Time of the second Activity) (Lanz et al., 2016) to this sub characteristic.

Resource utilization represents the capability of the BPMN element to use appropriate amounts and the types of resources when executed under stated conditions. For instance, we associate the measure "the list of actors that perform an activity" (Del-Rio-Ortega et al., 2016) to this sub-characteristic.

The second characteristic reliability is determined by the capability of the activity to maintain a specified level of performance when used under specified conditions (Heinrich and Paech, 2010). It is revealed by the sub characteristics Maturity and fault tolerance. Maturity is the capability of the activity to avoid failure as a result of faults in the activity. For instance, we associate to this sub characteristic, the N*umber of Detected Faults in an activity performed by an actor per day* ($NDFA_{Act}$).

Fault tolerance is the capability of the activity to maintain a specified level of performance in cases of faults. We quote for example the measure *Number of Error Event (NEE)* in an activity per day.

The third characteristic cost is expressed as a price or monetary value associated to BPMN element or actor in a period of time. The association "notifiesAbout" links the classes "Flow Element" and "Actor" to the "Cost" class. For instance, we associate *Cost of an actor in a Lane per Day* (CosDayact(L)) to this sub characteristic.

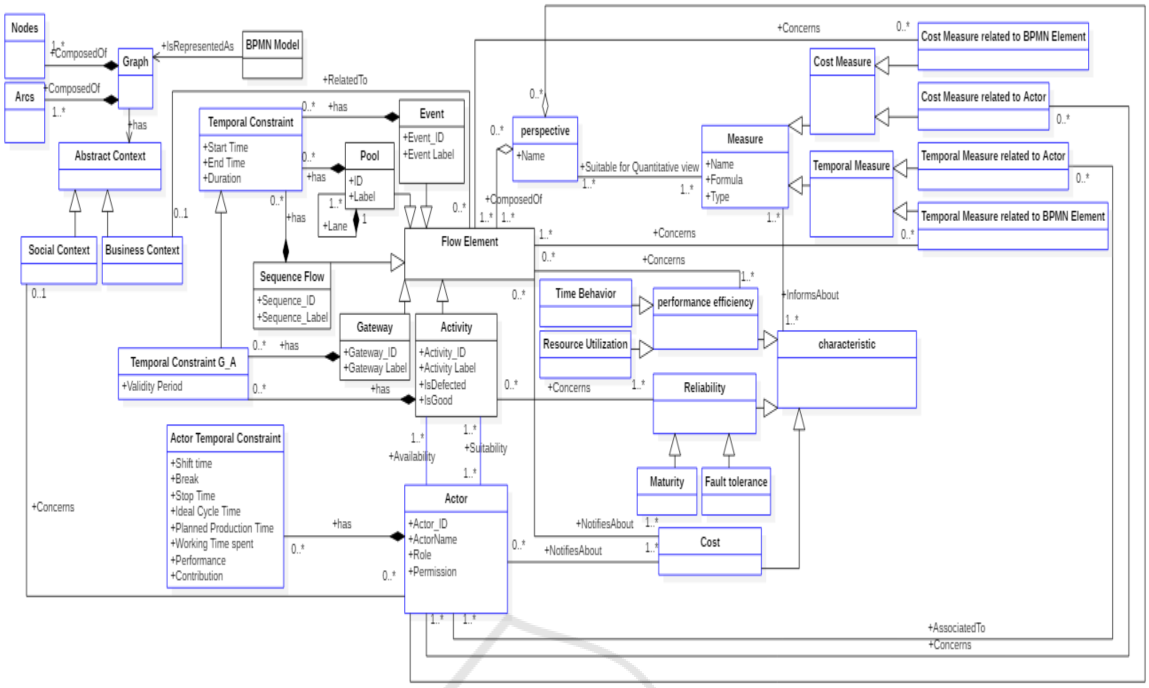

Figure 1: Classification framework.

The availability and suitability are considered as characteristics which capture attributes and measures related to the actor performance. Note that the actor characteristics differ from the BPMN element characteristics. Thus, we do not treat actor as an activity. Availability is the capability of the actor to be able to perform the activity in the required unit of time. In fact, we propose the *availability measure of an actor* ($AVDay_{act}$).

Suitability focuses on actor skills that cover his qualification, expertise, social competence, skills, motivation and performance ability. This aspect focuses on the extent to which all of the elements of an actor performance are intentionally and specifically addressed and appropriately configured to accomplish the desired organizational outcomes.

4.2.2 Applicative Example

In order to illustrate the classified measures, we use the "Travel agency Process" example modelled with BPMN in Figure 2. The model is annotated by temporal constraints and semantic information (cost and organizational aspects) that help analysis to evaluate the BP performance.

For instance, we suppose that three actors ("Ali", "Salah" and "Sami") are affiliated to "Management of Car/bus" lane, while two actors having the same position ("Omar" and "Olfa") work in the "Reservation Management" lane.

In the "Management of Car/bus" lane, "Ali" is the leader of "Sami" and "Salah". So, the permission attributed to "Sami" and "Salah" is also attributed to "Ali". "Sami" starts performing the task "Rent cars to customer" on Monday at 11:12 and he completes it at 11:42. Its duration is equal to 30 minutes. Since "Ali" is available on Monday at 10:40, and he can start the "Rent cars to customer" task before "Sami", the designer could affect it to "Ali". In addition, the latter can perform this task in a reduced laps of time (WT=20 mn) since he is the leader and he has more skills (suitability of Ali=1) than "Sami". Consequently, he is more suitable to perform the "Rent cars to customer" task. In this case, "Ali" reduces the behavior time and the cost characteristics. In the "Reservation Management" lane, "Omar" performs on Monday six tasks "create reservation", "determine date of rented and returned car", "check car availability", "cancel reservation", "validate reservation" and "establish payment". All the tasks are well performed except for the "check car availability" which is a defected one. In fact, the ratio of good (respectively defected) tasks performed by Omar is equal to RGA_{Omar}=83.3% (respectively RDA_{Omar}=16.7%). Certainly, a high ratio value of good tasks performed by Omar expresses his suitability. It reduces the task cost and reflects a good reliability of this task.

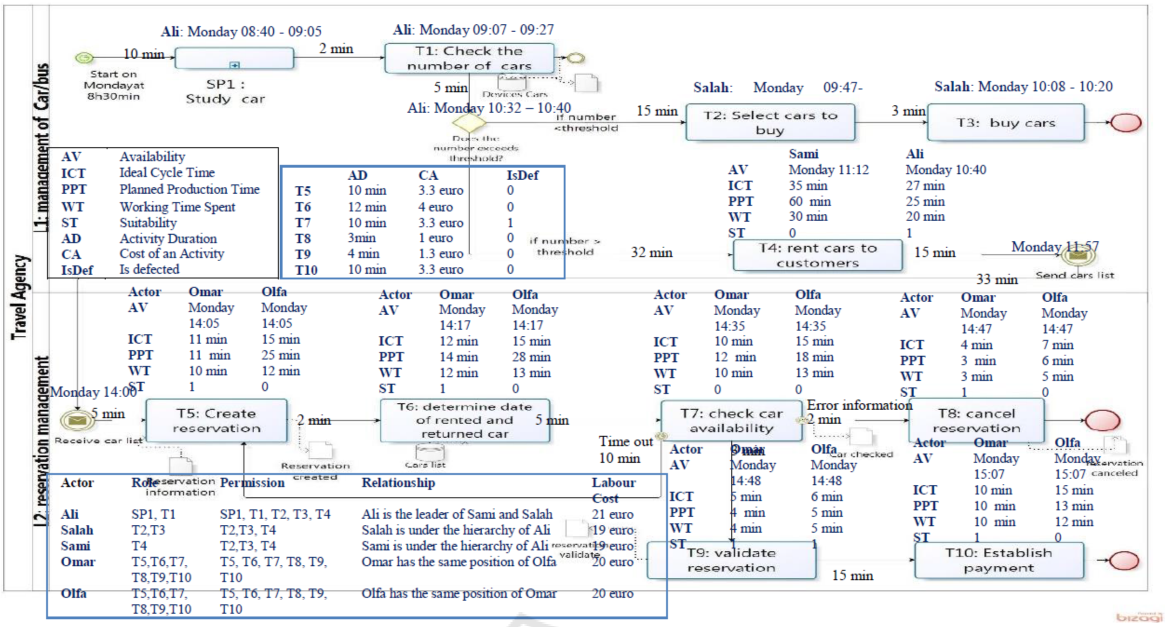

Figure 2: Travel Agency process example.

Furthermore, we note that "Omar" should work 6 hours per day ($TWTDay_{Omar}$=6 hours). He required one hour to perform one instance of all tasks in lane 2. In fact, his total working time is 6 hours per day ((WT_{T5}+ WT_{T6}+ WT_{T7}+ WT_{T8}+ WT_{T9}+ WT_{T10})*6) while his planned production time is 6 hours 30 minutes ((PPT_{T5}+ PPT_{T6}+ PPT_{T7}+ PPT_{T8}+ PPT_{T9}+ PPT_{T10})*6). This expresses that the availability of Omar is $TWTDay_{Omar}$/ $PPTDay_{Omar}$= 92.3% and he is capable to perform his job in the required unit of time.

Based on Figure 2, the ideal cycle time per day of "Omar" to perform the tasks is equal to 6 hours 18 minutes ((ICT_{T5}+ ICT_{T6}+ ICT_{T7}+ ICT_{T8}+ ICT_{T9}+ ICT_{T10})*6). Comparing the working time to the ideal one, allow to calculate his performance which is equal to 95%. The obtained value indicates that "Omar" has a high production speed. Furthermore, although "Omar" and "Olfa" have the same position, the former can perform the "Create reservation" task on 10 minutes, while "Olfa" requires 12 minutes. We explain this by the fact that "Omar" has more skills (Suitability ST_{Omar}=1) than "Olfa" (ST_{Olfa}=0). Certainly, reducing the activity duration improves the time behavior and the cost by decreasing the execution time of the whole process. Its cost is calculated by the product of the actor's actual Labour Costs per Hour (LCH_{Omar}=20 euro/hour) and the working time spent by "Omar" to perform the "Create reservation" ($CA_{Omar=}$ (20 euro/60)*10=3.3 euro). To determine the cost of "Reservation Management" lane, we calculate the sum of all BPMN elements cost in this lane (14+16.3= 30.3 euro).

It is important to note, that the presented model can be evaluated based on the obtained measures values. In this case, several measures should be minimized and others should be maximized to improve the BP performance. The interpretation of the performance measures gives an evaluation of the business process performance. For instance, the performance and availability measures of the actor "Omar" in a day should be maximized to improve the performance of the business process model. They represent respectively high values (95% and 92.3%). In addition, the ratio of defected activities performed by "Omar" should be minimized to improve the performance of the business process model. It represents a low value (RDA_{Omar}=16.7%). In our case, based on the majority measure values, the "Travel agency Process" model has a good performance.

However, for a better evaluation, it is mandatory to establish thresholds that reflect the optimal value of each measure.

Table 2 shows the classification of the performance measures in terms of all perspectives and presents the values for our running example. The symbol (*) indicates that the measure is derived and the symbol (**) indicates that the measure is aggregated. In this table, the sign - (minus) indicates that the measure should be minimized to improve the BP performance, while the plus sign + indicates that the measure should be maximized.

Table 2: Classification of the performance measures.

Perspectives		Performance measures				Source	Characteristics related to BPMN elements					Characteristics related to actor		Value
		Temporal Measures		Cost Measures			Performance efficiency		Reliability		Cost	Actor performance		
		Temporal measures for BPMN elements	Temporal measures related to actor	Cost measures for BPMN elements	Cost measures related to actor		Time Behavior	Resource Utilization	Maturity	Fault tolerance		Availability	Suitability	
Functional and temporal		AD^* : Activity Duration				Lanz et al., 2016	-				-	-	-	AD (T4:Rent car to customers) = 11:42 – 11:12 = 30 minutes
Functional and temporal				CA_{Act}^*:Cost of an Activity			-		-	-	-	-	-	CA_{Omar}(Create reservation) = 10 minutes * 20 euro/Hours = 3,33 euro
Functional and temporal		$NDFA_{Act}^{**}$: Number of Detected Faults in an activity per day					-		-	-	-	-	-	NDFA(Create reservation)$_{Omar}$=3
Informational and temporal		NEE^{**}: Number of Error Event per day					-		-	-		-	-	NEE(Check car availability)$_{Omar}$=2
Organizational and temporal	Business Temporal context				$CosDay(L)^*$:Cost of Lane per Day		-			-	-	-	-	CosDay(Reservation Management)= 30.3 euro
Organizational and temporal	Social Temporal context		$LAADay^{**}$: List of Actors that perform an Activity per day			Del-Río-Ortega et al.,-2016		-		-	-			LAADay (Validate reservation)= 2 (Olfa and Omar)
Organizational and temporal	Social Temporal context		RGA_{Act}^*: Ratio of Good Activities performed by an Actor						+	+	+	+	+	RGA_{Omar}=5/6=83.3%
Organizational and temporal	Social Temporal context		$AVDay_{act}^*$: Availability of an actor				+			+	+	+	+	$AVDay_{Omar}$ = 6 hours / 6 hours and 30 minutes = 92.3%
Organizational and temporal	Social Temporal context		$PerDay_{Act}^*$: Performance of an actor				+			+	+	+	+	$PerDay_{omar}$= 6 hours/ 6 hours 18 minutes =95%
Organizational and temporal	Social Temporal context				$CosDay_{act}(L)^*$: Cost of an actor in a Lane per Day					-	-	-	-	$CosDay_{Omar}$(Reservation Management)= 6 hours * 20 euro = 120 euro
Behavioural and temporal		GD^*: Gateway Duration					-				-			GD (Number of cars?) = 10:40-10:32 = 8 minutes
Behavioural and temporal				$CosGat_{Act}^*$: Cost of a Gateway			-				-			$CosGat_{Ali}$= 5 minutes * 21 euro/hour = 2.8 euro

5 CONCLUSION

In this paper, we focused on improving the performance of BPMN models. 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 and social contexts.

Since there is no consensual classification for the multiple measures, we defined a framework for classifying them. It facilitates their use in the evaluation of the business process performance.

This classification framework is organized in three levels. At the first level, the proposed measures represent the cost and the temporal aspects. They concern the BPMN element(s) and the Actor. At the second level, for each category, we classified a set of measures into perspectives. Thanks to this second level, our framework helps the designer to select the suitable subset of performance metrics dealing with his/her perspective. At the third level, we classify

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performance measures into base, derived and aggregated. To illustrate our proposed framework, an example as well as its validation on a real case study in the "Travel Agency Process" is presented. It allows to calculate and interpret the measures values in order to improve the performance of the business process model.

Our future work focuses on three main axes: 1) integrate our classification within a toolset for BPMN, 2) checking the proposed measures through empirical studies and identify thresholds, and 3) exploit the temporal and cost information to provide for assistance during the refactoring/improvement of a business process model in order to alert the designer of potential impacts of their decisions upon the various perspectives.

REFERENCES

Araújo, M., Filho, B. A. R, Gonçalves, R. F., 2016. Business process management notation for a costing model conception. In *ICIEOM'9, International Conference on Industrial Engineering and Industrial Management*, Aveiro, Portugal, pp. 244-251.

Bocciarelli, P., D'Ambrogio, A., Giglio, A., Paglia, E., 2014. Simulation-based performance and reliability analysis of business processes. In *WSC'14, International Winter Simulation Conference*, Savannah, GA, USA, pp. 3012-3023.

Del-Río-Ortega, A., Resinas, M., Durán, A., Ruiz Cortés, A., 2016. Using templates and linguistic patterns to define process performance indicators. In *Enterprise IS'16, International Journal of Enterprise Information Systems*, Volume 10, Num. 2, pp. 159-192.

D'Ambrogio, A., Paglia, E., Bocciarelli, P., Giglio,A., 2016. Towards performance-oriented perfective evolution of BPMN models. In *SpringSim'16, 49th International Conference on Spring Simulation Multi-Conference*, Pasadena, CA, USA, Volume 48, pp. 15.

El Hadj Amor, A. E., Ghannouchi, A. S., 2017. Towards Managing Key Performance Indicators for Measuring Business Process Performance. In *EMCIS'17, 14th Conference European, Mediterranean, and Middle Eastern on Information System*, Portugal, pp .579-591.

Gupta, M., Galloway, K., 2003. Activity-based costing/management and its implications for operations management. In *International Journal of Technological Innovation, Entrepreneurship and Technology Management*, Volume 23, pp. 131-138.

Heinrich, R., Paech, B., 2010. Defining the Quality of Business Processes. In *Modellierung'10, 4th International Conference of Modellierung*, Klagenfurt, Austria, pp.133-148.

Hompes, Bart F. A., Van der Aalst, W. M. P., 2018. Lifecycle-Based Process Performance Analysis. In *CoopIS, C&TC, and ODBASE'18, 17th International Conference on Cooperative Information Systems*, Valletta, Malta, pp. 336-353.

Kaplan, R. S., Cooper, R., 1998. *Cost and effect: using integrated cost systems to drive profitability and performance*. Cambridge, MA, 1st edition Harvard Business School Press.

Khlif, W., Ben-Abdallah, H., Elleuch Ben Ayed, N., 2017. A methodology for the semantic and structural restructuring of BPMN models. In *International Journal on Business Process Management*, Volume 23, pp. 16-46.

Kis, I., Bachhofner, S., Di Ciccio, C., Mendling, J., 2017. Towards a Data-Driven Framework for Measuring Process Performance. In *BPMDS'17, 18th International Conference on Enterprise, Business-Process and Information Systems Modeling*, Germany, pp. 3-18.

Kluza, K., Jobczyk, K., Wisniewski, P., Ligeza, A., 2016. Overview of Time Issues with Temporal Logics for Business Process Models. In *FedCSIS'16, Federated Conference on Computer Science and Information Systems*, Gdańsk, Poland, pp. 1115-1123.

Korherr, B., List, B., 2007. Extending the EPC and the BPMN with Business Process Goals and Performance Measures. In *ICEIS'9, International Conference on Enterprise Information Systems,* Funchal, Madeira, Portugal, pp. 287-294.

Lanz, A., Reichert, M., Weber, B., 2016. Process time patterns: A formal foundation. In *Inter. Journal of the Information Systems*, Volume 57, pp. 38-68.

Mendes, T., Santos, S., 2016. A Procedural Approach for Evaluating the Performance of Business Processes Based on a Model of Quantitative and Qualitative Measurements. In *ICEIS'16, 18th Inter. Conf. on Enterprise Information Systems*, Rome, pp. 515-534.

Peral, J., Maté, A., Marco, M., 2017. Application of Data Mining techniques to identify relevant Key Performance Indicators. In *Inter. Journal of Computer Standards & Interfaces*, Volume 50, pp. 55-64.

Sampathkumaran, P. B., Wirsing, M., 2013. Financial Evaluation and Optimization of Business. *In Inter. Journal of Information System Modeling and Design*, Volume 4, Number 2, pp. 91-120

Van der Aa, H., Leopold, H., Del-Río-Ortega, A., Resinas, M., Reijers, H. A., 2017. Transforming unstructured natural language descriptions into measurable process performance indicators using Hidden Markov Models. In *International Journal of the Information Systems*, Volume 71, pp. 27-3.

Wynn, M. T., Low, W. Z., Nauta, W., 2013. A Framework for Cost-Aware Process Management: Generation of Accurate and Timely Management Accounting Cost Reports. In *APCCM'9, Asia-Pacific Conference on Conceptual Modelling*, Adelaide, Australia, pp. 79-88.