A Methodology for Determination of Performance Measures Thresholds for Business Process

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Abstract: Business process performance is vital for organizations which aim to produce a high performance model. In the literature, performance of the business process can be evaluated through formal verifications, simulation, or a set of measures. In this paper, we adopt measures-based assessment to evaluate the performance of business process models, modelled with Business Process Modelling and Notation (BPMN), in terms of the characteristics related to BPMN elements (i.e. time behaviour, cost) and characteristics related to the actor (ie. availability, suitability and its cost). We propose a methodology based on fuzzy logic which apply performance measures to assess these characteristic's levels. In addition, it expresses the problem of defining threshold based on a set of BPMN models²s. Furthermore, our methodology evaluates the performance of business process models based on fuzzy logic. The efficiency of the proposed methodology is illustrated through a case study and a tool that fully support the developed system.

1 INTRODUCTION

Performance is necessary step for enterprises, seeking to improve their business process (BP). Evidently, BP performance aims to reduce time, cost and to indicate whether the company goals are achieved or not.

In the literature, BP model performance assessment shows two trends of approaches: those centred on the application of formal verification methods (Kluza and Nalepa, 2019) or those based on the use of a set of performance measures calculated on the BP model (Lanz et al., 2016) (Khlif et al., 2019) (Kchaou et al., 2019).

Formal methods are used to verify performance properties like measurement process and feedback process (Kluza and Nalepa, 2019). However, their application stills delayed by their time and cost. In addition, they are not able to analyse the model performance such as its time behaviour and cost of BPMN elements; and also availability, suitability and cost of the actor. These characteristics influence the performance of the BP.

In addition, several authors adopts a qualitative assessment of BP models by proposing a set of performance measures that are applied either on the BP model (e.g. (Kis et al., 2017) (Khlif et al., 2019)), or the simulated BP model (Heinrich, 2013) (D'Ambrogio et al., 2016). These measures are exploited to assess several quality characteristicS (Razzaq et al., 2018) (Gonzalez-Lopez and Bustos, 2019) or to predict the BP performance (case of simulated model assessment) (Heinrich, 2013) (D'Ambrogio et al., 2016).

Since the diversity of measures, several researchers proposed frameworks to evaluate the performance of a business process model e.g. (Wynn et al., 2013), (Kis et al., 2017) (Khlif et al., 2019). However, there is no consensus about threshold values of performance measures which are required to interpret/evaluate a BP model's performance.

This paper overcomes the problem of threshold identification based on fuzzy logic methodology which asses the BP performance in terms of characteristics such as the time behaviour and cost of BPMN elements; availability, suitability and cost of the actor. These characteristics are crucial to improve the business process model.

The proposed methodology proceeds in two phases: threshold identification and fuzzy logic application. First, it uses data mining to define the decision tree, which identify approximate thresholds for each performance measure. These thresholds allow the designer to interpret the characteristic of

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Business Process Modelling Notation (BPMN) elements (i.e., time behaviour, and cost levels) and those related to the actor (i.e., availability, suitability or cost levels). To this end, we used a database intituled "Business Process Database". We collect 100 business processes of organizations operating in different sectors, and then we annotate them by temporal and semantic information. Our database is available at:https://sites.google.com/site/kchaoumariemsi/resources.

The approximate thresholds produced in the first phase are considered as the input of the second phase. This phase uses the fuzzy logic (Zadeh, 2008) in order to obtain precise thresholds values.

The proposed methodology is developed in a tool that help to evaluate the performance of BPMN models in terms of time behaviour and cost of BPMN elements; and availability, suitability and cost of the actor. To illustrate the efficiency of our performance tool, we rely on two types of experimental evaluation. The former is accomplished with students while the second is done through the proposed tool.

In summary, this paper presents two contributions: the first one expresses the imprecise thresholds determination for performance measures in terms of time behaviour and cost of BPMN elements; and availability, suitability and cost of the actor. The second one handle the imprecise nature of the identified thresholds by applying fuzzy logic.

The remainder of the paper is organized as follows: Section 2 summarizes related work. In Section 3, we present the proposed methodology. Section 4 expresses how we apply fuzzy logic to support the imprecise thresholds. Section 5 illustrate the developed tool of BP model performance assessment and evaluate it based on two types of experiments. Section 6 identifies threats to the validity of our methodology. Finally, section 7 summarizes the presented work and outlines its extensions.

2 RELATED WORK

In this section, we overview works on the BP performance measures. These works are divided into two categories: measures related to the actor characteristics and those related to BPMN elements characteristics.

It is to note that the presented measures below are those having formula that allow calculating the value of each one in a BPMN model. Based on this criterion, we retain all of them for the determination of their thresholds.

2.1 Measures Related to the Actor Characteristics

In (Khlif et al., 2019) (Kchaou et al., 2019), to evaluate the performance of an actor, the authors propose measures related to the actor characteristics such as availability, suitability and cost.

Availability is the capability of the actor to be able to perform the activity in the required unit of time. Suitability expresses the skills that cover his qualification, expertise, social competence, skills, motivation and performance ability. The cost is expressed as a price or monetary value.

The following measures assess the availability and suitability of the actor:

- *Planned Production time of an Actor to perform an Activity* ($PPT_{Act}(A)$): is calculated by subtracting the *Actor's BReaks* (unproductive time where the actor is scheduled not to work) from Shift time (a period where an actor is scheduled to perform an Activity).
- *Working Time spent by an Actor to perform an Activity* ($WT_{Act}(A)$): is simply calculated by the difference between the Planned Production Time and Stop Time (the time where the actor was intended to work but was not due to unplanned stops or planned stops).
- *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.
- *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.
- *Performance of an Actor per Day* ($PerDay_{Act}$): compares the working Time spent by an actor per day to the Ideal Cycle Time which is defined as the theoretical minimum time to perform an activity by an actor.
- *Availability of an Actor in a Day* ($AVDay_{Act}$): is calculated as the ratio of Working Time spent by an actor to Planned Production 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.

In addition, several measures are proposed in (Khlif et al., 2019) (Kchaou et al., 2019) to assess the cost of an actor such as *Cost of an actor in a Lane per Day* ($CosDay_{act}(L)$) which 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}), *Cost of an actor in a Pool per Day* ($CosDay_{Act}(P)$) which is determined by the product of the total working time spent by an Actor in a Pool per Day ($TWTDay_{Act}(P)$) and its actual Labour Costs per Hour (LCH_{Act}).

2.2 Measures Related to BPMN Elements Characteristics

Time behaviour and cost are the characteristics of BPMN elements to evaluate the performance efficiency (Heinrich and Paech, 2010).

Time behaviour is defined as the appropriate transport time between different BPMN elements and processing times when executed; while cost expresses the price or monetary value related to BPMN elements.

On the one hand, a set of measures are proposed in (Khlif et al., 2019) (Kchaou et al., 2019) to assess the time behaviour of BPMN elements such as *Gateway Duration* (GD (Gateway) which represents the duration of a gateway. In addition, (Lanz et al., 2016) propose other temporal measures such as *Activity/Process Duration* (AD) which is calculated by the difference between the end time of the activity (Process) and the start time.

On the other hand, (Khlif et al., 2019) (Kchaou et al., 2019) proposed a set of measures to evaluate the cost of BPMN elements such as *Cost of an Activity realized by an actor* (CA_{Act}) which is calculated by the product of the actor actual Labour Costs per Hour and the working time spent by an Actor to perform an Activity; and *Cost of a Gateway* (CosGat(Gatway)) which represents the product of the gateway duration and the actor's actual Labour Costs per Hour (LCH_{Act}).

Table 5 and 7 show respectively the usability of these measures to assess the actor characteristics and BPMN element characteristics. However, to our knowledge, there is no works that focus on the determination of measures thresholds values.

3 DESIGN METHODOLOGY FOR THRESHOLDS DETERMINATION

Figure 1 depicts our methodology for threshold determination to assess the cost and time of BPMN elements and evaluate the suitability, availability and cost of the actor.

Our design methodology followed two major phases: "Analyze Data" and "Validate Data".

The activities of the "Analyze data" are organized essentially in three stages: the first one collects data based on a set of business process models annotated by temporal constraints and semantic information (cost and organizational aspects). The second step prepares data to test the database and the third one apply data mining technique to build decision trees. The second phase "Validate Data" is composed of two activities: Training Database based Validation and Test Database based Validation.

3.1 Analyze Data

The Analyze data phase goes through three major stages: 1) Collect a set of BPMN models that we annotated by semantic and temporal information, 2) Prepare these models through creating matrices related to actors and to BPMN elements to evaluate their characteristics and 3) Apply Data mining to build decision trees using WEKA system. The latter is based on algorithms that construct decision trees.

3.1.1 Collect Database

In the first step, we collect 100 BPMN models having small/ medium size, and belonging to different organizations such as banks, healthcare, institutions, commercial enterprises, etc. Then, we annotate them by semantic information that covers the cost, organizational aspect, and temporal constraints related to BPMN elements and the actor. For more details, reader can refer to (Kchaou et al., 2019). This information are used to evaluate the actor and BPMN elements characteristics.

Next, we examined business processes with experts according to measures values related to each characteristics associated to the actor and to BPMN elements. The objective is to organize them according to the level of each characteristic related to the actor and BPMN elements.

To end this purpose, we organized ourselves into two groups. First, each one examine 50 processes in term of characteristics related to the actor and to the BPMN elements. Then, we verify the cross-validation process among the two groups. Finally, to assess business processes based on the actor characteristics, we organized the "Business Process Database" into two levels of suitability (having the best skills and having low skills), two levels of availability (always available and rarely available)

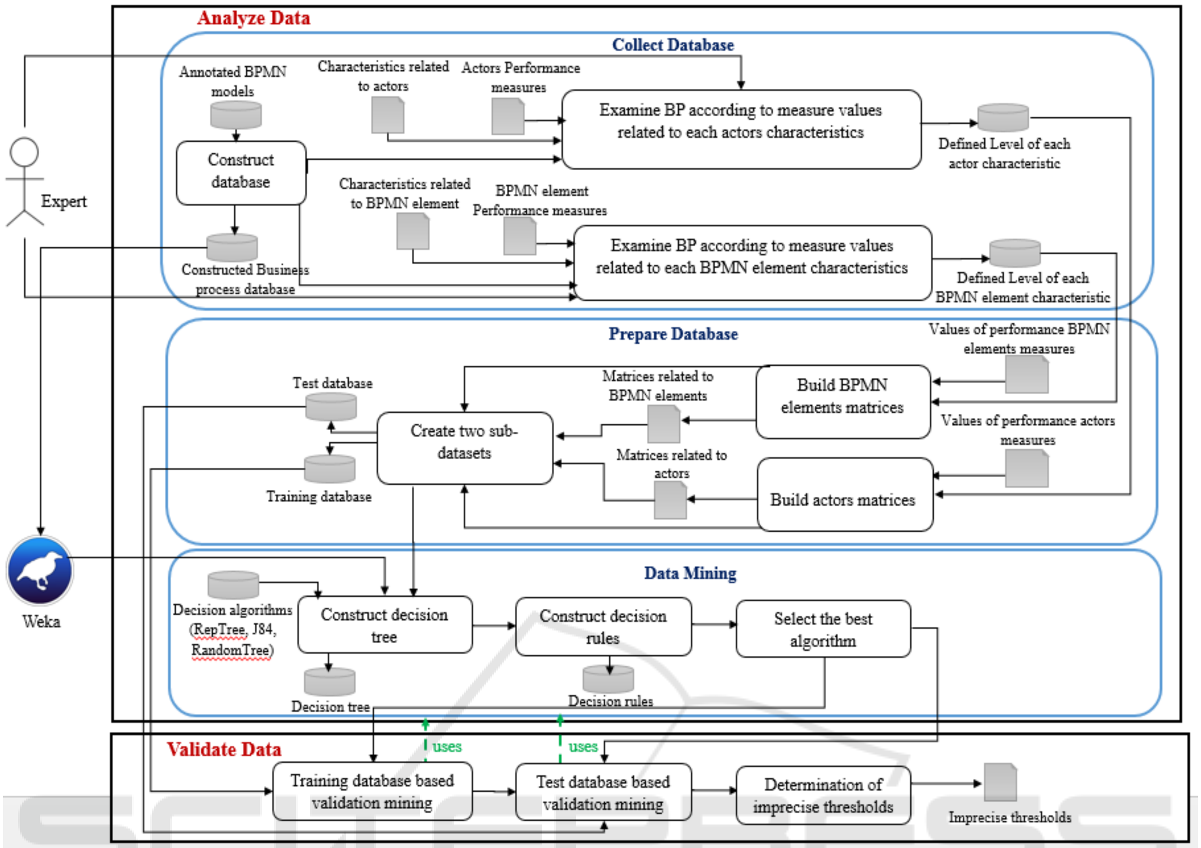

Figure 1: Design methodology for thresholds determination.

and three levels of the cost (expensive, acceptable and cheap).

To evaluate the process in terms of characteristics BPMN elements, we classified the "Business Process Database" in three levels of time behaviour (minimal, normal and maximal) and the three levels of cost (expensive, acceptable and cheap).

3.1.2 Prepare Data

In order to prepare data for the next stage, we take as input performance measures values and the level of each characteristics related to actors and to BPMN elements to produce nine matrices based on the "Business Process Database". Three matrices are devoted to the actor in order to measure his availability, suitability and cost; while the rest is associated to the BPMN elements (activity, gateway and sequence flow) to evaluate their time behavior and cost.

Each row in each matrix expresses the actor (respectively BPMN element); and each column depicts a performance measure used to assess the availability, suitability and cost of the actor (respectively time behaviour and cost of BPMN elements). The corresponding case representing the intersection of row and column details the values of these performance measures calculated for a specific actor (respectively BPMN elements).

The last column of each matrix represents the level of each actor characteristic (respectively BPMN element). For example, the last column of each matrix associated to the actor represents the level of his availability (i.e., actor is always available and rarely available), suitability (i.e., having the best skills and having low skills) and cost (i.e., expensive, acceptable and cheap).

The elaborated matrices are used to create two sub-datasets: one for learning "Training Dataset" which comprises 70% of the "Business Process Database" and one for testing needs "Test Dataset" which includes the rest of the "Business Process Database". The percentage choice is justified by the fact that the "Training Dataset" is the one on which we train and fit our model to adjust thresholds. Whereas "Test Dataset" is used only to assess the BP performance.

3.1.3 Data Mining

To extract thresholds for performance measures from the "Business Process Database" and evaluate the performance of a business process model (BPM), we used in the first stage decision trees and in the second stage decision rules.

A decision tree has a root node, intermediate and terminal nodes. The root node represents the "Business Process Database" which is divided into two or more homogeneous sets. Terminal node represent the level of each BPMN element characteristic (time behavior and cost) and each actor characteristic (the availability, suitability and the cost). The transitions from the root node to a terminal node are based on the values of performance measures. For each node, the value of performance measure that maximizes the homogeneity of child nodes is chosen. Node homogeneity is attained if all the BPs of this node belong to the same level (e.g., all the BP of a node are expensive, in the case of cost).

A homogeneous node is usually a leaf node. In the case of BPMN element characteristic, a leaf node represents a class, expressing the level of cost or the level of time behaviour.

At the same, we apply this interpretation to the actor characteristics. To create decision trees, we use the training dataset which contains the values of the performance measures calculated for a specific actor (respectively BPMN elements). The required nine decision trees is classified into three for the actor characteristics (Availability, suitability and cost) and six for BPMN elements characteristics (time behaviour and cost), we used WEKA system (Hall et al., 2009) which is a collection of machine learning algorithms for data mining tasks. It contains tools for data pre-processing, classification, regression, clustering, association rules, and visualization. WEKA is based on algorithms (J48, RandomTree, REPTree, etc.) that construct decision trees. We note that the J48 algorithm is an implementation of C4.5 algorithm (Chen et al., 2009). It produces decision tree classification for a given dataset by recursive division of the data.

It works with the process of starting from leaves that overall formed tree and do a backward toward the root. The RepTree uses the regression tree logic and creates multiple trees in different iterations. After that it selects best one from all generated trees. The Random Tree is a supervised Classifier; it is an ensemble learning algorithm that generates many individual learners. It employs a bagging idea to produce a random set of data for constructing a decision tree.

In this work, we first apply all of the algorithms, and then we choose the best one which have a lower error rate based on the validation phase (Section 3.2).

3.2 Validate Data

In order to evaluate the quality of a prediction model, we apply various ratios like precision (1), recall (2), f-measure (3), and global error rate (4). Afterward, we choose the most popular and best algorithms based on the values of the used ratios such as J48, RandomTree, and REPTree.

$$\text{Precision} = \frac{\text{CorrectEntitiesFound}}{\text{TotalEntitiesFound}} \tag{1}$$

$$\text{Recall} = \frac{\text{CorrectEntitiesFound}}{\text{TotalCorrectEntities}} \tag{2}$$

$$\text{F\_mesure} = 2 * \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}} \tag{3}$$

$$\text{GlobalErrorRate} = 1 - \frac{\text{CorrectEntitiesFound}}{\text{TotalEntities}} \tag{4}$$

3.2.1 Training Database based Validation Mining

We start by calculating the ratios after testing the resulting decision trees based on the availability, suitability and cost trees of the actor, and also based on time behaviour and cost trees of BPMN elements. Decision trees are applied on the "Training Database".

Table 1 expresses that we reached very acceptable results with REPTree algorithm, for evaluating the BP model actor characteristics. Regarding the availability, the values of precision, recall, and F-measure are 94.5%, 94.1% and 94.2% while the global error is equal to 5.8%. To evaluate the suitability, the values of precision, recall, and F-measure are 76.4%, 76.5% and 76.3% while the error is equal to 2.3%. In addition, regarding the cost, the values of precision, recall, and F-measure are 98.6%, 98.5% and 98.5% while the global error rate is 1.4%.

Table 2 shows that we achieved very acceptable results with REPTree algorithm, for assessing BPMN elements characteristics. To evaluate each characteristic, we calculate for each one the values of precision, recall, and F-measure and the corresponding errors.

Table 1: J84 vs RandomTree vs REPTree for decision tree of availability, suitability and cost of the actor using the "Training Database".

Ratios	Availability			Suitability			Cost		
	J48	RandomTree	REPTree	J48	RandomTree	REPTree	J48	RandomTree	REPTree
Precision	0,815	0,869	0,945	0,748	0,724	0,764	0,972	0,986	0,986
Recall	0,824	0,863	0,941	0,706	0,725	0,765	0,971	0,985	0,985
F-Measure	0,808	0,866	0,942	0,704	0,724	0,763	0,971	0,985	0,985
Global error rate	0.176	0.137	0.058	0.029	0.027	0.023	0.029	0.014	0.014

Table 2: J84 vs RandomTree vs REPTree for decision tree of time behaviour and cost of each BPMN elemnt using the "Training Database".

BPMN elements	Ratios	Time behaviour			Cost		
		J48	RandomTree	REPTree	J48	RandomTree	REPTree
activity	Precision	0,987	0,987	0,991	0,968	0,964	0,969
	Recall	0,986	0,986	0,991	0,968	0,964	0,968
	F-Measure	0,986	0,986	0,991	0,968	0,964	0,968
	Global error rate	0,013	0,013	0,009	0.031	0.036	0.031
Gateway	Precision	0,989	0,989	0,989	0,955	0,932	0,980
	Recall	0,988	0,988	0,988	0,955	0,932	0,977
	F-Measure	0,988	0,988	0,988	0,955	0,931	0,978
	Global error rate	0,011	0,011	0,011	0.045	0.068	0.022
Sequence Flow	Precision	0,980	0,975	0,980	0,967	0,983	0,983
	Recall	0,980	0,975	0,980	0,964	0,982	0,982
	F-Measure	0,980	0,975	0,980	0,964	0,982	0,982
	Global error rate	0,020	0,025	0,020	0.035	0.017	0.017

Table 3: J84 vs RandomTree vs REPTree for decision tree of availability, suitability and cost of the actor using the "Test Database".

Ratios	Availability			Suitability			Cost		
	J48	RandomTree	REPTree	J48	RandomTree	REPTree	J48	RandomTree	REPTree
Precision	0,917	0,887	0,917	0,702	0,634	0,870	0,889	0,923	0,965
Recall	0,917	0,875	0,917	0,700	0,633	0,867	0,885	0,923	0,962
F-Measure	0,917	0,879	0,917	0,700	0,627	0,867	0,884	0,923	0,962
Global error rate	0.083	0.125	0.083	0.030	0.036	0.013	0.115	0.076	0.038

3.2.2 Test Database based Validation Mining

To evaluate the performance of the proposed decision tree and select the best algorithm provided by WEKA, we use the "Test Database", which is extracted from the "Business Process Database".

Then, we assess the level of each characteristic related to the actor (the availability, suitability and cost levels of each actor) and BPMN elements (the time behaviour and cost levels of each BPMN elements) by applying each decision tree to all BPs of the "Test Database". Then, we compare this evaluation to the assessment already done by experts. The objective behind is to compare the obtained decision trees with expert judgment and therefore, to determine the error rate of our decision trees.

Tables 3 and 4 depict the values of the ratios presented in section 3.2 for assessing the performance of the proposed characteristics of decision trees (availability, suitability and the cost of the actor and time behavior and cost of BPMN elements).

Table 3 displays that we realized very acceptable results using the "Test Database" with REPTree algorithm, for assessing the actor characteristics. Regarding the availability, the values of precision, recall, and F-measure are 91.7%, 91.7% and 91.7% while the global error is equal to 8.3%. To evaluate the suitability, the values of precision, recall, and F-measure are 87%, 86.7% and 86.7% while the error is equal to 1.3%. In addition, regarding the cost, the values of precision, recall, and F-measure are 96.5%, 96.2% and 96.2% while the global error rate is 3.8%.

In addition, based on Table 4, we deduce that the attained results with REPTree algorithm are very acceptable, for assessing BPMN elements characteristics. To evaluate each characteristic, we calculate for each one the values of precision, recall, and F-measure and the corresponding errors.

Table 4: J84 vs RandomTree vs REPTree for decision tree of time behaviour and cost of each BPMN element using the "Test Database".

BPMN elements	Ratios	Time behaviour			Cost		
		J48	RandomTree	REPTree	J48	RandomTree	REPTree
activity	Precision	0,987	0,987	0,991	0,968	0,964	0,969
	Recall	0,986	0,986	0,991	0,968	0,964	0,968
	F-Measure	0,986	0,986	0,991	0,968	0,964	0,968
	Global error rate	0,013	0,013	0,009	0.031	0.036	0.031
Gateway	Precision	0,989	0,989	0,989	0,955	0,932	0,980
	Recall	0,988	0,988	0,988	0,955	0,932	0,977
	F-Measure	0,988	0,988	0,988	0,955	0,931	0,978
	Global error rate	0,011	0,011	0,011	0.045	0.068	0.022
Sequence Flow	Precision	0,932	0,979	0,979	0,946	0,946	0,946
	Recall	0,932	0,977	0,977	0,946	0,946	0,946
	F-Measure	0,931	0,977	0,977	0,946	0,946	0,946
	Global error rate	0,068	0.022	0.022	0.054	0.054	0.054

3.3 Discussion

According to the level of each characteristic related to the actor (availability, suitability and cost levels of each actor) and BPMN elements (time behaviour and cost levels of each BPMN element), we used decision trees to classify BPMN elements and actors extracted from "Business Process Database". This classification depend on the values of the used performance measures.

Furthermore, these decision trees are used to determine a set of decision rules and performance measures thresholds to asses the availability, suitability and cost of each actor (respectively time behaviour and cost of each BPMN element).

3.3.1 Evaluation of Actor Characteristics Levels

Table 5 illustrates the thresholds values and their interpretations which are determined by experts in our laboratory.

Table 6 depicts an extract of the decision rules which indicate the performance measures values for each characteristic level of the actor.

3.3.2 Evaluation of Actor Characteristics Levels

Table 7 illustrates thresholds and the corresponding linguistic interpretations, which are determined by the members of our research team.

Table 8 displays an extract of decision rules that define the level of each BPMN element characteristics based on the values of performance measures.

Table 5: Identified thresholds values for the evaluation of the characteristics related to the actor.

Performance measures	Threshold	Linguistic interpretation
Availability		
$PPT_{Act}(A)$	PPTAct(A) < 5	Low
	5<=PPTAct(A) <7	Moderate
	7<=PPTAct(A) <9	High
	PPTAct(A) >= 9	Very high
$WT_{Act}(A)$	$WT_{Act}(A)<3$	Low
	$WT_{Act}(A)>=3$	High
$PerDay_{Act}$	$PerDay_{Act}<78$	Low
	$PerDay_{Act}>=78$	High
$AVDay_{Act}$	AVDayact < 72.5	Low
	AVDayact >= 72.5	High
Suitability		
$PPT_{Act}(A)$	PPTAct(A) < 12.5	Low
	12.5<=PPTAct(A) <17.5	Moderate
	17.5<=PPTAct(A) <25	High
	PPTAct(A) >= 25	Very high
$WT_{Act}(A)$	$WT_{Act}(A)<3$	Very low
	$3<=WT_{Act}(A)<10.5$	Low
	$10.5<= WT_{Act}(A)<12.5$	Moderate
	$12.5<=WT_{Act}(A)<21$	High
	$WT_{Act}(A)>=21$	Very high
$TWTDay_{Act}(L)$	$TWTDay_{Act}(L)<17.5$	Low
	$17.5<=TWTDay_{Act}(L) <24.5$	Moderate
	$TWTDay_{Act}(L) >=24.5$	High
$TWTDay_{Act}(P)$	$TWTDay_{Act}(P)<60$	Low
	$TWTDay_{Act}(P) >=60$	High
$PerDay_{Act}$	$PerDay_{Act}<79.2$	Low
	$PerDay_{Act}>=79.2$	High
$AVDay_{Act}$	AVDayact < 72.5	Low
	AVDayact >= 72.5	High
RGAAct	RGAAct<37.5	Low
	37.5<= RGAAct<75	Moderate
	RGAAct>=75	High
RDAAct	RDAAct<58.3	Low
	RDAAct>=58.3	High
Cost		
CosDayAct(L)	CosDayAct(L)<4.8	Low
	4.8<=CosDayAct(L)<9	Moderate
	CosDayAct(L)>=9	High
CosDayAct(P)	CosDayAct(P)<10.16	Low
	CosDayAct(P)>=10.16	High

Table 6: Extract of decision rules to assess the level of actor’s characteristics.

Characteristics	Rule	Decision rules
Availability	R1	If (AVDayact < 72.5 and PPTAct(A) < 9 and WTAct(A) < 3) then the actor is rarely available
	R2	If (AVDayact < 72.5 and PPTAct(A) >= 9 and PerDayAct >= 78 and TWTDayAct(L) < 15.5) then the actor is always available
	R3	If (AVDayact >= 72.5 and PPTAct(A) < 7 and PPTAct(A) < 5) then the actor is always available
Suitability	R1	If (PerDayAct < 79.2 and RDAAct < 58.3 and WTAct(A) < 3) then the actor has low skills
	R2	If (PerDayAct < 79.2 and RDAAct < 58.3 and WTAct(A) >= 3 and AVDayact < 72.5) then the actor has low skills
	R3	If (PerDayAct >= 79.2 and 37.5<RGAAct < 75 and WTAct(A) < 12.5) then the actor has low skills
Cost	R1	If CosDayAct(L) < 4.8 then the cost of the actor is Cheap
	R2	If CosDayAct(L) >= 4.8 and CosDayAct(P) < 10.16 :then the cost of the actor is Acceptable
	R3	If CosDayAct(L) < 9 and CosDayAct(P) >= 10.16 then the cost of the actor is Acceptable

Table 7: Identified thresholds values for the evaluation of the characteristics related to BPMN elements.

BPMN elements	Performance measures		Time behaviour		Performance measures		Cost	
			Threshold	Linguistic interpretation			Threshold	Linguistic interpretation
Activity	AD	Activity	AD<6.5	Low	CA_{Act}	Activity	CA_{Act}<4.92	Low
			6.5<=AD<14.5	Moderate			4.92<=CA_{Act}<10	Moderate
			AD >=14.5	High			CA_{Act}>=10	High
		Process	AD<19.5	Low		Process	CA_{Act} < 18.67	Low
			19.5<=AD<28.5	Moderate			8.67 < CA_{Act} <= 24.95	Moderate
			AD>=28.5	High			CA_{Act}>=24.95	High
Gateway	GD		GD <2.5	Low	CosGat(Gateway)		CosGat < 0.45	Low
			2.5<=GD<4.5	Moderate			0.45<=CosGat <0.97	Moderate
			GD>=4.5	High			CosGat >= 0.97	High
Sequence Flow	SeqFD		SeqFD < 4.5	Low	CosSeqF		CosSeqF < 0.45	Low
			4.5<= SeqFD <8	Moderate			0.45<= CosSeqF < 0.99	Moderate
			SeqFD >= 8	High			CosSeqF >= 0.99	High

Table 8: Extract of decision rules to assess the level of each characteristic’s BPMN element.

BPMN elements		Rule	Time behaviour	Cost
Activity	Activity	R1	If AD<6.5 then the time of the activity is Minimal	If CA_{Act}<4.92 then the cost of the activity is Cheap
		R2	If 6.5<=AD<14.5 then the time of the activity is Normal	If 4.92<=CA_{Act}<10 then the cost of the activity is Acceptable
		R3	If AD >=14.5 then the time of the activity is Maximal	If CA_{Act}>=10 then the cost of the activity is Expensive
	Process	R1	If AD<19.5 then the time of the process is Minimal	If CA_{Act}< 18.67 then the cost of the process is Cheap
		R2	If 19.5<=AD<28.5 then the time of the process is Normal	If 18.67 <CA_{Act} <= 24.95 then the cost of the process is Acceptable
		R3	If AD>=28.5 then the time of the process is Maximal	If CA_{Act}>=24.95 then the cost of the process is Expensive
Gateway		R1	If GD <2.5 then the time of the gateway is Minimal	If GD <2.5 then the cost of the gateway is Minimal
		R2	If GD>=2.5 then the time of the gateway is Normal	If 2.5<=GD< 4.5 then the cost of the gateway is Normal
		R3	If GD>=4.5 then the time of the gateway is Maximal	If GD>=4.5 then the cost of the gateway is Maximal
Sequence Flow		R1	If SeqFD < 4.5 then the time of the sequence flow is Minimal	If CosSeqF < 0.45 then the cost of the sequence flow is Cheap
		R2	If 4.5<= SeqFD <8 then the time of the sequence flow is Normal	If 0.45<= CosSeqF < 0.99 then the cost of the sequence flow is Acceptable
		R3	If SeqFD >= 8 then the time of the sequence flow is Maximal	If CosSeqF >= 0.99 then the cost of the sequence flow is Expensive

In summary, these thresholds persist imprecise since they are influenced by the judgment of experts when we collect the database (Section 3.1.1). To handle this problem, we use the fuzzy logic.

4 FUZZY LOGIC FOR BP PERFORMANCE ASSESSMENT

Fuzzy logic is based on the observation that people make decisions based on imprecise and non-numerical information. In this paper, we use fuzzy logic to handle approximate and imprecise values like those for the performance measures thresholds. Fuzzy-logic application followed three major steps: fuzzification, inference and defuzzification.

Fuzzification operations used membership functions that can map mathematical input values representing the performance measures into fuzzy membership functions expressing linguistic values (i.e. High, moderate, low).

The inference is based on a set of fuzzy decision rules written in a linguistically natural language. These fuzzy rules are obtained based on the rules presented in Section 3.3.

The defuzzification produces crisp values of each performance measure.

In this section, we present in detail how we use the fuzzy logic to evaluate the performance of BP.

4.1 Fuzzification

Fuzzification transforms crisp values of performance measures representing the input variables into linguistic values that express fuzzy sets. This transformation is realized thanks to the membership functions that are determined based on the identified approximate thresholds (Section 3.3). One membership function is proposed for each possible fuzzy set per performance measure.

The first part of Figure 2 expresses the membership without fuzzification. In this part, the two values (x and y) express the approximate thresholds obtained based on the use of decision trees and fuzzy sets that are defined in different intervals. These intervals are determined by experts (i.e., low, moderate, high).

Figure 2 illustrates that each performance measure value, which has a membership degree equals to 1, belongs only to a single fuzzy set.

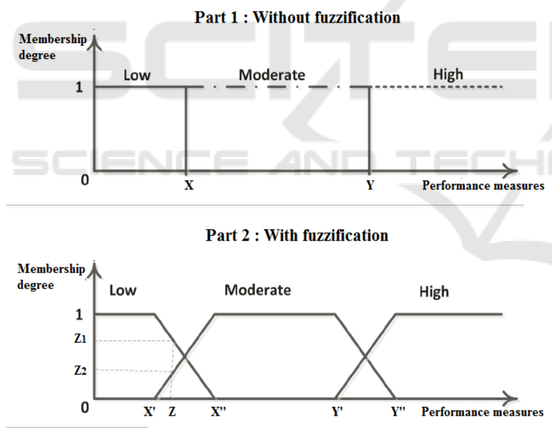

Figure 2: Membership function definition.

This situation is true if the identified thresholds are exact and precise. Nevertheless, since this case cannot be applied, we use in this paper, the membership function with fuzzification reflects the ranges by different experts. It is depicted in the second part of Figure 2. In this part, the experts defined four values (x', x", y', y") for each performance measure. Each value inside the interval [x', x"] and [y', y"] fits respectively in two fuzzy sets with different membership degrees. For instance, the value "z" belongs to the two fuzzy sets "low" and "moderate" with membership degree of "z1" and "z2".

4.2 Inference

The inference step used a set of fuzzy decision rules written in a linguistically natural language. A fuzzy rule is a simple IF-THEN rule with a condition and a conclusion. It should be written based on the following syntax: "if D is X and/or E is Y then F is Z". D and E represent the input variables, F is the output variable, and X, Y, Z are their corresponding linguistic values.

These rules are crucial to determine the values of the output variables representing levels of each BPMN element characteristics (time behavior and cost), and levels of the actor characteristics (his availability, suitability and cost) based on the input values expressing the set of performance measures.

To obtain the fuzzy rules, we start by using the set of decision rules obtained from the decision tree (Section 3.3). We changed the crisp values of performance measures with their corresponding linguistic values and rewrote the rules according to the syntax defined above. Table 9 shows the total number of defined fuzzy rules for each actor's and BPMN element characteristic.

Table 9: Total number of defined fuzzy rules for the actor characteristic and those corresponding to BPMN elements.

			Total number of fuzzy rules
Actor	Availability		50
	Suitability		207
	Cost		15
BPMN element	Time behaviour	activity	12
		Gateway	6
		Sequence Flow	6
	Cost	activity	12
		Gateway	6
		Sequence Flow	6

Table 10 (respectively Table 11) depicts an extract of the defined fuzzy decision rules for the availability, suitability and cost of the actor (respectively time behaviour and cost of each BPMN element).

4.3 Defuzzification

Defuzzification is the process of producing a quantifiable result in crisp logic, given fuzzy sets and corresponding membership degrees. This conversion is ensured thanks to a set of membership functions that we defined based on several rules that transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets.

Table 10: Extract of fuzzy decision rules to assess the level of availability, suitability and cost of the actor.

Fuzzy Rule	Fuzzy decision rules		
	Availability	Suitability	Cost
FR1	If (AVDayact is low and PPTAct(A) < 9 and WTAct(A) < 3) then the AvailabilityLevel is rarely available	If (PerDayAct is low and RDAAct is low and WTAct(A) is very low) then the SuitabilityLevel is having low skills	If CosDayAct(L) is low then the CostLevel is Cheap
FR2	If (AVDayact is low and PPTAct(A) >= 9 and PerDayAct >= 78 and TWTDayAct(L) < 15.5) then the AvailabilityLevel is always available	If (PerDayAct is low and RDAAct is low and WTAct(A) is low and AVDayact is low) then the SuitabilityLevel is having low skills	If CosDayAct(L) is moderate and CosDayAct(P) is low then the CostLevel is Acceptable
FR3	If (AVDayact is high and PPTAct(A) < 7 and PPTAct(A) < 5) then the AvailabilityLevel is always available	If (PerDayAct is low and RDAAct is low and WTAct(A) is low and AVDayact is high and TWTDayAct(L) is low) then the SuitabilityLevel is having low skills	If CosDayAct(L) is moderate and CosDayAct(P) is high then the CostLevel is Acceptable

Table 11: Extract of fuzzy decision rules to assess the level of time behavior and cost of each BPMN element.

BPMN elements		Fuzzy Rule	Time behaviour	Cost
activity	Activity	FR1	If AD is low then the TimeBehaviorLevel is Minimal	If CA_{Act} is low then the CostLevel is Cheap
		FR2	If AD is moderate then the TimeBehaviorLevel is Normal	If CA_{Act} is moderate then the CostLevel is Acceptable
		FR3	If AD is high then the TimeBehaviorLevel is Maximal	If CA_{Act} is high then the CostLevel is Expensive
	Process	FR1	If AD is low then the TimeBehaviorLevel is Minimal	If CA_{Act} is low then the CostLevel is Cheap
		FR2	If AD is moderate then the TimeBehaviorLevel is Normal	If CA_{Act} is moderate then the CostLevel is Acceptable
		FR3	If AD is high then the TimeBehaviorLevel is Maximal	If CA_{Act} is high then the CostLevel is Expensive
Gateway		FR1	If GD is low then the TimeBehaviorLevel is Minimal	If CosGat is low then the CostLevel is Cheap
		FR2	If GD is moderate then the TimeBehaviorLevel is Normal	If CosGat is moderate then the CostLevel is Acceptable
		FR3	If GD is high then the TimeBehaviorLevel is Maximal	If CosGat is high then the CostLevel is Expensive
sequence flow		FR1	If SeqFD is low then the TimeBehaviorLevel is Minimal	If CosSeqF is low then the CostLevel is Cheap
		FR2	If SeqFD is moderate then the TimeBehaviorLevel is Normal	If CosSeqF is moderate then the CostLevel is Acceptable
		FR3	If SeqFD is high then the TimeBehaviorLevel is Maximal	If CosSeqF is high then the CostLevel is Expensive

Several defuzzification techniques are proposed in the literature such as Center Of Gravity (COG), Centroid Of Area (COA), Mean Of Maximum (MOM), Center Of Sums (COS), etc. We use the Center Of Sums (COS) since it is faster than many defuzzification methods that are presently in use. In addition, the method is not restricted to symmetric membership functions. The defuzzified value X^* of the output variable is given by equation 5:

$$X^* = \frac{\sum_{i=1}^{M} X_i * \sum_{j=1}^{m} \mu_{A_j}(X_i)}{\sum_{j=1}^{m} \mu_{A_j}(X_i)} \quad (5)$$

Where *m* is the number of fuzzy sets, *M* represents the number of fuzzy variables and expresses the membership function for the j-th fuzzy sets.

Defuzzification determines the level of each actor and BPMN element characteristic as well as the degree of certainty of each level. For example, an actor can be estimated as the most suitable having best skills with a certainty degree of 80%.

5 FUZZYPER: FUZZY PERFORMANCE TOOL

We present in this section our tool that implements the proposed methodology. The validation is based on the experimental evaluation.

5.1 FuzzPer Tool

We have developed a tool, bapized "FuzzPer" for evaluating the cost and time of BPMN elements and assessing the suitability, availability and cost of the actor named. Our tool is implemented in Java as an EclipseTM plug-in (eclipse, 2011). It is composed of four main modules: Extractor, Measures calculator, Decision Maker and Fuzzy-logic control as illustrated in Figure 3.

The extractor takes as input a business process modeled by BIZAGI tool (ISO/IEC 19510, 2013) transformed into XPDL file (Shapiro, 2006). Based on the generated file, the information extracted by the extractor reflects the semantic (cost and organizational aspects), temporal and the structural information. This information involves all BPMN elements contained in the business process model and the actors. The use of the standard ensures that our

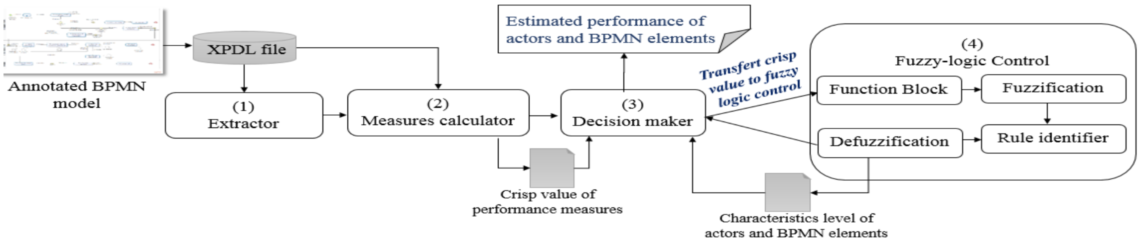

Figure 3: Architecture of FuzzPer tool.

tool can be integrated within any other modeling tool that supports this standard.

The measures calculator takes as input the XPDL file, calculates and displays the crisp values of each used performance measures for estimating either the cost and time of BPMN elements or the suitability, availability and cost of the actor.

The Decision Maker takes the crisp values of performance measures representing the input variables and transfers them to the fuzzy control module. This module runs the Fuzzy Control Language (FCL) for approximating the performance of BPMN elements and the actor.

Fuzzy-logic Control is implemented in Fuzzy Control Language (FCL) which is a standard for Fuzzy Control Programming. It was standardized by IEC 61131-7. FCL is composed of four main modules: Function Block Interface, Fuzzification, Rule identifier, Defuzzification.

- Function Block Interface: determines input and output parameters.
- Fuzzification: transforms crisp values of performance measures representing the input variables into linguistic values (fuzzy sets) that will be used by the inference engine (Section 4.1). This transformation is realized thanks to the membership functions that are determined based on the identified approximate thresholds.
- Rule identifier: is based on a set of fuzzy decision rules written in a linguistically natural language to determine the values of the output variables representing the level each BPMN element characteristic (time behavior and cost), and the level of the actor characteristic (his availability, suitability and cost) (Section 4.2).
- Defuzzification: determines the level of availability, suitability and cost of the actor and the level of time behaviour and cost of each BPMN element as well as the degree of certainty of this level using the Center Of Sums (COS) technique (Section 4.3).

Based on the obtained result provided by the Defuzziification, the decision maker estimates the performance of the actor and BPMN elements.

5.2 Experiments

In order to validate our methodology, we are based on two experiments. The first experiment involved students from our college while the second experiment use "FuzzPer" tool. These experiments use the following additional resources:

- Business Process Model: we use the "Travel Agency process" example modelled with BPMN in Figure 4. The model is annotated by temporal constraints and semantic information (cost and organizational aspects).
- Participants: During these experiments, we asked 50 students from our faculty to assess the actor characteristics (availability, cost suitability) and to evaluate BPMN elements characteristics (time behaviour and cost).
- Actor characteristics exercise: students should respond to a set of questions to evaluate the performance of the actor. The questions are classified into three categories: those that focus on the availability of the actor, those related to the suitability of the actor and those related to the actor cost. Finally, each student should select the level of each actor characteristic (i.e. availability, suitability and cost). For instance, the actor is always available or rarely available. In addition, he has the best skills or low skills. The exercise is available at: https://sites.google.com/site/kchaoumariemsint/resources.
- BPMN elements characteristics exercise: students had to evaluate the time of performing an activity, the time of make decision and the transfer time. Finally, each one choose the time level and the cost level of each BPMN element. For instance, the activity's cost is cheap, acceptable or expensive. The exercise is available at: https://sites.google.com/site/kchaoumariemsint/resources

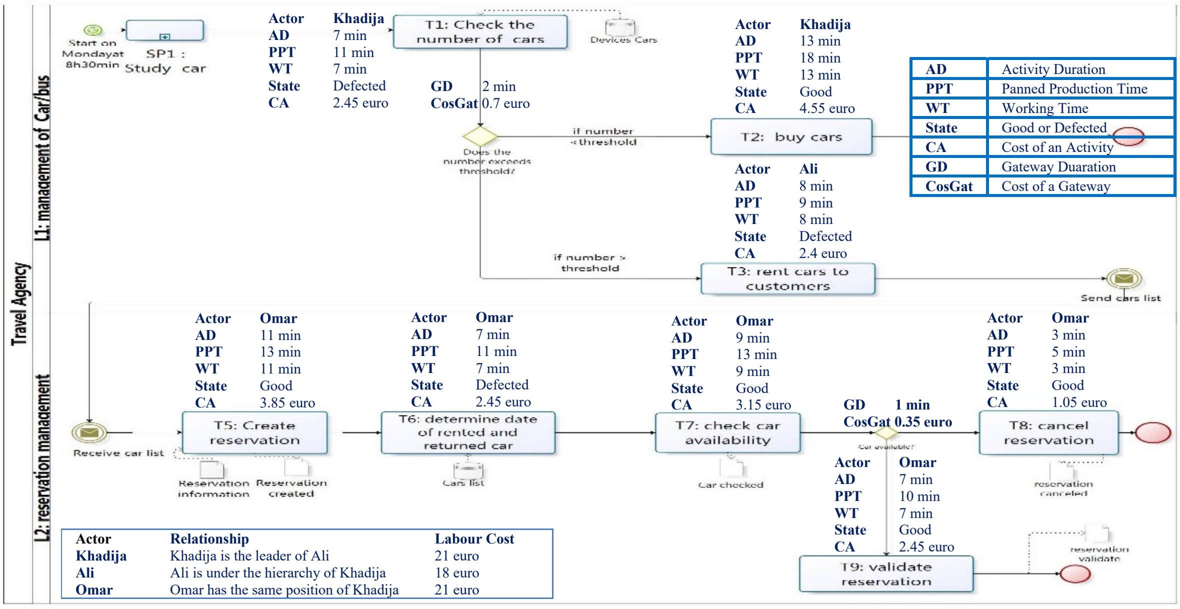

Figure 4: "Travel Agency process".

Experiment 1: According to the actor character-istics exercise, 75% of the responses are correct. The result expresses that the majority of students can assess the performance of the actor. This result is also established based on their responses to the last question for each category of the first exercise, which is about the availability, suitability and cost of the actor.

Indeed, 78% of students considered the actor as always available, 22% as rarely available. In addition, 69% of the responses are correct. They show that a good number of students have correctly evaluate competences of actors having low skills. In addition, 52% of students considered the actors as expensive, 29 % as acceptable, and 19% as cheap.

According to BPMN elements characteristics exercise, 67% of the responses are correct. Based on this result, we can deduce that the majority of students can evaluate the performance of BPMN elements. This result is also established based on their responses to the last question for each category of the second exercise, which is about the time behaviour and cost of BPMN elements.

Indeed, 61% of students consider the time of activities in the BPMN model as normal, 23% as maximal and 16 % as minimal. In addition, 74% of students considered activities as expensive, 16 % as acceptable, and 10% as cheap.

Experiment 2: Uses our tool to estimate the actor characteristics levels and the BPMN element characteristics levels of the business process model illustrated in Figure 4. Our BPMN model is annotated by temporal constraints and semantic information (cost and organizational aspects).

Considering the limited space, we present an example of the actor characteristic (suitability) and an example of BPMN element characteristic such as the time behaviour of an activity.

For instance, the estimated suitability level of the actor "Omar" is "*Having Low Skills with a certainty degree of 63%*". Figure 5 shows the interface for actor suitability assessment.

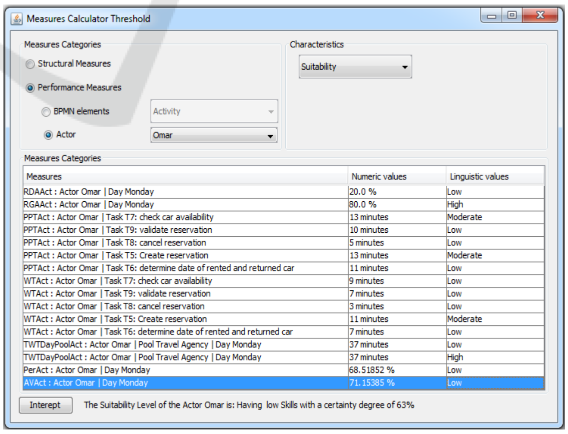

Figure 5: Availability characteristic assessment interface.

In addition, the estimated time behaviour level of the BPMN element "Activity" is "*Normal with a certainty degree of 67%*". Figure 6 shows the interface for the activity assessment.

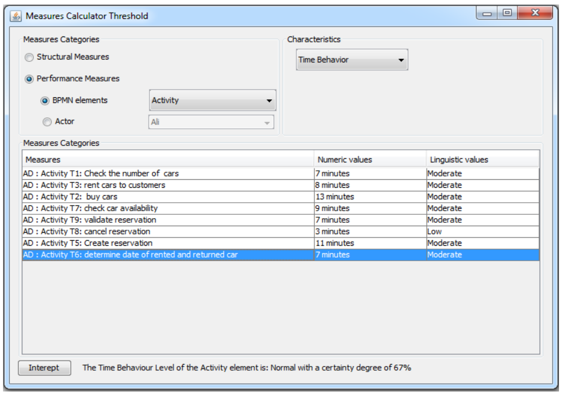

Figure 6: Time behaviour characteristic assessment interface.

Based on responses of students to the suitability questions, experiments reveal that the suitability of actors as having low skills. This result is conform with the evaluation effected by FuzzPer, which reflects that the actors in the presented BP model as “having low skills”. As the same, regarding the time behaviour, students consider the time of activities in the BPMN model “Travel agency process” as normal. These compliant results demonstrate that our methodology provides promising results that should be shown based on further experiments.

6 THREATS TO VALIDITY

This study, as every other empirical business process study, is subject to two type of threats: internal, external (Wohlin et al., 2000).

The internal validity threats are related to the following issues: The first issue is the use of three algorithms (J48, RandomTree, REPTree) to find the imprecise thresholds using our methodology. We chose REPTree algorithm for finding threshold values as it is the one that yielded the best results. Of course, we should find other algorithms to determine more objectively the values of thresholds. The second issue is that although the annotation of BPMN models are listed in the datasets used, these information has not been tested. Therefore, some errors may not have been discovered in some BPMN models. Considering this, our thresholds could have found faults that are yet undiscovered.

The external validity is related to the limited number of the used databases (one datbase). Our study covers only BPMN models having small/ medium size. This means that the findings of this study cannot be generalized to all BPMN models, particularly those having complex size. Further tests on many other BP from different domains would be needed to generalize obtained results.

7 CONCLUSION

In this paper, we proposed a methodology to assess the performance of actors and BPMN elements. Our methodology use a set of performance measures. It followed two major phases: threshold determination and fuzzy logic application.

The first phase “Threshold determination” is based on “Business process database”. It is composed of two stages: Analyze data and Validate Data. The first stage starts by collecting a set of BPMN models annotated by semantic and temporal information, then preparing these models through creating matrices related to actors and to BPMN elements to evaluate their characteristics and finally, applying Data mining to build decision trees using WEKA system. The system determine approximate thresholds for each used performance measures.

The second phase of the proposed methodology uses fuzzy logic to handle approximate and imprecise nature of the obtained thresholds in the first phase. To automate BP models performance evaluation, we developed a FuzzPer tool. To illustrate the efficiency of the performance tool, we rely on two types of experimental evaluation. The former is accomplished with students while the second is done through the proposed tool.

The preliminary experiments’ results of the proposed tool display encouraging results related to the evaluation of the actor and BPMN elements performance.

Our future work focuses on two main axes: 1) validate the proposed fuzzy methodology for BP performance evaluation through some real case studies with business experts and 2) evaluate the performance of actors and BPMN elements in terms of other characteristics.

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