2009 IEEE Conference on Commerce and Enterprise Computing

CEC 2009

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Prediction Models for BPMN Usability and Maintainability

Elvira Rolón
Autonomous University of Tamaulipas
University Centre Tampico-Madero S/N, 89336, Tampico, Tamps. México
erolon@uat.edu.mx

Laura Sánchez[1], Félix García[1], Francisco Ruiz[1,2], Mario Piattini[1]
[1]Alarcos Research Group, University of Castilla-La Mancha
Paseo de la Universidad Nº 4, 13071 Ciudad Real, Spain
{Laura.Sanchez, Felix.Garcia, Francisco.RuizG, Mario.Piattini}@uclm.es

[2]University of Cantabria, Department of Mathematics, Statistic and Computing
Santander, Spain

Danilo Caivano, Giuseppe Visaggio
University of Bari, Department of Computer Science
Via Orabona, 4 – 70125, Bari, Italy
{caivano, visaggio}@di.uniba.it

Abstract

The measurement of a business process in the early stages of the lifecycle, such as the design and modelling stages, could reduce costs and effort in future maintenance tasks. In this paper we present a set of measures for assessing the structural complexity of business processes models at a conceptual level. The aim is to obtain useful information about process maintenance and to estimate the quality of the process model in the early stages. Empirical validation of the measures was carried out along with a linear regression analysis aimed at estimating process model quality in terms of modifiability and understandability.

Keywords :business process models; measurement; regression model;

1. Introduction

Measurement has a long tradition and is a fundamental discipline in any type of engineering. Engineers need to be skilled in estimation and measurement [1] which implies: a) understanding the activities and risks involved in a development process, b) predicting and controlling the activities involved, c) managing the risks, d) a reliable delivery, and e) proactive risk management in order to avoid crises.

The management of measurement and derived information makes it possible to learn from the past in order to improve performance and achieve better predictability over time. Measurement helps engineers to track and estimate effort, improve artefacts and processes, plan, set goals and to convey reasons for improvement [2]. Thus, one of the objectives of a measurement process is to collect quantitative indicators of entities, where an entity is an element to which it is possible to apply a measurement process and which is characterized by a series of attributes [3]. Measures are therefore applied to these attributes and entities, and objective information concerning the state of processes and products is eventually obtained. Following the indications of the Software Measurement Ontology [3] we choose the term 'measure' rather than 'metric'. In our case, measurable entities are business processes since they generate most of the cost of any business, so improving the efficiency in any organization generally necessitates improving its processes.

Business processes also strongly influence the quality of the product and customer satisfaction, both of which are of fundamental importance in the marketplace. Any well engineered business process is one in which management establishes the measurements of process performance, and influences process performance in a desired direction by using these measurements to control the process [4]. These measurements are essential in organizations which intend to attain a high level of maturity in their processes, so it is important to integrate measurement as a fundamental part of their business objectives in order to obtain more mature organizations [5].

978-0-7695-3755-9/09 $25.00 © 2009 IEEE
DOI 10.1109/CEC.2009.53

In this work we present the empirical validation results of a set of measures defined to evaluate the structural complexity of BPMN models. The paper is organized as follows: section 2 presents related works. In sections 3, 4 and 5 the results of an empirical study and a linear regression analysis are described respectively. Our main objective is to identify those measures that may be useful in predicting different aspects of the understandability and modifiability of business process models at the time of carrying out future maintenance tasks of the models, thus making models easier to understand and to modify for all stakeholders.

2. Related Works

The interest in measurement for business processes has increased in recent years, particularly with regard to design measures in business process models. One reason for this might be that the scientific community is aware of the importance of carrying out these activities in the early stages of the process lifecycle to avoid errors, since eliminating them in later stages is more costly.

In 2001, the author of [6] adapted software complexity metrics to business processes, which were represented with graphs, since graphs are a general means of representation which do not have the restrictions that specific notations usually have. However, other authors use EPC or a simplification of Petri nets as the notation for their research. In [7] the author describes understandability and modifiability metrics as coupling and cohesion; these are software adapted metrics for business process models represented with a graph notation. The proposal of [8] also shows error probability metrics in business process models with EPC notation.

On the other hand, validity is also an important aspect of defining a measure to confirm utility, so these measures should be validated by following theoretical or empirical frameworks. In [11] the author describes the goodness measure for business process models, which is used to obtain the most adequate model extracted from a log file. This measure has not yet been validated, but this process is under way. A proposal concerning complexity measures for business process models is described in [12], and these are validated by following the Perry framework [13] and using experiments to obtain real data. Once the data are obtained they are evaluated with statistical correlation techniques to validate the initial hypothesis. The understandability measures of [14] are also validated, and are based on the idea of the mental effort involved in understanding the structural relationships between elements in a business process model. This is an empirically validated measure using experiments, and the authors conclude that the lower the value of the measure, the lower the probability of finding errors in process models. The cognitive complexity of business process models was used to define the measure of [15], in which mental states are analyzed to understand models, i.e., to quantify the level of understandability or maintainability of business process models. Its validity has not yet been published. Another measure concerning understandability is described by [16], whose documentation shows different characteristics for understanding models. This measure is empirically validated with experimental techniques. A further validation technique is used in [17], specifically a case study technique. This proposal describes execution measures regarding the efficiency and effectiveness of business processes. The most recent proposals with regard to business process measures are described in [18] and [19], which in each case describe variability or uncertainty of the execution and the time of execution or costs of resources. Both measures have yet to be validated.

3. Empirical Validation of Measures for Business Process Models

In previous works [20] a set of measures for business process models (BPMs) represented in BPMN [21] was defined with the aim of evaluating the complexity of business processes by starting from the model which represents them at a conceptual level. These measures were placed in two categories: a) Base Measures, which consist principally of counting the process model's significant elements, and b) Derived Measures, defined by starting from the base measures. The latter allow us to discover the proportions that exist between different elements in the model. An advantage of these measures is their simplicity, which is considered as a desirable property in metrics [27] [30]. Moreover, we proposed a numerous set of measures to evaluate complexity. As suggested in [29] it is not realistic to measure complexity with a unique measure.

The usefulness of these measures was demonstrated with theoretical and empirical validation. Initially, these measures were theoretically validated according to the Briand et al. framework [22]. As a result, it was possible to group them according to the different properties of structural complexity they evaluate such as size, coupling and so on. These characteristics are related to internal quality. However, we believe that the structural properties of a business process model affect two characteristics of its external quality (according to ISO 9126): usability and maintainability, and therefore their subcharacteristics understandability and modifiability, respectively.

In order to validate the defined measures two families of experiments were carried out. The main objective was to corroborate that a correlation exists between the process models complexity and the understandability and modifiability, which allowed us to discover which of the measures defined could provide useful and objective information about the external quality of BPMs. The results obtained in the empirical validation of the first family are presented in [23]. These results were considered as preliminary, as they were not conclusive enough, given the high number of measures initially proposed and evaluated (60 in total). Anyway, these results were very useful in the second family of experiments planning, where those measures which were considered to be most meaningful with regard to the structural complexity of BPMs in the first family were selected. This was done by carrying out both correlation and a principal components analysis which made it possible to select and group the proposed measures according to their relevance. With regard to the Base Measures, three main groups were created with a total of 18 measures (Table 1): Group A included measures involving control-flows and gateways. Group B was composed of measures involving pools, lanes, message-flows and data objects. Group C included measures involving activities, events and sequence flows. A set of 11 Derived Measures was also identified.

In order to validate the 29 selected measures, a second family composed of five experiments was carried out, in which the understandability and modifiability aspects were investigated. The difference between the first and the second family was that in the latter, separate experiments were designed in order to investigate each aspect. Five experiments were planned in the second family: the first three were carried out to analyze the understandability (und) of the models; modifiability (mod) was evaluated in the last two experiments. The experimental plan for the experiments in the second family was the same as that used for the first family. However, only the main characteristics of the second family experimental plan are described in this paper owing to space limitation. Reader is referred to [24] for a detailed description of the design and the material used in the second family of experiments.

Table 1. Structural complexity measures for business process models

Base Measures			Derived Measures	
Group A: Control-Flow from Gateways	**NEDDB**	Number of Exclusive Data Based Decision	**TNG**	Total Number of Gateways *TNG = NEDDB+NEDEB+NID+NCD+NPF*
	NEDEB	Number of Exclusive Event Based Decision	**CLP**	Connectivity level between Participants $CLP = \frac{NMF}{NP}$
	NID	Number of Inclusive Decision		
	NCD	Number of Complex Decision		
	NPF	Number of Parallel Forking	**PLT**	Proportion of Pools/Lanes and Activities of the Model $PLT = \frac{NL}{TNT}$
	NSFG	Number of Sequence Flows from Gateways		
Group B: Pools/Lanes	**NP**	Number of Pools	**TNDO**	Total Number of Data Objects of the Model *TNDO = NDOIn + NDOOut*
	NL	Number of Lanes	**PDOPIn**	Proportion of Data Objects as incoming products and Total Data Objects of the model $PDOPIn = \frac{NDOIn}{TNDO}$
Messages	**NMF**	Number of Message Flows between Participants		
Data Objects	**NDOIn**	Number of Data Objects of Input to activities	**PDOPOut**	Proportion of Data Objects as Outgoing Products and total Data Objects $PDOPOut = \frac{NDOOut}{TNDO}$
	NDOOut	Number of Data Objects of Output to activities	**PDOTOut**	Proportion of Data Objects as Outgoing Product of Activities of the model $PDOTOut = \frac{NDOOut}{TNT}$
Group C: Events	**TNSE**	Total Number of Start Events	**TNE**	Total Number of Events of the Model *TNE = NTSE + NTIE + TNEE*
	TNIE	Total Number of Intermediate Events		
	TNEE	Total Number of End Events	**TNA**	Total Number of Activities *TNA = TNT + TNCS*
	NSFE	Number of Sequence Flows from events	**CLA**	Connectivity Level between Activities $CLA = \frac{TNA}{NSFA}$
Activities	**TNT**	Total Number of Tasks		
	TNCS	Total Number of Collapsed Subprocess		
	NSFA	Number of Sequence Flows between Activities	**TNSF**	Total Number of Sequence Flows of the model TNSF = NSFG + NSFE + NSFA

Subjects. The participant subjects in each experiment of the second family were students from differents universities (Table 2).

Table 2. Groups of participants in the second family

Exp.	Group	Nº Sub.	Profiles
1 (Und)	UCLM (Spain)	22	PhD students and students in Computer Engineering.
2 (Und)	UCLM (Spain)	40	Students of 4th year in Computer Engineering.
3 (Und)	UCLM (Spain)	9	PhD students and students in Computer Engineering.
4 (Mod)	University of Bari (Italy)	29	Students in Computer Engineering
5 (Mod)	UAT – (Mexico)	15	Master's students in Information Systems.

Material. The experimental material used to analyze understandability consisted of fifteen BPMN models with different structural characteristics and degrees of complexity. A questionnaire with three questions related to the understandability of the process model was produced for each model. In order to analyze the modifiability, twelve BPMN models and a questionnaire with two modification requirements for each model were provided. Moreover, in all cases the experimental subjects answered a question regarding the perceived complexity of the process model. The answers were given on a subjective base.

The hypotheses proposed with regard to the research objective in the first three experiments were:

- Null hypothesis, H_{0m}: There is no significant correlation between the structural complexity measures and understandability.
- Alternative hypothesis, H_{1m}: There is a significant correlation between the structural complexity measures and understandability.

The hypotheses in the last two experiments were:

- Null hypothesis, H0m: There is no significant correlation between the structural complexity measures and modifiability.
- Alternative hypothesis, H1m: There is a significant correlation between the structural complexity measures and modifiability.

The experiment variables defined were:

- Independent variables: the 29 structural complexity measures shown in Table 1.
- Dependent variables: business process model understandability and modifiability as defined in Table 3.

Table 3. Dependent variables

Dependent variable	Measures of the dependent variables
Understandability: The ease with which the model can be understood by the user.	**Answer Time**: Time required by the subjects to solve the understandability tasks
	Success rate: Number of correct answers related to understandability
	Efficiency: the ratio between the number of correct answers and the time
	Subjective evaluation: The subjective rating with regard to the complexity of required tasks
Modifiability: The ease with which the model can be modified, by possible errors, by requesting a specific modification or by new requirements.	**Answer Time**: Time required by the subjects to solve the modifiability tasks.
	Success rate: Number of correct answers related to modifiability
	Efficiency: the ratio between the number of correct answers and the time
	Subjective evaluation: The subjective rating with regard to the complexity of required tasks

4. Data Analysis and Interpretation

This section shows the results obtained from the empirical validation carried out for the experiments in the second family. In order to validate the results, a summary with the descriptive data was initially made. This summary included both the values of the 29 measures for each business process model, and the mean values of the marks given by the subjects for the sub-characteristics analysed and the average time of understandability and modifiability. Only the average time observed for understandability and modifiability is provided here for reasons of space (Table 4). The highlighted data in the table indicate the process models in which the subjects spent more effort when carrying out the requested tasks. After data summary was carried out, and in order to prove whether the distribution of the data obtained was normal, the Kolmogorov-Smirnov test (K-S test) [28] was applied.

Table 4. Values of answer times

Process model	Second Family				
	Understandability Times			Modifiability Times	
	Exp1	Exp2	Exp3	Exp4	Exp5
1	135	137	178	308	137
2	137	124	137	331	124
3	238	245	331	253	245
4	135	137	205	--	--
5	52	53	63	181	53
6	120	122	163	--	--
7	102	114	142	242	114
8	101	96	108	180	96
9	92	97	159	294	97
10	56	53	57	171	53
11	123	126	178	--	--
12	94	97	122	144	97
13	174	161	262	312	161
14	111	112	192	184	112
15	49	53	116	162	53

As a result of this it was obtained that the distribution was not normal, and we therefore decided to use a non-parametrical statistical test such as the Spearman correlation coefficient with a level of significance of $\alpha = 0.05$ which indicates the probability of rejecting the null hypothesis when it is certain (type I error). That is to say, a confidence level of 95% exists.

The Spearman correlation coefficient [31] was used to separately correlate each of the 29 structural complexity measures (Table 1) with the dependent variables as regards each of the aspects evaluated in the descriptive analysis (Table 3). Tables 5 and 6 shows the results obtained from the correlation analysis.

Table 5. Results of correlation analysis for understandability

Understandability												
Measure	Answer Times			Correct Answers			Efficiency			Subj. Evaluation		
	Exp-1	Exp-2	Exp-3	Exp-1	Exp-2	Exp-3	Exp-1	Exp-2	Exp-3	Exp-1	Exp-2	Exp-3
NEDDB	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓
NEDEB	✓	✓	✓		✓		✓	✓	✓		✓	✓
NID	✓	✓	✓		✓		✓	✓	✓		✓	✓
NCD	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓
NPF	✓	✓	✓		✓		✓	✓	✓		✓	✓
NSFG	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓
TNG	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓
NP	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
NL		✓	✓		✓			✓	✓		✓	✓
NMF	✓			✓	✓		✓			✓	✓	✓
NDOIn		✓	✓		✓			✓	✓		✓	✓
NDOOut		✓	✓					✓	✓		✓	✓
CLP		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
PLT		✓	✓		✓			✓	✓		✓	✓
TNDO		✓	✓		✓	✓		✓	✓		✓	✓
PDOPIn		✓	✓		✓			✓	✓		✓	✓
PDOPOut	✓	✓	✓		✓		✓	✓	✓		✓	✓
PDOTOut		✓	✓		✓			✓	✓		✓	✓
TNSE		✓	✓		✓			✓	✓	✓	✓	✓
TNIE		✓	✓		✓			✓	✓		✓	✓
TNEE	✓			✓	✓		✓			✓	✓	✓
NSFE		✓	✓					✓	✓		✓	✓
TNT	✓			✓			✓			✓		
TNCS		✓	✓		✓			✓	✓		✓	✓
NSFA	✓			✓			✓			✓	✓	✓
TNE	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
TNA	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
CLA						✓						
TNSF	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓

The measures for each aspect related to the dependent variable indicate, as a result of the analysis carried out, that there is a correlation with a level of significance greater than 0.05 between the structural complexity measures, Answer Time and the Correct Answers sub-characteristics of understandability (Table 5). Thus the null hypothesis can be rejected.

The analysis concerning the Efficiency and Subjective Evaluation also indicate a significant correlation between all the structural complexity measures and Understandability, except in the CLA measure.

Table 6 shows the results obtained with regard to the correlations between the measures and Modifiability. In particular, with regard to the fourth experiment, the results show a widespread correlation, while in the fifth experiment only a small number of measures (NEDDB, NEDEB, NID, NSFG, TNG and PDOTOut) are correlated with Modifiability sub-characteristics.

Table 6. Results of correlation analysis for modifiability

Modifiability								
Measure	Answer Times		Correct Answers		Efficiency		Sub. Evaluation	
	Exp-4	Exp-5	Exp-4	Exp-5	Exp-4	Exp-5	Exp-4	Exp-5
NEDDB	✓	✓			✓		✓	✓
NEDEB	✓	✓			✓		✓	
NID	✓	✓			✓		✓	
NCD	✓				✓		✓	
NPF	✓				✓		✓	
NSFG	✓	✓			✓		✓	✓
TNG	✓	✓			✓		✓	✓
NP								
NL	✓		✓		✓		✓	
NMF								
NDOIn								
NDOOut	✓				✓		✓	✓
CLP								
PLT	✓		✓		✓		✓	
TNDO					✓		✓	
PDOPIn				✓				
PDOPOut	✓	✓			✓		✓	✓
PDOTOut			✓		✓		✓	
TNSE	✓		✓		✓		✓	
TNIE	✓		✓					
TNEE							✓	
NSFE								
TNT	✓				✓			✓
TNCS			✓					
NSFA	✓				✓			✓
TNE	✓							
TNA	✓				✓			✓
CLA	✓		✓		✓		✓	
TNSF	✓				✓		✓	✓

These measures refer to sequence flows and decision nodes. The difference in the results between experiments can be explained by the differences in the sample size (about 50%). Moreover, the measures validated in both experiments may be useful for carrying out improvements or for choosing functional models, and thus simplifying the models' modifiability tasks.

5. Regression Analysis

Once the correlation analysis had been carried out, the following step consisted of determining the existing relation between the variables. In order to obtain the functional models that allow us to carry out predictions with regard to the understandability and modifiability of BPMs, we carried out a Principal Component Analysis (PCA) to detect measures that could be related to one another when measuring a common aspect of the structural complexity of BPMs. PCA is a useful statistical technique which supports the reduction of a complex data set to a lower dimension [32].

As a result, for both dependent variables (understandability and modifiability) the factorial analysis identified a set of 17 measures from a total of 29 independent variables. In particular, for Understandability, the set of 17 variables was obtained from 6 main components which explain 91.59% of the total variance, while for Modifiability, the 6 components identified explain 93.91% of the variance. The results are presented in Table 7.

Table 7. Summary of PCA results – family 2.

Dependent Variable	Independents Variables (Measures)	% of Accumulated Variance
Understandability	NEDDB, NCD, NPF, NSFG, TNG, NL, NMF, NDOIn, NDOOut, CLP, TNDO, PDOPOut, PDOTOut, TNSF, NSFE, TNE y CLA	91,59 %
Modifiability	NEDEB, NIC, NCD, NSFG, TNG, NL, NMF, NDOIn, NDOOut, CLP, TNDO, PDOTOut, TNIE, TNEE, NSFA, TNA y CLA.	93,91 %

We next used a multiple linear regression analysis to analyze the relationship between the dependent and independent variables, i.e. the relation between Understandability and Modifiability and the set of identified measures by developing a linear equation with predictive aims.

5.1 Building a Regression Model

We first took into account the results obtained from the Principal Component Analysis carried out in order to select the independent variables with high loadings in the rotated components. We then estimated models for each dependent variable by following the stepwise forward selection of the independent variable. The criterion used to select the models was simple: the lower the p-value of the F-test, the better the goodness of fit (R^2), where F-test is used to demonstrate hypotheses [33] and goodness of fit is a coefficient of determination to provide a measure of how well future outcomes are likely to be predicted by the model [34]. When building the regression equation, 80% of the data collected in the empirical study were used with regard to the following three dependent variables related to Modifiability and Understandability: the Answer Times, number of Correct Answers and Efficiency. Table 8, Table 9 and Table 10 show the obtained equations.

After building the regression models, the remaining 20% of the collected data was used to validate the precision of the model. Two criteria widely used in Software Engineering to evaluate prediction models are: 1) Mean Magnitude of Relative Error (MMRE) and 2) the Prediction Level ($Pred_n$), which represents the proportion of the foretold values with an MRE smaller or equal to a specified value (generally 0.25 or 0,30) [25]. The MMRE and Pred (n) measures are used to select the best model from two or more alternative models. The model with the lowest MMRE or • 0,25 and/or Pred (0,25) • 0,75 or Pred (0,30) • 0,70 is deemed to be the best [26]. Table 8, Table 9 and Table 10 show the obtained values of MMRE and Pred (n).

In Table 8, although the resulting models are not within the desired rank, they obtain values near these intervals. In particular, given the values of MMRE and Pred, the best predictive linear model for the Understandability time is that obtained from the data of experiment 1.

Table 8. Linear regression analysis - times.

Exp.	Regression Models for Times	MMRE	Pred (0,25)	Pred (0,30)
Exp-1 (Und)	**40,622343-0,205153*TNSF+ 9,562413*TNE-8,387718*NSFE+ 5,411965*TNG+1,973189*NMF**	**0,27**	**0,60**	**0,68**
Exp-2 (Und)	48,104707+0,012743*TNSF+ 3,836635*NMF+8,588339*TNG- 10,555917*NEDDB+3,228044*TNE	0,35	0,49	0,58
Exp-3 (Und)	47,673868+1,647713*TNSF+ 7,014526*TNE	0,32	0,47	0,53
Exp-4 (Mod)	**158,073512+3,467248*NSFG+ 31,664625*NL-7,905191*NMF+ 3,379862*TNA**	**0,85**	**0,26**	**0,29**
Exp-5 (Mod)	All the variables were eliminated			

This model can be used to predict Understandability based on the total number of sequence flows (TNSF), the total number of events (TNE), the number of sequence flows coming from an event (NSFE), the total number of gateways (TNG), the number of message flows (NMF) and the number of exclusive nodes data based (NEDDB) of a business process model. Analogously, we can predict the Modifiability times starting from: the number of lanes (NL), number of message flows (NMF) and the total number of activities (TNA) of a business process model.

Table 9. Linear regression analysis – correct answers.

Exp.	Regression Models for Correct Answers	MMRE	Pred (0,25)	Pred (0,30)
Exp-1 (Und)	2,968785-0,078781*CLP	0,15	0,85	0,89
Exp-2 (Und)	**2,922682+0,003581*TNSF- 0,026920*NMF+0,062145*NL- 0,012397*NSFG**	**0,13**	**0,82**	**0,85**
Exp-3 (Und)	All the variables were eliminated			
Exp-4 (Mod)	**0,774070-0,244445*NL+ 0,962727*CLA**	**0,26**	**0,72**	**0,72**
Exp-5 (Mod)	All the variables were eliminated			

Table 9 shows that for both Understandability and Modifiability, the obtained models are very good predictive models. According to the Understandability regression models, if we know the connectivity level between pools (CLP), the total number of sequence flows (TNSF), the number of sequence flows coming from a gateway (NSFG) and the number of lanes (NL) of a business process model, we can predict the number of Correct Answers. As regards Modifiability, if we know the number of lanes (NL) and the connectivity level between activities (CLA) of a business process model, we can predict the number of Correct Answers in the modifiability tasks.

Finally, Table 10 shows the regression models for Efficiency with regard to Understandability and Modifiability. In general, the regression models do not seem to be very good since they are very distant from the rank of desired values, with the exception of the prediction model of Experiment 2.

Table 10. Linear regression analysis - efficiency.

Exp.	Regression Models for Efficiency	MMRE	Pred (0,25)	Pred (0,30)
Exp-1 (Und)	0,060523-0,000381*TNSF-0,009979*NDOOut-0,003511*CLP+0,004177*TNDO	0,43	0,43	0,51
Exp-2 (Und)	**0,063530-0,000431*TNSF-0,008013*CLP-0,008838*NDOOut+0,005739*NDOIn-0,003917*NSFE+0,001941*NMF+0,003726*NL+0,001604*TNE**	**0,33**	**0,48**	**0,58**
Exp-3 (Und)	0,058983-0,000598*TNSF-0,002226*NDOOut	0,62	0,27	0,33
Exp-4 (Und)	**.-0,003386-0,000222*NSFG-0,002153*NL+0,014281*CLA+0,00064*CLP**	**0,62**	**0,25**	**0,25**
Exp-5 (Und)	All the variables were eliminated			

Therefore, if we know the total number of sequence flows (TNSF), the number of data objects of output (NDOOut), the connectivity level between participants (CLP), the total number of data objects (TNDO), the number of data objects of input (NDOIn), the number of sequence flows coming from an event (NSFE), the number of message flows (NMF), the number of lanes (NL) and the total number of events (TNE) of a business process model, we can predict the Efficiency for Understandability.

Finally, for Modifiability, we must know the number of sequence flows coming from a gateway (NSFG), the number of lanes (NL), the connectivity level between activities (CLA) and the connectivity level between participants (CLP).

6. Conclusions

As a result of carrying out a correlation and a multiple linear regression analysis from the data collected in a family of experiments, it has been possible to identify a reduced group of measures that may be useful in predicting aspects such as Answer Times, Correct Answers and Efficiency when evaluating the Understandability and Modifiability of business process models expressed with BPMN.

Of the 29 measures analyzed, and after carrying out a correlation and a principal components analysis of the variables, we know that 12 of the measures (TNSF, TNE, NSFE, TNG, NMF, NEDDB, CLP, NL, NSFG, NDOOut, TNDO, NDOIn and NSFE) are extremely useful for predicting the three aspects of Understandability of a business process model.

With regard to Modifiability, only 6 measures (NSFG, NL, NMF, TNA, CLA and CLP) were identified as good predicting variables. By crossing the data obtained we can see that the measures NSFG, NL, NMF and CLP can be considered as good predictors for both dependent variables.

The regression models obtained represent a very good guideline for defining understandable and modifiable processes or for predicting such characteristics in those which already exist. They are also useful for guiding process improvement initiatives.

Future works will be focused on refining the regression models built by carrying out new experiments and building indicators from the validated measures by means of the definition of decision criteria.

Acknowledgments. This work has been partially financed by the INGENIO Project (Junta de Comunidades de Castilla-La Mancha, Consejería de Educación y Ciencia, PAC 08-0154-9262); ALTAMIRA (Junta de Comunidades de Castilla-La Mancha, Fondo Social Europeo, PII2I09-0106-2463) and ESFINGE Project (Ministerio de Educación y Ciencia, Dirección General de Investigación/Fondos Europeos de Desarrollo Regional (FEDER), TIN2006-15175-C05-05.

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