BUSINESS PROCESS MODEL IMPROVEMENT BASED ON MEASUREMENT ACTIVITIES

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Keywords: Business process, Measurement, Continuous improvement, BPMN.

Abstract: The current importance of Business Process improvement lies in the fact that it is a key aspect for organizational improvement. Since business process improvement can be dealt from different perspectives, we propose the use of measurement as a technique by which to collect information concerning the quality of the process. We have specifically applied measures to the design stage of the business process lifecycle, which signifies measuring conceptual models. Measurement in Design and Analysis lifecycle stage has several advantages, principally in that it is a means to avoid the propagation of errors to later stages, in which their detection and correction may be more difficult. We therefore propose certain steps for business process model improvement, based on measurement activities (measurement, evaluation, and redesign). These activities have been applied to a real hospital business process model. The model was modified by following expert opinions and modelling guidelines, thus leading to the attainment of a higher-quality model. Our findings clearly support the practical utility of measurement activities for business process model improvement.

1 INTRODUCTION

In recent years, business process (BP) modelling and improvement has become an important means of ensuring changes in an organization's structure and functioning, thus leading to the creation of a more competitive and successful enterprise (Damij, Damij et al. 2008). BP influences product quality and customer satisfaction, which are fundamental aspects in a market environment, and enterprises are therefore forced to improve their processes in order to improve products and services (Cardoso 2006).

The first step towards improving business processes is to collect any data regarding their design, deadlocks, bottlenecks, etc. Measurement is a good means of collecting this kind of data, and serves at least the following three purposes: understanding, control and improvement (Park, Goethert et al. 1996). The use of measurement information therefore makes it possible for organizations to learn from the past in order to improve their performance and achieve better predictability over time.

A business process is a complex entity with a characteristic lifecycle. In our work we consider the approach defined by Weske (Weske 2007), who organizes the lifecycle in a cyclic structure with logic dependences between the design and analysis, configuration, enactment, and evaluation stages. We focus on the first stage, *design and analysis*, in which the principal activity is that of process modelling. The main purpose of design and analysis is to capture the business schema and general procedures (Sparks 2000). The conceptual models produced in this stage are first required to be intuitive and easily understandable in order to facilitate communication among stakeholders. Measuring and improving BP models has several advantages, principally that of avoiding the propagation of errors or bad-structures to later lifecycle stages, in which corrections and modifications may involve a high economic cost and effort (Wand and Weber 2002).

Measures for conceptual models deal with the static properties of BP and are defined upon the BP model at the time of the design. Several initiatives concerning the measurement model have recently been published, owing to the advantages of improving business processes in this stage. Most of the measures published to date have been collected

Sánchez-González L., Ruiz F., García F. and Piattini M..
BUSINESS PROCESS MODEL IMPROVEMENT BASED ON MEASUREMENT ACTIVITIES.
DOI: 10.5220/0003462201040113
In *Proceedings of the 6th International Conference on Evaluation of Novel Approaches to Software Engineering* (ENASE-2011), pages 104-113
ISBN: 978-989-8425-57-7

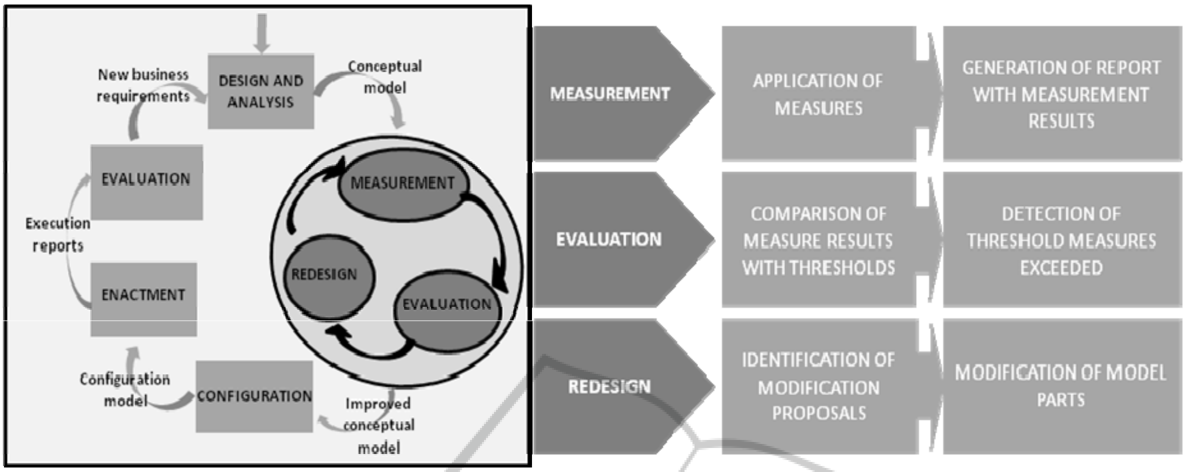

Figure 1: Improvement activities in BP lifecycle.

in (Sánchez-González, García et al. 2010b). This work shows that there is no consensus among researchers as to which measurable concepts it is most interesting to measure (complexity, structuredness, cohesion, coupling, etc). It also highlights that most of the proposals have not been empirically validated. This lack of validation particularly emphasises the need for research in this area. The work presented herein contributes to the maturity of BP measurement through the collection of measures and the demonstration of their practical utility in an experience report.

The principal idea behind our proposal is to apply measurement during the early stages of the lifecycle, the *design and analysis stage*, in order to obtain feedback controlled by measures and thereby achieve a higher-quality implementation of the process, with a lower value of complexity, therefore making it easier to maintain (Mendling 2008). The measurement process is divided into three activities: applying measures, evaluating measurement results and redesigning the model. The pragmatic idea of these activities is to discover unsafe design, hazardous structures or unexpected. Finally, one critical aspect of the improvement activities is to demonstrate that they are potentially useful in practice. We therefore present an experience report of the application of improvement activities to a real hospital business process.

The remainder of the paper is as follows. In Section 2 we describe the improvement activities in which measures were applied, evaluate the measurement results and redesign the model. In Section 3 we present an experience report of the application of these activities to a real business process, specifically a hospital business process. In Section 4, we describe some implications and limitations of this research. Finally, Section 5 shows our conclusions and presents topics for future research.

2 BUSINESS PROCESS MODEL IMPROVEMENT

In this article, we propose certain activities for business process model improvement. The principal idea is to collect as much information as possible about the static properties of the business process. The activities are: applying measures collected in previous works, evaluating measurement results against threshold values and redesigning the model. These three activities can be executed in a cyclic manner, signifying that multiple iterations can be run to obtain a high-quality model. This idea is depicted in greater detail in Figure 1.

In Figure 1 the lifecycle stages are represented as a square and the improvement activities as ellipses. The *design and analysis stage* initially produces a conceptual model. This model serves as input for the improvement activities. The improvement of the model can be carried out in several iterations of the 3 activities (*measurement, evaluation and redesign*). These activities can be introduced in the BP lifecycle as an extended stage, which can enrich the final product. After the *configuration stage*, the execution model is enacted through the generation of log files, which describe all the steps followed to achieve the business goals. These log files can be measured (processed) in order to discover certain important aspects such as execution time, deadlocks, etc. The measurement initiatives for improvement in the execution stage are described in (Delgado, Ruiz et al. 2009). The evaluation of these execution reports implies the generation of new business requirements which had not previously been considered.

2.1 Measures for Business Process Conceptual Models

In recent years, the number of measurement approaches for conceptual models has grown considerably owing to the advantage of improving business processes in the early phases. BP model measures are used to quantify structural aspects of models, which signifies measuring their internal quality. This internal quality is understood as the model's total number of characteristics from an internal view, and this is measured and evaluated against the internal quality requirements (ISO/IEC 2001). Internal quality (quality in general) can be seen from different points of view, and should therefore be quantified with more than one measure in order to obtain as much information as possible with regard to the model. For example, model complexity cannot be measured solely with the Control-flow Complexity (CFC) measure, because this measure only takes into account decision node elements.

As we mentioned, various measures are found in literature (Sánchez-González, García et al. 2010b), and Table 1 specifically shows references to their measurement initiatives and provides a brief description of them.

However, it is also important to consider external quality in conceptual models. External quality refers to the total number of characteristics in the model from an external view (ISO/IEC 2001), such as how understandable the models are, how difficult it is to modify them, etc. From the point of view of a top-down quality SEQUAL framework (Krogstie, Sindre et al. 2006), understanding is an enabler of pragmatic quality, which relates to model and modelling and its ability to enable learning and action. In order to clarify this idea, Figure 2 shows the relationship between internal and external quality and some examples of measurable attributes.

Most authors have carried out experiments focused on the relationship between measures and external quality attributes: understandability and modifiability. These belong to the more general concepts of usability and maintainability respectively (ISO/IEC 2001).

To the best of our knowledge, very few articles concerning the relationship between measures for internal quality and measures for external quality

Table 1: Proposals of measures for business process models.

Measure	Description
Coupling, cohesion and connectivity level (Vanderfeesten, Cardoso et al. 2007; Vanderfeesten, Reijers et al. 2008)	Cohesion and coupling between activities and cross connectivity in the relationship between nodes and directed arcs.
Structural complexity (Rolón, García et al. 2006)	Measures related to the number of different elements of BPMN models.
Error probability (Mendling 2008)	Number of nodes, diameter, gateway mismatch, depth, density, average and max connector degree, cyclicity, sequentiality and separability.
Control flow complexity (Cardoso 2006)	Related to the number of OR-split, AND-split and XOR-split
Entropy (Jung 2008)	Uncertainty or variability of workflow process models
Structuredness (Laue and Mendling 2009)	Number of unstructured parts
Complexity (Meimandi Parizi and Ghani 2008)	Activity, control-flow, data-flow and resource complexity
Goodness (Huan and Kumar 2008)	Goodness of models regarding execution logs

have been published to date, although some research has been published in (Rolón, Cardoso et al. 2009; Rolon, Sanchez et al. 2009; Sánchez González, García et al. 2010), and these works obtained a subgroup of measures which can be considered as good indicators for understandability and modifiability. This subgroup of measures is shown in Table 2. The application of this subgroup of measures is produced in a pair *(measure, result)*, which should be reported in a document in order to be used in next activity: evaluation.

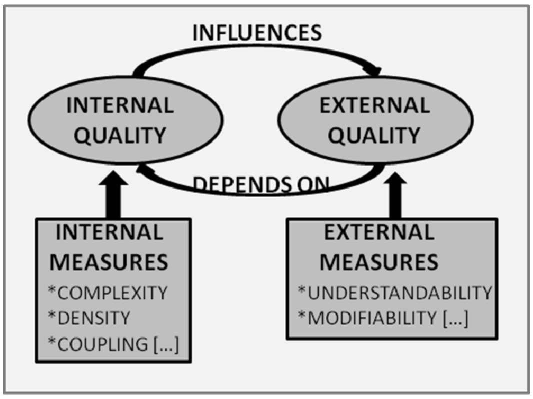

Figure 2: Internal and external quality in conceptual models.

2.2 Evaluation of Measurement Results

The evaluation of measurement results involves providing an objective assessment of them. Numerical results only offer information in terms of comparison between models rather than an independent interpretation. For example, given two process models, it is possible to discover not only which of them is best in the relative terms of a specific measure, but whether the values are acceptable or not. It is therefore necessary to consider the threshold or limit values in order to indicate for what specific value the measure's quality begins to decline.

Table 2: Empirically validated measures and their relationship with understandability and modifiability.

Measure	Description	U *	M *
Measures of Rolón (Rolón, García et al. 2006)			
TNSF	Total Number of sequence flows	X	
TNE	Total Number of events	X	
TNG	Total Number of gateways	X	
NSFE	Number of sequence flows from events	X	
NMF	Number of message flows	X	
NSFG	Number of sequence flows from gateways	X	X
CLP	Connectivity level between participants	X	
NDOOut	Number of data objects which are outputs of activities	X	
NDOIn	Number of data objects which are inputs of activities	X	
CLA	Connectivity level between activities		X
Measures of Cardoso (Cardoso 2006)			
CFC	Control flow complexity. Sum over all gateways weighted by their potential combinations of states after the split	X	X
Measures of Mendling (Mendling 2008)			
Number of nodes	Number of activities and routing elements in a process model	X	
Gateway mismatch	Sum of gateway pairs that do not match each other, e.g. when an AND-split is followed by an OR-join	X	X
Depth	Maximum nesting of structured blocks in a process model	X	
Connectivity coefficient	Ratio of total number of arcs in a process model to its total number of nodes	X	
Density	Ratio of total number of arcs in a process model to the theoretically maximum number of arcs		X
Sequentiality	Degree to which the model is constructed from pure sequences of tasks	X	X

Various proposals for the extraction of threshold values exist in literature, principally in the Software Engineering field. Some proposals for thresholds are derived from experience (McCabe 1976; Nejmeh 1988; Coleman, Lowther et al. 1995), but the lack of scientific support has led to disputes about their values. Some authors, on the other hand, have used statistical techniques to obtain thresholds. For example, Shatnawi (Shatnawi 2010) extracted thresholds for Object Oriented (OO) code measures in order to study the relationship between OO and error-severity categories. This author also validated the Bender method (Bender 1999) and found that there are effective thresholds for the measures analyzed.

With regard to business process measurement, we have attempted to extract threshold values for some measures in previous works. This is the case of *Control-flow complexity* measure, *structural complexity* and *error probability* measures, which were used to apply the Bender method in order to extract thresholds. These works were published in (Sánchez-González, García et al. 2010a; Sánchez-González, Ruiz et al. 2011). Table 3 shows extracted thresholds for some empirically validated measures. This table divides the domain of the measure into 4 different groups, depending on the level of efficiency: "very efficient", "fairly efficient", "fairly inefficient" and "very inefficient".

2.3 Redesign of Business Process Models

In this section, we focus on modifying some parts of the model in order to improve its general quality. Those parts that are candidates for alteration have been identified through the use of measures. For example, let us imagine that we are analyzing the results of the CFC measure in a specific model, and we obtain a numerical value which is higher than the threshold: "If CFC is higher than 44, the model is difficult to understand". These results indicate that the number of decision nodes must be reduced in the model, since it may be difficult for stakeholders to understand.

Nevertheless, modifying the model using only the information collected from measures and thresholds can be quite difficult. Some guidelines therefore exist to assist modellers in this task. In literature, it is possible to discover various guidelines for inexpert modellers, whose purpose is to obtain higher-quality models that can ensure a more reliable execution. Mendling et al. (Mendling, Reijers et al. 2010) proposed seven pieces of advice for modellers (denominated as 7PMG) which are built on strong empirical insight. This advice is related to the maximum number of nodes before decomposition, number of events, OR-routing elements, routing paths per element or the use of a verb-object activity label. On the other hand, Becker et al. (Becker, Rosemann et al. 2000) define certain guidelines of modelling (GoM), which are specifically six general techniques for adjusting models to the perspectives of different types of user and purposes. To illustrate the used of these guidelines, let us imagine the following example. If the measure "total number of events" is higher than 20 (very inefficient), 7PMG advises that the use of "one start and one end event" is the best way to reduce the measure value.

Redesign therefore involves changing those specific parts of the model with low quality detected by measures. Modelling guidelines can also help to ensure the quality of the model but a previous measurement effort is necessary to identify any potential problems.

Table 3: Thresholds for business process model measures.

	1: very inefficient	2: fairly inefficient	3: fairly efficientt	4: very efficient
Understandability				
Nºnodes	65	50	37	31
GatewayMismatch	29	16	6	1
Depth	4	2	1	1
Coefficient of connectivity	1,7	1,1	0,6	0,4
Sequentiality	0,1	0,35	0,6	0,7
TNSF	72	49	34	20
TNE	20	12	7	2
TNG	17	10	5	0
NSFE	28	13	4	0
NMF	27	15	7	1
NSFG	40	22	11	0
CLP	7,5	4,23	2,2	0,2
NDOIN	31	44	4	0
NDOOUT	23	11	3	0
CFCxor	30	17	8	1
CFCor	9	4	1	0
CFCand	4	2	0	0
Modifiability				
GatewayMismatch	46	22	4	1
Densitiy	0,6	0,22	0,001	0
Sequentiality	0	0,18	0,6	0,86
NSFG	25	13	9	0
CLA	0,53	0,875	1,1	1,3
CFCxor	27	16	8	1
CFCor	9	4	1	0
CFCand	6	2,3	0	0

3 EXPERIENCE REPORT: HOSPITAL PROCESS

In order to demonstrate the practical utility of this proposal, we describe an experience report which was developed in the General Hospital of Ciudad Real (GHCR) in Spain. First, a specific work group was created, consisting of specialists in modelling tasks (Software Engineers) and health professionals at the hospital:

a) Those responsible for processes: the assistant director of nursing and the person responsible for hospital's admissions units.
b) Collaborators: head of human resources and finances, head of computer services and head of out-patients' healthcare.

The work group then modelled various processes which had previously been selected by the hospital's managerial and quality staff, although in this paper we shall focus on the "Incorporation of a new employee" (INE) process, which includes the training plan, information and suitability of those people involved in the hospital in order to facilitate their integration into the new job. The process model is shown in Figure 3.

This process was selected as a low-complexity process, although the services provided are very important. It is a purely administrative process (it is not related to patient care), but moves a large number of users (in 2007, the hospital staff consisted of 2.600 workers, and 6989 new contacts were made with regard to substitutions and new incorporations). This process involves different professional categories: doctors, pharmacists, nurses, psychologists, administrative and technical staff and others. Specific process characteristics were the following:

a) Mission: to promote the organization of the INE process, which includes a plan for training, information and adaptation of the people involved to the hospital requirements in order to facilitate their integration into the new job.
b) Limits: the INE process starts when the professional comes to the hospital and finishes when he/she is incorporated into the new job.
c) Clients: new professionals
d) People responsible: those responsible for nursing, medical aspects and management.
e) Participants: new professionals in hospital, human resources, computer services, lingerie, pharmacy, prevention services, nursing and management service.

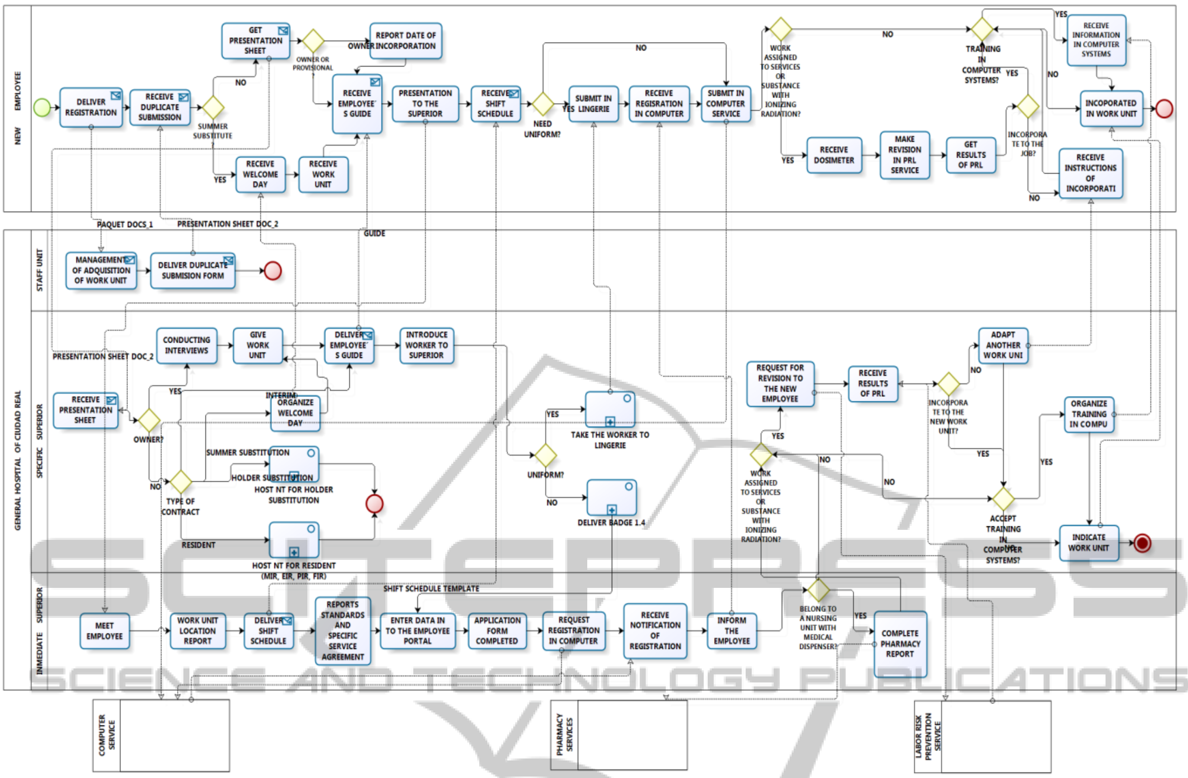

Figure 3: BPMN model for the Incorporation of the New Employee (INE) hospital process.

f) Suppliers: human resources, provisions, maintenance, training and information systems.

The results of the application of the improvement activities are described in the following sub-sections:

3.1 Applying Improvement Activities

The design of the INE process model is represented in BPMN (OMG 2006) (Figure 3), the *de facto* standard for BP modelling. This conceptual model was a candidate for improvement. We therefore applied the three measurement activities previously presented.

A) Measurement

We applied most of the measures published to date, particularly those measures which had been empirically validated. It was not possible to apply all of them owing to the absence of certain elements in this specific model. The results obtained are shown in Table 4 (pair measure/result).

Table 4: Measurement results for the INE process.

Measure	Result	Understandability	Modifiability
Nº of nodes	59	Fairly inefficient	-
Density	0,02	-	Fairly efficient
Sequentiality	0,396	Fairly inefficient	Fairly inefficient
Connectivity coefficient	1,54	Very efficient	-
Mismatch connector	16	Fairly inefficient	Fairly inefficient
Control flow complexity	22	Fairly inefficient	Fairly inefficient
CLA	0,61	-	Very inefficient
CLP	3	Fairly efficient	-
TNE	5	Fairly efficient	-
NSF	73	Very inefficient	-
NMF	18	Fairly inefficient	-

B) Evaluation

After obtaining the measurement results, we evaluated them by following the threshold values shown in Table 3. The conclusions were as follows:

- Number of nodes is 59, so the model is fairly inefficient in understandability tasks

- Density is 0.02, so the model is fairly efficient in modifiability tasks
- Sequentiality is 0.396, so the model is fairly inefficient in understandability and modifiability tasks
- Connectivity coefficient is 1.54, so the model is very inefficient in understandability tasks
- Mismatch connector is 16, so the model is fairly inefficient in understandability and modifiability tasks
- Control flow complexity is 22, so the model is fairly inefficient in understandability and modifiability tasks
- CLA is 0.61, so the model is very inefficient in modifiability tasks
- CLP is 3, so the model is fairly efficient in understandability tasks
- TNE is 5, so the model is fairly efficient in understandability tasks
- TNSF is 73, so the model is very inefficient in understandability tasks
- NMF is 18, so the model is fairly inefficient in understandability tasks

After the evaluation, we detected some potential parts for alteration. For example, number of nodes was a very high value, and could have compromised the understandability of the model. The same applies to connectivity coefficient, control-flow complexity, CLA and TNSF, which obtained the worst results of the measurement activity. On the other hand, density, CLP and TNE obtained acceptable results and did not need to be analyzed for further improvement initiatives. These results guided us in our definition of some proposals for redesign.

C) Redesign

After the selection of those parts of the INE model that are potential elements for modification, the redesign activity is carried out. This is the most critical activity, since it depends on the successful implementation of improvement activities.

Redesign was classified into two different groups: changes proposed by specialists in modelling tasks following guidelines of modelling and changes proposed by health professionals.

Changes proposed by Health Professionals

Professionals at the hospital proposed certain modifications which implied some differences in the way in which some parts of the model were designed.

The work group created to model tasks proposed changes which produced several semantically equivalent models. The Dephy method (Linstone and Turoff 2002), was used to allow the work group to select the most suitable changes. Each of these changes produces a different version to the original, specifically 4 different versions are generated:

A) The "belongs to a nursing unit with medical dispenser" decision node was eliminated in the immediately superior lane.

B) Some activities were added: "complete pharmacy report" "send registration request to pharmacy services", "receive registration in computer services", "inform the employee" in the immediately superior lane.

C) The "belongs to a nursing unit" decision node was eliminated and another decision node was added in order to distinguish two categories: planned or urgent in specific superior lane.

D) Combination of version B and C.

The work group's opinion and a first application of the measures revealed that version D is the best option, and we

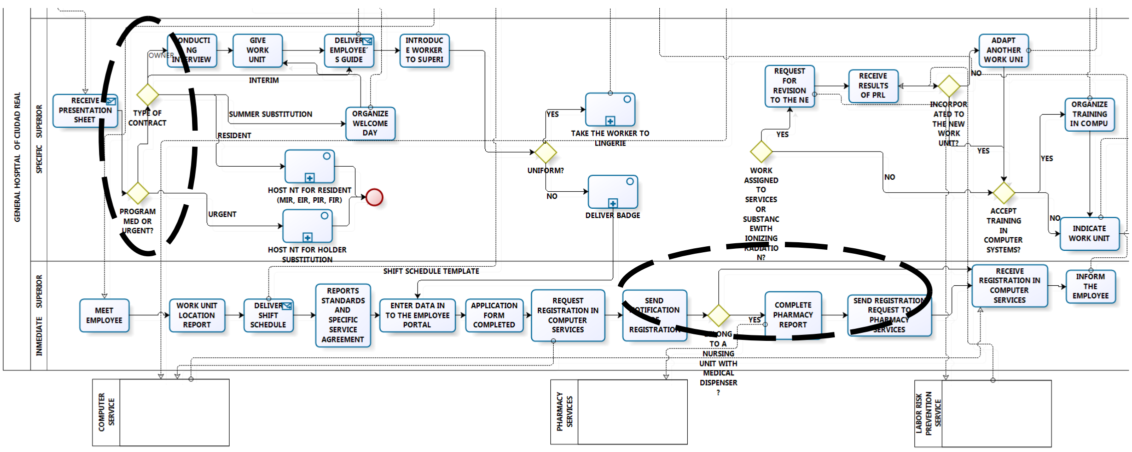

Figure 4: Model of INE process applying changes proposed by health professionals.

selected it as the candidate for the improved conceptual model. The results of these changes are depicted in Figure 4. This change obtained better results with regard to measures in comparison to the original model. Table 5 shows the measures analyzed and the results obtained. The measurement values for the original model are shown in brackets for the purpose of comparison. This comparison shows an evident improvement in the model quality.

Table 5: Measure values of the improved model generated by health professionals.

Measure	Result
Mismatch connector	16 (15)
Control flow complexity	22 (21)
CLA	0,61(0,64)
NSF	73 (71)

Changes Proposed following Guidelines of Modeling

On the other hand, the changes proposed by modelling experts was based on the *guidelines for modellers* published in (Mendling, Reijers et al. 2010). The following modifications were therefore applied to the INE process model:

1. To reduce number of nodes:
    a. Decompose a model with more than 50 elements.
    b. Use one start and one end event.
2. To reduce TNF:
    a. The elimination of some nodes reduces the number of sequence flows.
3. To reduce NMF:
    a. The grouping of activities in a subprocess reduces the number of messages.
4. To reduce control-flow complexity and mismatch connector:
    a. Avoid OR routing elements.
5. A further improvement that is not taken into account in the measures is "use verb object activity labels".

The proposed changes to the model are depicted in Figure 5, and the measures' improved results are described in Table 6.

Table 6: Measure values of the improved model generated by IT expert.

Measure	Result
Nº of nodes	48(59)
Sequentiality	0,47(0,396)
Mismatch connector	10(16)
Control flow complexity	19(22)
TNE	3(5)
NSF	63(73)

D) Selection of the improved Business Process Design

The application of measures in both alternatives allowed us to discover that the most acceptable design is that obtained by professionals in modelling. Specifically, 35% of the measures analyzed improved their values when following guidelines for modelling, as opposed to 23% of the measures obtained when following the advice of professionals in the health sector.

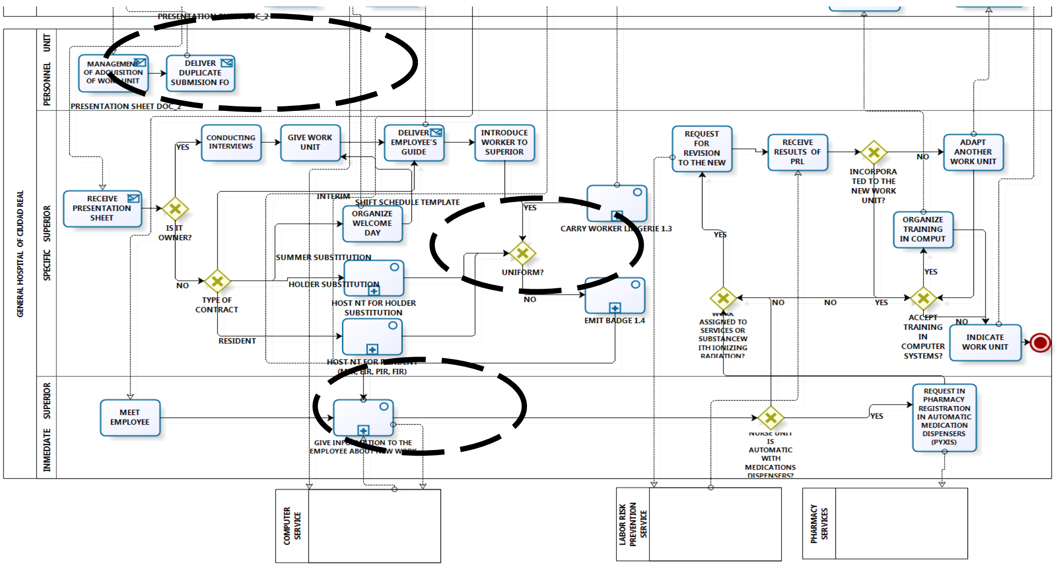

Figure 5: Version of INE process, including changes proposed following guidelines of modelling.

This signifies that the conceptual model depicted in Figure 5 obtained better measurement results, thus suggesting that the model is a good choice and can increase the probability of obtaining a correct process enactment.

4 IMPLICATIONS AND LIMITATIONS

In this section we highlight some of the implications and limitations of our research. In the previous section, we described the process used to improve conceptual models. In the first part, some measures were applied to an INE process model, obtaining certain measurement results. One limitation is related to applied measures. Although more measurement initiatives have been published, it is not possible to apply them because of their lack of empirical validation. This is an important disadvantage in business process measurement and may have limited our research.

On the other hand, measurement values were assessed by following thresholds in order to guide us in redesigning tasks. In a real situation (Incorporation of a new employee) we had two different initiatives for redesigning. One of them was based on the opinion of health experts. After seeing some business issues as a conceptual model, represented in BPMN, they discovered that some parts can be realised in a different way with the same results. These changes to the original model were made, and some improvements were made to the measures (i.e. Control flow complexity was 21 rather than 22 in the original model). Nevertheless, some improvement initiatives can be also be made by following theoretical guidelines, with which even better results are obtained (nº of nodes, sequentiality, mismatch connector, control flow complexity, TNE and NSF). These results reveal that theoretical guidelines produce better modification proposals than changes based on experience. Despite this result, we believe that the changes proposed by guidelines should not be applied in isolation, but should be accompanied by the opinions of domain experts. If the BP is modified by domain experts in a controlled manner, it will be possible to avoid the rejection of changes in the lifecycle enactment stage.

5 CONCLUSIONS AND FUTURE WORK

We conclude this article by summarizing its contributions and by providing an overview of future research. We have discussed the importance of measuring business processes, specifically in the design and analysis stage, because it is known that improving conceptual models in the first stage implies several advantages in the case of avoiding the propagation of errors to later stages, in which their elimination might be more difficult and expensive. This finding has a strong implication for the way in which business process improvement is confronted. A high-quality conceptual model can therefore ensure an acceptable execution.

The experience report allows us to demonstrate the practical utility of measurement activities, obtaining a higher-quality model. The application of measurement to conceptual models detected some potential parts for alteration (number of nodes, reducing sequence and message flow, reducing decision nodes, or reducing number of events). Guidelines of modelling also assisted us in making these modifications. Finally, we obtained an improved quality model which can ensure a better execution.

As a future work, we wish to provide more empirically validated measures in order to make the measurement process more reliable. We also intend to design more guidelines for inexpert modellers. Finally, our idea is to apply measurement activities in other real business processes at the hospital and in other real organizations in order to ensure their practical utility.

ACKNOWLEDGEMENTS

This work was partially funded by the following projects: INGENIO (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), ESFINGE (Ministerio de Educación y Ciencia, Dirección General de Investigación/Fondos Europeos de Desarrollo Regional (FEDER), TIN2006-15175-C05-05) and PEGASO/MAGO (Ministerio de Ciencia e Innovación MICINN and Fondo Europeo de Desarrollo Regional FEDER, TIN2009-13718-C02-01).

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