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ScienceDirect

Procedia Computer Science 126 (2018) 39–48

Procedia Computer Science

www.elsevier.com/locate/procedia

International Conference on Knowledge Based and Intelligent Information and Engineering Systems, KES2018, 3-5 September 2018, Belgrade, Serbia

Improvement of Quality for Business Process Modeling Driven by Guidelines

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Abstract

The improvement of quality in business process models should be objective by applying measures. However, an evaluation of measurement results is not a simple task. It also requires the identification of relevant threshold values and indicators, which make it possible to distinguish between different levels of quality for BP models. In this context, a prototype named BPMoQualAssess (Business Process Model Quality Assess) is described. This prototype is including useful metrics defining the syntactic aspect of BP models also their threshold values. The obtained results are guidelines containing recommendations that aim at improving an input model by modifying it in order to obtain a higher level of quality.

Keywords: Business Process Model, Quality, Measure, Threshold, BPMoQualAssess, Improvement, BPMN, Guidelines, Higher education.

1. Introduction

Nowadays, modeling and improving the quality of Business Process (BP) models has become an important means for ensuring changes in an organization's functioning and structure. Indeed, it leads to creating a more successful and competitive enterprise. It can also provide the concept of coherence, transparency and effectiveness of their activities. In addition, obtaining a high quality BP model allows the production of various advantages such as reducing design flaws, avoiding dysfunctions of the process once deployed, and helping the designer to produce a BP Model that is easier to understand and maintain[1].

Speaking about this relevant topic, it is necessary to define the quality concept in general and also specify it for BP models. For this, the standard NF X 50-120 (1992) presents quality as being: "the set of characteristics of an entity that gives it the capacity to provide implicit and expressed needs".

On the other hand, concerning the quality of BP models, it is important to keep consistency between processes and customer needs to guarantee that the services or products associated with the processes will meet the needs of the users. Furthermore, ensuring the quality of a process consists in trying to define in advance all the deviations and

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10.1016/j.procs.2018.07.207

anticipating the possible risks. For this reason, several methodologies or references interested in quality have been defined in literature such as: Lean, six sigma, Total Quality Management (TQM), Human Performance Technology (HPT), Plan-Do-Check-Act (PDCA), Define-Measure-Analyze-Improve-Control (DMAIC) …

However, these methods or references are all generic. They cannot be used in state. It is necessary to adapt them to each one's context. Therefore, we can conclude that the stage of defining the quality of the process (s) is fundamental. Quality consists in identifying a set of concrete metrics (and possibly thresholds associates), measurable, allowing to define this. Our contribution is based towards this direction.

Because of this, many researchers identified a set of measures in order to assess the quality of their model by proposing new measures specific to BP or by adapting software metric [2, 3]. This adaptation is argued by the fact that a BP model presented by Petri nets, Event-Driven Process Chain (EPC), activity diagrams, BP Modeling and Notation (BPMN) [4], or any other modeling language, manifests a great number of similarities with software programs[5].

As a result, the measurement of BP models plays an important role in obtaining useful information to the direction of potential improvement [6]. In this context, the main contribution consists in the development of a complete quality prototype for BP models. BPMoQualAssess prototype attempts to collect a group of criteria for quality assessment of BP models and measures that define these criteria for a given model. These criteria were selected following a questionnaire developed and distributed to domain experts in order to identify a set of typical and consistent criteria considered as substantial for BP models, by focusing on the needs of stakeholders with the aim of achieving good quality[7]. Also, a number of guidelines related to measure results are given.

The remainder of this article is as follows: in section 2, we provide related work; in section 3, a short description of our framework is given; the fourth section describes the different modules of BPMoQualAssess prototype, while based on defining the threshold values and guidelines for the BP model; in section 5, we present a conclusion for this work and an outlook on future research.

2. Related work

The Quality of BP models presents a huge interest in different disciplines in the recent years of research. Hence, a myriad of standards have been proposed to define, monitor, measure, manage and improve the quality of BP models[8]. In this part, we synthesize the related work dealing with quality of BP models. First, a summary of works related to the determination of threshold values is given. Then, a list of research works about the guidelines for the purpose of respecting threshold values is summarized.

2.1 *Threshold values for Business Process Modeling measures*

The extraction of thresholds is not an easy task. It also requires a practical and theoretical base; it should meet a number of guidelines[9]: a) not be based on the view of an expert but on the measure of data; b) respect the statistical properties of the measure, such as the distribution and metric scale and being resilient against the outlier values and c) be transparent, easy and repeatable. Many authors have determined the thresholds based on experience. Besides, a lot of proposals have been elaborated to solve this problem of objectivity.

For instance, based on calculations with the standard deviation and mean of data, Erni and Lewerentz[10] determined a minimum and maximum threshold. The minimum threshold value is determined by subtracting the standard deviation value of the mean value. The maximum threshold value is calculated by adding it. However, this method presents crucial limitation, which is that the measurements analyzed have to follow a normal distribution.

In order to avoid the normality restriction, French[11] then defined a method for threshold extracting based on standard deviation and mean using at the same time the Chebyshev's inequality theory. The major limitation of this methodology is that for measures with a high range or high variation, it will identify a smaller percentage of observations than its theoretical maximum[12].

Sanchez, Garsia, Mendling, Ruiz, and Cardoso[13, 14] study the structural metrics and their impact on the quality of the BP models called understanding and modifiability. The authors analyzed the performance measurements from a family of experiments to establish the correlations with all the structural measures of the BP model in order to obtain threshold values to distinguish the different quality levels of BP model. Besides, in[12], the authors focus on determining the threshold values for gateway complexity measures for example Gateway Mismatch (GM), Gateway Heterogeneity (GH), and Control Flow Complexity (CFC).

Herbold, Grabowski and Waack [15] proposed the use of a machine learning algorithm to describe an approach for the identification of the threshold. This utilizes the learning of axis-aligned d-dimensional rectangles for the calculation[12]. However, the methodology presents a binary classification and can then compare between the good and the bad, other shades of gray are not possible.

Mendling, Sanchez, Garsia and Rosa[16] proposed the thresholds for a set of structural metrics for predicting errors in the conceptual BP models. Significant thresholds were identified based on ROC (Receiver Operating Characteristic) and the Area Under the Curve[17] and adapted in order to refine the existing modeling guidelines (seven PMG) in a quantitative way[18].

Yoon, Kwon, and Bae[19]also proposed a technique for the threshold extracting based on the K-means cluster algorithm. The threshold values can be determined by the observations that appear either in isolated clusters or far away from other observations within the same cluster[12]. This algorithm needed a parameter that affects the accuracy and the performance of the results. The thresholds' determinations are manually accomplished and the input parameters are influenced by the results.

2.2 *Business Process Modeling guidelines*

Speaking about the guidelines for BP modeling, some authors tried to identify them. In this part, we quote the major sources we considered from the literature.

Becker, Rosemann and von Uthmann[20]defined a set of guidelines in order to improve six characteristics of a BP model namely clarity, correctness, relevance, economic efficiency, comparability and systematic design. These guidelines below aim at improving the quality during the creation of BP model process also the conceptual model itself and help designers in creating BPMN models that are complete, clear and correct.

- The principle of clarity defines that a model must be understandable.
- The principle of correctness is there by proposed as the fact that the real world excerpt has to be depicted correctly with respect to its content[18].
- The principle of relevance announces the presentation of the pertinent elements only relevant for the modeling.
- The principle of economic efficiency requires that the costs of creating models do not exceed the expected utility.
- The principle of comparability defines the possibility of comparing models with each other.
- The principle of a systematic design proposes that multiple views must be used for the modeling of different aspects, which should be adjusted to each other[18].

Mendling, Reijers and van der Aalst [21] defined seven recommendations for improving the quality of an existing BP model or for the way of presenting a BP model from scratch. They are named seven process-modeling guidelines (7PMG). These guidelines are presented in Table 1.

Table 1. Overview 7 PMG[22].

Name	Description
G1	Do not use more than 31 nodes
G2	No more than 3 inputs or outputs per connector
G3	Use no more than 2 start and end events
G4.a	Models as structured as possible
G4.b	Use design patterns to avoid mismatch
G5.a	Avoid OR-joins and OR–splits
G5.b	Minimize the heterogeneity of connecter types

G5.c	Minimize the level of concurrency
G6	Use verb-object activity labels
G7	Decompose a model with more than 31 elements

Furthermore, Oca, Isel and Monique[23] present an overview of pragmatic guidelines for BP modeling tasks. These guidelines are supplemented with many pertinent aspects (threshold values, action, description, and example) in order to make them more useful.

Moreover, Bruce Silver wrote a book[24], which defines a disciplined approach named "method and style" to assist the modeler to create BPMN models that are complete, correct and clear.

Other works for BP modeling guidelines are presented online such as the contribution of Doe[25], also that of Silver[26], and the web pages entitled BPMN 2.0 Best Practices[27], Modeling Best Practices[28], BPMN Modeling Guidelines[29] and Best Practices in modeling[30].

After getting an overview of the related work on quality for the BP models, we have noticed that this research field is very active. Several proposals based on BP quality can be found in literature, but to the best of our knowledge there are, to date, no approaches in which the three main keys measures, thresholds and guidelines are combined. For this reason, the key contribution of this work consists in linking the measures and threshold values to the resulting guidelines because they have been explored separately in literature. In addition, we define for each measure its own recommendation in order to solve the corresponding problem. This is considered as an added value of our work because there was a lack of work on this axis.

Furthermore, various works focused on the application of BP modeling and improvement in many domains such as healthcare, insurance and banking, but unfortunately not in higher education domain. Nevertheless, it presents one of the important areas for development in the economic world. Hence, it must adapt to the strategic, organizational and technical changes. This requires, in particular, good control of its business processes. Based on these limits, we have developed a prototype where we attempt to contribute in this domain by linking the measures and threshold values to the resulting guidelines in order to obtain a high level of quality for BP model in higher education domain. In the next section, we present a short description of our framework, which presents a primary stage for the development of our prototype.

3. Background: Framework for Continuous Improvement of Higher Education

Our framework named “Framework for Continuous Improvement of Higher Education”[31] is inspired from the life cycle of BPM. In fact, it treats a BP model as input and an improved BP model as a result. The input models are characterized by the fact that they are uncontrolled and without assessment of quality, but the output model meets the threshold and criteria values which set the targeted quality level.

For this, the framework involves four steps: first, we select the quality criteria of a BP model based on its syntactic aspect. In fact, evaluating this aspect provides a means for avoiding the propagation of subsequent errors for which their detection and correction may become more difficult; at the second level, for each selected criterion, we identify all the measures or performance indicators specific to the selected criterion (see Fig.2); third, we apply these measures on a BP model in order to evaluate and analyze these obtained measures; fourth, we insure to improve the quality level of BP model. Based on these aspects of our framework we developed a prototype for the evaluation of quality in BP models named BP Models Quality Assess: BPMoQualAssess.

4. BPMoQualAssess prototype

This prototype is developed in JAVA and is specified for BP models in the field of higher education. The main idea of BPMoQualAssess is to help designers to obtain BP models with a high level of quality. It is based on measurements and thresholds and their results are recommendations that present the practical utility of giving to users means for improving the quality of BP design. For this, a set of criteria were selected through a study conducted based on the use of questionnaire distributed to experts in order to establish a classification of the criteria that have been consider in this work. The analysis and the explanation of the obtained results are available in[7]. For each selected criterion, we identified a selection of measurements (see Fig. 1) which have been implemented in our prototype. A short description of each measure is presented in Table 2.

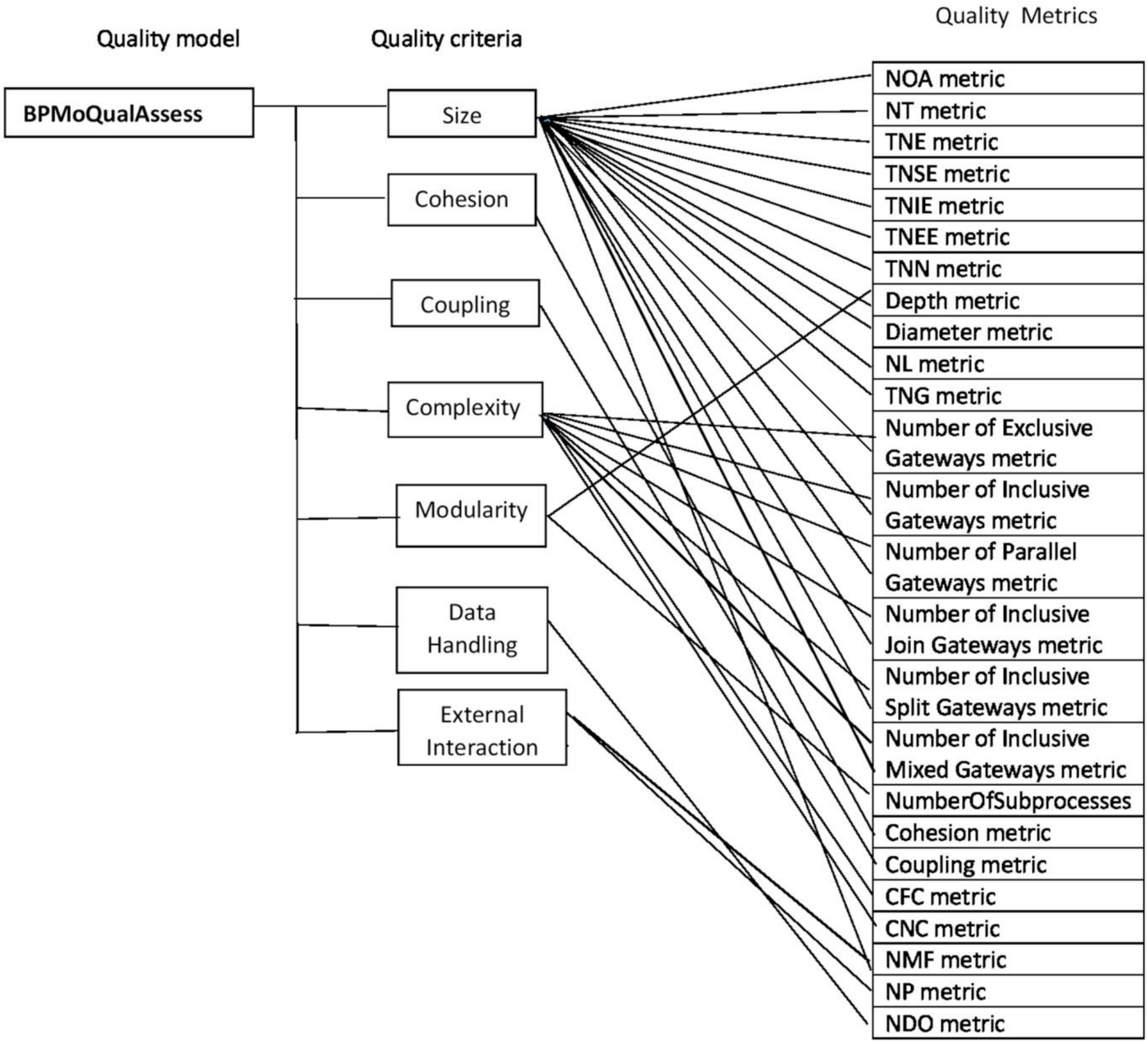

Fig.1. A schema of the Hierarchical Structure of Measures

Following the definition of the measures used in BPMoQualAssess, the next sub section consists in defining the four main modules included in our prototype. Fig 2 presents an overview of the main elements of the prototype. In fact, the modeling module presents a BPMN model as output and this BPMN model becomes an input for the measurement module that needs in addition indicators and measures. As a result for this module, a report of measure can be obtained. In the evaluation module, we need the threshold values in order to compare them to the obtained measures. Finally, a list of guidelines is defined as input for the improvement module as a basis for the improvement quality.

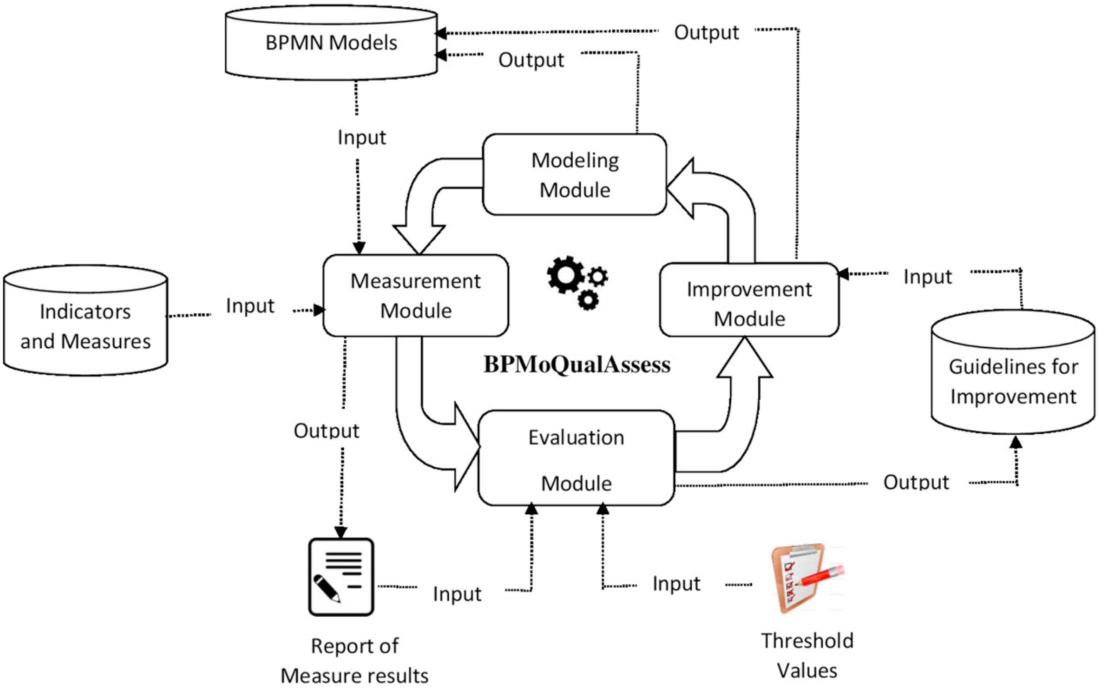

Fig.2. Element of BPMoQualAssess Prototype

4.1 *Modeling of the BP model*

The Modeling Module allows a process engineer to model a BP using the BPMN notation language. BPMN is a graphical notation for defining BP through a Business Processes Diagram (BPD) and has become the standard de facto for representing BP. The latter makes modeling easy and allows obtaining simple diagrams. At the same time, it is capable of managing the complexity inherent to BP[32]. A process engineer performs the modeling for BP in the modeling module, producing an output BPMN model.

4.2 *Measurement of the BP model*

The measurement Module consists in calculating the measures automatically using two tools. Vanderfeesten, Reijers, Van der Aalst[33] developed a tool named CoCoFlow that was used to calculate the coupling and cohesion measurements. For the other measurements, Ivanchikj[34] have developed a tool called BPMeter that provides a simple web application to view the results of applying more than 100 different size and structure measures to BPMN process models.

4.3 *Evaluation of the BP model*

After uploading the BPMN model as input of this module and calculating the measurements, a report with the generated results is sent to the user in the JavaScript Object Notation (JSON) format. Subsequently, our evaluation module interprets and compares the obtained results with the threshold values of the metrics.

Accordingly, these threshold values presented in Table 2 are principally adopted from Sanchez and Mendling. We justify our choice of these two authors by the advantage that they are the most important ones who founded their research on identification and calculating the thresholds for BP model.

As a result, this module gives an evaluation of the quality of the process model being analyzed. The comparison process is as follows: M is a set of measurements, T is a set of threshold values, R is a set of a result, $m \in M$ and r_m

$\in R$ defines the result value for measurement m, and $t_m \in T$ defines the set of values within threshold for measurement m.
If $r_m \in t_m$, then the result for measure m is within threshold and the quality of the model is good with respect to this measure.
Else, the value of this metric is not acceptable (exceeding the threshold value) and a bad quality of the model is observed with respect to this metric. A similar treatment is realized in the case of a limit value corresponding to a minimum value or that of an interval (between a min and a max value). It can be concluded that the evaluation of the measurement results in relation to the threshold values implies an objective evaluation of this latter. It allows us to determine which values are acceptable and which are not and then decide if the model has a good quality or not. Therefore, it is necessary to examine the threshold values or limit values in order to indicate from which specific values the measurement of quality becomes unacceptable.

4.4 *Improvement of the BP model*

Improvement Module consists in improving the quality of the model by using the guidelines and, for each of them, recommendations will be displayed to the user (see Table 2) in order to modify certain parts of the model. The parts to be modified have to be identified by the use of the corresponding metrics and indicators. Let us take as example the case of a model with Total Number of nodes (TNN) > 45, the latter is not acceptable, we can then deduce that the model is difficult to understand. These results indicate that the number of nodes should be reduced. Consequently, to remedy this problem, the model must be redesigned by applying appropriate guidelines for the modification of certain parts of the model in order to improve its overall quality. Thus, the proposed solution for the above problem is "Guideline Reduce Model Size in Terms of Nodes" by calling the specific recommendation cited in Table 2. In summary, we can deduce that in order to improve a model, it will be necessary to redesign certain parts of this model that suffer from a low quality detected by measurement. Modeling guidelines can ensure the quality of the model, but a preliminary calculation of measures is needed to identify potential problems.

Table 2. Thresholds and Guideline for BP modeling

Metric Name	Description	Threshold value	Guidelines
TNN	The total number of activities and routing elements in a process model	Do not use more than 45	**Recommendation 1:** Put a hierarchical structure with sub-processes: modularize the business process model by using the sub-processes. The higher is the value of the node; the most likely it is to have errors in the overall model.
Diameter	The length of the longest path from a start node to an end node in the process model	Must not be higher than 16	**Recommendation 1:** Keep the way from a beginning node to the end as short as possible. **Recommendation 2:** In order to hide complexity, try to decompose the model by creating sub-processes.
Depth	The maximum nesting level of a sub-process	Must not be higher than 1	**Recommendation 1:** Be away from very deep nesting structured blocks and avoid very deep nesting sub-process. **Recommendation 2:** Create sub-processes for hiding complex or flattening subsequent decision gateways into a single or a lower number of gateways.
TNE	The total number of events in a process model	Not use more than 11	**Recommendation 1:** The modeler ought to include in the model just one start and one end event by participant.
TNEE	The total number of end events in a process model	Not use more than 3	**Recommendation 1:** The modeler ought to distinguish failure and success end states in a sub-process or process with separate end events. Flows that end in the same end state ought to be merged with the same end events. Hence, separated end events, which are not representing distinct end states, have to be merged in one end event.

			Recommendation 2: Modify all identical end events with just one end event preceded by a join gateway. Link this gateway to each activity, which was followed by the original end events.
TNIE	Total Number of intermediate events in a process model	Not use more than 5	**Recommendation 1:** Try to be away from duplicated and non-necessary intermediate events in the process model.
TNSE	The total number of start events in a process model	Not use more than 3	**Recommendation 1:** The modeler ought to include in the model just one start event. When it is needed, the alternative instantiations of the process ought to be depicted with separate start events by using an event based on start gateway. **Recommendation 2:** Modify all the start events with just one start event succeeded by a XOR split gateway. Link this gateway to each activity that was preceded by one of the original start events.
CFC	The sum of overall gateways weighted by their potential combinations of states after the split	Must not be higher than 10.3	**Recommendation 1:** Be away from OR routing every time it is possible because they maximize the general complexity of the model. **Recommendation 2:** Merge various gateways whenever the decisions specified in the gateways are related.
CNC	The ratio of total number of arcs in a process model to its total number of nodes	Must not be higher than 1.021	**Recommendation 1:** Reduce the coefficient of connectivity metric by equitable use of the two metrics, of arcs and nodes numbers because the higher for these metrics the more likely it is to have errors in the overall model. **Recommendation2:** Reduce general complexity of the model if possible by applying some patterns given in other guidelines.
NT	The number of all tasks (of different types) used in the model	Not use more than 12	**Recommendation 1:** A set of consecutive tasks in one lane and at the same time, can be integrated in one activity. **Recommendation 2**: When a set of consecutive tasks is in one lane, it may miss some participant details, a lot of details or a misalignment in scope. Try to merge it in order to create chances for task integration.
NOA	The number of all activities used in the model (of different types)	Not use more than 22	**Recommendation 1:** Mix the activities or eliminate the ones which have a low level of granularity. **Recommendation 2:** Relocate the activities from the major process to the sub-process or vice versa.
Cohesion	The relationships between elements within a module	Must be included between 0 and 1	**Recommendation 1:** Maximize the relationship between the elements within a module because a model with low cohesion will contain more errors than a model with higher cohesion. High value of cohesion in the activities of a BP model defines a better modular decomposition of its activities.
Coupling	The strength of interconnections among the tasks of a process model	Must be included between 0 and 1	**Recommendation 1:** Reduce the number of interconnections between activities in a process model. Thus, the higher is the coupling value of the process, the more difficult it is to change the process and the more probable it is to find errors in the process.
NL	Number of lanes in a process model	Not use more than 5	**Recommendation 1:** Establish a lane in a pool, unless at least one activity or intermediate event is done in it. **Recommendation 2:** Do not establish lanes to represent the entity or area that carries out automatic tasks or gateways.
NP	The number of pools used in the model	Not use more than 4	**Recommendation 1:** Eliminate the participants that are seen as a black box when they do not have relevant information.
NMF	The number of message flows used in the model	Must not be higher than 7	**Recommendation 1:** reduce the number of message flows by grouping activities in sub processes: this will reduce the number of messages.
Number of Data Objects	The number of data objects in the model	Must not be higher than 7	**Recommendation 1:** The modeler should reduce the usage of Data objects (Data object input, Data object output).

Number of Sub-processes	The number of sub-processes used in the model	Must not be higher than 10	**Recommendation 1:** Try to avoid decompositions into small sub-processes with less than five activities. **Recommendation 2:** Make sub-processes from those fragments of a business process model, which are components having only one input and only one output control flow arcs. **Recommendation 3:** Make sub-processes from those fragments of a business process model of which the nodes are more tightly connected by arcs to each other than the nodes outside this collection.
TNG	The total number of gateways used in the model	Must not be higher than 12	**Recommendation 1:** Merge the different gateways as soon as the decisions specified in the gateways are related. **Recommendation 2:** If it is possible, reduce the diversity of the gateways.
Number of Exclusive gateways	The number of exclusive gateways(have been used in the model	Not use more than 10	
Number of Parallel Gateways	The number of parallel gateways used in the model	Not use more than 7	
Number of Inclusive gateways	The number of inclusive gateways used in the model	Not use more than 4	**Recommendation 1:** The modeler ought to minimize the usage of inclusive gateways (OR-joins and OR-splits) that reduce the level of understandability of the model. **Recommendation 2:** Decrease the number of inclusive OR gateways by substituting them by AND/XOR gateways each time it is possible without modifying the semantics of the model.
Number of Inclusive Join gateways	The number of inclusive join gateways used in the model	Must not be higher than 1	**Recommendation 1:** Avoid the inclusive (split, join, mixed) gateway each time it is possible in order not to reduce the level of understandability of the model. **Recommendation 2:** Decrease the number of inclusive (split, join, mixed) gateways by substituting them by AND/XOR each time it is possible without modifying the model's semantics. Basing on this guideline, every split ought to match a respective join gateway of the same type.
Number of Inclusive Split gateways	The number of inclusive split gateways used in the model	Must not be higher than 1	
Number of Inclusive Mixed Gateways	The number of inclusive split gateways used in the model	Must not be higher than 2	

5. Conclusion and future work

In summary, the quality of BP models is a very active research topic. Consequently, this paper focuses on a practical proposal of prototype called BPMoQualAssess for quality improvement of BPMN models. The latter is based on three main elements: measures, threshold and guidelines. Indeed, the analysis fulfilled with the measurements of quality and their comparison with threshold values is a good way for improving the quality of a model while redesigning some of their parts by applying recommendations, which are presented as a useful guide to obtain high quality models. In addition, we illustrate our prototype by treating two real cases of BP models in higher education domain. The first is related to the process of tracking master's degree theses and the second concerns the tracking of curriculum offer process.

As future research, we will try to improve our prototype by adding other measures and we intend to apply our prototype to many processes in order to guarantee their practical utility.

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