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Quality Criteria and Metrics for Business Process Models in Higher Education Domain: Case of a Tracking of curriculum Offers process

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Abstract

The quality of business processes has been recognized as an important factor for modeling success in several domains, especially in higher education.
In fact, quality of business process model could be the object to various interpretations; it must be treated in the most objective way, by using measures.
Consequently, this paper presents an overview of the criteria and measures for quantifying the various aspects of business process models quality by citing the concepts that have been used for defining quality software programs. After that, these measures have been applied to a real business process model related to the tracking of curriculum offer process more commonly named "habilitation process".

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1. Introduction

BPM provides a significant way to ensure changes in the structure of a company and particularly in higher education, since it corresponds to one of the most important domains for development in the economic world. For that

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reason, we must boost the culture of quality within higher education institutions on the one hand and improve the quality of business processes on the other hand.

In this context of quality in BP models, several authors were motivated to define a variety of approaches to measure as well as to improve the quality of a Business Process (BP) model.
A thorough study is conducted in literature allowing us to classify these approaches into three categories.
The first category consists in approaches based on methods, defining methodological guides and good practices to determine the quality of BP models. Second, we have approaches of quality assessment for business processes, which are mainly applied during their execution and their control.
Finally, we have approaches of quality assessment applied to BP models.

Through our research, we focus on the assessment and improvement of business process models (last category). This approach is founded on quality criteria and metrics. Authors who use such approaches have focused on software measures because there is a strong analogy between software programs and business processes[1]. (table1).

Table1.Similarities between Software programs and Business Process (Vanderfeesten, 2004)[2].

Software	Business Process
Module/Class	Activity
Method /Function	Operation
Variable/Constant	Data Element

Such measures are considered for processes in the higher education domain, in order to verify their adequacy.

In this paper, we present an overview of selected existing metrics for defining different aspects of BP models. Then, we give an overview on the way of applying them for higher education processes. Section 2, refers to the diverse criteria and measures in the software engineering domain. As for section 3, it is an illustration devoted to the application of such measures regarding a process in higher education domain. As for section 4, it spots the light on some recommendations and metrics for ensuring quality in BP models. We end up with the fifth section which sums up our conclusion and future works.

2. Quality metrics stirred from software engineering domain

This part is dedicated to present the quality measures of business processes that have been adapted from the software engineering domain.

2.1. Coupling

The coupling measure is used to describe how the activities of a BP model are connected. An activity is associated to another in case they share information with each other (e.g. data).
Differently expressed, it counts all pairs of activities in the BP model that are connected to each other[3].
Vanderfeesten &al, (2007) presented a mathematical formula of measure for this criterion:

$$CP = \frac{\sum_{t1,t2 \in T} \text{Connected}(t1,t2)}{|T| * (|T|-1)} \qquad (1)$$

$$\text{Connected}(t1,t2) = \begin{cases} 0, \text{if } (t1 = t2) \\ 1, \text{if } \quad (t1 \rightarrow t2) \wedge (t1 \neq t2) \\ 1, \text{if } (t1 \rightarrow \text{AND} \rightarrow t2) \wedge (t1 \neq t2) \\ \frac{1}{m.n}, \text{if } (t1 \rightarrow \text{XOR} \rightarrow t2) \wedge (t1 \neq t2) \\ \frac{1}{(2^m-1).(2^n-1)} + \frac{(2^m-1)(2^n-1)-1}{(2^m-1)(2^n-1)} * \frac{1}{m.n}, \text{if } (t1 \rightarrow \text{OR} \rightarrow t2) \wedge (t1 \neq t2) \end{cases}$$

Where t1 and t2 are elements of the set of activities T in the BP model, m is the number of ingoing arcs to the connector, n is the number of outgoing arcs and connected (t1, t2) is a function that gives a weight for each branch between two activities t1 and t2 according to the connection type[4].

Moreover the average value of the measurements is determined by a ratio between the total number of connections for all activities and the total number of activities. The outcome is always between 0 and 1.

Since the value of the coupling depends on the nature of the connections (XOR, OR, AND) and its complexity, this quality criterion is very important for a BP model. If we take the example of an activity with a high coupling value, this means that it is strongly linked to other activities of the model. Therefore, a produced error in this activity introduces the dysfunction of other activities which causes an overall process dysfunction and marks a vulnerable process and a difficult maintainability. Thus, this metric has a limit since it does not present information on the reusability of a BP model.

A second limit that can be highlighted is the focus on the data interchange and non-provision of information regarding the activity dependency in terms of data usage[3]. This limit is resolved via the cohesion criterion that will be described through the next section.

It is worthy to mention that Reijers and Vanderfeesten (Reijers and Vanderfeesten, 2004) also established a similar coupling metric counting the overlap of data elements for each pair of activities using a static description of the product represented by a Product Data Model (PDM)[5].

2.2. Cohesion

First, we need to state that Vanderfeesten et al[6] introduced cohesion metrics that are adapted from software engineering domain. This measurement determines the different operating numbers that are connected within an activity. Moreover, it determines, for each operation of an activity, how many other operations it overlaps with, by sharing an input or output[3]. We can conclude that we will have more errors when we have a low cohesion comparing with a model with high cohesion. The cohesion of a BP model is calculated via a ratio between the sums of all the values of cohesion of activities and the number of activities.

In addition, concerning this criterion, Vanderfeesten et al, 2008 define the cross connectivity metric (CC) which quantifies the ease of understanding and the interplay of any pair of model elements[4] (for the mathematical formula and the explanation of this metric, the readers is referred to[7]).

Moreover, a high value of cohesion in the activities of a BP model defines a better modular decomposition of its activities. Both Principles of cohesion and coupling are important for BP model to build processes that are highly coherent and weakly coupled to one another. It is noteworthy that the coupling value is always between 0 and 1.

2.3. Complexity

Cardoso (2006), proposed the control flow complexity (CFC) metric for measuring control flow complexity of a BP model[8]. This metric is an adaptation of Cyclomatic Metric (MCC). This measurement determines the simplicity as well as the understandability of a model. It can be handled from different perspectives since they are high-level concepts, which are made up of countless different elements (splits, joins, resources, data, etc). The main idea behind this metric is to assess the complexity introduced in a process because of the existence of gateways such as XOR–Split, OR–Split, AND–Split. It is noted as follows:

For XOR-split gateway: $CFC_{XOR\text{-}split}(a) = \text{fan-out}(a)$ (2)

For OR-split gateway: $CFC_{OR\text{-}split}(a) = 2^{\text{fan-out}(a)} - 1$ (3)

For AND-split gateway: $CFC_{AND\text{-}split}(a) = 1$ (4)

Where fan-out is the output points number of splits[9].

Accordingly, it is easy to calculate the complexity of a BP model, by the sum of different CFC from all splits in the business process model.

$$CFC(p) = \sum_{i=0}^{n} CFC_{XOR\text{-}split}(i) + \sum_{j=0}^{n} CFC_{OR\text{-}split}(j) + \sum_{k=0}^{n} CFC_{AND\text{-}split}(k) \quad (5)$$

Furthermore, Sanchez et al[10], mentioned that a model is considered as very easy to understand if these complexity measures do not exceed 6 for $CFC_{XOR\text{-}split}$, 1 for $CFC_{OR\text{-}split}$, and 1 for $CFC_{AND\text{-}split}$. However, it is hard to understand it if it contains 46 for $CFC_{XOR\text{-}split}$, 14 for $CFC_{OR\text{-}split}$, and 7 for $CFC_{AND\text{-}split}$.

We can also measure the complexity by another method based on HPC measure. Cardoso & al[11] introduced the notion of Halstead-based Process (HPC) measures. This requires calculating: length N, volume V and difficulty D of a BP model, calculated as follows:

$$N = n_1 * \log_2(n_1) + n_2 * \log_2(n_2) \quad (6)$$
$$V = (N_1+N_2) * \log_2(n_1+n_2) \quad (7)$$
$$D = (n_1/2) * (N_2/n_2) \quad (8)$$

Where: n_1: describes the number of activities, control flow, and different gateways for a BP model.
n_2: describes the different number of treated data by the activities of the process.
N_1 and N_2 can be easily derived directly from n_1 and n_2 as the total number of control flows and elements[12].

2.4. Modularity

Modularity is a measure that describes the modularity (M) of a BP model. It corresponds to the degree of decomposition of the model into sub-models. Besides, modularization may encourage the understanding of a process model by its “information hiding” quality[13]. The degree of modularization affects the quality of a design. As for the over-modularization, it is as undesirable as under-modularization[5]. Moreover, Mendling & al[14] proposed that a model with more than 50 elements should be modularized. It is determined as follows:

$$M = (\text{fan-in} * \text{fan-out})^2 \quad (9)$$

Where Fan-in: describes all the modules calling another module m of the model.
Fan-out: describes all the modules called by a module m.

2.5. Size

Speaking about the size, we can measure it by adopting the LOC (Line of Code). This metric comes from software engineering and measures the size of a BP model. More precisely, we adopted the three following metrics:

NOA: sums up activities (tasks and sub-processes) in a BP model[15].
NOAC: Number of activities and control-flow elements [16].
NOAJS: Number of activities, splits, and joins, is NOAC used for processes that are not well-structured (there is at least one splitting of process flow that is not closed) [17].

We justify our choice of all these selected metrics by the fact that they are the most cited in literature. Moreover, other metrics can be derived from them.
In the next section, we present a real case of a business process model for the higher education, which is the tracking of curriculum offer process. At that point, we are going to indicate obtained values for the selected quality metrics.

3. A real case of the tracking of curriculum offer process in higher education domain

Figure 1 presents an overview of the tracking of curriculum offer process in higher education domain. We realized the BPMN model from a document presented in the official website of the higher education and scientific research Ministry in Tunisia. Moreover, it has been validated by involved actors.

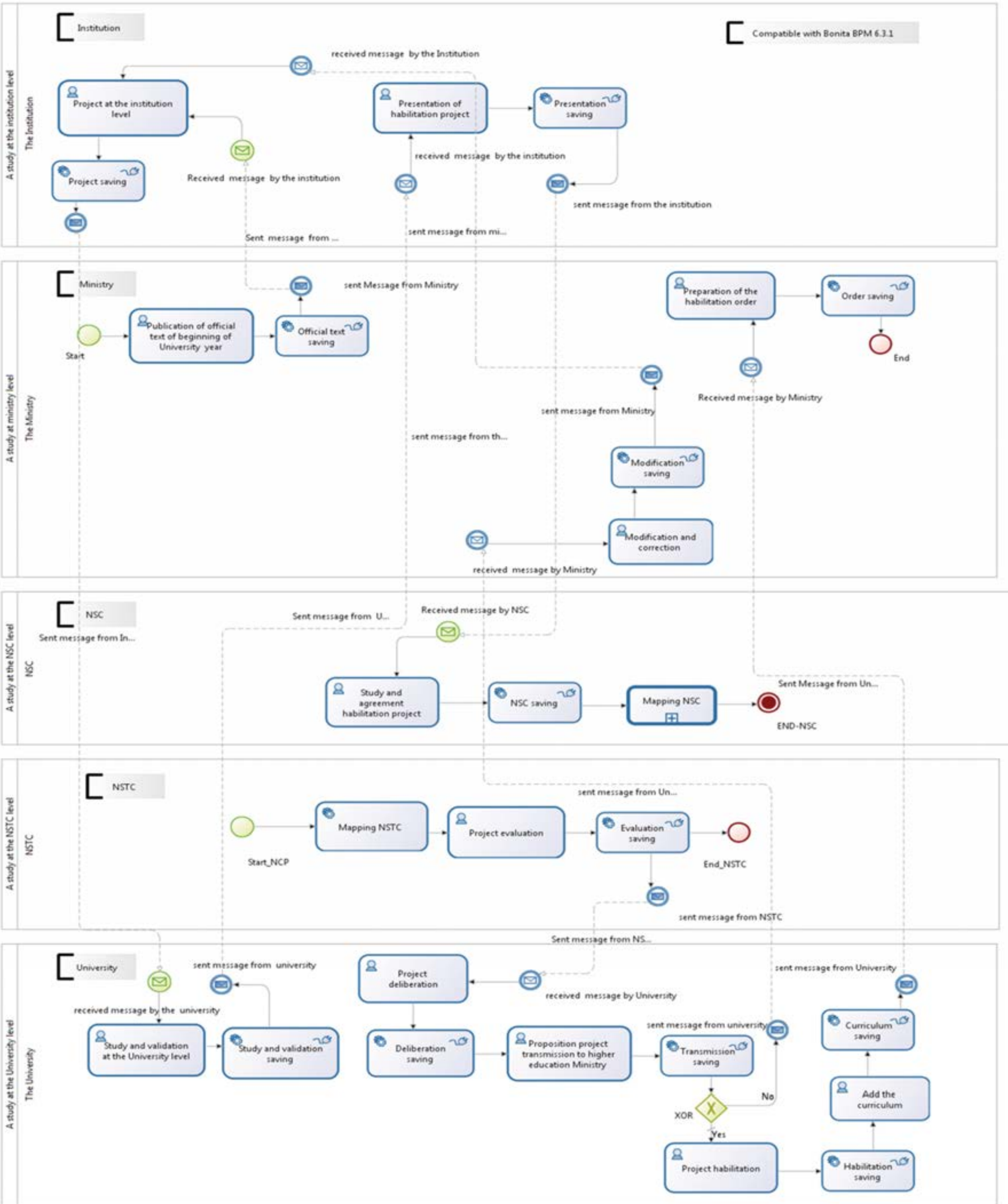

Fig. 1. BPMN model of the tracking of curriculum offers process in higher education domain.

3.1. Description and modeling

In order to improve the quality of processes in institutions of higher education and increase their benefits on several levels, through the establishment of the Business Process Management (BPM) approach, we illustrate our ideas on this case study.

Through this paper, we tend to present the case of the tracking of curriculum offer process. We can justify our choice concerning this real case by the importance it has in the domain of higher education. In fact, a curriculum offer is defined as a starting point on which is grounded on the offered curricula in higher education institutions. Its adaptations can define new employment opportunities for the upcoming graduates. However, it should be noted that it is quite difficult to deal with curricula offers because they require a long time to be established and a large number of involved actors. This tracking of curriculum offer process is known as the habilitation process. Five actors intervene in this process which is the ministry, the university, the higher education institution, the national sectorial committee (NSC), and the national Steering committee (NSTC).

This process of habilitation starts with the publication of the official text of beginning the university year by the ministry. At that juncture, a proposition of project is triggered at the institution level. A study of this proposition will be fulfilled at the university level. Then, the results of this study are presented at the institution level. Afterwards, an assessment of the NSTC of the project proposition following a validation and an agreement of the NSC are dealt with. After that, the university deliberates on the project then they transmit the project proposition to the Higher Education ministry. In this phase, a decision will be taken in order to decide if the project has to be modified. We must return to the step of project proposition at the institution level and redo these phases after a modification is realized by the ministry. However, if the decision is positive (yes), then the habilitation of the project is accomplished, the curriculum is added by the university and the ministry prepares the habilitation order. In order to make our process executable, after each activity, saving data in MYSQL database must be accomplished.

3.2. Measures and their interpretation

We will calculate a number of measures for this business process model, by considering the criteria mentioned above. It is not possible to apply all of them due to the absence of some specific elements in this model. These measures are manually calculated.

They contribute to evaluate the quality of this model. The result of calculated measures is obtained, and then we compare the obtained values with the existing thresholds published in literature, to examine in case our model has parts that must be modified in order to improve their quality. The measurement results are presented in Table 2.

Table2. Selected calculated metrics for our process model.

Metric	Result
$CFC_{AND\text{-}split}$	0
$CFC_{OR\text{-}split}$	0
$CFC_{XOR\text{-}split}$	2
NOA= NOAC	26
NOAJS	27
HPC-N	134.36
HPC-V	254.53
HPC-D	21,84
M	1
CP	0.04
CC	0.18

After getting the results of the selected measures, we compared them to threshold values defined in literature. We conclude that according to Sanchez & al (2011), our model is very easy to understand. We can judge that our model has low complexity.

Cp=0.04, CC=0.18, M=1 obtained values are considered as acceptable results for a good quality model.

Otherwise, measuring HPC gave very high values specially HPC-N and HPC-D. These results indicate that the number of data variables and elements in the model must be reduced. Therefore, we will have to focus on an analysis of some parts of the model in order to improve its quality.

4. General recommendations for ensuring quality in BP Models

We devote this paragraph to recommendations and tips for business process modelers. In order to achieve a BP model with good quality, Mendling & al[16] proposed seven recommendations for the way of presenting a process model from scratch, or for improving the quality of an existing process model. They are named seven process modeling guidelines (7PMG). These guidelines are the following[16]:

1. Reducing the number of the elements because the size affects the understandability and the error probability of a model;
2. Minimizing the routing paths per element;
3. Attempting the use of one start and one end event;
4. Having a well-structured model for which every split connector matches a respective join connector of the same type.
5. Avoiding the use of OR routing elements;
6. Applying a verb-object form of the activity label;
7. Decomposing a model if it contains more than 50 Elements.

After giving recommendations on designing a good model of business processes, we give recommendations on BP model measures. In fact, a low coupling measurement value is sought after. The higher is the coupling value of the process, the more problematic it is to change the process and the higher is the probability that there will be errors in the process[18]. We can solve this problem if we have a high value for this measurement by applying the first and the fifth guidelines from 7PMG.

High cohesion measure values are preferable for high quality Models. Vanderfeesten et al. (2008) have stated that a model with a low measure of CC is more likely to include errors. If CC value of the model is high, we can solve this problem by applying the second guideline from 7PMG.

Low NOA, NOAC, and NOAJS measures values are desired. These metrics presented some information to understand the model design. To remedy to the raised problem by these three values, the idea is to apply the first guideline from 7PMG. On the other hand for NOAC metric, if we moreover apply the fourth guideline from 7PMG, we get a high value for this metric.

Low control flow complexity (CFC) measures are wanted. The greater the overall structural complexity of a process is, the higher value of the CFC will be obtained[12]. If CFC value of the model is high, we can reduce this value by applying the first and the fifth guidelines from 7PMG.

As a final point, low HPC measures are desired. Cardoso et al. (2006) noted that the measures calibration needs should be examined through the empirical experiments. If HPC value of the model is high, we can solve this problem by applying the first guideline from 7PMG. If HPC value of the model is high, we can solve this problem by applying the first guideline from 7PMG.

5. Conclusion and Future works

Quality measure and improvement for business processes is nowadays one of the most evoked research domains. Through this paper we have presented a number of criteria and measures that are considered as important in order to describe the various aspects of business processes. Thereafter, we define a case study related to the tracking of a curriculum offer process in the domain of higher education and we determine a number of measures to improve the quality of the latter.

In future research work we aim to develop a prototype to automate the measurement of quality metrics values for process models in higher education and obtain recommendations on the way to transform them in order to improve their quality.

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