

## Guidelines and a software tool for quality assessment of BPMN business process models

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**Abstract:** This paper considers the problem of quality measurement of Business Process Model and Notation business process models. Business process models presented using BPMN and other notations are graphical schemes similar to flowcharts or UML (Unified Modeling Language) activity diagrams utilized in software engineering. Business process modeling strives to capture current enterprise workflows for analysis and improvement using automation through workflow systems deployment. Therefore, designed high-quality business process models have to be understandable and maintainable. It can help efficiently identify and replace all "weak spots" of described organizational workflows with more efficient solutions. Whereas business process models which are not understandable, unstructured and uncertain may cause even more errors than benefits. Therefore, this study proposes guidelines and a software tool for errors detection in business process models.

**Keywords:** Business process, Modeling guidelines, Process model, Quality assessment, Software tool

### 1. Introduction

Business process modeling is a key activity within the Business Process Management (BPM) domain. Process modeling ensures Information Technology (IT) and business alignment by making easier communication between business users, such as chief officers, managers and other stakeholders on the one side, and IT engineers who design and maintain enterprise information system(s) on the other side. Graphical business process models are used to capture and analyze current workflows in order to find ways for their improvement by means of improvement of current IT systems or introducing new IT system modules if considered workflows are still not automated. Hence, captured business process models shall be understandable, well-structured, and may not have any uncertainties; otherwise, it will not be possible to properly analyzed current enterprise activities and suggest efficient ways for their improvement. Moreover, improper business process models may signalize improper business processes themselves, so modeling mistakes may appear because the reflected real business process has certain faults.

Business processes are increasingly vital components and key assets in any competitive enterprise. Furthermore, business process challenges are crucial for organizational management activities. BPM is the primary research and development topic for process-aware information systems, encompassing techniques,

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methods, and software tools for business process modeling, performing, and monitoring. Numerous issues of BPM development include business process specification and design (Al-Fedaghi & Makdessi, 2020).

Organizational operations are defined by business processes. They are built up of groups of activities that work together to produce a valuable result for a business or its customers. Business process models have become the de facto standard for capturing information on such processes and are thus featured in almost every aspect of the business process management lifecycle. As a result, documenting business activities with process models has become a must-do for many enterprises (Sola, Meilicke, Aa& Stuckenschmidt, 2021).

To capture the various parts of a business process, appropriate process modeling methodology, tools and standards has to be used. Process modeling approaches are a collection of graphical components and guidelines for combining them. There are languages ranging from very simple to quite advanced in this universe of business process modeling approaches. The most advanced business process design approaches consider the development of information systems, including accounting systems, quality management systems, or workflow execution systems. Business Process Modeling Notation (BPMN), Event-driven Process Chain (EPC), Unified Modeling Language (UML), and Integration DEFinition (IDEF) are some of the primary business process modeling approaches (Entringer, Ferreira & Nascimento, 2021).

One of the challenges of business process design is the large variety of methodologies for representing business processes and taking into account their needs, which makes it difficult for business process designers to make a choice. As a result, process modelers has to deal with the problem of choosing the appropriate modeling techniques. Among the several notations available for business process design, the following are the five most popular nowadays (Guizani & Ghannouchi, 2021): BPMN is now regarded as a standard, EPC is a part of the well-known Architecture of Integrated Information Systems (ARIS) software suite, Unified Modeling Language Activity Diagrams (UML-AD) established by the Object Management Group (OMG), Petri Nets, and Yet Another Workflow Language (YAWL).

BPMN, UML, EPC and IDEF are the business process modeling notations mentioned the most in the studies collected in the Scopus database presented by the bibliometric review (Entringer et al., 2019). As indicated in Fig. 1 below, around 55% of published works refer to the BPMN business process design methodology, whereas other approaches are not so widespread: UML (21%), EPC (12%), IDEF (7%), and other modeling techniques (5%). According to the findings of a survey (Entringer et al., 2019), BPMN is the de-facto standard language in the BPM field.

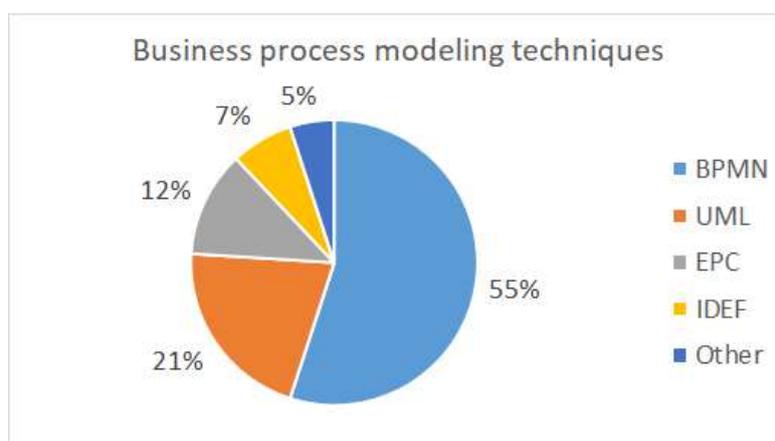


Figure 1: The most widespread business process modeling techniques (Entringer et al., 2019)

The BPMN is a widely used standard language for modeling business processes in both academia and industry. BPMN is an International Organization for Standardization (ISO) standard. In its most recent iteration, BPMN has five fundamental types of symbols: flow elements, data elements, connecting flows,

pools and lanes. BPMN 2.0 has an extension method for describing extra concepts and linking them to its basic elements to describe domain-specific properties (e.g., insurance, accounting, e-commerce, and many more). Configurable and flexible BPMN metamodel allows developers to obtain its advantages (e.g., standardization, tool support) while bypassing the costly development of a domain-specific modeling language (DSML) for a certain problem (Zarour, Benmerzoug, Guermouche & Drira, 2019).

Because business process modeling is regarded as the core of BPM, it is necessary to create understandable and maintainable process models that are used to assess and enhance represented business workflows. The primary purpose of business process modeling is to provide high-quality diagrams that depict the understandable and maintainable structure of the business process. Hence, it is vital to design business process models that are expressible but simple enough to understand and modify (Kopp & Orlovskiy, 2019).

Table 1 below contains a review of the most remarkable and relevant related studies that consider the quality analysis of business process models published over the last few years (2018-2021).

**Table 1:** The list of related studies

Paper	Approach	Results
Ayech, Ghannouchi & Amor, 2021	A solution based on a new BPM lifecycle extension to increase the maintainability of business process models.	A set of static maintainability measures closely related to the modifiability and maintainability of business process models.
Corradini et al., 2018	A thorough literature review was used to develop business process modeling guidelines.	Approximately one hundred guidelines were identified and tested on a dataset of 11,294 models.
Correia, Gonçalves & Simões-Marques, 2018	Create a framework for quantifying and connecting various quality attributes of process models.	A measurement terminology for process modeling was established.
Kbaier & Ghannouchi, 2019	Determine the quality metric threshold values to assist modelers in assessing the quality of business process models.	Gathered a collection of high-quality BPMN business process models from diverse sources.
Khudori, Kurniawan & Ramdani, 2020	Uses syntactic correctness and completeness criteria for experimental evaluation of process model transformation in ARIS Architect/Designer.	The outcome opens up new research opportunities to increase the quality of EPC to BPMN model transition.

A brief overview of the related work (see Table 1 above) shows that recent studies consider guidelines, measures, thresholds and criteria to assess the correctness of business process models. Hence, we can propose a set of guidelines for quality assessment of BPMN business process models and the respective software tool that modelers may use to produce high-quality business process models. This software tool may become a part of the BPM lifecycle and encourage modelers to design well-structured BPMN models.

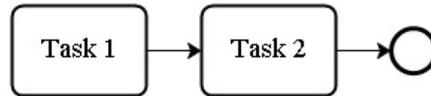
This study aims to provide guidelines and a software tool for errors detection to improve business process modeling and analysis activities of BPM projects. A research object includes business process modeling and analysis activity, conducted by business analysts or IT management specialists. It also includes guidelines and the software tool for errors detection in BPMN models used nowadays the most to capture organizational workflows.

## 2. Materials

The creation of business process models is subjective, which leads to inaccuracies related to the analyst’s skill, an inadequately precise description of the subject area, and so on. As a result, before a BPMN model can be used in a BPM system to reflect organizational knowledge, it must be evaluated for flaws.

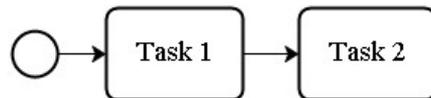
The set of “anti-patterns” of BPMN modeling includes the most common and frequent errors committed by modelers during BPMN business process design. These “anti-patterns” show incorrect use of sequence flow and linking objects (Kopp & Orlovskiy, 2018). The set of “anti-patterns” include:

1) a business process model does not have the start event (see Fig. 2);



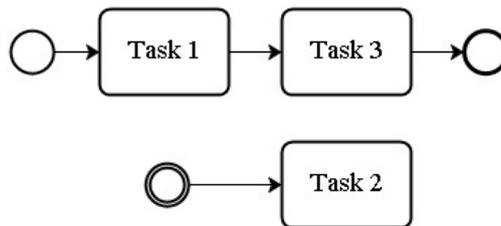
**Figure 2:** The start event is missing

2) a business process model does not have the end event (see Fig. 3);



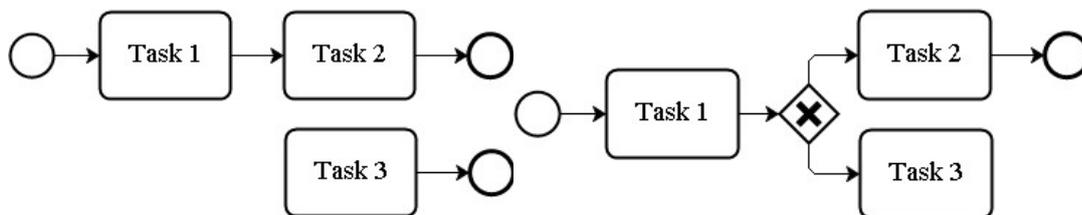
**Figure 3:** The end event is missing

3) a business process model includes intermediate events that start or end the process flow (see Fig. 4);



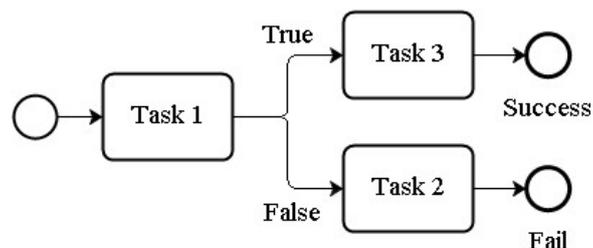
**Figure 4:** The intermediate event starts the process flow

4) a business process model includes activities that initiate or terminate the process flow (see Fig. 5 and 6);



**Figure 5:** The activity initiates the process flow    **Figure 6:** The activity terminates the process flow

5) a business process model has missing branching gateways (see Fig. 7).



**Figure 7:** The split gateway is missing

Depicted BPMN snippets (see Figure 2 – 7) demonstrate the most common and frequent mistakes committed by business process modelers. These mistakes originate from violations of BPMN syntax due to the lack of the modeler’s experience or other reasons. However, such mistakes may also affect the semantics of a business process since the poor model is not understandable and hardly maintainable. Furthermore, syntax mistakes detected in BPMN models may signalize flaws in real-world business processes. Hence, Table 2 below demonstrates a set of guidelines for the quality assessment of BPMN business process models.

**Table 2:** The set of guidelines for the quality assessment of BPMN models

No.	Guidelines	Elements	Restrictions
1	A model should have a start event.	Start Event	The number of start events is 1, $NSE = 1$
2	A model should have at least one end event.	End Event	The number of end events is greater than or equal to 1, $NEE \geq 1$
3	Intermediate events should not start the business process flow.	Intermediate Event	The number of incoming sequence flows is greater than or equal to 1, $Fin \geq 1$
4	Intermediate events should not end the business process flow.	Intermediate Event	The number of outgoing sequence flows is equal to 1, $FOut = 1$
5	Activities should not initiate the business process flow.	Activity (Task)	The number of incoming sequence flows is greater than or equal to 1, $Fin \geq 1$
6	Activities should not terminate the business process flow.	Activity (Task)	The number of outgoing sequence flows is equal to 1, $FOut = 1$
7	A process flow should be branched only using split gateways.	Start Event, Intermediate Event, Activity (Task)	The number of outgoing sequence flows is equal to 1, $FOut = 1$

Using the formulated guidelines (see Table 2), we propose the following procedure for BPMN models assessment (see Fig. 8).

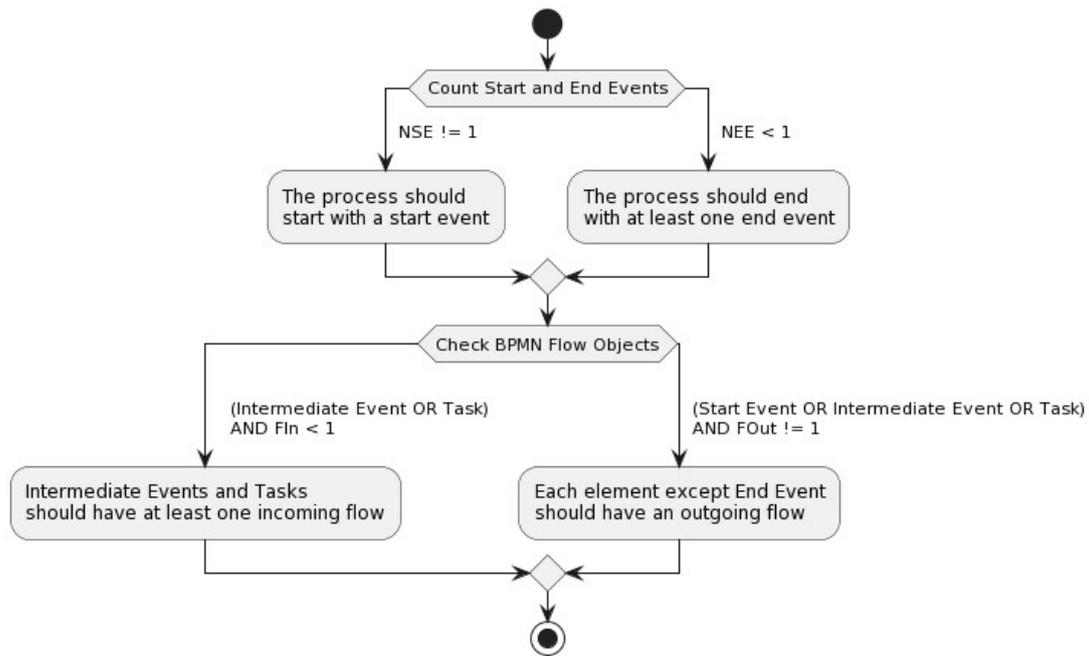


Figure 8: The procedure of BPMN models assessment based on guidelines

The proposed procedure of BPMN models assessment (see Figure. 8 above) will serve as the basis for the software tool for errors detection in BPMN business process models. The software tool should process collections of BPMN models stored as files on a modeler’s computer. We propose to use the Java programming language, which is cross-platform, object-oriented, relatively simple, and easy to use (Gao & Bai, 2021).

For the efficient processing of BPMN model files, we suggest using the Camunda BPMN model API (Application Programming Interface). It offers a simple and compact solution for performing reading and writing operations with BPMN 2.0 XML (eXtensible Markup Language) documents (Menski, 2014). In general, we develop the software tool using Eclipse Integrated Development Environment (IDE) and WindowBuilder plugin that makes it easy to design Java Graphical User Interface (GUI) applications powered by the Swing library (Voormann, 2022).

Therefore, Figure 9 below outlines the UML component diagram of the application we created for the BPMN models assessment.

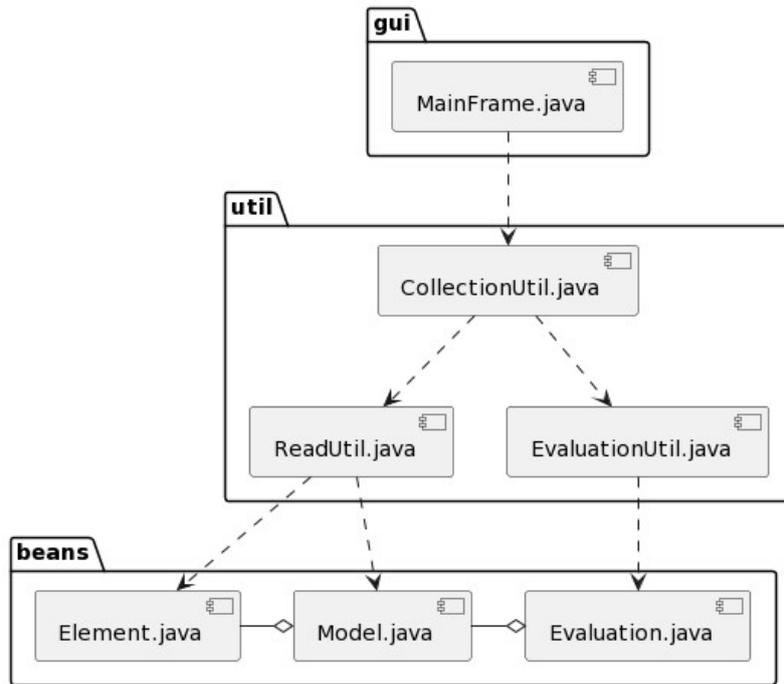


Figure 9: The component diagram of the developed application

Depicted component diagram of the developed application includes the following elements:

- 1) "MainFrame" is the Swing Java component that implements a GUI for the software tool that demonstrates BPMN models assessment results;
- 2) "CollectionUtil" is the collection of static Java methods for processing BPMN files stored in a pointed folder;
- 3) "ReadUtil" is the collection of static Java methods for reading BPMN files, extracting model elements and connections;
- 4) "EvaluationUtil" is the collection of static Java methods for checking BPMN models toward formulated guidelines;
- 5) "Element" is the plain Java class (so-called "bean") for representing data about a single BPMN model element;
- 6) "Model" is the Java bean for representing data about a BPMN model, including its name and elements;
- 7) "Evaluation" is the Java bean for representing data about evaluation results of a single BPMN model.

Finally, Fig. 10 below demonstrates the main window of developed Java application for errors detection in BPMN business process models.

Model	Start Events	End Events	Intermediate Events (in)	Intermediate Events (out)	Tasks (in)	Tasks (out)	Start Events (out)	Warnings
Credit_Scoring_7840de1bde374062bdf1fff4786bc668.bpmn	✗	✓	✓	✓	✓	✓	✓	[A model should have a single Start Event]
Credit_scoring_ae633fa3ecc14bceb7aeb6a7804d1856.bpmn	✗	✓	✓	✓	✓	✓	✓	[A model should have a single Start Event]
Credit_Scoring_cf0e56ba1f6747d6a21978128da3fe4c.bpmn	✗	✓	✓	✓	✓	✓	✓	[A model should have a single Start Event]
Dispatchin_of_goods_ca3ac1d3e9ce4cda979953ebc59bf6b7.bpmn	✓	✓	✓	✓	✓	✓	✓	☐
Dispatch_01_6a478fb945e4464abc19d1a74b903390.bpmn	✓	✓	✓	✓	✓	✓	✓	☐
Dispatch_1cb656bdb9ec435fe33bf4df633c2f5.bpmn	✓	✓	✓	✓	✓	✓	✓	☐
dispatch_of_goods_2a1f9e8760a844f9b1794af65d2746ee.bpmn	✓	✓	✓	✓	✓	✓	✓	☐
Dispatch_of_goods_42528d54df304f9fa9c747c8d40deb35.bpmn	✓	✓	✓	✓	✓	✓	✓	☐

Figure 10: The main form of the developed Java application

The main window of the developed software tool demonstrates BPMN models assessment results in a tabular view, including the name of a BPMN file, conformance to guidelines formulated in Table 2, and suggested warnings for model fixing.

### 3. Results and discussion

To validate the software tool for BPMN models assessment (see Fig. 11), we used the set of BPMN models provided in the Camunda GitHub repository utilized in the previous study (Kopp & Orlovskiy, 2020).

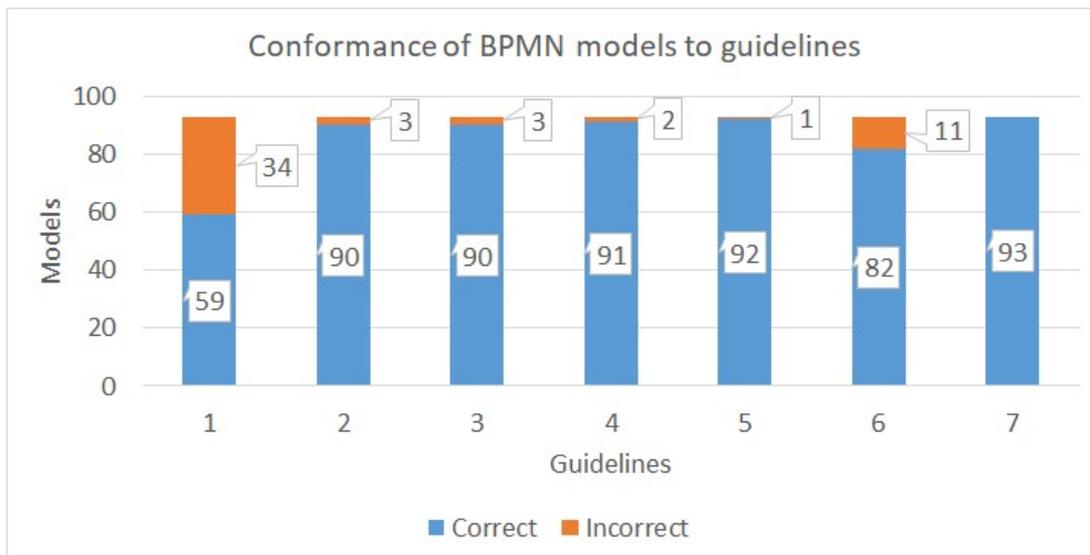


Figure 11: Conformance of BPMN models to guidelines (see Table 2)

In total, we evaluated 93 BPMN models using the developed software tool. These models belong to the collection of BPMN diagrams created during Camunda training sessions for different business domains, including goods dispatch, insurance recourse, credit scoring, and a self-service restaurant.

According to the obtained results, only 51 of 93 evaluated BPMN models correspond to formulated guidelines (see Table 2). The remaining 42 models violate at least one of the guidelines. It is approximately 45% of designed BPMN models in the Camunda dataset.

Figure 11 demonstrates that:

- 1) 37% of designed BPMN models do not correspond to the guideline (1) – 34 of 93 models;
- 2) 3% of designed BPMN models do not correspond to the guideline (2) – 3 of 93 models;
- 3) 3% of designed BPMN models do not correspond to the guideline (3) – 3 of 93 models;
- 4) 2% of designed BPMN models do not correspond to the guideline (4) – 2 of 93 models;
- 5) 1% of designed BPMN models do not correspond to the guideline (5) – 1 of 93 models;
- 6) 12% of designed BPMN models do not correspond to the guideline (6) – 11 of 93 models;
- 7) all 93 designed BPMN models correspond to the guideline (7).

Hence, we consider guidelines (1) and (6) as the most important to check since they are the most violated ones by real-world BPMN models. These results say that frequently (37%) in BPMN diagrams, Start Events can be missing, or there could be several Start Events that can mislead stakeholders. Also, we observe the tendency (12%) when Tasks are used instead of End Events to terminate workflows or instead of Gateways to split the workflow into several paths.

We can explain the most frequent violation of guideline (1) (see Fig. 11) by the desire of business process modelers to depict complex workflows that contain more than one start event. However, several start events can mislead model readers. The presence of two or more start events signalizes that a BPMN model has to be split into several ones. Using the analysis results of BPMN models' conformance to guidelines (see Figure 11), we propose the quality assessment scorecard for BPMN business process models (see Table 2).

**Table 3:** The quality assessment scorecard for BPMN business process models

No.	Guidelines	Conformance rates	Weights
1	A model should have a start event.	37%	63%
2	A model should have at least one end event.	3%	6%
3	Intermediate events should not start the business process flow.	3%	6%
4	Intermediate events should not end the business process flow.	2%	4%
5	Activities should not initiate the business process flow.	1%	2%
6	Activities should not terminate the business process flow.	12%	20%
The total quality assessment			100%

Business process modelers can use the proposed scorecard (see Table 3) to self-analyze designed BPMN diagrams. We did not mention guideline (7) since all models in our dataset follow it. The scorecard includes the remaining guidelines (1) – (6) with weights calculated by re-scaling conformance rates. Hence, the assessed quality of a BPMN model is the sum of weights for guidelines to which the model corresponds. Furthermore, we can use obtained results to rank guidelines by their severity for quantitative assessment of BPMN business process models.

#### 4. Conclusion

In this study, we suggested guidelines and the application for the quality assessment of BPMN business process models. Research outcomes supposed to improve business process modeling and analysis activities

of BPM projects by detecting BPMN design errors. High-quality business process models that do not have design errors are understandable and maintainable. They have less probability of having errors in described workflows. Well-designed business process models are efficient for analysis, re-design, and automation of workflows; they reduce the risk of extra costs to fix possible errors.

Obtained results include the following:

- 1) defined the set of so-called “anti-patterns” that summarize incorrect constructs within BPMN models that decrease their quality;
- 2) formulated guidelines that help to examine BPMN models and detect considered “anti-patterns”;
- 3) suggested the procedure of BPMN models assessment based on guidelines;
- 4) developed the cross-platform software tool for checking BPMN models toward formulated guidelines;
- 5) analyzed the set of real-world BPMN models that belong to different business domains;
- 6) identified guidelines violated the most frequently by BPMN modelers.

Future research includes quantitative techniques for numerical quality estimation of BPMN models based on suggested guidelines and experimental results. We also plan to extend the software tool with quality computing and other features, such as database and server-side components. We have chosen the BPMN modeling notation as the most popular for business process modeling. But we also plan to consider other modeling notations in the future, such as EPC, UML, or IDEF.

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