A Transparency-oriented BPMN Model Inspection Checklist: From conception to expert evaluations

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ABSTRACT

Process modeling is a key component for the success of an information system. Ensuring the quality of these models is essential for developing effective systems, including accessibility, auditability, understandability, informativeness, and usability. This article presents the design and evaluation of the Transparency-oriented Process Checklist (TPC), a structured inspection instrument for BPMN models emphasizing transparency-related quality characteristics. The TPC was developed by analyzing and integrating items from two existing checklists (CMP and BPCheck), refining them based on transparency dimensions, and structuring it with 51 verification items. A comparative evaluation was conducted to assess the applicability and effectiveness of the TPC. The evaluation team was divided into two groups. One group used the TPC, while the other applied BPCheck to inspect a real-world BPMN model. The results demonstrated that the TPC facilitated the identification of more quality problems (21 vs. 17), achieved greater agreement with the predefined "Oracle" answers (68.63% vs. 36.36%), and received more favorable assessments regarding understandability and support for identifying auditability issues. These findings underscore the TPC's potential as a valuable instrument for supporting the inspection for the enhancement of BPMN process models.

KEYWORDS

Transparency, Inspection, Process Model, Business Process Modeling Notation (BPMN)

1 Introduction

Process models capture actual or future organization practices, and as such they are an important information source for eliciting software requirements [15]. Thus, ensuring the quality of these models becomes essential for the quality for software construction development. Conceptually, explicit representations of business processes helps the construction of software for information systems (IS) [14]. BPMN models are valuable in the requirements engineering process for IS.

Requirements that are not met by the software bring out defects. High-quality process models contribute to software cost reduction by preventing defect propagation. Conversely, low-quality models can result in defective software. Identifying defects in software artifacts earlier is cheaper than repairing modeling errors later in a project [29].

Inspection checklists integrate a structured process with a list of verification items that must be observed for defect identification and quality parameter detection [35]. The use of checklists for software artifacts is a practice extended beyond code. Therefore, inspecting requirements documents is an important practice. During inspection, using a "*good checklist*" helps inspectors to pay attention to process detail, improving defect identification. Consequently, the fewer defects found, the better the quality of the inspected artifact. In this context, inspection not only improves the detection of defects, but also promotes the removal of defects during the construction/evolution of software [5], thus improving the overall software production [4].

Among inspection instruments, the checklist stands out for ensuring the desired quality in the process. Structured checklists, with clear and objective criteria, become essential tools for ensuring model quality [5]. This is where the concept of Transparency [4] becomes paramount. It is essential for enhancing process models and their quality, as well as for effective information sharing. Transparency contributes towards process models that are not only technically sound (syntactically and semantically) but are also clear, understandable, and accessible to all relevant stakeholders, thereby truly supporting business operations and decision-making.

Regarding organizations, transparency is classified as process transparency and information transparency [22]. In both cases, it is essential to establish clarity regarding the policies, standards, and procedures to be followed, ensuring that system behavior aligns with stakeholder expectations. This alignment often involves not only functional aspects but also Non-Functional Requirements (NFRs), such as transparency itself. Although the importance of identifying and fulfilling NFRs is increasingly acknowledged, their elicitation and specification continue to pose significant challenges. For NFRs to be effectively addressed, they must be adequately specified and subsequently implemented, considering the system architecture, expected behaviors, and the usage environment.

In this context, requirements elicitation, especially when supported by models, such as process models that describe the intended behavior of system functionalities and user interactions, offers an approach that promotes more complete requirements coverage [30].

Few studies have focused on the inspection of Business Process Model and Notation (BPMN) models [24], when compared to other modeling languages, such as, for example, UML. However complementary BPMN and UML are, BPMN is more geared towards clients as UML is more geared to developers. Our focus is on the BPMN language due to its distinct advantages. BPMN is a leading language for business processes and workflows, with different tool vendors and service providers. Above all, BPMN provides the concept (lanes) that allow workflows to be assigned to organizational actors (responsibilities), which fits well for organizational processes, and provides representational support for data and activities.

The main problem tackled by this research lies in the gap in quality assurance for BPMN models. Despite the growing importance of these models for business success and systems development, there are few studies that comprehensively address the issue of BPMN model quality. Among the most relevant contributions are the BPCheck checklist proposed by Mello [11] and the analysis of human inspection challenges by Haisjackl *et al.* [17, 18]. This scarcity is concerning, given that the widespread adoption of BPMN coexists with neglected quality aspects, which affect the comprehensibility and usability of the models [8].

Moreover, an evaluation of checklists for BPMN model transparency, complemented by an expert-based inspection using the checklist on a model [31], exposed limitations in the BPCheck de Mello et al. [11], as criteria are often subjective, leading to inconsistent interpretations by different inspectors. Furthermore, an absence of items was noted to mitigate comprehensibility issues, such as problems with activity labeling, a challenge mentioned in the literature [20].

Given this scenario, our research studied two different checklists, compared them, and used transparency knowledge to design an improved checklist. The result is the "*Transparency-Oriented Process Checklist (TPC)*." It is based on the analysis and search for similarities between the Checklist for Technical Review of Work Process Models (CMP) and BPCheck de Mello et al. [11]. The CMP is an auditing instrument of the Process Manual of the Bahia Court of Justice Appendix 7 (page 33) [1]. The transparency knowledge came from the PUC-Rio CTS catalogue[2] and the Cappelli thesis [4].

This article presents the research design that produced the TPC, but focus on its evaluation, emphasizing transparency-related quality characteristics. The results demonstrated that the TPC facilitated the identification of more quality problems, achieved greater agreement with the predefined answers, and received more favorable assessments regarding understandability and support for identifying auditability issues.

The article is organized as follows. Section 2 presents a literature review of the main concepts of Process Modeling and Inspection. Section 3 discusses the works related to the theme, highlighting relevant studies that served as a basis for the development of the article. The methodological procedures for the design and initial evaluation of the proposal are found in Section 4. Section 5 describes the preliminary results of the evaluation. Finally, Section 6 provides a brief discussion and Section 7 contains the final considerations and future work.

2 Background

In this section we will focus on the topics that anchored our research. Each brings an overall explanation, together with relevant literature.

2.1 Modeling

Process modeling allows for the identification of information necessary to define a set of requirements capable of supporting the organization's operations and enabling system analysis and design. In this sense, Rocha and Reis [28] reinforce the importance of process modeling, which, when applied to software development in the requirements elicitation phase, provides for the reduction of requirements redundancies and offers a higher probability of ensuring they reflect business needs.

Quality process models are important, as their quality influences software quality [20]. Many problems in software development are caused by poorly defined or incomplete requirements [3]. To avoid undesirable problems and obtain structured process models, the construction of requirements, such as non-functional ones, is still a challenge to be overcome [23].

To address these challenges and ensure the quality of process models, inspection is a practice that extends beyond code to other software artifacts such as interface prototyping, UIProtoCheck [10], and Data Protection Law, LGPDCheck [25]. Inspection has the potential to detect inconsistencies, standards violations, and anomalies in software artifacts from the initial stages of development. The analysis is based on reading and static analysis for defect detection as early as possible, reducing the costs to correct them.

2.2 Process Inspection

Based on visual examination, "*inspection*" is a technique that allows for the detection of inconsistencies, standards violations, and anomalies in software artifacts from the initial stages of the process. The literature presents different types of inspection techniques, such as ad-hoc, checklists, and perspective-based [12].

Among inspection techniques, the checklist stands out for ensuring the desired quality in the process. Structured checklists, with clear and objective criteria, become essential tools for ensuring model quality. When well-structured, with questions that direct the inspector, the checklist allows for "*Yes*" or "*No*" answers [5].

An advanced literature search in the main databases ACM Digital Library[3], IEEE Xplore[4], and SCOPUS[5], from January 2013 to December 2024, revealed a scarcity of studies on Inspection in BPMN process models. Only three studies were identified, and the only known checklist proposal for human inspection of BPMN process models is BPCheck by de Mello et al. [11].

The first study [11] demonstrated that a lack of correspondence between the textual description and the model can compromise the latter's quality. The second work [17] showed that humans face challenges in detecting quality problems in process models. A follow-up study [18] from [17] points out that a systematic approach, such as using checklists with domain-specific questions and classification of the addressed quality problem, can contribute to identifying problems and ensuring model quality.

2.3 Transparency

The concept of transparency is emerging in modern companies and their information systems [19]. In the context of information, transparency assists in decision-making by supporting the relationship of trust [9]. Trust based on transparency has become a relevant demand amidst global transformations, as the disclosure inherent

[1] http://www5.tjba.jus.br/estrategia/wp-content/uploads/2023/03/Manual-de-Gest%C3%A3o-de-Processos-V2.0-Final.pdf
[2] https://tinyurl.com/2yw9utyt

[3] https://dl.acm.org
[4] https://ieeexplore.ieee.org
[5] https://www.scopus.com

in this practice offers competitive advantages, such as contributing to an increase in business negotiations. When applied in organizations, transparency provides a clear view of processes and their information, reducing the possibility of data omission, enabling control over products and services, facilitating investigations, and increasing confidence.

However, transparency is not achieved merely through the disclosure of information [13]. While in some contexts transparency refers to the visibility or openness of information, in others it may refer to the quality of an object itself [33]. In software, it must be treated as a quality requirement, addressed by the field of Requirements Engineering [22].

This goes beyond simply publishing data; the very processes that produce the information must also be transparent (Process Transparency). This allows stakeholders to understand not just the data, but also how it was promulgated.

The challenge lies in operationalizing an abstract concept like "*transparency*" into concrete, verifiable attributes. A key approach from the literature for this is the use of the Non-Functional Requirements (NFR) Framework and the Softgoal Interdependency Graph (SIG), an intentional modeling instance that decomposes abstract concepts into more concrete qualities [22]. Using this approach, Cappelli [4] proposed a graph to represent the qualities that constitute transparency, defining a systematic method for prioritizing and treating dependencies by decomposing transparency NFRs into specific quality characteristics.

Leite and Cappelli work resulted in the Software Transparency Catalog (CTS), developed by the PUC-Rio requirements engineering group [22, 27]. The CTS serves as a knowledge base that provides a comprehensive set of qualities to help achieve transparency in software artifacts. According to Gomes et al. [16], three dimensions are pillars of transparency: the scope of producible information, the quality of information, and the universe of access to information. These dimensions are directly related to the qualities of Informativeness, Usability, and Accessibility detailed in the CTS.

Building on these concepts to support the representation of processes, Cappelli [4] defined transparency in organizational processes, referred to in this research as Organizational Process Transparency (OPC), using the CTS as a foundation. Although the catalog was originally conceived for software artifacts, it provides a comprehensive set of qualities that serves as an anchor for building other artifacts, including process models, with the objective of being transparent [22].

3 Related Work

Haisjackl et al. [17] investigated the strategies used by humans and the challenges they face during the inspection of process models. The structure used in their investigation allowed the authors to understand the inspection process by classifying defects in an exploratory study with experienced subjects [18]. They identified three strategies that subjects used to inspect models and identify quality problems: a) Obtaining an overview of the process model before checking for quality problems; b) Using a pre-defined list of potential quality problems to guide the inspection; c) Reading and verifying the model without a prior general analysis. The results show that humans face challenges when detecting quality problems in process models. Some of these challenges include a lack of domain knowledge, a lack of BPMN knowledge, unclear inspection criteria, and numerous false positives.

In de Mello et al. [11], the authors proposed BPCheck, a checklist-based inspection technique for detecting defects in BPMN process models. Motivated by the need to ensure the syntactic and semantic correctness of BPMN models, the authors developed BPCheck with 55 verification items, divided into three groups—static, process flow, and data objects—with "*Yes*," "*Not*" or "*Not applicable*" as response options, based on a defect taxonomy categorized as Omission, Incorrect Fact, Inconsistency, Ambiguity, and Extraneous Information.

The evaluation of BPCheck was based on an observational study. Twelve participants were trained before execution and divided into three groups to analyze the semantic and syntactic aspects of three models of varying complexity (low, medium, and high). Thus, de Mello et al. [11] demonstrated that a lack of correspondence between the textual description and the model can compromise the model's quality, especially concerning semantic defects.

The works of [1] and [21] are proposals based on automation, with greater emphasis on syntactic verification. Table 1 presents a summary of related work.

Table 1: Analysis of related approaches to support model inspection

Study	Contributions and Limitations
[11]	Notably, quality aspects are considered in BPCheck. Especially, semantic aspects, through a defect taxonomy (omissions, incorrect facts, and inconsistencies) for the model's verifiability. However, a lack of operationalization is observed for actions to detect quality aspects, for the understanding and usability of the process model. A model that is syntactically correct but not understandable to stakeholders compromises the purpose of process modeling.
[17]	Reinforces the importance of tools that support reviewers during model inspection. It also highlights the relevance of classification to facilitate the understanding of the process. However, it does not propose an operationalizable instrument.
[18]	This study is a follow-up of [17], providing a more in depth study on the topic of human inspection.
[1], [21]	Work related to automatic verification, tackling mostly syntatic problems in the models.

From this analysis, it was possible to understand the importance of correlating models with quality requirements, as well as to obtain insights for proposing a checklist for inspecting process models. This scenario is aggravated by the scarcity of non-automated instruments (such as checklists) and by the limitations of automation frameworks, which are often generic and do not include checklists. They focus on syntactic verification, not offering advanced support for the analysis of behavioral semantics [21]. Consequently, semantic errors remain undetected during design time, due to BPMN semantics, which are considered ambiguous and not concise [1].

4 Research Design

For the specification of the Transparency-oriented Process Checklist, multiple foundational sources were combined to support a comprehensive and systematic approach. The research design consisted of four phases:

(1) An initial investigation of an existing checklist used by practitioners (CMP) [6] to produce a transparency oriented checklist based on a transparency catalog, generating a TCP v0.0 [32].
(2) Comparisons of the CMP with BPcheck, and of each one with the catalog (CTS) and with the operationalization of transparency for business processes (OTP) [4], generating a TCP v1.0 [31].
(3) A first evaluation and further evolution of the TCP, generating TCP v2.0 [31]
(4) The final version (v2.0) of the checklist was evaluated by comparison with BPCheck. The evaluation was carried out by 10 experts.

Below we will give a short description of the first three phases. The last phase will be detailed in Section 5.

4.1 TPC: v0.0

Our first study on the quality of process models [32] was motivated by the professional work of the first author, who works in inspecting BPMN models. The study looked at the concept of transparency as a way to improve the quality of models by addressing the quality of inspection checklists applied to BPMN.

The starting point was the CMP checklist, developed by the TJBA (Tribunal de Justiça da Bahia – Bahia State Court of Justice). The study was based on three inputs:

(1) The Transparency Catalog (CTS) from PUC-Rio[7],
(2) The TJBA's Process Modeling Policies (PMP), and
(3) The CMP itself.

The study involved comparing and identifying checklist items related to transparency. This identification can either recognize that a CMP item already addresses a transparency attribute as defined in the catalog or identify a gap if the item does not address the catalog attribute. In the latter case a new question must be added to the checklist to cover that specific aspect of transparency. A process was designed using BPMN, enacted, and resulted in version v0.0.

4.2 TPC: v1.0

In this phase v1.0 was produced.

This phase was data intensive, comprising the comparison of CMP and BPcheck with the CTS and Cappelli CTS operationalizations (OPT), as well as a direct comparison of both checklists.

First, to strengthen the focus on transparency, both CMP and BPCheck items were scrutinized to identify opportunities to adopt the operationalizations proposed by OPT [4], which translate the CTS into practical evaluation criteria. These operationalizations helped refine the CMP and BPCheck items and guided the inclusion of new ones. In this process, the CTS main qualities (Accessibility, Auditability, Understandability, Informativeness, and Usability) were analyzed to derive specific criteria. When analyzing the CTS Uniformity (a quality that helps Usability) quality, for example, several operationalizations (OPT) were observed, including, but not limited to, the standardization of notational colors, syntax and semantics of symbols, and graphical representation. This process supported the definition of new improved checklist items, such as "*Do all elements used in the model follow the BPMN notation color standard?*". These opportunities for both checklists were organized in a set of spreadsheets.

Second, each item of the CMP was analyzed, one by one, in relation to all items of the BPCheck (literature checklist). A correlation is considered positive when there is similarity between the items analyzed and the identifier of the correlation item is evidenced. These relations were registered in a set of spreadsheets.

Third, using the data collected in the set of spreadsheets, TPC v1.0 was designed. It is comprised of 29 items.

4.3 TPC: v2.0

In this third phase the v1.0 was evaluted and a new improved version, v2.0, was produced.

The evaluation was conducted as follows: five professionals, each with over five years of experience, inspected a public process model available on the Gov.Br platform between May 28 and May 31, 2024. The purpose of the inspection was to assess the usability, efficiency, and efficacy of the developed checklist.

The inspectors analyzed the BPMN process model by answering the 29 TCP v1.0 items with "yes" or "no" and recording their observations for each item in the "comments" field. After the inspection, the professionals answered 3 open questions regarding usability, efficiency and efficacy.

- Usability – assessed by the inspectors' understanding of the checklist questions and the completeness of the inspection process. The inspectors suggested:that 6 items be split, and 5 items be rewritten out of the 29 items.
- Efficiency – measured by the number of defects identified in the model and the time each inspector spent conducting the inspection. The evaluation revealed a significant variation in application time, with an average duration of one hour and three minutes. All five inspectors were able to follow the established process in under two hours. One inspector finished in just twenty minutes.
- Efficacy – determined by comparing the number of defects found by the inspectors with the total number of discrepancies identified by the oracle. The five inspectors' results revealed consistent conclusions when compared to the oracle's responses. Based on agreement from more than half of the inspectors, the analysis showed that the first inspector correctly answered 84% of the items, the second 69%, and the third 61%.

The inspectors demonstrated solid expertise in process modeling, providing valuable feedback on the quality of the questions and responding to all evaluation items related to usability, efficiency, and efficacy. Additionally, some inspectors spontaneously recorded information about defects found in the inspected model.

Based on this evaluation, a new TCP version, v2.0 was proposed (see Table 2). This final version of the TCP, with 51 items/questions,

[6] Appendix 7 (page 33) at http://www5.tjba.jus.br/estrategia/wp-content/uploads/2023/03/Manual-de-Gest%C3%A3o-de-Processos-V2.0-Final.pdf
[7] https://tinyurl.com/2yw9utyt

targets inspectors and domain experts, supporting both the evaluation and the development of transparent and high-quality process models. Following its specification, an initial expert evaluation was conducted to assess its applicability and effectiveness. The next Section will detail its evaluation.

Table 2: Transparency Oriented Process Checklist

Nº	Items
01	Are the pools clearly described in the BPMN model, i.e., do they represent an organizational participant or the process name when referencing a main process?
02	Does the Pool in the process model use terminology specific to the application domain?
03	Is the Pool easily and directly identified in the process model descriptions?
04	Does the Pool labeling follow the standard of capitalizing the first letter of each word (Title Case)?
05	Do the pools in the model adequately reflect the process context, representing the participants and their respective activities in the lanes?
06	Are all activities that are immediately after the start event and before the end event positioned in the correct lanes?
07	Do the activities ensure that the process conclusion is visually coherent and logically organized ?
08	Does the activity name in the model correspond to the action to be performed and its functions in the process?
09	Does each process activity have its label started with an infinitive verb, followed by a noun, and contain 1 to 5 words, without conjunctions?
10	Are the descriptions of the activities in the process model concise, focusing on essential aspects, with operational details recorded in annotations, for example?
11	Are there information in the "Activities" that indicates they should be represented by other elements (type: events, data objects, annotations)?
12	Are there overly complex activities that, to align with the desired level of abstraction, require subdivision into multiple smaller activities or a new process?
13	Is there an activity that would be more effectively represented as a subprocess to improve modularity and reusability within the model?
14	Does the sequence of activities demonstrate coherence and alignment with the established process model, ensuring a flow that meets organizational needs?
15	Are there activities that do not contribute to the defined objectives of the process model and affect the correct representation of concurrent activities?
16	Have activities considered essential to the process model been omitted?
17	Are critical activities to the process model inadequately described?
18	Are there similar or identical activities in different pools/lanes?
19	Is the start event represented in the model and named with the term *"Start"*, to indicate the initial point of the process?
20	Is the end event represented in the model and named with the term *"End"*, to indicate the terminal point of the process?
21	Do intermediate events, except for timer and connector events, have descriptions starting with a noun, indicating what is being sent, followed by a past participle verb (e.g., "model inspected")?
22	Are all intermediate events positioned to facilitate immediate identification of their function, occurrences, or results of actions (activities)?
23	Are intermediate events adequately assigned to the lanes of those responsible for generating them?
24	Do connection intermediate events, such as "Link" events, labeled with a noun, show the sending and receiving to connect process sections, avoiding sequence flow crossings?
25	For each intermediate event, are the respective responsibilities (role and its contribution) well-defined in the process flow, in the sense that they must occur for the process to be executed?
26	Are events based on temporal conditions aligned with the specific needs of the process, indicating a temporal condition to be met?
27	Is the labeling of timer events presented with a gerund verb and a temporal indicator, to facilitate immediate identification of its role in the process?
28	Do gateways ensure proper synchronization between activity flows?
29	Are the conditions established in the outgoing flows of Gateways precise, clearly defined, and viable for the process model?

5 TPC Evaluation

This section deals with phase 4 of our research design. It is organized as follows: the instruments used in the evaluation, the inspectors selection, the production of the oracle, and the results of the evaluation of the TPC v2.0 and BPcheck. A public process model from the Gov.br Platform was used as the artifact to be inspected.

5.1 Evaluation Instruments

The TPC and BPCheck evaluation process used an online form, subdivided into five sections: (0) Free and Informed Consent Form; (1) Participant Profile Identification; (2) Instrument for Process Model Inspection, containing the designated checklist (TPC or BPCheck); (3) Checklist Evaluation; and (4) Declaration of No Prior Knowledge of the specific checklist used. The effectiveness of the TPC was measured by comparing its ability to identify quality problems in the model with that of the BPCheck.

The *"Profile Identification"* section, composed of 8 closed-ended questions, aimed to outline the profile and experience of the inspectors in process modeling and process model inspection. A form was used addressing aspects related to: ability to analyze and interpret process models (Id 1.1); ability to identify quality problems for model improvement (Id 1.2); familiarity with BPMN process modeling (Id 1.3); experience time with BPMN process modeling (Id 1.4); age (Id 1.5); education level (Id 1.6); field of study (Id 1.7); and professional category (academic, professional, or both) (Id 1.8).

Nº	Items
30	Are the labels of gateway outputs unambiguously described?
31	Are gateway exit labels located close to the respective gateways, making it easy to visually identify possible flow directions?
32	Do the combinations of events and gateways correctly reflect all execution scenarios of the process model?
33	Do annotations in the process model exclusively contain additional and relevant information about the process?
34	Is it possible to convert some annotations into "Events" or "Activities" to improve the clarity, efficiency, and functionality of the model?
35	Do the labels of data objects offer interpretability, representing an applicable state and facilitating immediate identification of their functions and uses within the process?
36	Do the data objects represent a repository of information (database, systems) to be persisted?
37	Are the data objects consulted by the activities associated with them?
38	Are data objects linked to the process model labeled using a noun?
39	Does the arrangement of data objects represent the data manipulation behaviors generated or consumed by the activity?
40	Are the data association arrows from data objects to activities correct?
41	Does the header present the information: author identification, version, and description of the process model?
42	Does the description in the model header explicitly state the objective of the process model concisely?
43	Does the process model minimize the number of sequence flow crossings between elements?
44	Do all elements used in the model follow the BPMN notation color pattern?
45	Do all elements used in the model follow a font size standard?
46	Do all elements used in the model follow an element size standard?
47	Does the labeling of model elements follow a consistent style, with activity labels centered, for example?
48	Are there elements or information in the model that could be removed, keeping only essential data for its interpretation?
49	Are there inconsistencies or contradictions between elements in the BPMN model (e.g., subsequences of activities or gateways that are mutually exclusive)?
50	Are there inconsistencies or contradictions that affect the integrity and executability of the model?
51	Is the process model accessible, for example, is the access link or sharing location made available?

The *"Checklist"* section contains each checklist with their respective items, each being identified by a number (Id). This section allowed the inspector's response to the item/question.

The form's *"Checklist Evaluation"* section, composed of six questions (three open-ended and three closed-ended), aimed to collect the inspectors' perceptions of the checklist used. The closed-ended questions addressed: *"Did the checklist allow you to observe non-evident quality aspects during the analysis of a process model?"* (Id 3.1); *"Does the checklist enable the identification of auditability problems in the process model?"* (Id 3.2); *"Is the Checklist easily understandable?"* (Id 3.3). The open-ended questions explored: *"One of the main reasons for process modeling is the possibility of making process models more transparent. Given this, how do you understand that the checklist helped in discovering problems related to transparency?"* (Id 3.4); *"Was it possible to understand the quality aspects identified by the checklist in the process model?"* (Id 3.5); and *"What aspects of the checklist did you consider most important for the quality of process models?"* (Id 3.6).

5.2 Inspectors

For the inspector selection process, sixteen candidates were invited who declared no prior knowledge of the TPC and BPCheck checklists and had not participated in the TPC's initial evaluation (phase 3). Inclusion criteria were: interest, availability, and experience in BPMN process modeling. After accepting the invitation, an individual online meeting was scheduled with each inspector to present the research objectives, evaluation instructions, and clarify doubts. At the end of the meeting, the complete documentation was provided, including the access link to the evaluation form and the respective checklist (TPC or BPCheck). Ten of the sixteen invitees agreed to participate.

For the inspection, a public process model [8] from the Gov.br Platform was used [9]. Two distinct groups were structured, each composed of five inspectors who worked independently: one group applied the TPC and the other applied the BPCheck.

The allocation of inspectors to the groups did not follow a criterion of randomness (random draw). As inspectors accepted the invitation, the researcher, acting as a mediator, allocated them sequentially to the groups (the first to accept to the TPC group, the second to the BPCheck group, the third to the TPC group, and so on) to ensure a balanced distribution as participants confirmed. This strategy was adopted considering the logistics and availability of the inspectors, which made a random draw unfeasible.

Regarding the ability to analyze and interpret process models (Figure 1), for Id 1.1: on a scale of 0 to 4, for the TPC, 60% stated they totally agreed, while 40% stated they partially agreed. For BPCheck, 80% totally agreed, and only 20% partially agreed.

Regarding the professional category, 100% of TPC inspectors were area professionals, while for BPCheck, 80% were area professionals and 20% were academics and area professionals (two options).

5.3 Oracle

The oracle was developed by the first author, whose expertise and experience in BPMN inspection enabled the identification of defects. The evaluation of the public process was conducted with detailed justifications for each decision. As usual in the production of an oracle for a subjective task, although being the gold standard, it needs to be taken with a grain of salt. Portugal et. al. [26] reported

[8]https://www.gov.br/transferegov/pt-br/sobre/mapeamento/parcerias/arquivos/lei-de-incentivo-ao-esporte-lie/02lie_captao

[9]This public process is different from the one used in the previous evaluation (phase 3)

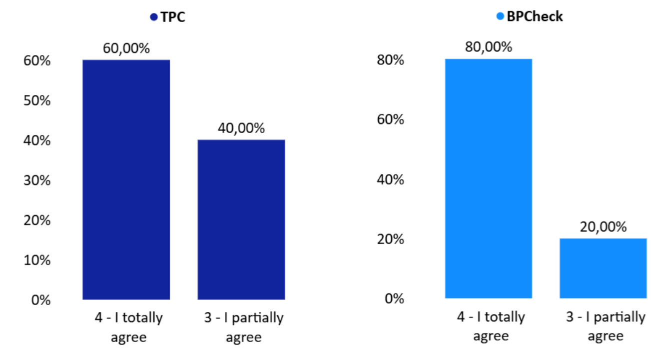

Figure 1: Ability to analyze and interpret process models.

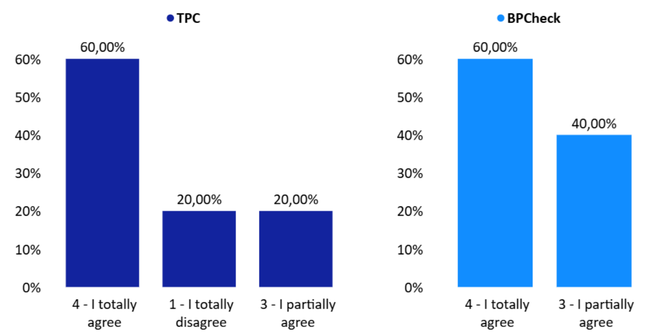

Figure 2: Ability to identify quality problems in BPMN models.

on the production of an oracle by different experts and showed how this is a hairy task[2]. Notwithstanding, for the sake of comparing the performance of the 10 inspectors, the gold standard produced is considered a proper one.

5.4 Results

Of the inspectors who managed to identify quality problems (Figure 2), for Id 1.2, for improving process models: for the TPC, 60% totally agreed, 20% partially agreed, and 20% totally disagreed. For BPCheck, 60% totally agreed, while 40% partially agreed.

Regarding Id 1.3, familiarity with BPMN process modeling, represented in Figure 3: for the TPC, 100% stated they totally agreed, while for BPCheck, 80% totally agreed and 20% partially agreed.

Considering experience time, for Id 1.4, in BPMN process modeling: for the TPC, 100% of inspectors had over 5 years of experience. It was observed that for BPCheck, 60% of inspectors had over 5 years of experience, 20% had 2-3 years, and 20% had 4-5 years.

Analyzing inspectors' education, for Id 1.5, it was noted that 100% from both the TPC and BPCheck groups were area specialists.

Regarding age range, for Id 1.6, it was observed that 60% of inspectors from both checklists were in the 45-54 age range. For the TPC, 20% were in the 35-44 range and 20% in the 65-74 range. For BPCheck, 40% of inspectors were in the 35-44 age range. The predominant age range in both checklists was 45-54 years.

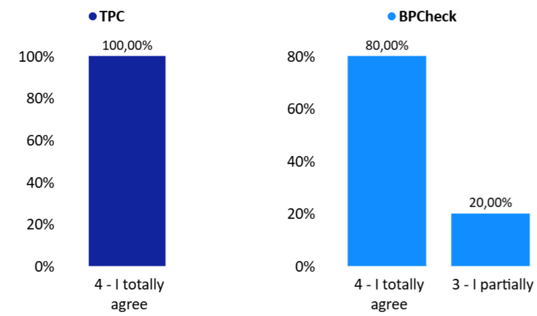

Figure 3: Familiarity of inspectors with process modeling.

Regarding inspectors' field of study, for Id 1.7, it was found that for the TPC, 40% were from other areas; 40% from Information Systems; and 20% from Systems Analysis. BPCheck showed a different distribution, with 60% of inspectors from other areas; 20% from Systems Analysis; and 20% from Computer Science.

Regarding the professional category, 100% of TPC inspectors were area professionals, while for BPCheck, 80% were area professionals and 20% were academics and area professionals (two options).

In the TPC, twenty-one quality problems were identified in the model (Ids 2.1, 2.2, 2.3, 2.4, 2.5, 2.7, 2.8, 2.10, 2.11, 2.13, 2.14, 2.15, 2.16, 2.17, 2.19, 2.22, 2.30, 2.35, 2.41, 2.42, and 2.48), while in BPCheck, with 55 items, seventeen quality problems were detected (Ids 2.2, 2.4, 2.8, 2.9, 2.13, 2.14, 2.15, 2.16, 2.19, 2.20, 2.26, 2.40, 2.46, 2.49, 2.50, 2.52, and 2.54). The TPC has the potential to identify quality problems in process models.

To evaluate the checklists' inspection in detecting quality problems, items were measured for agreement or disagreement with the *"Oracle"*. It was observed that three-fifths of TPC inspectors agreed with the *"Oracle's"* answers on thirty-five items, equivalent to 68.63%. The same analysis was done for item disagreements: three-fifths of inspectors did not agree with the *"Oracle's"* results on eleven items (equivalent to 21.57%). On five items (Ids 2.8, 2.10, 2.24, 2.26, and 2.49), equivalent to 9.80%, results were divergent, which can be attributed to the interpretation of different quality aspects: two inspectors agreed with the *"Oracle"* two disagreed, and one inspector chose a third option.

For the five items where the inspectors disagreed, the oracle constructed by the first author was used. The author has experience and knowledge in defect identification and performed the model evaluation, accompanied by detailed justifications for each decision to resolve the impasse. For five items, there was disagreement among the inspectors. For example, two of them identified errors in the model, two reported that the item did not apply to the model, and one noted that the model did not contain this type of defect, in items 2.24 and 2.26. When disagreements occurred, the items were reanalyzed. However, the consistency and prior reasoning of the oracle were decisive for the final result. This approach ensured that the final evaluation of each divergent item was objective and traceable to the justification established in the oracle.

An aspect observed in the response to item Id 2.51 *"Is the process model accessible, e.g., is the access link or sharing location provided?"*.

An observed aspect in the item's response, referring to the Accessibility quality, is the contradiction between the model's disclosure and its effective accessibility. Although the model was used in the inspection, which was only possible because the access link was provided, inspectors did not consider the process model accessible, even having used the model in the inspection, which highlights the relationship between accessibility and usability. Accessibility encompasses *"Making process information available through applications"*, denoting that the process model should be easily accessible. Just as transparency quality itself indicates, model availability represents the way to make its information available to stakeholders.

To ensure intuitiveness and consistency of the model's elements, thereby promoting process understanding by all stakeholders and making the models recognizable, the TPC sought to incorporate ease-of-use features. This was achieved by addressing aspects such as color differences (Id 2.44), font sizes (Id 2.45), and element box sizes (Id 2.46), as well as secondary notation and different labeling styles, elements that can negatively impact the process model's understanding.

The responses from inspectors who used BPCheck showed that more than three-fifths of BPCheck inspectors agreed on twenty items, equivalent to 36.36% of the *"Oracle"* On sixteen items, equivalent to 29.09%, inspectors disagreed with the *"Oracle"*. On nineteen items, equivalent to 34.55%, divergences were observed in inspectors' responses. In BPCheck, this approach achieved low agreement (36.36%) compared to divergences (34.55%).

Preliminary analyses indicate that the TPC required a longer average application time (0:35:12) than BPCheck (0:21:36). One possible interpretation stems from the fact that TPC inspectors had more experience than BPCheck inspectors. Another hypothesis is that the effort dedicated to recording perceptions about the model in the observations field may have increased their productivity and, consequently, reflected more engagement with the inspection activity.

One of the perceptions pointed out by inspectors about BPCheck is that it *"is very technical, and I have doubts if it is fully understandable"*, leaving uncertainty about *"whether it can really help, as the highly technical language employed requires a high level of specialization in BPM"* for Id 3.4, presenting difficulties in understanding quality aspects in the model, as mentioned by one of the inspectors *"(...) I found it difficult to make an association"* Another inspector mentioned, *"In parts, a more detailed level of verification is still lacking"* For example, when questioned on Id 3.1, the third inspector marked only two qualities, Accessibility and Informativeness, and the fifth inspector marked the qualities Informativeness and Usability. The first, however, identified all qualities (Accessibility, Auditability, Understandability, Informativeness, and Usability) in the process model and reported understanding the quality aspects identified by the checklist. Inspectors' responses to Id 3.5 indicated an inconsistency in the results they presented.

When questioned, on Id 3.2, *"Does the checklist enable identification of auditability problems in the process model?"*, 60% of inspectors who used the TPC *"totally agreed"* and 40% were *"neutral"*. For BPCheck, 40% *"partially agreed"*, 20% *"partially disagreed"*, 20% *"neutral"*, and 20% were *"totally agreed"*.

On a Likert scale of 0 to 4, for Id 3.3, *"Is the checklist understandable?"*, for the TPC: 40% of inspectors *"partially agreed"* and 40%

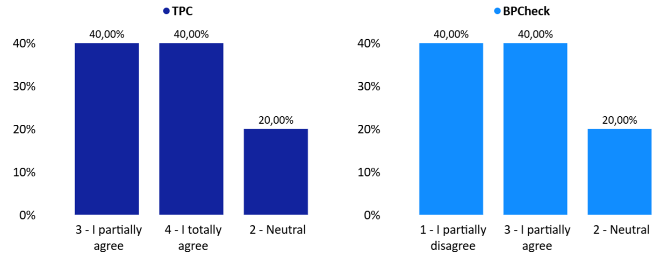

Figure 4: Comparative analysis of understanding the TPC and BPCheck.

of inspectors *"totally agreed"* while for 20% it is *"neutral"*. On the other hand, BPCheck obtained the same percentages, but contrastingly: 40% *"partially disagreed"*, 40% *"partially agreed"* and only 20% positioned themselves as *"neutral"*. Figure 4 summarizes the results.

Regarding the TPC, for the same Id (3.5), inspectors' positioning was *"Yes. Almost all!"*, *"I believe that despite some difficulty in this process, the questions were clear" "Yes, but the checklist was extensive" "Partially possible"*, and *"Yes! It was very clear and objective.*

At the end of the evaluation, for Id 3.6, *"What aspects of the checklist did you consider most important for the quality of process models?"*, it was observed that the most important aspects of the TPC were *"need to change the identification of start events"*, *"questions about the objects used," and "Possibility of standardization in modeling development"*.

Based on the quantitative data, each checklist was evaluated using the "Oracle" as a reference. It was observed that 100% of the items in both the TPC and the BPCheck were answered regarding the declaration of knowledge (or lack thereof) of the checklist used (Id 4). In the TPC group, 100% of the inspectors stated that they were unfamiliar with it, while in the BPCheck group, 80% reported being unfamiliar and 20% stated they were familiar with it.

The results obtained from the model inspection by experts were considered important, receiving positive evaluations, including reports of quality problems in the model.

As the comparison between different checklists is performed, the coverage of the TPC in identifying quality problems is monitored. The summary of the preliminary results of the two instruments (TPC and BPCheck) is presented in Figure 5, where item 1 denotes the number of items per checklist; item 2 shows the average time for conducting inspection with each checklist; item 3 presents the quantification of quality problems identified in the model, referencing the *"Oracle"*; item 4 displays the percentage of responses in agreement with the *"Oracle's"* results; item 5 shows the percentage of responses in disagreement; item 6 highlights the percentage of divergent responses; item 7 demonstrates the quantity of qualities identified in the model; item 8 exhibits the percentage of agreement regarding the checklist's ability to allow identification of auditability problems in the model; item 9 indicates the percentage of agreement regarding the checklist's ease of understanding.

6 Discussion

Our work has provided an overview of the literature regarding quality of BPMN modes, and argued of why quality should be a job

Nº	Description	TPC	BPCheck
1	Quantity of items	51	55
2	Average Inspection Time	00:35	00:21
3	Defect Identification	41,18%	30,91%
4	Item Agreements	68,63%	36,36%
5	Item Disagreements	21,57%	29,09%
6	Discrepancies between Items	9,80%	34,55%
7	Id 3.1 Qualities Identified	More than three qualities	Up to two qualities
8	Id 3.2 Auditability of the Model	60% Strongly Agreed and 40% were neutral.	40% partially agreed, 20% completely agreed, 20% partially disagreed, and 20% were neutral.
9	Id 3.3 Understanding the Checklist	40% Strongly Agreed, 40% Partially Agreed and 20% were neutral	40% completely disagreed, 40% partially disagreed, and 20% were neutral

Figure 5: Comparison of TPC versus BPCheck Results.

one for BPMN models, since they are frequently used in the requirement engineering process for organizational information systems. Assuming this fact, we selected the inspection strategy as a promoter of quality, and in this domain we have focused our research question in how to improve inspection checklists, considered a key element in promoting quality inspections. As such, we designed a research agenda, with four phases, which incrementally provided a checklist instrument oriented towards transparency. This paper reports on the results of the last phase of your research, which was the evaluation of the proposed checklist with the only checklist in the literature.

We have conducted two evaluations. One in phase 3 and the last in phase 4. In total we had 15 experts, 5 in the first evaluation, and 10 in the second. The first focused on the usability, effectiveness, and efficiency of the TPC v1.0, assessing the checklist's ability to guide inspectors in detecting defects for these dimensions. The evaluation also provided the designer with important feedback regarding the checklist, which was used to redesign the TPC producing v2.0. The second evaluation was different, instead of evaluating just the TPC checklist, the inspectors were asked to evaluate the only checklist in the literature as well (BPCheck). In order to perform this, two groups were formed and the their answers were compared.

The evaluations consisted of the inspection of two federal public process models, both modeled in BPMN, representing financial domain services and available on the Gov.br Platform , demonstrating the representativeness of business process management and modeling. Despite the similarities, it is important to highlight the differences in the representation of elements between the two models. For the second evaluation, a model with different element representations than the first evaluation model was used. It can be seen that the model contains 29 elements: 5 events, 18 tasks, and 6 gateways. These findings are consistent with studies on BPMN comprehensibility, which state that the control flow metric is the most appropriate for assessing BPMN complexity. Both the first and second evaluations demonstrated the Process Checklist's ability to benefit the inspection; however, it is essential that the modeler adhere to the process modeling guidelines (standards), which provide guidelines for structuring and implementing the model.

The evaluation conducted by different experts demonstrated meaningful impacts in two evaluations. The first one, involving five experienced experts with training in Computing and Systems, as well as familiarity with BPMN notation, was essential for determining the effectiveness of the TPC in a real model, resulting in incremental improvements to make detection efficiency more consistent. The second, involving ten experienced experts, different from those who participated in the first evaluation, divided into two groups with equivalent numbers and knowledge, inspected the TPC v2.0. This evaluation highlighted the positive effects of incorporating quality characteristics into the TPC items, when compared to the only checklist identified in the literature. The results indicate an increase in productivity and the quality of defect identification in the models, which translates into more effective and early problem detection, reducing rework and optimizing the BPMN process model development process.

The second evaluation also have used tan Oracle-based benchmark. The comparison revealed that our approach was able to tackle transparency issues with a level of coverage and clarity that was comparable to, and in some cases exceeded, those derived from conventional techniques. Participants also recognized the role of visual representations in fostering richer discussions about responsibilities, information flow, and access policies, which are central elements of organizational transparency. We understand that these productivity and quality gains found in our research may impact current practices that lack audit instruments to support BPMN model quality. This is particularly valuable in domains where ethical, regulatory, and governance concerns intersect with system behavior, such as public administration, healthcare, and financial services.

It is clear that the analysis and comparison processes provided insights for the development of the TPC. The evaluations provided interesting insights and led to the conclusion that BPCheck addresses limited aspects of quality characteristics. Quality is based on the CTS and OPT definitions. The evaluation allows us to investigate the quality of the description, that is, how the item ensures the quality of the model. Nonetheless it is important to address threats to validity of our research. We outline these below.

Construct Validity: The concept of transparency, although widely discussed due to its importance, grounded in literature and contextualized through two real-world processes, can vary significantly between domains and organizational cultures, with its use and interpretation being highly context-dependent. To mitigate this, we used the CTS which was collaboratively constructed, thoroughly substantiated, and validated by researchers with expertise in process analysis and Non-Functional Requirements (NFRs). Another strong point is that we have used an industry instrument (CMP) that has been used in practice for years, and also absorbed the knowledge of the only one checklist in the literature. The work was performed by the performed by the first author with guidance from the other co-authors, so there is a strong dependency on the viewpoint of the first author, but this was balanced with a proper research design that tried to mitigate subjectivity, which part of this type of research.

External Validity: There is a threat to external validity regarding the identification of others BPMN inspection checklist. Due to the lack of other checklists for comparing the inspection of BPMN process models, the TPC was developed using sources such as the CTS, OPT, and comparative analyses with BPCheck and CMP to build a quality instrument. The evaluation was conducted by 15 inspectors in two models, but the checklist was not yet used by third parties, besides those inspectors and the designer. The two co-authors did not use the checklist. On the other hand by publicizing the results [6], we hope that other interest parties from the research community conduct other evaluation, and that interest parties from industry consider using the checklist.

Internal Validity: A threat to internal validity is the potential influence of inspectors' varying experience and knowledge on their defect identification capabilities, thereby impacting the assessment results. In the TPC assessment, we prioritized experienced experts in BPMN process modeling. While the participation of such individuals may enhance the completeness and quality of the assessments, it also introduces a potential bias where findings might be skewed towards highly skilled individuals rather than solely reflecting the instrument's effectiveness. To mitigate other forms of bias and ensure a standardized approach, inspectors received uniform instructions and assessment forms. Furthermore, they signed a declaration declaration attesting to their lack of prior knowledge of the instrument, to avoid bias in the model assessment. We have also addressed the issue of the main designer in the construction validity, it is also correct to say that it is a threat, but several steps were taken to minimize their impact, either by feedback from the co-authors, as well as the feedback from the first evaluation, together with the discipline of organizing and publicizing the design and evaluation data in spreadsheets [6].

7 Conclusion

This article presented the development and an evaluation of the TPC, an instrument for inspecting BPMN models oriented towards transparency, expanding on the research by [32] and detailed in [31]. Given the importance of process models for software requirements, the TPC emerges as a promising instrument for identifying quality problems in models and also for demonstrating the potential effectiveness of Fagan's inspection on process models. As stated before, earlier detection of problems implies less rework cost after in the software construction process.

The findings of this study suggest that incorporating quality characteristics into checklist items can positively impact inspection performance, contributing to the identification of quality problems in BPMN process models. Our data indicate that experts have achieved better results using the TPC, reinforcing its potential as a more effective inspection technique. The impact of the TPC in identifying quality problems in the process model was evident. The findings reveal its superior performance compared to BPCheck and its potential as a valuable instrument for inspectors.

It is important to stress that by having 5 experts on the preliminary evaluation [32] and 10 experts on the TPC evolution we have dealt with the possible threat of the number of participants in the evaluation. We posit this by the fact participants with expertise in BPMN process modeling and an understanding of the essence of the inspection process embodied an uncommon body of knowledge. This fact, together with the time spent by each participant in inspecting the publicly available model makes a strong argument for the quality of their work, and as such, stressing the quality of our results.

The evaluation conducted by different experts demonstrated meaningful impacts in two evaluations. The first one, involving five experienced experts with training in Computing and Systems, as well as familiarity with BPMN notation, was essential for determining the effectiveness of the TPC in a real model, resulting in incremental improvements to make detection efficiency more consistent. The second, involving ten experienced experts, different from those who participated in the first evaluation, divided into two groups with equivalent numbers and knowledge, validated the TPC proposal. This validation highlighted the positive effects of incorporating quality characteristics into the TPC items, when compared to the only checklist identified in the literature. The results indicate an increase in productivity and the quality of defect identification in the models, which translates into more effective and early problem detection, reducing rework and optimizing the BPMN process model development process.

However, despite the promising results, it is important to emphasize that the approach has not yet been deployed in real development projects. As such, its full impact on software development practices and long-term system quality remains to be explored in future work. We understand the importance of prior work on guidelines for the design of BPMN models. Two exemples of this kind of work are [7] and [34], and we should also look in future work how guidelines may compare to our auditing oriented process.

Future work may also explore AI opportunities to automate the classification and analysis of checklist items. The effort for this activity, a manual and time-consuming task, can generate opportunities for item improvements. The use of Large Language Models (LLMs), such as ChatGPT and Gemini, among others, allows for data utilization and adaptation to solve specific problems.

ARTIFACT AVAILABILITY

Aiming at research reproducibility and the practice of Open Science, the artifacts supporting this study are publicly available on Zenodo. These materials include the TPC, analysis spreadsheets, and the process models that guided the development and evaluation of the TPC. Access to these artifacts is provided via the following [6].

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