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Process Modeling Guidelines: Systematic Literature Review and Experiment

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ABSTRACT

Process modeling is an indispensable task in the discipline of *Business Process Management*. The process models created in this task help its readers in to acquiring a higher comprehension of a process, allowing for the discovery of opportunities for its improvement. However, the comprehension of a process model is not guaranteed, as process modeling is a complex task that depends on the proficiency of the process modeler to avoid the creation of badly designed constructs. Process modeling guidelines are an essential tool in this regard, though they are dispersed across the many studies of the literature and not all of them have empirical evidence validating their effects. In addition to this problem, it is still an open questions if a set of process modeling guidelines makes the process modeling task more challenging and how effective modelers are in using them. It is also unclear how receptive process analysts are to the modeling guidelines. This dissertation presents a systematic literature review we conducted to collect and analyze the modeling guidelines found in the literature. It investigated a total of 520 articles, extracting a total of 45 modeling guidelines spread across 4 different categories. These 45 guidelines were simplified into a set of 20 guidelines, based on their significance to create more comprehensible process models and their practicality. This dissertation also presents the findings of an empirical experiment performed by 13 subjects that compared the results of two process modeling tasks with and without the support of the 20 modeling guidelines presented by the review, in which it was possible to observe that the subjects recognize the usefulness of the guidelines, but find them difficult to understand and use.

Keywords: Process modeling. process modeling guidelines. business process. BPM. BPMN. systematic review. experiment.

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LIST OF ABBREVIATIONS AND ACRONYMS

BPM	Business Process Management
RQ	Research Question
BPMN	Business Process Model and Notation
UML	Unified Modeling Language
EPC	Event-Driven Process Chains
OMG	Object Management Group
XOR	Exclusive OR
AND	Parallel
OR	Inclusive OR
GoM	Guidelines of Modeling
SEQUAL	SEmiotic model QUALity.
PMF	Process Model Factor
7PMG	Seven Process Modeling Guidelines
StArt	State of the Art through Systematic Review
CC	Cross-Connectivity
CFC	Control Flow Complexity

CONTENTS

1 INTRODUCTION

A business process (also called process in this text) is the work an organization performs to manufacture its products and offer its services. Regardless of its type, be it governmental, enterprise or non-profit, the management of a business process is fundamental to assure the quality and efficiency of the work being done, ensuring the competence and the competitiveness of an organization (DUMAS et al., 2013).

The discipline of Business Process Management (BPM) is a selection of principles, methods and tools to model, administrate, configure, execute and analyze business processes. These processes are composed of a collection of events, activities and decisions, whose result is vital for the clients of an organization (WESKE, 2012). Through its application, BPM turns processes more effective, more efficient and more adaptable, which, in turn, improves productivity and reduces costs (AALST, 2013). Because of this, organizations are increasingly interested in improving the quality and the efficiency of their processes.

One of the most important applications of BPM is the modeling of an organization's processes, in which a process analyst elaborate a comprehensive description of the business process in a graphical modeling notation. Process models are a crucial tool used for learning, analysis, improvement and communication of the business process (RITTGEN, 2010). However, it is widely accepted that process modeling is a difficult task (MENDLING; REIJERS; AALST, 2010), as the modeling notation, its many different elements and their respective semantics (LEOPOLD; MENDLING; GÜNTHER, 2016) are complex and the resulting process model often depends on the expertise of the process modeler (FIGL, 2017; NELSON et al., 2012). Therefore, it is not uncommon for process models to have modeling issues, such as control flow errors, badly designed structures and layouts or incorrect labeling (MENDLING; STREMBECK, 2008; LEOPOLD; MENDLING; GÜNTHER, 2016), which may significantly impair their comprehensibility, causing them to become less useful (WESENBERG, 2011). Thus, it is very important that the process modeling task results in high quality process models (REIJERS; MENDLING; RECKER, 2015).

Given the importance of process model comprehension, there are two approaches to improve it. One approach is to train the people who work with process models, whether they be process modelers or someone reading it. This approach however does not solve the root of the problem, i.e. that the process model has inherent proprieties which make it more complex, thus hindering its comprehension. The second approach tries to manipulate these proprieties, by transforming the model to one that is more suitable for any reader to comprehend (KROGSTIE, 2012).

Along these lines, one solution proposed in the literature is the use of process modeling guidelines (MENDLING, 2013; GSCHWIND et al., 2014; LEOPOLD; MENDLING; GÜNTHER, 2016; KOSCHMIDER; FIGL; SCHOKNECHT, 2016; SÁNCHEZ-GONZÁLEZ et al., 2017), that guide process analysts by defining simple rules to be followed, with the goal of increasing comprehensibility and comparability of process models in order to facilitate efficient model analysis (MENDLING; REIJERS; AALST, 2010). They are usually aimed at beginner process modelers, that do not yet have the teaching or the experience necessary to create process models of high quality. However, more experienced modelers may also benefit from using them, as the guidelines can be employed both proactively, to enhance the process modeling task, and retroactively, to find if the process model has any modeling issues. Furthermore, process modeling guidelines are an important tool for ensuring the consistency and integrity of a process model, especially in the case of larger modeling initiatives with several people involved (DUMAS et al., 2013).

1.1 Motivation

Many of the process modeling guidelines are the result of the experimental research done to understand what process model characteristics influence its quality. In spite of this, one significant problem is the dispersion of these guidelines amongst many authors and many years of research, which presents an obstacle in finding and using them for any process modeling endeavor. Also, not all guidelines have been presented with significant evidence of their effects, specially with regards to the comprehensibility of a process model (FIGL, 2017). Because of this, it is a challenge for process analysts to find and choose which guidelines to use in their own modeling initiatives. This demonstrates the necessity of a consolidation of the current state of the art on the field of process modeling guidelines with a focus on model comprehension.

Another open question about process modeling guidelines is how difficult it is to apply them during the process modeling task and what effects they have on the perception of the process analyst. Most empirical studies around modeling guidelines focus on analyzing the effects of a single guideline, discussing whether or not it contributes to the overall process model quality and ease process model comprehension (FIGL, 2017). In reality, most process modeling tasks will have either no guidelines to support it, as may be the majority of cases, or they will use multiple guidelines, either based on conventions established by the analyst's employer or based on whatever set of guidelines the analyst has found in the literature. However, given the high number of existing guidelines and their complexity, its unclear if their use as a group will make the process modeling task more challenging and if process analysts will be successful in applying them. It is also uncertain how receptive process analysts are to using a grouping of modeling guidelines.

1.2 Research Questions, Objectives and Contributions

Based on our motivation, we established two research questions:

RQ1 What business process modeling guidelines to increase model comprehension exist in the literature and what evidence exist that support their effects?

RQ2 How does process modeling guidelines influence the process modeling task and how receptive process analysts are to their use?

To solve RQ1, a review of the literature about process modeling guidelines and process model comprehension is necessary. To perform a good review, though, it is important that the research methodology be thorough, unbiased and replicable. These virtues may be accomplished by performing a systematic literature review (often referred as a systematic review) (KITCHENHAM; CHARTERS, 2007), that studies the literature based on a well-defined methodology and research protocol. Therefore, the first objective of our research was to **perform a systematic review to identify, interpret and evaluate process modeling guidelines and the evidence that support their effects**.

With the completion of our systematic review, it became possible for us to use the guidelines found during its course to answer RQ2. To do this, we hypothesized how process modeling guidelines affects the process modeling task based on theory and designed an experiment that would evaluate these effects in a controlled environment, in an effort to gather sufficient data to test our hypotheses. Thus, the second objective of our research was to **perform a experiment in which the use of process modeling guidelines during a process modeling task is analyzed to evaluate the difficulty and the impact of their use.**

The main contributions of this research are:

- A systematic literature review that consolidates and discusses the existing process modeling guidelines of the literature.

- A recommendation of a simplified set of process modeling guidelines based on the conclusions made on the systematic review.
- The results of the experiment we performed, along with its protocol for future replication and improvement.

1.3 Dissertation Organization

The next chapters of this dissertation are organized as follows: chapter 2 introduces the theoretical background on BPM, process model quality and process modeling guidelines; chapter 3 presents the systematic literature review on process modeling guidelines, its protocol, its results and a discussion on what was found; chapter 4 shows the experiment we performed, with its protocol, its results and the test of the experiment's hypotheses; chapter 5 discusses other works related to this dissertation; chapter 6 concludes the dissertation.

2 THEORETICAL BACKGROUND ON BUSINESS PROCESS MANAGEMENT

This chapter presents two fundamental concepts about BPM, the BPM lifecycle and the *Business Process Model and Notation*. It also displays a framework to understand and define process model quality, along with the factors that influence the qualities related to process model comprehension. Finally, it shows how process modeling guidelines interact with the quality of a process model.

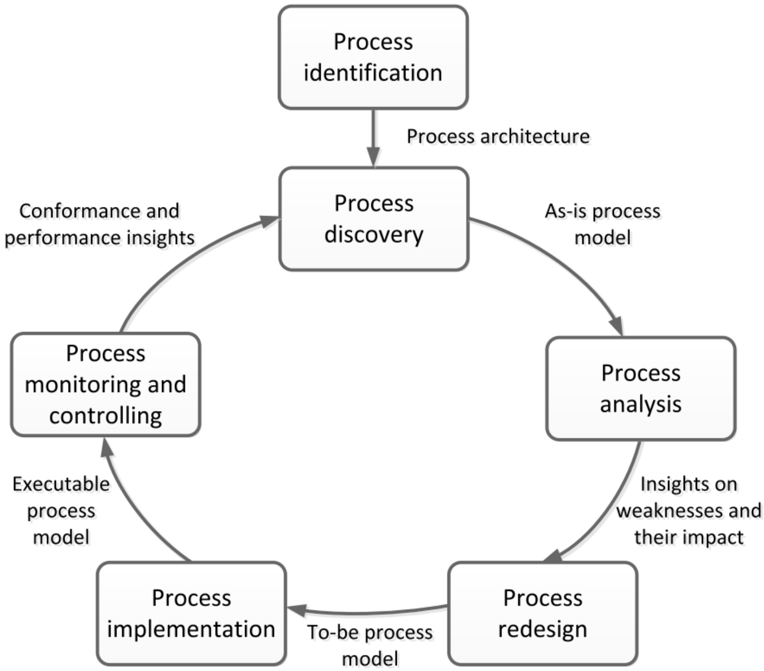
2.1 BPM Lifecycle

A useful perspective to view how a business process is managed by the BPM discipline is through the BPM lifecycle (figure 2.1). It defines six stages through which a process is identified, discovered, analyzed, improved, implemented, monitored and controlled. In each stage there are methods, techniques and tools that support the application of BPM in a organization, though the most important artifact in all stages is the process model.

The stage most relevant to this dissertation is the *process discovery* stage, where the process model is first created. In this stage, process analysts use techniques to gather information in order to understand and document the inner-workings of a process as it currently exists, creating what is called a "As-is" model. This model is meant to be a tool for all further stages of the lifecycle, supporting them primarily by facilitating the communication of how the process is actually done between the process' stakeholders (DUMAS et al., 2013). Therefore, it is important that this model is easy to understand.

Although it is possible to model processes in a textual format, the ambiguity inherent in the medium and the difficulty in reading the text makes modeling using graphic diagrams a better option. There are several notations for process modeling (DUMAS et al., 2013), such as flowcharts, Unified Modeling Language (UML) activity diagrams ((OMG), 2015), or Event-driven Process Chains (EPC) (KELLER; SCHEER; NÜTTGENS, 1992), however, in the context of BPM, there is a standard notation for process modeling, called *Business Process Model and Notation* (BPMN) ((OMG), 2011).

Figure 2.1: BPM Lifecycle



Source: Dumas et al. (2013)

2.2 BPMN

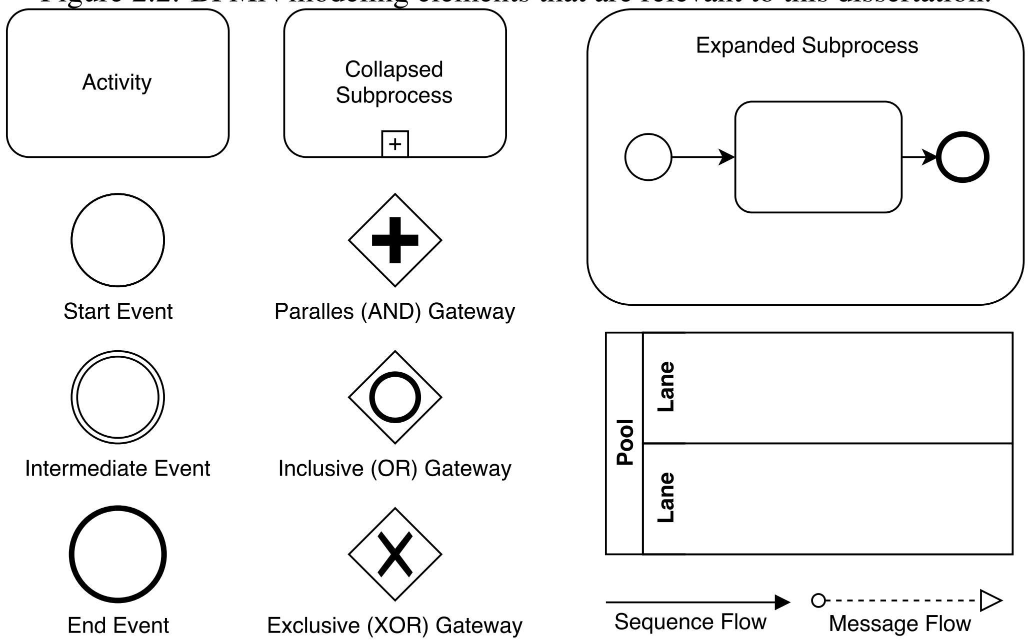
The *BPMN* was developed by the *Object Management Group* (OMG), with its 2,0 version being released in 2011. Since then, BPMN has been rising in popularity, with several modeling tools supporting it, such as the Signavio [1], Bizagi[2] and Camunda [3]. In 2013, BPMN has been defined a ISO standard (ISO, 2013). The main objective of BPMN is to provide user-friendly notation for all stakeholders, including the process analysts who create the initial drafts of the processes, the technical developers who are responsible for implementing the technology that will execute these processes, and the people who will administer and monitor the processes ((OMG), 2011).

There are five basic categories of elements in BPMN: *Flow Objects, Data Objects, Connecting Objects, Partitions, and Artifacts*. For the most part, process modeling guidelines focus only on *Flow Objects*, *Connection Objects* and *Partitions*, since most process models do not use elements of the other categories as they are not required to define the behavior of a process. Hence, this dissertation also focuses on these categories. All relevant modeling elements are show in figure 2.2.

Flow objects are the main elements of BPMN. They are node-type elements that

[1] www.signavio.com
[2] www.bizagi.com
[3] www.camunda.com

Figure 2.2: BPMN modeling elements that are relevant to this dissertation.



Source: (OMG) (2011)

define the behavior of a process, through three basic types: *activities, events and gateways*. **Activities** are the elements that represent the work performed during the process (e.g. pay a bill). They can be an atomic activity, i.e, a simple task, or a composite one, which represents multiple smaller units of work within a single element called subprocess. Subprocesses can be represented in two forms: as a *collapsed subprocess*, in which the details of the subprocess are not visible, and as an *expanded subprocess*, in which the details are visible withing the boundaries of the subprocess. **Events** represent something that happens instantly in a process (e.g. bill has been received). Events may be start, intermediate or end events, depending whether or not the event determine the boundaries of the start or the end of the process. Both activities and events may have further sub-types that further define the behavior of the element (e.g. time events define that some amount of time must pass), but generally there aren't process modeling guidelines specifically designed for them, as their use is uncommon.

Gateways control the divergence and convergence of the process flow. Gateways have three main types:

- **Exclusive (XOR) gateways** define the beginning or end of a split in the process flow. For example, a XOR-gateway may split into multiple outputs. These outputs are mutually exclusive, that is, only one path can be taken. Therefore, each output branch must have a condition to define which branch is taken. On the other hand, a XOR-gateway may also join multiple inputs. In this case, it is only necessary for the flow of only one input branch to end to activate the gateway's output.

- **Parallel (AND) gateways** fork and merge the process flow between all connected inputs and outputs, allowing for the process flow to be executed in parallel.
- **Incluive (OR) gateways**, similarly to *exclusive (XOR) gateways*, split the process flow, but in this case the outputs and inputs are not mutually exclusive. Because of this, an OR-split may cause multiple output flows to become active, while an OR-join requires that all currently active input flows end before the output is activated.

Partitions group process elements through **pools** and **swimlanes**. *Pools* represent the participants of a process, such as an organization. These pools contain the activities realized by this participant and they may be further divided by *swinlanes* (or lanes) that represent the different actors present inside this pool.

Connecting objects are the lines that connect the flow objects to each other or other element types. In the context of this dissertation, there are two main types of connecting objects:

- **Sequence flows** connect two different flow objects and define the order in which they are executed.
- **Message flows** connect flow objects of two different pools, representing the communication of messages between two participants during the execution of the process.

2.3 Process Model Quality

According to Reijers, Mendling and Recker (2015), it is important that process models have a high quality. Yet, process model quality is not something that is easily quantifiable. Multiple frameworks have been created to define what is the quality of a process model and classify the different quality types that compose it. Examples of these efforts are the Guidelines of Modeling (GoM) (SCHUETTE; ROTTHOWE, 1998), the SIQ framework (REIJERS; MENDLING; RECKER, 2015) and SEQUAL Framework (KROGSTIE, 2012).

2.3.1 SEQUAL Framework

The SEmiotic model QUALity framework (SEQUAL) framework is an approach that builds on semiotic theory and defines diverse aspects of quality based on the relationships between a model, a body of knowledge, a domain, a modeling language, and the activities of learning, taking action, and modeling (MENDLING; NEUMANN; AALST, 2007). It was originally proposed by Lindland, Sindre and Solvberg (1994) and revised by Krogstie, Sindre and Jørgensen (2006). According to it, quality may be divided in seven quality types: physical, deontic, social, semantic, syntactic, pragmatic and empirical. Of these, this dissertation focuses on the latter three:

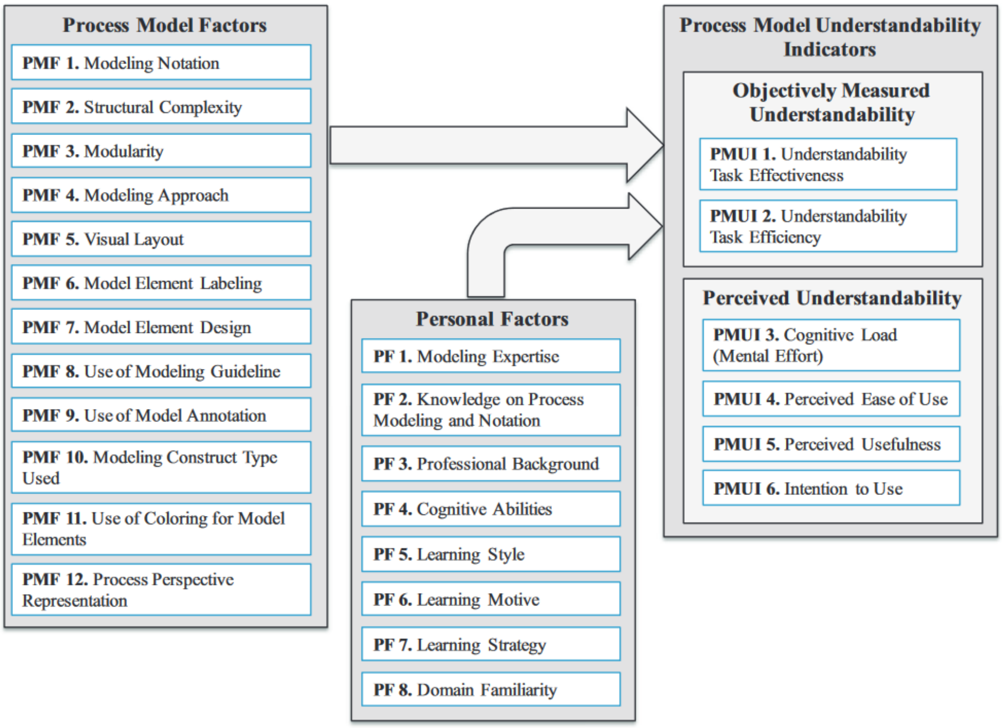
Syntactic quality identifies if a process model conforms to the rules defined by the notation utilized to create it. In other words, if a model follows the syntax and the vocabulary of its modeling language, then it is possible to verify that model and affirm it to be correct. A syntactically correct model is very important, as an incorrect model causes its readers to doubt if their understanding is correct (REIJERS; MENDLING; RECKER, 2015). This ambiguity compromises the pragmatic and empirical quality of the model, so any further consideration about them has to assume that the model is syntactically correct. In most cases, this is possible, as the majority of process modeling tools are able to verify this quality.

Pragmatic quality is defined by the relationship between a model and its readers. It asks whether or not the readers comprehend the model, that it is comprehensible by someone. Pragmatic quality is an important goal of a model, as not even the best model possible will be useful if it is not understood (WESENBERG, 2011). As such, any interpretation of a process model must correctly reflect the process that was modeled there, because, by doing so, it would possible for a reader to follow the actual real-world behavior of the process by analyzing the process model (KROGSTIE, 2012).

Empirical quality is linked to pragmatic quality. It defines if a model possesses desirable characteristics that make it inherently more comprehensible. It has an advantage over pragmatic quality in that it does not depend upon an interpreter to evaluate if the model has this quality. It is also obvious that the comprehensibility of a model influences if it will be comprehended by one of its readers. Thus, a model's empirical quality is positively correlated to its pragmatic quality (KROGSTIE, 2012).

While the insights provided by SEQUAL are invaluable, the qualities it defines are too abstract to be applicable by novice modelers, with no straightforward method existing

Figure 2.3: An integrated framework of process model understandability.



Source: Dikici, Turetken and Demirors (2018)

for their implementation in a modeling project (MENDLING; REIJERS; AALST, 2010). Therefore, further analysis on which factors influence the comprehension of a process model (i.e. its pragmatic quality) is required.

2.3.2 Process Model Comprehension

Ensuring human understanding of a process model is not a trivial task. There are multiple factors that may influence the comprehension of a process model, though they can be separated in two categories: personal factors that are inherent to the model's creator and its readers, and process model factors that are related to proprieties of the process model. Dikici, Turetken and Demirors (2018) and Figl (2017) both present a review of these factors, with the first providing a framework for how these factors related to process model understandability. Figure 2.3 presents this framework, defining a total of 20 influence factors. Figl (2017) also points out that studies have shown that the type of analysis performed by a model's reader may impact their comprehension, although she argues that this effect is more relevant with regards to measuring process model comprehension than actually improving it.

Table 2.1: The Seven Process Modeling Guidelines (7PMG)

	Guideline
G1	Use as few elements in the model as possible
G2	Minimize the routing paths per element
G3	Use one start and one end event
G4	Model as structured as possible
G5	Avoid OR routing elements
G6	Use verb-object activity labels
G7	Decompose a model with more than 50 elements

Source: Mendling, Reijers and Aalst (2010)

In order to improve process model comprehension it is necessary to improve some of these factors. Of the two categories, personal factors usually cannot easily be changed, since, for any process model we don't know who creates or reads it. From our perspective, these factors are effectively random. The ability to improve process model factors (PMF) such as modeling notation, approach and design (PMF1, PMF4 and PMF7 in figure 2.3) is usually limited as well, considering BPMN's popularity. As such, to ensure the pragmatic quality of process models, most research focuses on analyzing and improving factors related to their characteristics (i.e. their empirical quality), such as their size(PMF2), their topology (PMF2, PMF3), their layout (PMF5, PMF11) and their labels (PMF6). This can be done by using process modeling guidelines (PMF8).

2.3.3 Process Modeling Guidelines

One way to improve the comprehensibility of a process model is to transform it to a version which has greater comprehensibility, while preserving the process behavior (KROGSTIE, 2012). This is the goal of process modeling guidelines, which tell how this transformation should be done. They restrict the use of unsuitable constructs, in order to help the process analyst to reduce the complexity and number of modeling errors in a process model.

Most research related to process modeling guidelines started with the creation and analysis of process model metrics, such as the work of (ROLóN et al., 2006), (GRUHN; LAUE, 2006), (VANDERFEESTEN et al., 2007) and (MENDLING, 2008). These metrics have been inspired by similar endeavors that happened in software engineering field, serving as indicators of the complexity of process models. Later on, research shifted to focus on empirical studies to analyze the connection of these metrics and other process model characteristics to process model comprehension. Optimal thresholds were also defined for the process model metrics, which provided a basis for creating guidelines that are easy to understand and use, greatly aiding beginner process analysts.

The most prominent example of modeling guidelines is the "Seven Process Modeling Guidelines (7PMG)" by Mendling, Reijers and Aalst (2010). These guidelines were some of the first that were proposed based on a strong empirical foundation, while also trying to keep the instructions simple and related to concrete actions that process modelers execute during the process modeling task. This focus on practicality can be seen in the listing present in table 2.1.

3 SYSTEMATIC LITERATURE REVIEW

In this section we report on the systematic review we performed to identify, interpret and evaluate process modeling guidelines and the evidence that support their effects, which corresponds to our first research question. At the end of this, we present which process modeling guidelines we've found, along with a discussion analyzing the theory and the empirical evidences presented for them. With this analysis, we try to expose any opportunities for future research, while also providing a simplified set of modeling guidelines based on those that have been more throughly studied.

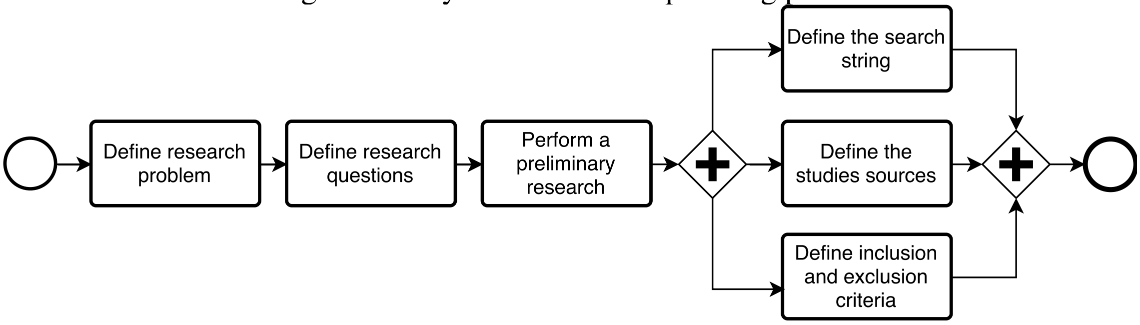
3.1 Research Method

A systematic review is a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest (KITCHENHAM; CHARTERS, 2007). The primary reasons to perform a systematic review are to summarize existing evidence concerning a treatment or technology, to identify any gaps that exists in current research and to provide a background in order to appropriately position new research activities.

In performing our systematic review, we followed the guidelines and methodology proposed by Kitchenham and Charters (2007). This methodology is comprised of 3 main phases: *planning the review*, *conducting the review* and *reporting the review*. As shown in figure 3.1, during the planning phase a review protocol is established, defining the questions the review is supposed to answer, assessing the results of a preliminary research and defining the systematic search strategy for the review. It is important that the protocol created through these steps covers as much of the relevant research as possible so that the systematic review is comprehensive. In the context of our systematic review, these steps can be seen in sections 3.1.1, 3.1.2 and 3.1.3.

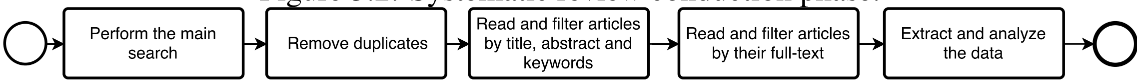
Once the protocol has been completed, the conduction phase may start. It begins by applying the search string to each data source and gathering the resulting articles. After, the duplicate articles are removed and each article is filtered twice, one time by examining the articles title, abstract and keywords based on the inclusion and exclusion criteria and a second time by reading their full-text. Once the final set of articles is selected, the data that answers the review questions is extracted. These steps can be seen in figure 3.2 and in sections 3.1.4 and 3.1.5 we provide further details on how these steps

Figure 3.1: Systematic review planning phase.



Source: The author

Figure 3.2: Systematic review conduction phase.



Source: The author

were performed during our systematic review. Finally, the results of the review can be reported, which we do in sections 3.2 and 3.3.

We used the "State of the Art through Systematic Review (StArt)"[1] tool to assist us in the conduction of the selection of studies and extracting their data and we used a spreadsheet to store and organize the extracted information, to calculate numerical results and create related charts. The systematic review was performed by two people: this author, which had the lead role and worked through all steps, and a student assistant, which helped with the study selection and data extraction.

3.1.1 Systematic Review Research Questions

The most important part of any systematic literature review is establishing its research questions (KITCHENHAM; CHARTERS, 2007). They will guide the entire methodology to identify the studies that address these questions and extract the relevant answers. As such, they must represent the main objective of the review in a clearly defined manner. In our study we first established this question:

Review Question What business process modeling guidelines to increase model comprehension exist in the literature?

We want to find the many process modeling guidelines that exist in the literature, proposed by both practitioners and researchers. However, we are not interested in guidelines created for the purpose of enhancing the operation of a business process, such as

[1] http://lapes.dc.ufscar.br/tools/start_tool

reducing costs or increasing time efficiency. These type of guidelines usually alter the semantics of the process model and later are implemented in the real world process itself. Instead, we want to focus on guidelines that enhance the comprehension accuracy of process models while preserving its semantics.

However, we don't want to simply consolidate all proposed guidelines, since not all of them have been empirically validated. It's not uncommon for some authors to propose guidelines based only on theoretical knowledge, which is often inspired by other areas of research, e.g. other types of diagrams like UML (PURCHASE et al., 2001) or graphs (PURCHASE, 1997). Therefore, for each guideline we find, we are interested in finding what type of empirical evidence exist that support their validity. This is summarized in the following sub-question:

Review Sub-question What empirical evidence exist that support the validity of these guidelines?

3.1.2 Preliminary Research

Prior to the start of our systematic review, we looked into the literature in search of other systematic reviews about process modeling guidelines. Presently, there are a number of systematic reviews around various topics about process model comprehension (see section 5.1 for more details), but none that focused on analyzing modeling guidelines existed when we started. The closed work we identified was that done by Oca and Snoeck (2014) that presented a overview of process modeling guidelines, whose purpose was to support both experienced and beginner process modelers in the process modeling task, focusing on obtaining process models that are highly comprehensible and do not contain syntactical errors. This overview was based on the results of another systematic review (OCA et al., 2015) which both authors performed about business process model quality. Their systematic review examined articles that had been published between the year 2000 and up to August 2013.

Based on this, we chose to start our own systematic review by separating the references found in the work of Oca and Snoeck (2014) that were related to process modeling guidelines. As a result, we obtained 59 articles, which would be included in our review set lated for analysis of their contents and to extract their data. We also tailored our review protocol to find newer articles, from the year 2013 and up to January of 2017.

3.1.3 Search Strategy

To find the relevant articles in the literature it is necessary to create a search criteria to narrow down the total number of articles to a reasonably sized set. To do so, we need to derive keywords from the review's questions that are related to the area of research (KITCHENHAM; CHARTERS, 2007). These keywords are then going to form a search string that will be used as an input for different bibliographical databases.

The three primary keywords we derived from our review's questions are "process modeling", "guidelines" and "comprehensibility". They define the subject being studied, the technique being applied and the consequences of that technique, respectively. In addition to these, we also added other keywords that are closely related to the primary ones, such as synonyms. The final search strategy is as follows:

- *Search fields:* title, abstract, keywords and full-text.
- *Search string:* ("Model Quality" OR "Quality of models" OR comprehensibility OR guideline OR "Pragmatic Quality" OR understandability OR readable OR "Ease of Use") AND Title = (BPM OR BPMN OR "Process Model" OR "Process Modeling" OR "Process Modelling")
- *Publication Date*: From the year 2013 and up to January 2017
- *Article Language:* English

The bibliographical search was performed on four digital databases: IEEE, Springer Link, ACM and Scopus. For each database, the search string needed to be adapted to conform with the format and limitations presented by the database's search fields. One notable example was Scopus, which could not perform a full-text search because it only indexed articles of other databases, without storing the actual text of the articles.

This search strategy yielded 721 articles. Removing duplicate articles, it resulted in a total of 520 articles. Then, the titles and abstracts of these articles were then manually scanned for their relevance according to the inclusion and exclusion criteria described in the following section.

3.1.4 Article Selection and Inclusion and Exclusion Criteria

In a systematic literature review, the inclusion and exclusion criteria define a strategy to filter the high number of articles extracted from the literature databases and reduc-

Figure 3.3: Proportion of articles that fit into each exclusion criteria.

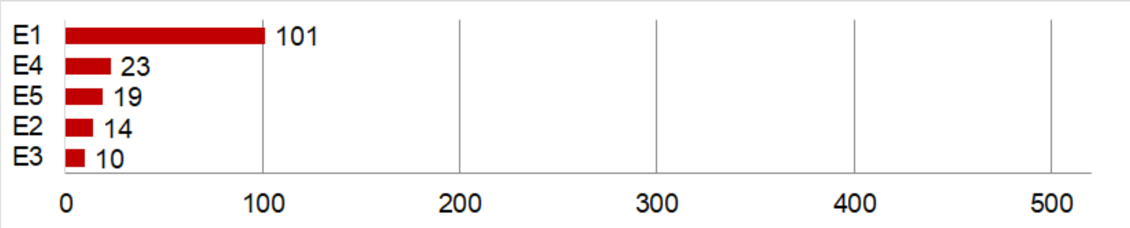
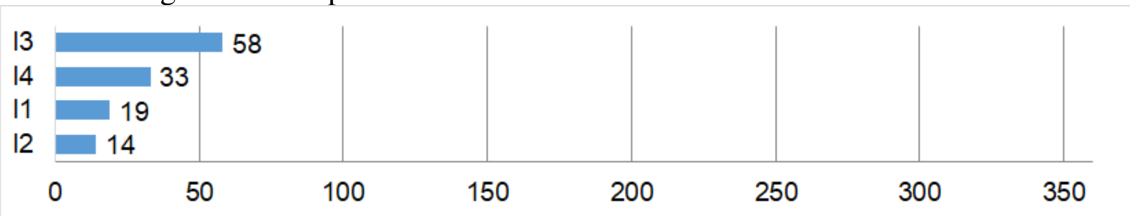


Figure 3.4: Proportion of articles that fit into each inclusion criteria.

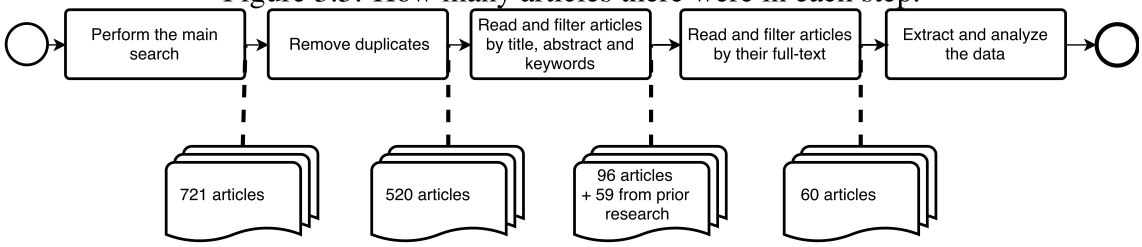


ing it to a reasonable quantity that can be reviewed in a feasible timespan. In this review, the title and abstract of a each article was analyzed and each article that fit into a inclusion criteria and didn't fit into a exclusion one was selected to be read in its entirety in the next step.

Through our exclusion criteria we removed articles that (E1) were not primarily about business process models (e.g. articles about medical or software development processes). As per the objectives of this review, we also focused on the area of process model comprehension, therefore the articles related to the characteristics of the real world process (such as effort, cost or time) were also excluded (E2). Similarly, articles dealing only with (E3) the syntax (i.e. correctness) or (E4) the semantics of a process model were unlikely to contain useful information, therefore they were not considered. Finally, there were articles that expressed process models in the declarative paradigm. They too were eliminated (E5), since process models in this paradigm are known for being difficult to understand since they contain hidden information (PICHLER et al., 2012). A total of 160 articles were excluded. Figure 3.3 shows the results for each criteria, with overlaps since some articles were excluded by multiple criteria.

To further reduce the number of articles to be revised, our inclusion criteria selected articles that made assertions on what proprieties a process model should have to acquire high accuracy of comprehension. This consists of (I1) process modeling guidelines (our main focus), (I2) process model metrics (and thresholds that define good values for comprehension accuracy) and (I3) insights about specific characteristics of a process model, whether they be purely theoretical or empirically evidenced. We also selected ar-

Figure 3.5: How many articles there were in each step.



Source: The author

ticles that deal with the process of process modeling or process modeling patterns (I4), in hope of finding different and useful process model trait that a specific modeling technique could create. Figure 3.4 shows how many articles were selected by each criteria (with some overlaps).

In the end, only 96 articles were selected for our review set, with the remaining 264 being removed since they did not fit into any criteria. Together with the 59 articles that came from our preliminary research, a total of 155 articles were set for having their full-text read in detail. If any of these articles did not contain modeling guidelines or any insights about process models that can be transformed to or interpreted as modeling guidelines then it was also removed. In the end, our final review set had 60 articles. The number of articles after each step of the article selection is summarized in figure 3.5.

3.1.5 Data Extraction

To answer our review questions we extracted two types of data from the articles: the process modeling guideline presented in the article and the evidence that supports it. Prior to any analysis, the modeling guidelines took the format of a quote from the articles. It is possible that these guidelines were not proposed in the context of BPMN and instead were based on other notations, most often being EPC. In these cases, the guideline was adapted to fit in the rules and elements of BPMN.

Once all guidelines were extracted, they were classified according to the type of process model characteristics they deal with, such as the model size, its topology, its layout or the labels of its elements. In each of these categories, they were further classified and grouped together by their similarity, with, for example, the guidelines for the maximum number of events being separate from those for the maximum number of sequence flows.

Regarding the evidence supporting the modeling guidelines, we found not only

Table 3.1: Levels of Evidence

Rank	Statistical results
Not Investigated	The effect was not investigated.
No Significant Evidence	The effect was investigated but it was not significant.
Conflicting	The effect has a positive influence in one test and a negative in another.
Weak	The effect was measured by variables other than comprehension accuracy.
Moderate	The effect was significant in one test and not in others.
Strong	The effect was reported as significant in all tests.

that the effect of some guidelines were not empirically studied, but also that those that were studied were measured and evaluated based on many different variables. Additionally, there were a number of empirical studies that reported non-significant or conflicting results. Ideally, it is desired that the positive effect of modeling guidelines to model comprehension be supported by significant results in some, if not all, statistical tests.

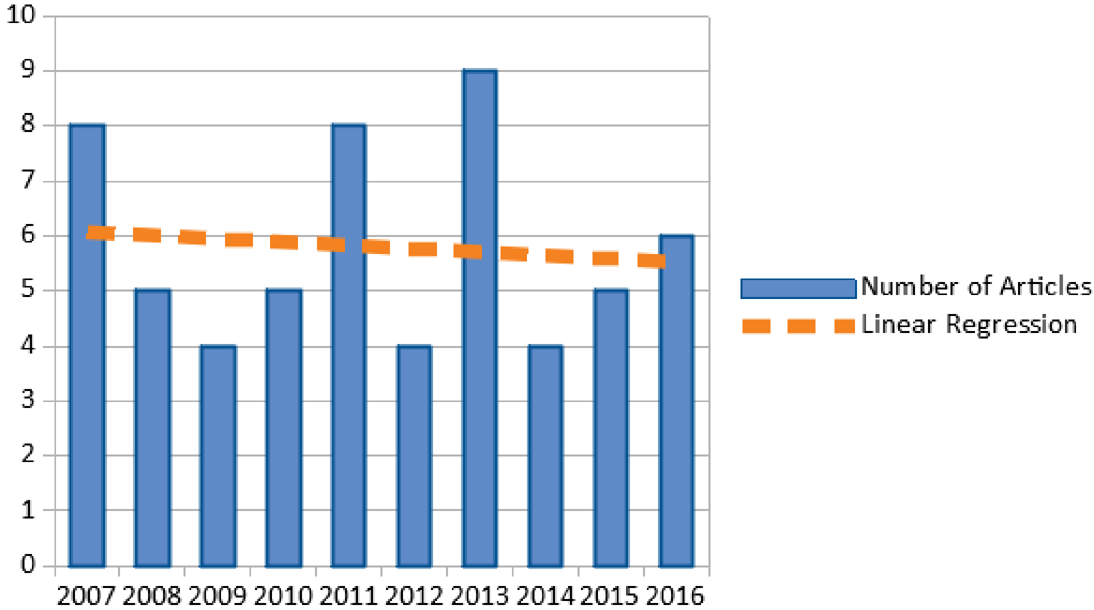
Because of this, we ranked all guidelines based on the strength of the reported evidenced in relation to the comprehension accuracy variable. Each of the rankings we used represents the level of evidence found that supports the positive effect of the guideline, with the lowest rank representing that it hasn't been investigated and the highest that it has been and with significant results in all statistical tests, thus being strongly evidenced. Also, if a study measured variables other than comprehension accuracy we chose to rank it lower instead of rejecting it completely, as we do not know the relationship between these variables and comprehension accuracy. Table 3.1 shows all the ranks that were used. Furthermore, if an article made a reference to another article about a guideline, then we have searched that reference for the supporting evidence we sought.

3.2 Results

3.2.1 General Findings

Figure 3.6 show the distribution of articles per year, from 2007 to 2016, with the highest peak being 2013. We can observe, through the linear regression, that the number of articles per year is slightly decreasing, if not stable. On the date we finished our search strategy (January 2017). there was already one article published for 2017, which we

Figure 3.6: Number of Articles per Year.



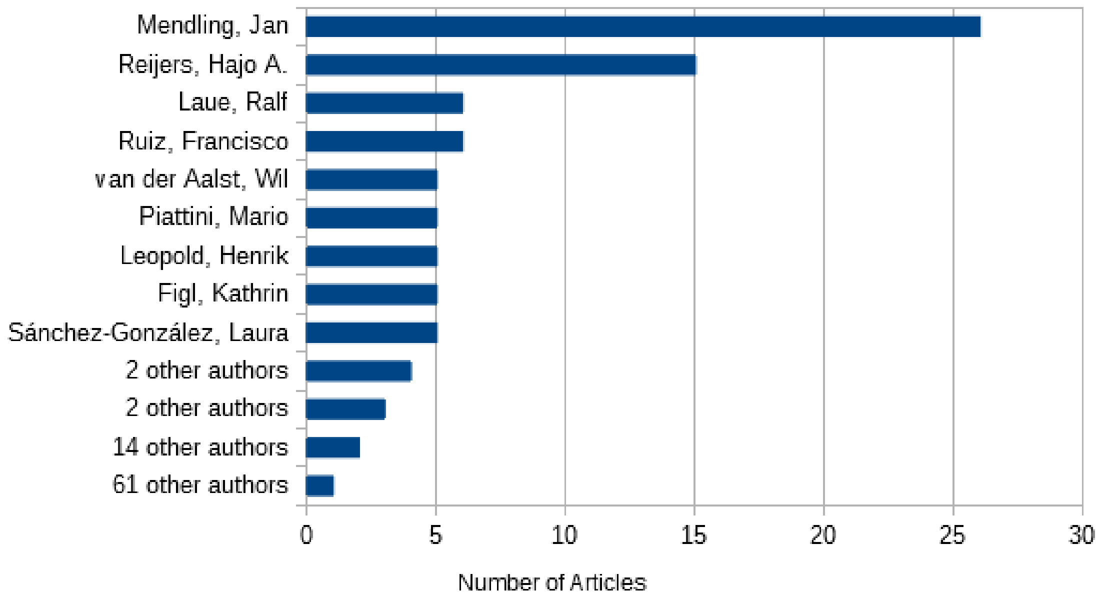
Source: The author

removed from the chart so that it would not exacerbate the decreasing trend.

Figure 3.7 shows how many articles each author participated in. Jan Mendling has been a common name in the area of modeling guidelines, which has been reflected in our review by appearing in 26 articles. His early work on error metrics in 2007-2008 made him a very prominent author, which eventually culminated in his publication of the 7PMG in 2010, after a number of studies analyzing process model comprehension. After 2013, we noticed a reduction of his publications related to modeling guidelines. Hajo A. Reijers also follows a similar trend, having also participated in the publication of the 7PMG, as well as many other empirical studies about process model comprehension, with a total of 15 articles. In fact, Reijers and Mendling have often collaborated with each other. In recent years, the most prominent authors are Laura Sánchez-González, with her work about thresholds for process model metrics, and Kathrin Figl, who participated in empirical studies about modularity, process model flow direction and the visual design of labels.

The eight most common authors of our review participated in 46 of the 60 articles. Of these, in 29 articles they were the first author. Therefore, their influence in the area of modeling guidelines is great, but there are 79 other authors participating in this area of research. Thus, this area is still very open for other authors to publish in.

Figure 3.7: Number of Articles per Author.



Source: The author

3.2.2 Guidelines about the Size of a Model

Guidelines in this category are recommendations regarding the size of a process model. When a process model contains too many elements it can be hard for someone to accurately comprehend the represented process (DUMAS et al., 2012), simply because the amount of information being show is too high. The common solution to this problem is to reduce and simplify large process models, either by decomposing them into multiple models or by hiding more complex details within subprocesses. Table 3.2 summarizes the guidelines for this category.

While it is generally agreed that smaller process models, that have fewer modeling elements (activities, events, gateways), are ideal, there isn't a clear consensus on how much smaller they should be. The majority of guidelines about a process model's size come from previous studies on process model metrics, which quantify the different aspects of a process model. Based on theses metrics, many articles sought to prove a correlation between the metrics and the comprehension of the process model, but very few went further on to determine a threshold, most notably being the already mentioned work of Sánchez-González et al. (2011, 2012, 2013). We use these thresholds (when applicable and available) for our guidelines.

A1 Number of Elements

The simplest size guideline is to reduce the number of all node-type elements (i.e

Table 3.2: Guidelines for Model Size

	Guideline	Threshold	Highest Level of Evidence
A1	Use as few elements as possible	≤ 37	Strong
A2	Use as few activities as possible	≤ 31	Strong
A3	Use as few events as possible	≤ 7	Moderate
A3.1	Use one start and one end event	$= 1$	Strong (Start) Moderate (End)
A3.2	Use as few intermediate events as possible	N/A	Moderate
A4	Use as few gateways as possible	≤ 18	Strong
A4.1	Avoid using inclusive (OR) gateways	N/A	Moderate
A4.2	Do not use implicit gateways	N/A	Strong
A5	Use as few lane and pools as possible	≤ 4	Moderate
A6	Use as few sequence Flows as possible	≤ 34	Strong
A6.1	Minimize the degree of all elements.	N/A	Weak
A6.2	Minimize the degree of all gateways	≤ 5	Strong
A7	Minizine the longest path from the start event to the end event.	≤ 15	Weak

Source: The author (Thresholds by Sánchez-González et al. (2013))

activities, events and gateways). Mendling et al. (2007, 2007, 2007, 2007) proposed and measured the effect of this guideline on error probability, later on featuring it in the 7PMG (MENDLING; REIJERS; AALST, 2010). Other authors have proposed or referenced this guideline (GRUHN; LAUE, 2009; MENDLING et al., 2012; FERNANDEZ-ROPERO et al., 2013), but it was Sánchez-González et al. (2013, 2017) that eventually provided strong evidence for comprehension accuracy and recommended thresholds.

A2 Number of Activities.

Considering that activities are the most recurrent part of process models, it is reasonable to assume that a guideline for reducing their number (MENDLING; NEUMANN; AALST, 2007; MENDLING; STREMBECK, 2008; WEBER et al., 2011; KAHLOUN; CHANNOUCHI, 2016) will have an effect similar to the previous, more broad guideline. Even when considering different types of activities, such as collapsed subprocesses, there is moderate to strong evidence that suggest the inverse correlation between their number and comprehension accuracy, according to Rolon et al. (AGUILAR et al., 2007; ROLÓN et al., 2009). A common cause for the high number of activities is the existence of too many superfluous or out of context tasks (HAISJACKL et al., 2015) that could be removed or combined with other activities, either implicitly or through subprocesses (SÁNCHEZ-GONZÁLEZ et al., 2017). This reduces the granularity of the process model and, as such, make it easier to understand.

A3 Number of Events.

Regarding events, several studies have found that reducing their number also increases comprehension (AGUILAR et al., 2007; MENDLING; NEUMANN; AALST, 2007; ROLÓN et al., 2009; SÁNCHEZ-GONZÁLEZ et al., 2013; SÁNCHEZ-GONZÁLEZ et al., 2017). However, events have three distinct types: Start, end and intermediate events. Intermediate events are much like activities in that reducing their number should increase comprehension (AGUILAR et al., 2007; ROLÓN et al., 2009). Start and end events, on the other hand, have a much more specific meaning, given that they define the boundaries of the flow of activities. The conservative approach recommends the explicit (SILVER, 2009) use of a single start and a single end events for each pool of a process model (AGUILAR et al., 2007; ROLÓN et al., 2009; BERNSTEIN; SOFFER, 2015; SÁNCHEZ-GONZÁLEZ et al., 2017). This way, there is no ambiguity in where a process starts or ends and there is less room for error (MENDLING; NEUMANN; AALST, 2007; MENDLING, 2007; MENDLING; REIJERS; RECKER, 2010). Yet, there is some theoretical benefit to distinguish semantically different end states (e.g, success and failure) in multiple end events (SILVER, 2009; MENDLING et al., 2012; MENDLING, 2013).

A4 Number of Gateways.

Gateways are perhaps the most influential element type in terms of a process model's complexity. They are the main cause for allowing process models to be more than a simple sequence of tasks. It is no surprise that the majority of the topology guidelines consists on how to use them.

With respect to their number, on the other hand, it is generally agreed by several studies that reducing them is moderately to strongly correlated with comprehension accuracy (MENDLING; NEUMANN; AALST, 2007; AGUILAR et al., 2007; MENDLING et al., 2008; ROLÓN et al., 2009; RODRIGUES et al., 2015; SÁNCHEZ-GONZÁLEZ et al., 2012; SÁNCHEZ-GONZÁLEZ et al., 2017). Gateways also have different types, but besides the clear discouragement of using inclusive (OR) gateways (KOEHLER; VANHATALO, 2007; MENDLING; NEUMANN; AALST, 2007; MENDLING, 2007; MENDLING; REIJERS; AALST, 2010; MENDLING et al., 2012; MENDLING, 2013; SÁNCHEZ-GONZÁLEZ et al., 2012; SÁNCHEZ-GONZÁLEZ et al., 2017; JOHANNSEN; LEIST; BRAUNNAGEL, 2014), there is no consensus in how many exclusive (XOR) and parallel (AND) gateways should be used. Sánchez-González et al. (SÁNCHEZ-GONZÁLEZ et al., 2012) suggests allowing more exclusive gateways than parallel, but

Figl and Laue (FIGL; LAUE, 2015) found no difference between them, arguing that no theoretical considerations exist that would suggest so.

Finally, while it is possible to avoid the use of gateways in a process models to represent AND-splits and XOR-Joins, J. Recker (RECKER, 2013) has hypothesized and concluded, with significant results, that the explicit use of gateways in these cases positively affects the comprehension of a process model.

A5 Number of Pools / Lanes.

Not much study was done in regards to the use of pools and lanes. A possible reason for this is their optional nature, since the main participant in a process may have a "implicit" pool. Nevertheless, the excessive use of pools and lanes is not recommended (ROLÓN et al., 2009), especially in the case of black box pools (pools that do not contain any elements) (SÁNCHEZ-GONZÁLEZ et al., 2017).

A6 Number of Sequence Flows.

It is surprisingly difficult to measure the effect the quantity of sequence flows has on the comprehension of a process model. It is generally recommended to use less of them (MENDLING; NEUMANN; AALST, 2007; MENDLING; REIJERS; CARDOSO, 2007; MENDLING et al., 2008; AGUILAR et al., 2007; ROLÓN et al., 2009; SÁNCHEZ-GONZÁLEZ et al., 2013; SÁNCHEZ-GONZÁLEZ et al., 2017), but most of the time they are a symptom and not the cause of the complexity and size of the process model, since the more model elements there are, the more sequence flows are required to connect them.

Instead, the effect of the number of sequence flows can be measured by how (much) they connect the elements. For example, metrics such as the Coefficient of Connectivity (CNC) and Density (MENDLING; NEUMANN; AALST, 2007; MENDLING; REIJERS; CARDOSO, 2007; MENDLING, 2007) try to minimize the influence of node-type elements, providing a better indicator of when a high number of sequence flows is decreasing the comprehension of a process model (REIJERS; MENDLING, 2011; FERNANDEZ-ROPERO et al., 2013). However, these metrics also translate to a simple guideline that suggests reducing their number. More complex metrics, such as Cross-Connectivity (CC) (VANDERFEESTEN et al., 2007), may measure the effect of sequence flows better, but their complexity makes it difficult to know how to change the process model for better comprehension.

A suitable middle ground are the average and maximum gateway degree metrics

(MENDLING; NEUMANN; AALST, 2007; MENDLING, 2007; REIJERS; MENDLING, 2011; SÁNCHEZ-GONZÁLEZ et al., 2012). By measuring the number of input and output sequence flows for each element it is simple to identify and fix outliers. For example, if a process model avoids the use of implicit gateways (according to guideline 1.4.2), all of its activities and events would have at most one input and one output sequence flow. On the other hand, should one of its gateways have a high number of incoming and outgoing sequence flows then their complexity may increase the probability of errors and impair its comprehension.

The most common solution to decrease a gateway's degree would be to split the sequence flows between two or more gateways (SILVER, 2009; MENDLING; REIJERS; AALST, 2010), although this would increase the number of elements in the process model, going against guideline 1.1 and 1.4. It is not clear which case is preferable, but Mendling et al (MENDLING; REIJERS; AALST, 2010) have consulted process modeling professionals that ranked the number of elements of the process model as bigger priority than the degree of its elements.

A7 Longest Path

One of the earliest proposals by Mendling, Neumann and Aalst (2007), Mendling (2007) has been that the diameter of the model, similarly to its size, is a minor indicator of the of error probability of that model. It hasn't been until recently that Sánchez-González et al. (2017) suggested that the longest path between the start event and end event should not be higher than 16. Regardless, no further evidence has been provided.

3.2.3 Guidelines about the Topology of a Model

This category contains guidelines that deal with how the elements of a process model are combined with each other and how this can increase its comprehension without altering its semantics. Just as a process modeler can diminish comprehension by adding extraneous elements, he can also make structurally flawed process model. These flaws causes a process model to be too interconnected and confusing. Holl and Valentin (2004) appropriately call this a "Spaghetti" model, as it is too hard to keep track of and understand all the possible paths of sequence flows. Table 3.3 summarizes the guidelines for this category.

Table 3.3: Guidelines about the topology of the model.

	Guideline	Highest Level of Evidence
B1	Model as structured as possible	Moderate
B2	Avoid nesting structured blocks too deep inside one another, when possible.	Strong
B3	Minimize the level of concurrency, when possible.	Weak
B4.1	Minimize the number of cycles, when possible.	Weak
B4.2	Do not create cycles with multiple exit points.	Not investigated
B5	Avoid the use of more gateway types, when possible.	Moderate
B6	Minimize the connectivity of process elements.	Strong
B7.1	Decompose models that are too large.	Strong
B7.2	Use subprocess to depict model fragments that occur multiple times or that benefit from being grouped together or hidden.	Moderate
B7.3	Do no overly decompose or modularize the process model.	Strong

Source: The author

B1 Structuredness

The problem of Spaghetti models (ARKILIC; REIJERS; GOVERDE, 2013) is usually caused by the lack of proper block-structuring of gateways, that is, splits and joins being nested in such a way that each split has a corresponding join of the same type (LAUE; MENDLING, 2010). It is measured by the Gateway Mismatch metric (MENDLING, 2007), which has been show to be positively correlated with the increase of the probability of errors (LAUE; MENDLING, 2010; MENDLING; NEUMANN; AALST, 2007; MENDLING, 2013; SÁNCHEZ-GONZÁLEZ et al., 2017), such as deadlocks, livelocks or lack of synchronism that leads to multiple executions of subsequent tasks (LEOPOLD; MENDLING; GÜNTHER, 2016).

To solve this, Mendling et al. have recommended the use of block-structuring as much as possible (MENDLING; NEUMANN; AALST, 2007; MENDLING, 2007; MENDLING; NEUMANN, 2007; MENDLING et al., 2008; MENDLING; REIJERS; AALST, 2010; MENDLING et al., 2012; MENDLING, 2013). However, this is not always possible and it may not happen without an increase of the model's size (DUMAS et al., 2012), therefore a balance is required between this increase and the complexity of the structure (SÁNCHEZ-GONZÁLEZ et al., 2017).

This issue is complicated by the fact that the benefit of block-structuring is not well evidenced for the comprehension accuracy of the process model. Sanchez-Gonzales et al. (SÁNCHEZ-GONZÁLEZ et al., 2012) have found significant evidence correlating gateway mismatch to comprehension efficiency (that is, comprehension accuracy divided by comprehension time), but Dumas et al. (DUMAS et al., 2012) have found conflicting results, suggesting that in certain cases a unstructured model may be more easily understood than its structured equivalent. Gruhn and Laue (GRUHN; LAUE, 2007b) have presumed similarly, analyzing and discussing the benefits of three unstructured modeling patterns based on their proprieties.

B2 Depth and Nesting

Related to block-structuring, the nesting depth is correlated with the error probability of a process model (MENDLING; NEUMANN; AALST, 2007; MENDLING, 2007), likely due to its relationship with other complexity metrics (GRUHN; LAUE, 2007a). This can be further inferred from the sequentiality metric (MENDLING; NEUMANN; AALST, 2007; MENDLING; NEUMANN, 2007; MENDLING, 2007; MENDLING et al., 2012), since highly sequential models likely do not contain many nesting blocks. With regards to comprehension, model elements from different nesting blocks have been shown to be significantly harder to understand based on the number of gateways that separate the blocks (KABICHER; RINDERLE-MA, 2011) and the type of those gateways (FIGL; LAUE, 2011).

B3 Parallelism

Not much is proposed about the level of concurrency of a process model, beyond simple recommendations to minimize it (MENDLING et al., 2012; MENDLING, 2013). As Mendling et al. have concluded, AND-split and OR-split gateways create concurrent paths that, in high numbers, increase the error probability of the process model (MENDLING; NEUMANN; AALST, 2007; MENDLING, 2007), likely due to the difficulty of keeping track of those paths and synchronizing them appropriately (MENDLING; NEUMANN, 2007). This burden is eased by the use of block-structuring.

B4 Cyclicity

Similarly with parallelism, Mendling el al. have also linked cyclicity with error probability (MENDLING, 2007; MENDLING et al., 2008; MENDLING; NEUMANN, 2007; MENDLING et al., 2012), therefore cycles should be avoided if possible. In their use, cycles in process models are ideally structured blocks with a single exit, that is, just one XOR-split gateway at the end of the cycle that either loops back to the beginning or exits the cycle. Cycles with multiple exits, however, are inherently unstructured (DUMAS et al., 2012), which is undesirable, according to guideline 2.1.

B5 Control Flow

In guidelines 1.6.1 and 1.6.2, we have touched upon the complexity of the control flow of process models based on average and maximum degree of connectivity measures, but they don't consider how the types of gateways influence the complexity. This is addressed by the studies of our review in two ways: the first is through the gateway heterogeneity metric, which has been correlated with error probability (MENDLING, 2007) and comprehension efficiency (SÁNCHEZ-GONZÁLEZ et al., 2012) and thus studies have recommended to minimize the types of gateways used (MENDLING et al., 2012; MENDLING, 2013; SÁNCHEZ-GONZÁLEZ et al., 2017); the second is by the Control Flow Complexity (CFC) metric (CARDOSO, 2006), which has also been correlated with error probability (MENDLING, 2007) and comprehension efficiency (SANCHEZ-GONZALEZ et al., 2011; SÁNCHEZ-GONZÁLEZ et al., 2012), but of which no study in this review has interpreted as a simple guideline for process modeling beyond minimizing it (RODRIGUES et al., 2015; KAHLOUN; CHANNOUCHI, 2016; SÁNCHEZ-GONZÁLEZ et al., 2017). Since calculating the CFC during the task of process modeling is time-consuming, it has been dismissed.

B6 Connectivity and Separability

The connectivity of a process model usually measures the ratio of sequence flows between activities of the model to its total number of activities. Multiple studies have shown this to be negatively related to comprehensibility (AGUILAR et al., 2006; ROLÓN et al., 2009; MENDLING; REIJERS; CARDOSO, 2007; FERNANDEZ-ROPERO et al., 2013; SÁNCHEZ-GONZÁLEZ et al., 2017). Additionally, Rolon et al. (ROLÓN et al., 2009) has found strong evidence that the connectivity between participants (or pools) is also correlated with understandability.

An alternative measure to connectivity is separability, which considers the opposite perceptive. It measures the frequency of cut-vertices in a process model, i.e the elements or sequence flows that, when removed, split the model into two models. This division clearly delineates a "before" and a "after" section of the process model, with the cut-vertex as its reference point. By doing this, the cut-vertex would ease the understanding of the process model and reduce the likelihood of errors (MENDLING, 2007; MENDLING et al., 2012; MENDLING; NEUMANN, 2007). Strong evidence of this has been found initially (MENDLING; STREMBECK, 2008), however further studies were unable to replicate these results (FIGL; LAUE, 2011; MENDLING; NEUMANN; AALST, 2007; REIJERS; MENDLING; DIJKMAN, 2011), which proves the necessity of further research.

Finally, a few studies (KAHLOUN; CHANNOUCHI, 2016; BRAUNNAGEL; JOHANNSEN; LEIST, 2014) have also explored the use of the coupling and cohesion metrics (VANDERFEESTEN et al., 2007), which were inspired from the software engineering domain, but no empirical infestation was performed upon their validity. Regardless, all these studies show that it is important to minimize the level of connectivity of a process model, by allowing process models to have clear sections that can be separated from the rest of the model.

B7 Decomposition and Modularization

The connectivity and separability of fragments of a process model are also good indicators to perform its decomposition or modularization. These two terms have been often been used in the literature interchangeably, but they may actually refer to two different procedures. For example, Reijers et al. (REIJERS; MENDLING; DIJKMAN, 2012) have indicated that strongly connected fragments that have a single entry and a single exit points (or cut-vertices) are good candidates to be modularized into subprocesses. Subprocess relocate model elements from the main process to itself (SÁNCHEZ-GONZÁLEZ et al., 2017) and is said to foster the understanding of the process model (REIJERS; MENDLING; DIJKMAN, 2011) by hiding unnecessary information from the model reader (REIJERS; MENDLING, 2008; SILVER, 2009). This is specially important in large, monolithic models, as they may cause "map shock" in model readers (FIGL; KOSCHMIDER; KRIGLSTEIN, 2013; MOODY, 2006). Subprocesses may also be used to simplify redundant fragments of a process model, that is, fragments that have the same control-flow logic (WEBER et al., 2011).

These reasons may also justify the decomposition of process models into simpler models (LASSEN; AALST, 2009), where, instead of using subprocesses, the process model is split into multiple and usually sequential models. Of course, in either case, no information must be lost during these procedures (JOHANNSEN; LEIST; BRAUNNAGEL, 2014).

Many studies argue in favor of decomposition and modularization (LASSEN; AALST, 2009; SILVER, 2009; MENDLING; REIJERS; AALST, 2010; MENDLING et al., 2012; MENDLING, 2013; REIJERS; MENDLING, 2008; REIJERS; MENDLING; DIJKMAN, 2011; REIJERS; MENDLING; DIJKMAN, 2012; WEBER et al., 2011;

SÁNCHEZ-GONZÁLEZ et al., 2017) of processes, however the evidence supporting this is weak (MENDLING; REIJERS; AALST, 2010; MENDLING et al., 2012; MENDLING, 2013; SÁNCHEZ-GONZÁLEZ et al., 2017) or moderate (REIJERS; MENDLING, 2008; REIJERS; MENDLING; DIJKMAN, 2011; REIJERS; MENDLING; DIJKMAN, 2012; JOHANNSEN; LEIST; BRAUNNAGEL, 2014) at best. Recently, some studies have come to dispute this notion (ARKILIC; REIJERS; GOVERDE, 2013; FIGL; KOSCHMIDER; KRIGLSTEIN, 2013), with strong evidence supporting that fully-flattened models are easier to be understood than models with subprocesses (TURETKEN et al., 2016). They present that subprocesses may be overused, with its contents being too small (WEBER et al., 2011). Also, they question the benefit the "information hiding" quality of decomposition and modularization, since this may cause the reader to have their attention split between multiple documents, making the comprehension of the process model difficult (TURETKEN et al., 2016).

It is clear that further research is necessary. Still, the decomposition and modularization of process models are valuable guidelines, should they not be overused. Weber et al. (WEBER et al., 2011) recommend that subprocess should have, at minimum, 5 to 7 activities, otherwise they should be transfered to the main process model.

3.2.4 Guidelines about the Layout of a Model

This category contains guidelines that advise on the layout of a process model. Most modeling notations, such as BPMN, only establish the symbols used to represent its elements and how they may be used. For other visual characteristics, such as the size, color or position of the modeling elements, the modeler is free to choose as they see fit. This is known as the model's *secondary notation* (PETRE, 1995), as they are "typically not formally part of the notation, but that they can be used to exhibit relationships and structures that might otherwise be less accessible". Even if these characteristics do not change the semantics of process models, studies have determined them to be an influence in understandability of process models (MOHER et al., 1993; PETRE, 1995). Table 3.4 summarizes the guidelines for this category.

C1 Colors

Some process modeling tools, such as Bizagi, may allow for model elements to be freely colored. This can be used by process modelers to highlight specific model elements,

Table 3.4: Guidelines about the layout of the model.

	Guideline	Highest Level of Evidence
C1	If necessary, use colors to highlight model elements.	Strong
C2.1	Minimize the drawing area of the model (preferably within a page)	Not investigated
C2.2	Make the process flow from left to right.	Not significant
C3.1	Minimize the number of bends in sequence flows.	Strong
C3.2	Minimize the crossing of sequence flows.	Not significant
C4	Avoid overlapping elements.	Not investigated
C5	Make use of symmetry between elements.	Weak
C6	Keep model elements related to one another close to each other.	Not investigated

Source: The author

which may help the reader in understanding the semantics of the process. Two studies have been found that explored this concept: Firstly, Reijers et al. (2011) hypothesized that using colors to highlight matching gateways would impact the understanding accuracy of readers and they have found significant evidence to support this effect, specially in the case of novice readers. Secondly, (KUMMER; RECKER; MENDLING, 2016) studied the use of colors to differentiate element types while presuming that members from the Confucian culture may be more receptive to this than those from the Germanic culture. Through the execution of an experiment, they did not find significant evidence that coloring element types increased model comprehension, however members from the Confucian culture did report that the colors made the models less difficult to understand in their opinion. These studies imply that colors may be beneficial to the understandability of process models, but they also may not be well received, so they should be used sparingly.

C2 Model Dimension and Shape

The dimension (or size) and shape of the layout of a process models are characteristics that refer to their general appearance as a diagram. Dimension has not yet been empirically evidenced to affect understandability, even if multiple studies recommend that the drawing area of a process model should be minimized (BERNSTEIN; SOFFER, 2015; EFFINGER; JOGSCH; SEIZ, 2010; SILVER, 2009; GSCHWIND et al., 2014). Process models may be represented in both paper and digital formats, but only the former has a maximum threshold (an A3 page) that has been recommended in a study (LEOPOLD; MENDLING; GÜNTHER, 2016). For digital formats, perhaps the most appropriate guideline is to be able to fit the process model in whatever screen space is available, as long as its textual information is still readable at the reasonable levels of zoom.

The shape of a process model is linked with the flow direction of its activities. Older notations, such as EPC, are usually modeled from top-to-bottom, contrary to BPMN's usual left-to-right. The uniformity of a model's flow direction was suggested to be important for its understandability (EFFINGER; JOGSCH; SEIZ, 2010; REGGIO; LEOTTA; RICCA, 2011; LEOPOLD; MENDLING; GÜNTHER, 2016; HAISJACKL et al., 2015; BERNSTEIN; SOFFER, 2015), though the actual direction of left-to-right, while theoretically beneficial (FIGL; STREMBECK, 2014), has not been found to have significant evidence supporting it (FIGL; STREMBECK, 2015).

C3 Lines

Due to their purpose, the most used type of process model element are the lines connecting objects (sequence flows and message flows). Therefore, it is important that they are represented clearly in any process, in order for them to be easily understood. However, a common problem that lines may have is a high amount of bends, which reduces their clarity. Multiple studies have advocated for the minimization of line bends (SCHREPFER et al., 2010; EFFINGER; JOGSCH; SEIZ, 2010; GSCHWIND et al., 2014), some even suggesting that the "Manhattan layout" (in which lines are only drawn in the four cardinal directions) is preferred (GSCHWIND et al., 2014; HAISJACKL et al., 2015), but no study was found that presented significant evidence to support this assertion.

Another common problem are line crossings, in which two lines have go over one another. While solving this problem is often impossible, reducing the number of crossings has also been suggested to improve the understandability of a process model (HAISJACKL et al., 2015; SCHREPFER et al., 2010; EFFINGER; JOGSCH; SEIZ, 2010; GSCHWIND et al., 2014), with Schrepfer et al. referencing a study about graphs that provides weak evidence supporting this effect.

C4 Overlaps

While it is important to reduce the dimension of the process model, doing this too much often causes modeling elements to overlap, which affects the understandability of the model (LEOPOLD; MENDLING; GÜNTHER, 2016). This is especially true when dealing with the connecting elements, as overlapping lines may hide the relationship of node-type elements (EFFINGER; JOGSCH; SEIZ, 2010).

C5 Symmetry

Placing modeling elements in a symmetric fashion has been associated with making a model easier to read (SCHREPFER et al., 2010; BERNSTEIN; SOFFER, 2015), though evidence of this effect has been studied and found not significant for the understandability of graphs by Purchase (1997).

C6 Proximity

The proximity between modeling elements may be used to express their relationship, as it would imply that their semantics are related to one another. This essentially creates an implicit grouping of elements, which may make them easier to recognize and lead to a higher understanding of the process model (SCHREPFER et al., 2010). It's also important, however, to allow some space between elements to exist. Leopold, Mendling and Günther (2016) consider that at least 50 of an element's size is appropriate spacing.

3.2.5 Guidelines about the Labels of a Model

This category comprises guidelines that instruct on how to create text labels for process model elements. In BPMN, labeling activities is not mandatory, but it is expected that at least activities are labeled to define their semantics. In any case, the modeler is free to label elements however they wish, as BPMN provides no instructions in how this should be done. Often, this means that labeling modeling elements is more of an art than a science (MENDLING; REIJERS; RECKER, 2010), but there are many studies that propose labeling styles for each type of modeling element. Beyond that, there are also studies which instruct on how to prevent the ambiguity of vagueness of the actual label or how to ensure that it is efficiently readable. Table 3.5 summarizes the guidelines for this category.

D1 Labeling Style

For any type of modeling element, there exists a variety of labeling styles to describe it. For example, the two most notable styles to label activities are the "Verb-Object" and the "Action-Noun" styles, which instruct the reader to perform a business related activity (LEOPOLD et al., 2013). The absence of a uniform style to label modeling elements is acknowledged to decrease the understandability of a process model (LEOPOLD, 2013; REIJERS; MENDLING; DIJKMAN, 2011), as evidences suggest that readers perceive

Table 3.5: Guidelines about the labels of the model.

	Guideline	Highest Level of Evidence
D1	Use a consistent labeling style.	Weak
D1.1	Use verb-object style for activity labels.	Weak
D1.2	Use object-particle style for event labels.	Not investigated
D1.3	Use object-particle question style for gateway labels.	Not investigated
D2	Label everything that is necessary, with meaningful information.	Not investigated
D2.1	Avoid labels that are vague or ambiguous.	Strong.
D2.2	Write information relevant to the type of element being labeled (e.g. time information on timer events).	Not investigated
D2.3	Use a well-maintained glossary of terms. Avoid synonyms and homonyms.	Not investigated
D3	Place labels close or inside model elements.	Not investigated
D3.1	Use short labels.	Strong
D3.2	Use Sans-serif, non-bold fonts.	Strong
D3.3	Use left-aligned labels.	Weak
D3.4	Use short words within labels.	Weak
D3.5	Have a high contrast between the labels and the background.	Weak

Source: The author

this mixing of styles to be more ambiguous and less useful (MENDLING; REIJERS; RECKER, 2010). Therefore, according to Becker (2015), it is important that naming conventions are enforced in organizations.

To determine which labeling style is best, studies have recommended that "Verb-object" be used for activities (SILVER, 2009; ARKILIC; REIJERS; GOVERDE, 2013; LEOPOLD; MENDLING; GÜNTHER, 2016), with Mendling et al. (MENDLING; REIJERS, 2008; MENDLING; REIJERS; AALST, 2010; MENDLING; REIJERS; RECKER, 2010) providing weak evidence to this effect, based on the perceived ambiguity and perceived usefulness of this style to model readers. Events and gateways also have labeling style recommendations ("Object-Participle" and "Object-Participle-?", respectively) (SILVER, 2009; LEOPOLD; MENDLING; GÜNTHER, 2016), though no studies have been found that empirically support them. It is important to emphasize that these recommendations are valid for labels of the English language, as the common labeling conventions of other languages, such as Brazilian Portuguese and German, may differ (LEOPOLD et al., 2013).

D2 Ambiguity, Vagueness and Vocabulary

While labeling most modeling elements is not required, it is crucial that the process logic is clearly visible in the process model, which requires that most modeling elements be labeled, with the exception of AND-gateways and non-decision related sequence/message flows (SILVER, 2009; EFFINGER; JOGSCH; SEIZ, 2010; JOHANNSEN; LEIST; BRAUNNAGEL, 2014). The element type should also be considered to add information relevant to it, such as a duration or a date to a timer event (SILVER, 2009; LEOPOLD; MENDLING; GÜNTHER, 2016). These tasks ensure that no information is missing to the model reader, although it is also imperative that the labels are not ambiguous (WEBER et al., 2011) nor vague (LAUE; MENDLING, 2010). One example is the use of "and" and "or" words in activity labels, which might imply that there are two actual activities to be executed or that part of the activity might be optional. One solution advocated for large process model collections are the use of a glossary (LEOPOLD; MENDLING; GÜNTHER, 2016; BECKER, 2015) to manage what vocabulary of process models and ensure that the terminology is clear and that synonyms and homonyms are avoided (MENDLING, 2013; PITTKE; LEOPOLD; MENDLING, 2013).

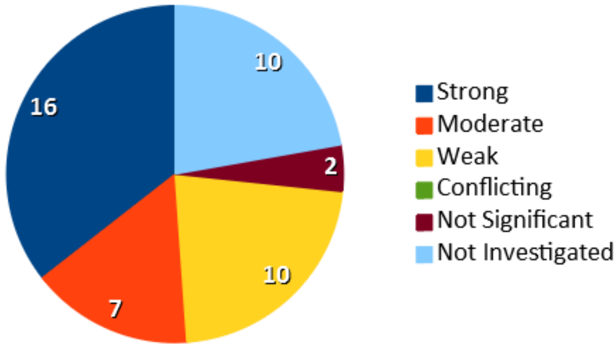
D3 Label Format

The notion that shorter labels (in number of words) improve model comprehension has been strongly evidenced by Mendling and Strembeck (2008). Additionally, Koschmider, Figl and Schoknecht (2016) have suggested that how the label is formatted also helps in easing the comprehension of the model, based upon multiple studies on the field of typography. The five factors they have provided recommendations for are size (words with fewer than 8 letters), shape (lowercase, sans-serif, non-bold font), direction (left-aligned), color (high contrast between font and background colors) and position (place labels inside or spatially close to model elements).

3.3 Discussion

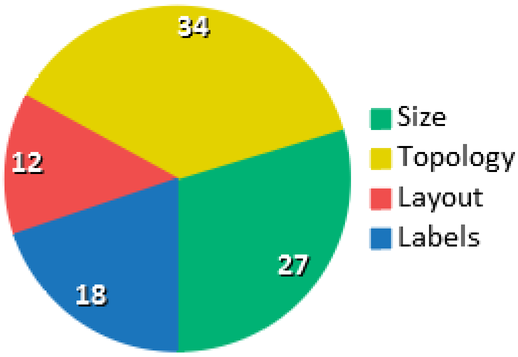
The total amount of modeling guidelines we found through our systematic review was 45, including the subtypes. Figure 3.8 shows how many guidelines that were classified in each level of evidence, based on the highest level of evidence we found. In this figure, it is possible to observe that the majority of guidelines have at least been investigated. Most of them also have significant empirical evidence supporting it (strong),

Figure 3.8: Number of guidelines for each level of evidence.



Source: The author

Figure 3.9: Number of articles for each type of guideline.



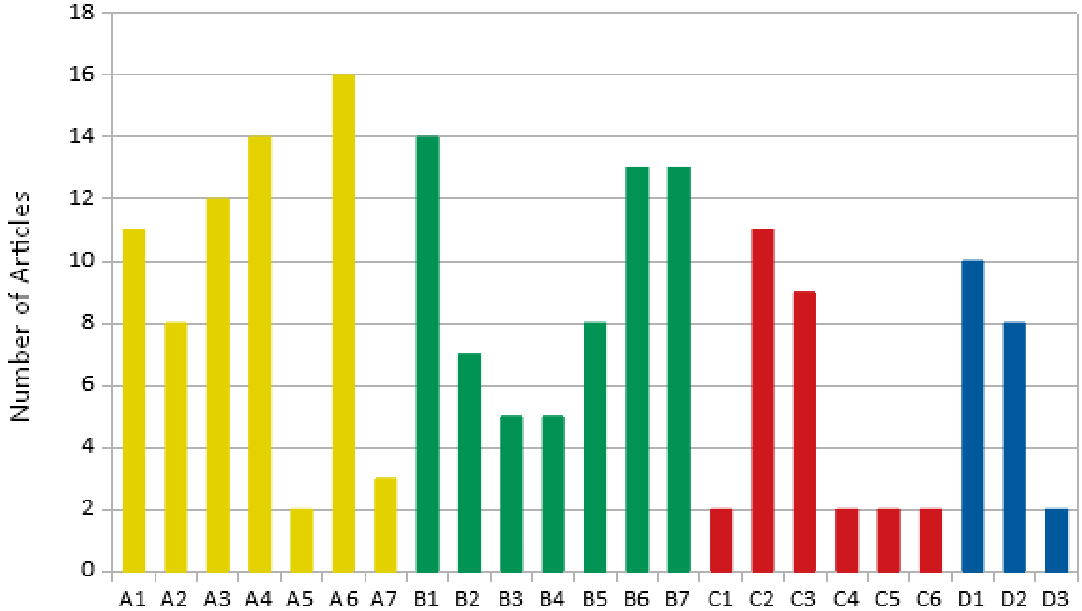
Source: The author

though a high number is also supported by research on variables other than comprehension accuracy (weak). Curiously, although we have found empirical research whose finding were conflicting, there are no individual guidelines which this is the highest level evidence.

As can be seen in figure 3.9, the number of articles from which we have found topology guidelines is higher than the number for layout and label guidelines combined. The number for model size guidelines is also high. This reflects how the area of research around process model comprehension and modeling guidelines started, with multiple authors proposing process model metrics and performing validation in order to create an objective measure that is correlated with the comprehensibility of a process model.

This is more easily noticed when analyzing the distribution of articles for each individual guideline (figure 3.10), where we find that the guidelines A1, A2, A3, A4, A6, B1, B5 and B6 have a high number since they are related to process model metrics. A6, B5 and B6 are particularly notable, given that they all influence the complexity of connections of the process model. However, it is curious that A5, A7, B2, B3 and B4 are on the mid to low end of the distribution, given that the metrics associated with them are

Figure 3.10: Number of Articles for each guideline.



Source: The author

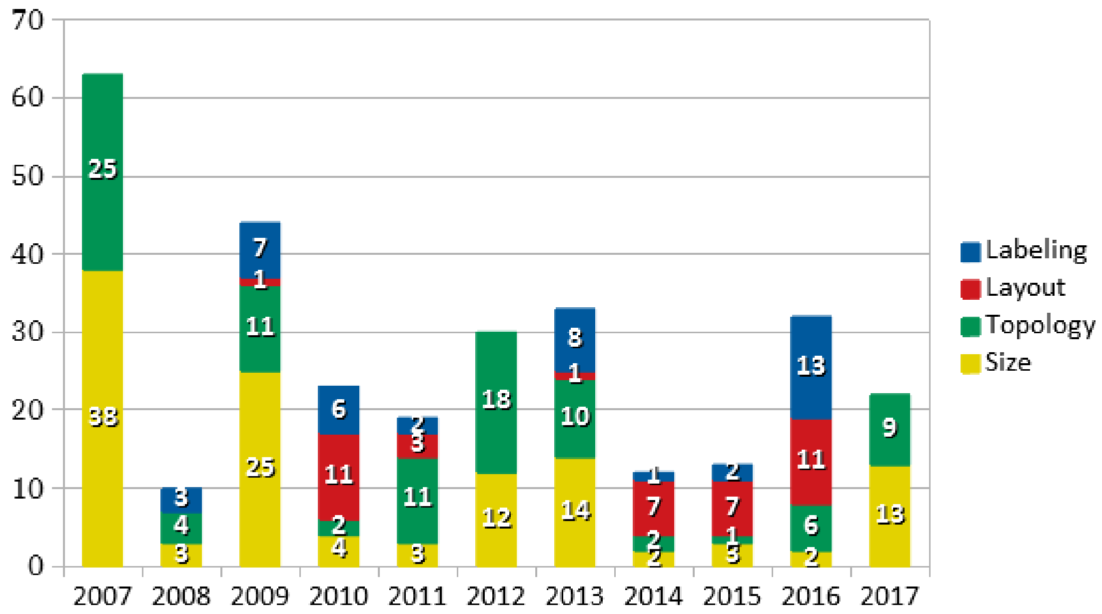
simple. Perhaps these guidelines are often assumed to have significant effect on process model comprehension, even if only B2 has been supported by strong evidence. This is a possible avenue for future research.

Another notable guideline is B7, but this time because of how controversial the topic of decomposition and modularity of process models is. Authors on both sides of the argument have exposed convincing theories on the advantages and disadvantages of this guidelines, but there is a lack of an empirical study of when and how a process model should be decomposed or modularized.

Articles on the layout of a process models are the fewest amongst our review set. A lot of emphasis has been put on the flow aspect of the process models, both in terms of the model shape and direction (C2) and how much the sequence and message flows bend and cross over one another (C3). It is possible that it is due to how complex and important it is for a person to comprehend the dynamics of the process model, how a model's events, activities and gateways interact to form the semantic of the process. The interest of authors in more static proprieties of the layout (C1,C4,C5,C6) is much lower.

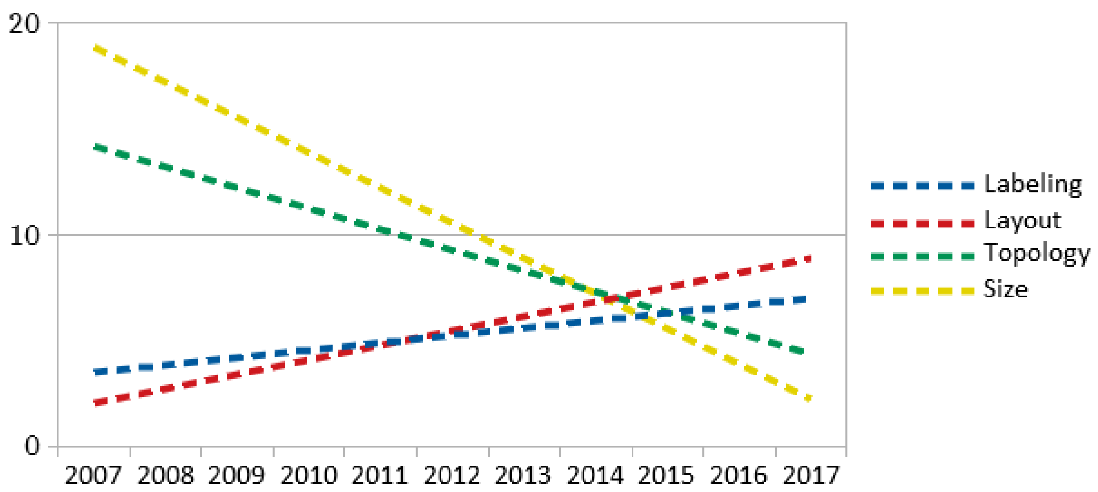
The natural language part of process models has seen a high number of articles that study it. It may not seen that way, since the number of articles about labeling guidelines is fewer compared to the size and topology categories, but there are fewer topics which can be explored about labels. First, studies about the structure of the label's sentence (D1) have established the verb-object style as the definitive style for English-written process

Figure 3.11: Number of times a guideline was presented per year, based on their type.



Source: The author

Figure 3.12: Linear regression of the data of figure 3.11. The vertical axis was zoomed in for clarity.



Source: The author

models, as this style has been recommended in the 7PMG. Nevertheless, the evidence provided for this style has yet to be measured a comprehension accuracy variable, seeing that the empirical studies referenced by the authors usually present subjective variables such as perceived ambiguity or perceived usefulness. Secondly, many studies emphasize that labels for modeling elements should be meaningful (D2). The approaches for categorizing these meaningfulness vary, but it is noteworthy that there is a absence of empirical studies around this necessity and around the means to solve this problem (at least beyond the simple "Do not be vague" guideline). Finally, the format of the label (D3) is often taken for granted. We've only found two studies about it, but perhaps most empirical studies about this topic have already been explored in the field of typography.

Figure 3.11 shows how many guidelines of each category have been presented in each year. This includes not only the first time a guideline was proposed, but every time after that. This way, we may see how much work has been done each year for each category of guidelines. Based on figure 3.11, we observe that, over the years, the number of guidelines about the size and topology of models has been slowly decreasing, with the opposite being true for layout and labeling guidelines. This can be more easily seen by the linear regression of this data in figure 3.12. As the interest in these latter two categories is increasing, we can presume there still exists more opportunities for research in them. On the other hand, while the size and topology guidelines seen to be well-established, this does not mean that there aren't any more open issues, as we have recently shown.

3.4 Proposal of a Simplified Set of Modeling Guidelines

As the results of our systematic review show, not all process modeling guidelines have been created equally. Most of them are a result of empirical research on process models, but not all of them have significant evidence to their effects. Also, there hasn't been consideration on how most of these guidelines can be applied during the process modeling task.

The use of modeling guidelines is important for any process modeling projects that wish to ensure that their process models can be easily understood by their readers. For this purpose, its also important that the the set of modeling guidelines used be comprised of those that are most useful, as superfluous guidelines may disrupt the process modeling task, perhaps even weakening the quality of the resulting process model.

After analyzing all guidelines we've gathered, we propose a simplified set of these

Table 3.6: Simplified set of process modeling guidelines.

	Guideline
A1	Use as few elements as possible.
A4.1	Avoid using inclusive (OR) gateways.
A4.2	Do not use implicit gateways.
A6.2	Minimize the degree of all gateways.
B1	Model as structured as possible.
B4.2	Do not create cycles with multiple exit points.
B7.1	Decompose models that are too large.
B7.2	Use subprocess to depict model fragments that occur multiple times or that benefit from being grouped together or hidden.
B7.3	Do no overly decompose or modularize the process model.
C1	If necessary, use colors to highlight model elements.
C3.1	Minimize the number of bends in sequence flows.
C3.2	Minimize the crossing of sequence flows.
D1	Use a consistent labeling style.
D1.1	Use verb-object style for activity labels.
D1.2	Use object-particle style for event labels.
D1.3	Use object-particle question style for gateway labels.
D2	Label everything that is necessary, with meaningful information, ambiguity .
D2.1	Avoid labels that are vague or ambiguous.
D3.1	Use short labels.
D3.2	Use Sans-serif, non-bold fonts.

Source: The author.

guidelines for use in process modeling projects, with the objective of assuring the comprehensibility of process models. This simplified set can be seen in table 3.6. We have considered three avenues for this simplification:

- **Redundancy**: We tried to avoid recommending guidelines whose goals were redundant with another guideline. In this case, the majority of size guidelines can be simplified to A1, which simply states to use as few elements as possible. This way, we removed 9 guidelines.
- **Practicality**: We eliminated guidelines that were too impractical to be used under common process modeling circumstances, like minimizing the level of concurrency (B3) or avoiding the use of more gateway types (B5). They either require for the process behavior to be changed or for significant tool support (such as an established vocabulary - D2.3). This way, we eliminated 6 guidelines.
- **Evidence**: We tried to keep in mind the level of supporting evidence each guideline has, as those with weak evidence or unconfirmed effects may only confuse the process analyst with no real gain. Still, some guidelines with weak evidence were

kept, due to the reputation they acquired (e.g D1). This way, we dismissed 10 guidelines.

4 EXPERIMENT

In this section we report on the experiment we performed to answer our second research question: "How does process modeling guidelines influence the process modeling task and how receptive process analysts are to their use?". We display each step of our methodology, starting with the definition of our hypothesis, passing through the design of the experiment and its instruments and finishing with the statistical analysis of the results.

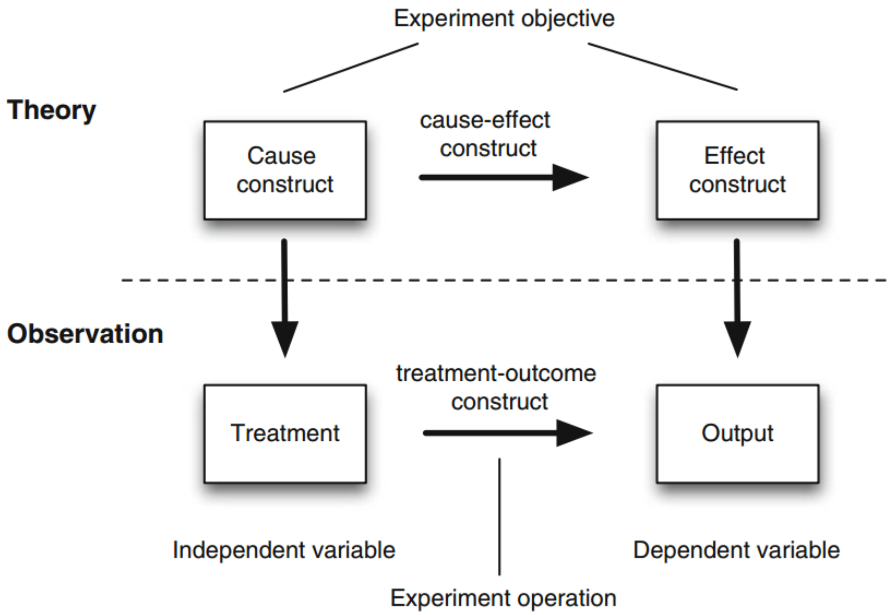
4.1 Experimentation Background

A controlled experiment (or simply experiment) is a type of explanatory research, that is, it is concerned with quantifying a relationship or to compare two or more groups with the aim to identify a cause-effect relationship (WOHLIN et al., 2012). It primarily relies on quantitative data, which is used to test the effects of some manipulation or activity. Because of this, experiments are fundamentally defined by the comparisons and the statistical analysis it performs on the data it captures.

Figure 4.1 illustrates the basic principles behind an experiment. It starts by having a theory on a cause and effect relationship between two constructs. In order to evaluate this theory, an experiment is used for us to be able to observe the outcome of a treatment (WOHLIN et al., 2012). When a experiment is well designed, the treatment and the outcome correctly represents the cause and effect constructs. As a consequence, it becomes possible to draw conclusions about the theory based on what we observe from the experiment. In this work, we follow the methodology defined by Wohlin et al. (2012), which categorizes the process to design and execute an experiment in five main steps. The first step is **scoping** the experiment, in which we define its general objectives and goals. It provides a foundation that determines why the experiment is conducted.

In **planning** it is determined how the experiment will be conducted. To do this, it is necessary to determine the problem that will be analyzed, defining hypotheses based on the theoretical cause and effect relationship. The hypotheses will in turn define the dependent and independent variables that will be observed during the conduction of the experiment. After this, the subjects who will participate are selected and it is defined the design of how the experiment will organized and run. Based on these, the instruments that will be used during the experiment are created. They are essential objects that either guide the participants through each test, that measure and collect the data that forms the

Figure 4.1: Experiment Principles.



Source: (WOHLIN et al., 2012) and adapted from (TROCHIM; DONNELLY, 2001)

results or that are necessary to perform the experiment's tests.

The **operation** step is the actual execution of the experiment. After it is performed, the resulting data has to be validated, removing incomplete or erroneous data. The validated data are then used during the **analysis and interpretation** step, in which the results are compared via descriptive and inferential statistics, in an effort to test the hypotheses. The type of statistical test is dependent on the type and the distribution of the variables defined during the planning step. Finally, the **presentation and package** is where the findings of the experiment are published.

The following sections 4.2, 4.3 and 4.4 describe how we performed each step of this methodology in the context of our experiment.

4.2 Scoping and Planning

We have established in our motivation that there aren't many empirical studies in the literature that focus on analyzing the use of multiple process modeling guidelines during the process modeling task. Yet, according to Dikici, Turetken and Demirors (2018) framework (see section 2.3.2), modeling guidelines are a important factor for the comprehensibility of the process model. Therefore, the primary goal of our experiment is to analyze the effects of using a set of process modeling guidelines during the process

Table 4.1: Process modeling guidelines used in the experiment.

	Guideline
A1	Use as few elements as possible.
A2	Avoid using inclusive (OR) gateways.
A3	Do not use implicit gateways.
A4	Minimize the degree of all gateways.
B1	Model as structured as possible.
B4.2	Do not create cycles with multiple exit points.
B7.1	Decompose models that are too large.
B7.2	Use subprocess to depict model fragments that occur multiple times or that benefit from being grouped together or hidden.
B7.3	Do no overly decompose or modularize the process model.
C1	Minimize the drawing area of the model (preferably within a page).
C2	Make the process flow from left to right.
C3.1	Minimize the number of bends in sequence flows.
C3.2	Minimize the crossing of sequence flows.
C4	Avoid overlapping elements.
C5	Make use of symmetry between elements.
C6	Keep model elements related to one another close to each other.
D1	Use a consistent labeling style.
D1.1	Use verb-object style for activity labels.
D1.2	Use object-particle style for event labels.
D1.3	Use object-particle question style for gateway labels.
D2	Label everything necessary.
D2.1	Avoid labels that are vague or ambiguous.
D3.1	Use short labels.

Source: The author.

modeling task. We want to evaluate how effective process analysts are in this context, as well as assessing how receptive they are to the set of modeling guidelines used in this experiment.

To fulfill this goal, it is necessary to define which set of modeling guidelines would be used during the experiment. We chose to use the guidelines found by our systematic review, though we didn't use all 45 of them as this number of guidelines is too high, which could make the experiment considerably longer and more difficult for the subjects. The simplified set we provided in table 3.6 was more adequate, but we added more layout guidelines to balance the number of guidelines in each categories. We also removed the guidelines "D3.2 Use Sans-serif, non-bold labels" as this is usually the default in process modeling tools. The set of guidelines presented to the subjects is show in table 4.1.

4.2.1 Problem Definition and Hypotheses

The influence multiple modeling guidelines have during the process modeling task is still an open question. To start with, it is possible that the use of modeling guidelines may turn the modeling task more difficult, since the analyst must keep track of not only the actual process that is being modeled but also if his process model is following the guidelines or not. This extra information may easily confuse or distract the analyst during the modeling task, requiring more time and effort to be used in what may have been an easier task. As a consequence, if the analyst believes that the modeling task is significantly more difficult with the use of modeling guidelines, he may be discouraged from using them in the future. Therefore, this would imply that some method or tool is necessary to support the analyst in using the modeling guidelines.

It's also unclear how effective a analyst may be in using a set of modeling guidelines after being presented with them. Pragmatically, modeling guidelines should be simple and well-founded rules that tell how to create a process model of better quality (MENDLING; REIJERS; AALST, 2010), yet there are guidelines that have no clear instruction of when they can be applied, e.g. when to use subprocesses. This vagueness may generate some difficulty to analysts, which may cause their process model to still have modeling issues that impair the comprehensibility of the process model and that could have been prevented by the use of the modeling guidelines. It's also possible that the analyst, by using the modeling guidelines, perceives their own models to be of a higher quality than before, as the guidelines would serve for them as a point of reference of how a process model with no modeling issues should be.

Considering these questions, we formulated three hypothesis:

H_1 Process analysts believe that they have more difficulty in modeling with the use of process modeling guidelines than without.

H_2 Process models created with the support of process modeling guidelines will have less modeling issues than those without.

H_3 Process analysts believe that their process models are of higher quality when they use process modeling guidelines than when they don't.

In addition to these hypotheses, there's also the inquiry of how receptive analysts are of the process modeling guidelines, specifically their opinions of how easy the guidelines are to use, how useful they are and if they intend to continue using the guidelines in the future.

4.2.2 Experiment Variables

Based on the hypotheses, we defined three dependent variables:

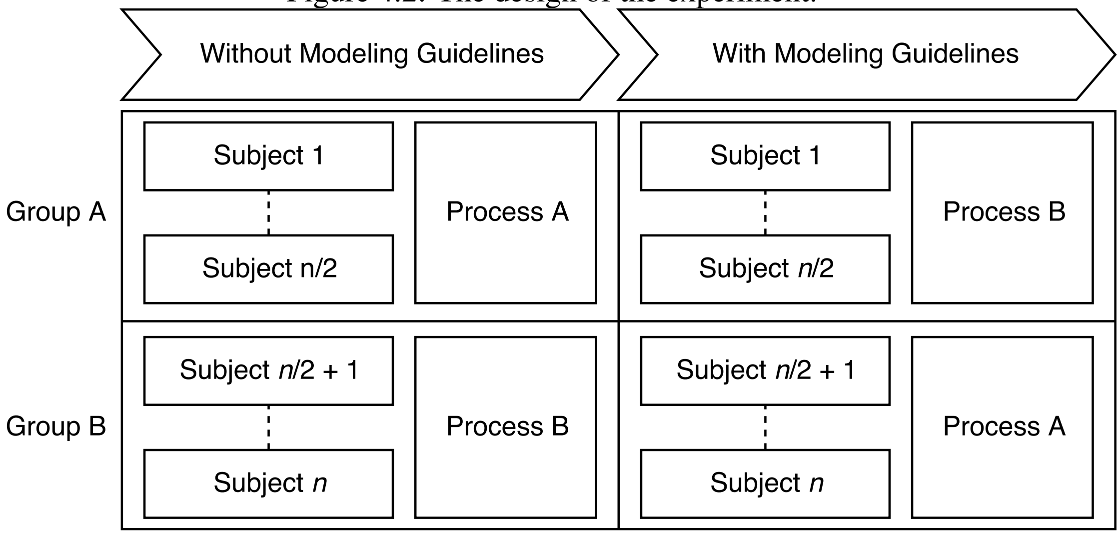
- For H_1, the perceived (subjective) level of difficulty the analysts had during the modeling task was defined. As this variable is an unobservable characteristic that is inherent to the analyst's opinion, it was measured through a 5-point Likert scale, ranging from "Very Easy" to "Very Hard".
- For H_2, each process models has to be analyzed by the number of modeling issues they have based on the modeling guidelines. To do this, each process model was evaluated for each guideline to see if it was disobeyed at least once. To keep it fair, multiple transgressions of that guideline beyond the first were ignored. After all guidelines were evaluated, the results were summed to a single value.
- For H_3, it was defined the level of quality of the process models created by the analysts, from their point of view. This was also measured through a 5-point Likert scale, ranging from "Easy to Understand" and "Hard to Understand".

Three other dependent variables were defined for the receptiveness of analysts to the modeling guidelines: the perceived ease of use, the perceived usefulness and the future intent of use. The opinions of the subjects about the modeling guidelines for each of these variables were measured through three 5-point Likert scales, ranging from "Strongly Disagree" to "Strongly Agree".

As Dikici, Turetken and Demirors (2018) framework established, personal factors such as modeling expertise are a possible influence on the understanding and the performance the subjects interacting with process models (OTTENSOOSER et al., 2012). Therefore, it is important for use to measure the subjects experience in modeling tasks similar to this experiment. We have done this by defining three variables: experience with process modeling; experience with BPMN; and experience with other process modeling notations. Each of these variables was measured through 5-point Likert scales that ranged from "Not experienced" to "Very experienced". These three variables were then averaged to define the modeling expertise of the subject.

It was also asked whether the subject already knew of a set of process modeling guidelines. This knowledge could influence the results of all dependent variables.

Figure 4.2: The design of the experiment.



Source:The author.

4.2.3 Experiment Design and Subjects

The goal of the experiment was to compare two different process modeling tasks based on whether they have or not the support of modeling guidelines. For this purpose, the experiment was performed through a paired comparison design, in which the subjects perform the experiment tasks twice, each time with a different treatment (WOHLIN et al., 2012). In our experiment, the subjects were given textual descriptions of two processes, one for each step of the experiment. On the first time they did the experiment, the subjects were asked to simply model the process contained in the first description. On the second time, they would be introduced to the list of modeling guidelines, which they were encouraged to use to model the second process. Since the subjects would learn the guidelines after they were introduced, the order of the experiment had to be fixed: the first process modeling task did not have the support of the guidelines and the second did. On the other hand, the order of which process was modeled in each task could also influence the results, so, to mitigate this, the subjects were randomly separated in two groups, with alternating processes. Figure 4.2 show the design of the experiment.

In the experiment, the subjects were 13 students that were taking, at the time, the introductory course to Business Process Management at the Federal University of Rio Grande do Sul. The subjects could be assumed to have knowledge of process modeling and BPMN. Prior to the start of the experiment, the subjects were told its overall goals and how it would proceed, along with a time limit for each step of the experiment. They were also encouraged to create process model with quality in mind.

The experiment was performed in one laboratory, with all 13 subjects and at the same time. The subjects had a limited time to perform each step of the experiment, which took, on average, 80 minutes to complete. Also, any doubts the subjects had about the procedure could be answered by this author.

4.2.4 Instrumentation

Four instruments were used in the experiment: textual descriptions of two processes, a list of the process modeling guidelines, a modeling tool to perform the experiment and an online questionnaire. With the exception of the modeling tool, all instruments were written in Portuguese, as all subjects spoke Portuguese as their native language.

The processes selected for the experiment came from a collection of real world process models from the university. This collection was analyzed in search of two process models of similar complexity that would provide opportunities for the subjects to utilize the modeling guidelines. As such, the selected process models were of a medium size (i.e over 20 model elements) and contained at least one cycle, one possible subprocess and multiple exclusive (XOR) gateways. It was also required that the subjects would not have any previous in-depth knowledge of the selected processes. Finally, the selected process models were manually transcribed into a textual description for use in the experiment. Each process model can be found at <https://goo.gl/tqpF4r>, although their labels were cleared due to their confidential nature.

The list of modeling guidelines was based upon the set of modeling guidelines we defined in table 4.1. It was physically distributed on paper to all subjects for the second part of the experiment and it was also available online through a link presented in the online questionnaire. Each guideline was supplemented by a small description detailing how to apply it. This document is shown in appendix 1.

A modeling tool was necessary for the subjects to model both textual process descriptions. Considering that the guidelines were written for BPMN, the subjects used the *Bizagi BPM modeler*[1], as this is the tool that is taught at the university's Business Process Management course.

The online questionnaire served multiple purposes. First, it characterized the subjects, measuring the independent variables (see section 4.2.2). After characterization, the questionnaire guided the subject through the experiment (see section 4.2.3). Finally, the

[1] www.bizagi.com/en/products/bpm-suite/modeler

questionnaire collected data on the dependent variables (see section 4.2.2), through questions and through the upload of the process models created during the experiment. The questionnaire also had open-ended questions where the subjects could provide reasons for their answers and their opinions about the modeling guidelines. The questionnaire can be found at <https://goo.gl/QFxkPq>.

4.3 Data Validation

The experiment was completed by all 13 subjects and the data collected through the questionnaire had no issues. 26 process models were also collected, but two subjects created process models with serious syntactical errors, therefore 4 models had to be excluded. Also, after analyzing all process models, there was no difference between the subjects performance with respect to guidelines A1, A2, A3, B7.1 and B7.3, that is, all subjects either followed or disobeyed these guidelines. Thus, we have removed them from consideration.

4.4 Experiment Results and Analysis

4.4.1 Descriptive Statistics

Regarding the subjects characterization, all subjects reported knowledge of the seven process modeling guidelines, proposed by Mendling (MENDLING; REIJERS; AALST, 2010). This was expected, considering that the 7PMG were taught during the BPM course of the subjects. They also reported an average experience of 2.87, with no significant outliers. Therefore, we can assume this group to be homogeneous.

Concerning the dependent variables, figure 4.3 shows the distribution of the answers for the perceived level of difficulty and the perceived level of quality and related to H_1 and H_3 respectively. While the perceived level of difficulty shows no expressive difference between the two modeling tasks, the perceived level of quality shows a slight increase during the second task.

Table 4.2, on the other hand, provides the descriptive statistics for the number of modeling issues, corresponding to H_2. The increase of average number of modeling issues between the two modeling tasks surprisingly contradicts our expectations, as we assumed

Figure 4.3: Data collected for perceived level of difficulty and perceived level of quality.

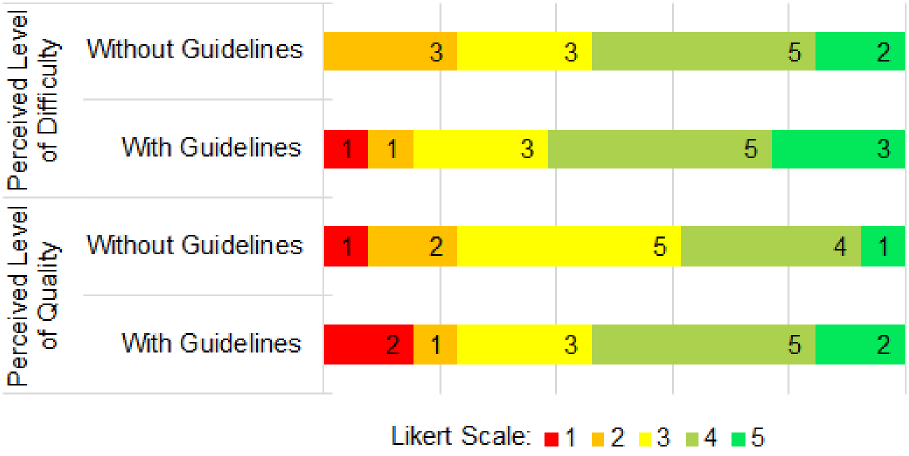


Table 4.2: Statistics for the Total Number of Modeling Issues.

	First Process	Second Process
Average	**6,73**	**7,45**
Std.Dev	2,53	2,07
Minimum	3	5
Maximum	12	11
Median	7	8

that using modeling guidelines would help process analysts in avoiding modeling issues. It is possible that some other factor has influenced these results.

For the receptiveness of the modeling guidelines, figure4.4 shows the distribution of the answers. Based on this data, it is possible to observe that the subjects recognize the usefulness of the modeling guidelines, but that they also did not see them to be easy of use. Through the open-ended questions, the subjects wrote that they had difficulty in understanding how to apply some guidelines. Despite this, one subject argued that his doubts could be cleared with practice and study, which is an indicative of the good results for the "intent of future use" variable.

Figure 4.4: Data collected for receptiveness to the modeling guidelines.

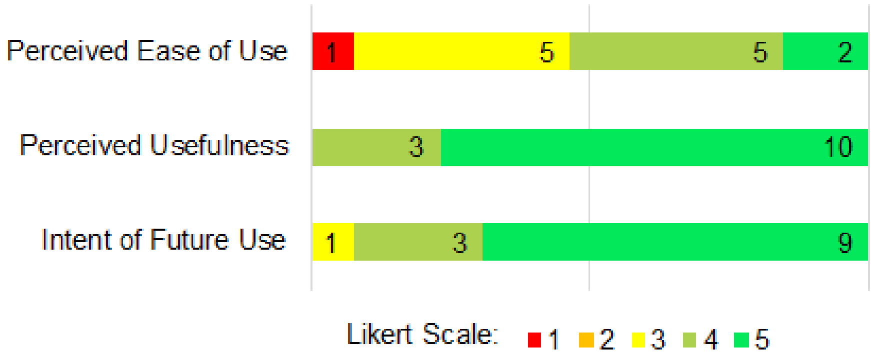


Table 4.3: p-values for the tests of the hypotheses

Hypotheses	p value	Test Applied
H_1	0.28185	Sign Test
H_2	0.79288	Paired T-Test
H_3	0.18285	Sign Test

4.4.2 Hypothesis Testing

To address the three hypotheses we defined, we have to determine if there is a statistical difference in the comparison of the dependent variables of the two modeling tasks. To determine which type of statistical test to perform, we first determined if the data we collected is normally distributed. We did this through a Shapiro-Wilk test (SHAPIRO; WILK, 1965), which is a test of normality with high statistical power (RAZALI; WAH et al., 2011). After that, we chose the appropriate parametric or non-parametric test depending on the type of the dependent variable.

For H_1 and H_3, the dependent variables perceived level of difficulty and the perceived level of quality were not found to be normally distributed. Also, both these variables were considered to be ordinal data, i.e. data that ranks the values based on an ordering criterion. Therefore, we chose to apply the non-parametric one-sided Sign test (SIEGEL; JR., 1988) for both hypotheses.

For H_2, the Shapiro-Wilk test did confirm that data for the number of modeling issues is normally distributed. This variable falls on an interval scale, since the difference between two measures can be quantified in absolute values. Because of this, we chose to apply a one-sided Paired T-test (MONTGOMERY, 2017), which is commonly used when the sample data comes from experiments with a paired design, such as ours.

For all three cases, the analysis indicated that there is no statistical difference between the two modeling tasks, since the resulting p-values, which can be seen at table 4.3, are not significant at 0.05 significance level. Therefore, no support is provided for all three hypotheses.

4.4.3 Experiment Discussion

The experiment we planned was performed successfully by all 13 subjects it was applied to. Based on the collected data, we were able to determine that the variables that were measured were appropriate to address the questions of this research. The results we gathered are an important first step in determining the effects of using modeling guidelines during process modeling.

However, despite the success of the execution of the experiment, none of our hypotheses were given support from the results. Therefore, it is important to analyze which conditions of the experiment are possible threats to its conclusion validity. The biggest risk is the sample of the experiment, whose small size makes it difficult for the statistical tests to have enough power to either confirm or reject the hypotheses. Another factor of risk is how the dependent variables were measured, specially for H_1 and H_3, since measuring subjective values through a single Likert scale limits the possible types of statistical tests that can be performed.

Contrastingly, the use of alternating processes to be modeled by the two groups of subjects, as defined in the design of the experiment, prevented them from influencing the results based on the order they were applied. This is particularly relevant considering that all subjects reported, through the open-ended questions, that one specific process was more complex than the other.

A possible clue to what may have affected our results can be seen on the data about the number of modeling issues of the resulting process models. Given that the average of this variable increased between the first and the second modeling tasks, which is contrary to our expectations, it is reasonable to assume an unknown factor has influenced the results. A simple explanation might be the fatigue of the subjects, as the modeling tasks are fairly long and mentally demanding, meaning that their performance could decline as they get more tired.

While we believe that the list of modeling guidelines and the Bizagi Modeler tool were appropriate instruments to be applied in this experiment, it was possible to observe how difficult it was for the subjects to interact with and use the modeling guidelines efficiently in a process modeling task focused on quality. Through the open-ended questions, many subjects reported that they struggled to model the processes of the experiment, because they required the use of too many modeling elements. While they primarily attributed this to how complex the processes were, one subject argued that the Bizagi modeler impaired his ability to stay organized when working with a high number of modeling elements.

Most subjects also wrote that they had difficulty in understanding the modeling guidelines and how to use them, even if they agreed that they are useful. This is reflected in the data collected for their receptiveness to the guidelines. This may imply that the modeling guidelines may require further refinement to make them easier to understand and use. One possible option may be to implement the modeling guidelines directly in a modeling tool, to support the process analyst in their application.

5 RELATED WORK

In this chapter we discuss works that share concepts with this dissertation. We concentrate primarily on a greater overview of process model comprehension and on the study and use of modeling guidelines in the literature and in practice.

5.1 Process Model Comprehension

Process model comprehension is perhaps one of the most studied aspects of process modeling that can be found in the academic literature. All three model quality frameworks we mentioned in this dissertation background (GoM (SCHUETTE; ROTTHOWE, 1998), SIQ (REIJERS; MENDLING; RECKER, 2015) and SEQUAL (KROGSTIE, 2012)) dedicate a portion of their structure to define what model comprehension is and why it is important. However, the systematic review of Oca et al. (2015) reveals that the studies in the literature do not share a consistent definition of process model quality. It analyzed the different terms the studies adopt to name the different aspects of quality of process models and it found that multiple terms were used to refer to any individual aspect. Furthermore, some specific terms, such as *correctness*, were used in different studies to refer to more than one aspect, e.g. syntactic and semantic quality. This lack of clear definition makes the studies difficult to compare.

The systematic review of this dissertation discovered many studies about what factors influence process model comprehension, the majority of them relating to characteristics that are inherent to a process model. Unfortunately, it missed the works of Figl (2017) and Dikici, Turetken and Demirors (2018), as they were published after our search of the literature finished. Both of these works are systematic reviews on process model comprehension, with one of their contributions being the identification of influence factors. This contribution was, in fact, the main focus of the latter study, which also provided a framework that we referenced in section 2.3.2.

Going slightly outside the field of process models, Houy, Fettke and Loos (2012) reports on a systematic review on the understandability of *conceptual models*. More specifically, the review analyzed how the empirical research on conceptual models conceptualized and operationalized model understandability, focusing primarily on evaluating the validity of the measures of each study. Similarly to the work of Oca et al. (2015), it found that studies have no clear consensus on how to conceptualize model understandability. In fact, based on the studies it analyzed, it identified six possible dimensions of model understandability. Process models are a type of conceptual model, as both are used to represent events, processes and their proprieties (WAND; WEBER, 2002), so most of this review findings can also be applied to empirical research on process models.

The main difference between these works and this dissertation is our focus on finding and analyzing modeling guidelines. We recognize that process analysts require a simple set of guidelines, but that this set must be well-founded in empirical knowledge. Thus, we proposed a reduced set of guidelines based on those that we discovered on our systematic review and we also evaluated this set on an empirical experiment.

5.2 Process Modeling Guidelines

As our systematic review revealed, studies analyzing process modeling guidelines are many. However, analyzing guidelines as a set is uncommon. The 7PMG proposed by Mendling, Reijers and Aalst (2010) is one of these works, as it has another contribution besides its set of guidelines. It asked expert analysts to rank and prioritize the 7PMG based on which of those they believe is more important for the quality of the process model. This resolves the issue of when a process analyst has the opportunity to apply multiple guidelines that guide him to conflicting solutions

Another important work is the one by Oca, Snoeck and Casas-Cardoso (2014), where a set of 30 modeling guidelines, that was discovered in their previous work (OCA; SNOECK, 2014), was presented to process modeling students, so that the students would evaluate each individual guideline by means of its perceived ease of use, its perceived usefulness and its behavioral intention. The results were then compared against each other to find the highest scoring guidelines for these variables and their correlations.

Also based on the guidelines discovered in Oca and Snoeck (2014), the work of (SNOECK et al., 2015) analyzes a six BPMN modeling tools for their support of modeling guidelines. It has found that the two tools with most support are the *Signavio Process Editor*[1] and the *Bizagi Process Modeler*[2], though both of them still lack support of over 40% of the modeling guidelines.

Corradini et al. (2017) tried to offset this deficiency. They collected a set of modeling guidelines and associated them with appropriate metrics and thresholds, if possible.

[1] www.signavio.com
[2] www.bizagi.com

Then, they implemented an algorithm to perform the automatic verification of each guideline and aggregated these algorithms in an open-source tool, which reads a BPMN model and informs which guidelines were violated by this model.

The work of Júnior et al. (2017) is similar, though it uses a BPMN ontology to first verify the model syntactic correctness. After this, it verifies the model according to the 7PMG. This work has also been extended in (JÚNIOR et al., 2018) to include an interface prototype to the verification, based on information visualization techniques.

This dissertation also analyzed modeling guidelines as a set. We recommended a set of guidelines based on the evidence we found in the literature and we analyzed the effects this set has on the process modeling task through an empirical experiment.

6 CONCLUSION

At the beginning of this dissertation we presented two problems. The first problem was about the dispersion of process modeling guidelines amongst many different studies, which made it difficult for process analysts and researchers to find and use them during their process modeling initiatives and their empirical research. For this problem, we established our first research question: "What business process modeling guidelines to increase model comprehension exist in the literature and what evidence exist that support their effects?"

To answer this question, we conducted a systematic literature review in order to collect process modeling guidelines from a diverse set of studies. Along with these guidelines, we analyzed what empirical evidence exists that supports the positive effects of these guidelines to the comprehension of process models. As a result, we investigated 520 articles, 60 of which were analyzed in detail to extract a total of 45 guidelines across 4 distinct categories. Based on our analysis, we reduced this collection to a simplified set of 20 guidelines. We recommend this set to be used in future process modeling projects and research, as these are the most significant and practical guidelines we have found. As far as we are aware, there are not other systematic reviews that had this purpose.

Our review made evident the existence of the second problem: There is a lack of empirical studies in the literature that analyze process modeling guidelines as a group, which is how they are most frequently used in practice. We theorized that using multiple modeling guidelines during the process modeling task may negatively impact the difficulty and the effectiveness of this task. Thus, we established our second research question: "How does process modeling guidelines influence the process modeling task and how receptive process analysts are to their use?"

Consequently, we planned and conducted an experiment in which 13 subjects were asked to model processes with and without the support of modeling guidelines. The modeling guidelines they used were based on the results of the systematic review. We evaluated their performance on process modeling task and asked how difficult they believed it was. We also surveyed their receptiveness towards our guidelines. This experiment was, to the best of our knowledge, unique in its goals and it was successfully conducted, producing appropriate results to address the hypotheses we defined.

However, the results were not able to provide significant evidence that the use of process modeling guidelines has an effect on the variables that were measured. The best possible reason for this is the low sample size of the experiment, which might have affected its statistical conclusion validity. We have also speculated that the fatigue of the subjects might have influenced their performance throughout the experiment.

Nevertheless, the findings of the experiment function as a evidence for the importance of the questions we tried to answer. They demonstrate the benefit of research on process modeling guidelines as a group. It also provided evidence for the usefulness of the guidelines we recommended in our systematic review, though their ease of use can still be improved.

6.1 Limitations and Future Work

Our research has some limitations which inspire us for future work. On the side of our systematic review, we are unable to guarantee the exhaustiveness of our search, as this is impossible (BROCKE et al., 2015). We are dependent on our search strategy to make the systematic review viable, by limiting the number of articles we analyze. Of course, this may cause us to miss an article that was relevant to our first research question. We are confident, however, that our search strategy was well developed and that it maximized the comprehensiveness of our review, as we followed a well defined methodology of its creation.

Another limitation of our search is the span of years we searched. We chose to search studies from the year 2013 onward, as all relevant studies from before 2013 that we found during our preliminary research were also present in Oca and Snoeck (2014) overview of modeling guidelines, so we used this work as our main reference for all studies prior to 2013. By limiting our search span this way, the total number of articles we had to analyze was reduced, allowing us to complete the review in a reasonable amount of time.

On the other hand, our experiment was performed by real subjects that had some experience with BPMN and process modeling, though we were limited by number of subjects who participated it in. A greater number might have allowed us to change our experiment design, improving the power of our statistical tests, thus improving the validity of the experiments conclusions. Yet, acquiring real subjects to participate in an experiment is difficult, particularly when technical knowledge is required.

In a future work, this experiment can be altered to address the outlined issues. It's also important to investigate other approaches to applying the modeling guidelines, such as using a modeling tool that automatically verifies if a process model follows them. Finally, it seems valuable to analyze which modeling guidelines need to be simplified or that may require further training, to address the problems the analysts may have with their ease of use.

6.2 Publications

During our research six papers were written for publication. Two of them were about the two main topics of this dissertation, i.e. the systematic review and the experiment. The other four were about topics related to process modeling guidelines, in which this author participated as writer or co-writer of the paper.

- **A Semiautomatic Process Model Verification Method Based on Process Modeling Guidelines**
  Authors: Diego Toralles Avila e Lucineia Heloisa Thom e Marcelo Fantinato.
  Conference/Journal: 2017 International Conference on Enterprise Information Systems - ICEIS 2017.
  Qualis: B2.
- **Assisting Process Modeling by Identifying Business Process Elements in Natural Language Texts**
  Authors: Renato César Borges Ferreir and Lucinéia Heloisa Thom and José Palazzo Moreira de Oliveira and Diego Toralles Avila and Rubens Ideron dos Santos and Marcelo Fantinato.
  Conference/Journal: 4th international workshop on conceptual modeling in requirements and business analysis - MREBA 2017.
  Qualis: N/A
- **An Interface Prototype Proposal to a Semiautomatic Process Model Verification Method Based on Process Modeling Guidelines**
  Authors: Valter Helmuth Goldberg Júnior and Vinicius Stein Dani and Diego Toralles Avila and Lucineia Heloisa Thom and José Palazzo Moreira de Oliveira and Marcelo Fantinato.
  Conference/Journal: Springer Book.
  Qualis: N/A
- **Recognition of Business Process Elements in Natural Language Texts**

Authors: Renato César Borges Ferreira and Thanner Soares Silva and Diego Toralles Avila and Lucinéia Heloisa Thom and Marcelo Fantinato.
Conference/Journal: Springer Book.
Qualis: N/A

- **An Experiment to Analyze the Use of Process Modeling Guidelines to Create High Quality Process Models**.
  Authors: Diego Toralles Avila, Lucineia Heloisa Thom and Marcelo Fantinato.
  Conference/Journal: (Submitted, currently in review) 30th International Conference on Advanced Information Systems Engineering - CAISE 2018.
  Qualis: A2.
- **A Systematic Literature Review on Process Modeling Guidelines**.
  Authors: Diego Toralles Avila and Lucineia Heloisa Thom.
  Conference/Journal: Yet to be submitted.

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APPENDIX 1: LIST OF MODELING GUIDELINES FOR THE EXPERIMENT

Boas Práticas de Modelagem

1 Tamanho do Modelo.

1.1 Use a menor quantidade de elementos possíveis.

Quanto menor a quantidade de elementos nós (atividades, eventos, gateways), mais fácil é a compreensão do modelo. Um limite de elementos adequado é 37.

1.2 Evite o uso de de gateways inclusivos (OR).

Gateways inclusivos são frequentemente a causa de ambiguidades ou de erros de semântica de um modelo. Recomenda-se evitar o seu uso.

1.3 Não use gateways implícitos.

Gateways implícitos são as atividades que possuem mais de um fluxo de sequência entrando ou saindo. Gateways implícitos são difíceis de compreender, pois eles escondem se os fluxos relacionados são paralelos ou exclusivos.

1.4 Minimize o grau de conexão de todos os gateways.

Gateways que possuem muitos fluxos de sequência conectados a si (aumentando assim o seu grau de conexões) são de difícil compreensão. Recomenda-se que gateways com mais de sete conexões sejam divididos em múltiplos gateways, de acordo com a semântica das opções.

2 Estrutura do Modelo.

2.1 Modele de forma mais estruturada possível.

Modelos de processo estruturados são mais fáceis de serem entendidos e evitam a ocorrência de erros. Um modelo de processo é estruturado se para cada gateway divisor existe um respectivo gateway juntor do mesmo tipo.

2.2 Evite criar ciclos com múltiplos pontos de saída.

Ciclos idealmente possuem somente uma saída, representada por um gateway exclusivo no final do ciclo que é conectado a um gateway exclusivo no início do ciclo. Desta forma, este ciclo é um fragmento estruturado do processo. Ciclos com mais de uma saída são, por sua natureza, fragmentos de processo não estruturados. Logo, eles devem ser evitados.

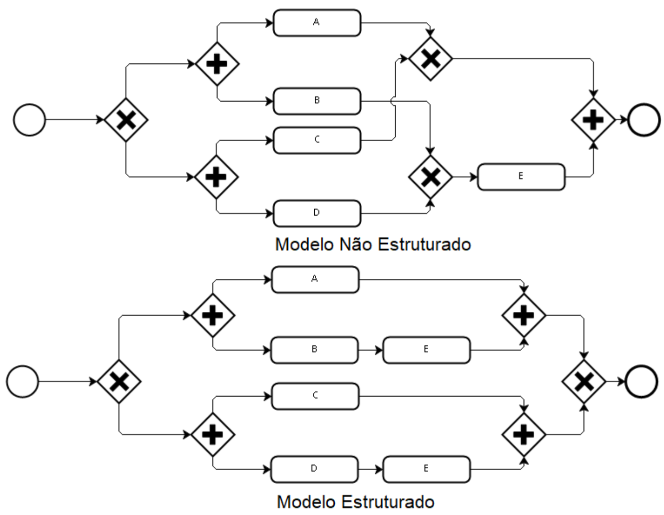

Figure 1: Exemplo de modelo não estruturado e sua versão estruturada.

2.3 Decomponha modelos que estiverem muito grandes.

De acordo com 1.1, modelos com muitos elementos são difíceis de compreender. Para resolver isto, um modelo pode ser divido em múltiplos modelos, onde o fim de um implica no início de outro.

2.4 Use subprocessos para representar partes do modelo que apareçam múltiplas vezes ou que se beneficiam de estarem agrupados ou escondidos.

Quando um modelos é muito grande, as vezes é benéfico que alguns elementos relacionados semânticamente sejam agrupados em um subprocesso para simplificar a compreensão do modelo. Subprocessos colapsados também permitem esconder informações não relevantes ao grande contexto.

2.5 Não decomponha ou modularize demais o modelo.

O uso demasiado de decomposição ou modularização espalha as informações do processo em múltiplos documentos, o que complica a sua compreensão.

3 Layout do Modelo.

3.1 Minimize a área de desenho do modelo.

Se possível, tente limitar-se ao equivalente a uma folha A4 ou a tela de um monitor com um zoom adequado para a leitura.

3.2 Faça o processo fluir da esquerda para a direita.

Evite o uso de fluxos de sequencia que iniciem a direita e voltem para a esquerda.

3.3 Minimize o número de dobras nos fluxos de sequência.

Quanto mais retos forem os fluxos de sequência, mais fácil é descobrir quais elementos eles conectam.

3.4 Minimize os cruzamentos dos fluxos de sequência

Quanto menos cruzamentos entre os fluxos de sequência, mais fácil é de se compreender as conexões do modelo.

3.5 Faça o uso da simetria entre elementos.

Mantenha um alinhamento adequado entre elementos, tanto na horizontal quanto na vertical.

3.6 Evite sobrepor elementos.

Isto inclui fluxos de sequência, pois é difícil acompanhar elementos escondidos por outros elementos.

3.7 Mantenha próximos elementos que são relacionados.

Se um conjunto de elementos cumpre um objetivo em comum, eles devem estar mais próximos entre si.

4 Nomenclatura dos Elementos do Modelo.

4.1 Nomeie tudo o que for necessário

Todos as atividades, os eventos e os gateways devem possuir alguma nomenclatura que os descreva. Caso um fluxo de sequência represente uma escolha, ele também deve ser nomeado.

4.2 Use um estilo de nomenclatura consistente.

Elemento	Estrutura	Exemplo
Atividades	Verbo (no infinitivo) + Objeto	Enviar Pacote
Eventos	Objeto + [Verbo aux.] + Particípio	Pacote Enviado
Gateways	"Objeto + [Verbo aux.] + Particípio + ?	Pacote foi enviado?

4.3 Evite nomenclaturas que são muito vagas ou ambíguas.

Seja claro e explícito ao nomear qualquer elemento.

4.4 Use nomenclaturas curtas.

Evite nomenclaturas com mais de 5 palavras.