

A Research Program for Studying the Impact of Process Representation on Risk Analysis

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Abstract. Business processes modeling plays an important role in helping organizations analyze and implement existing business processes. Specifically, business process understanding is an essential aspect for conducting risk assessment and for detecting internal control weaknesses. In current risk assessment practice, a broad spectrum of notations is used to capture processes with relative strengths and weaknesses. These notations range from pure text-based to purely visual diagrammatic formats. This gives rise to the question whether any of these notations should be preferred in the specific audit and accounting information system domain in order to provide better analysis results. Given the mixed results from prior research, this paper aims to establish a theoretical basis for discussing this question. Based on cognitive research, we identify propositions and derive associated hypotheses. Furthermore, we discuss how analysis performance can be measured in an audit context.

Keywords: Business process models, risk and control, audit, BPMN, text.

1 Introduction

Representing business processes in the form of a model has evolved into a primary focus in information system research and practice. Practitioners conduct process modeling for various purposes, among others, to document organizational processes and to specify information system requirement [1], to conduct process improvement, understanding and communication between participants [2], and to provide specification of an executable automation or semi automation workflow [3].

Understanding business processes becomes increasingly important in risk-based audit and other attestation programs. The International Federation of Accountants's International Standard on Auditing (IFAC's ISA) places stronger emphasis on understanding business processes pertinent to financial position of entities [4], which is crucial for subsequent risk identification tasks. Moreover, as organizational processes are increasingly implemented through information systems, the risks embedded in those processes must be considered when performing risk assessment relevant to potential misstatement in the financial accounts. Technically, this requires

the identification, analysis, and measurement of risks of material misstatement as well as linking business risks with associated controls. A proper documentation of the company's processes on a detailed level therefore provides a suitable foundation towards the analysis of the company's risk situation [5].

In a more general context, the importance of information presentation in conceptual models has been studied for quite some time. These works involve comparing external representation alternatives in an attempt to identify the most effective format for judgment and decision-making tasks [6]. Despite ample of studies that have been carried out both theoretically and empirically on external presentation [7,8,9,10], there is hardly consensus on the potential superiority of two opposing extremes of representation, namely text and diagrams. Prior studies in accounting information systems (AIS) and auditing showed mixed results when comparing both. These works come with varying degrees of support on whether using diagrammatic representations can actually outperform textual representations for different tasks [11,12,13,14]. This gives rise to the question whether business process models, as opposed to text, should be preferred in risk analysis. Given the importance of business process understanding for the effective risk assessment and the lack of studies comparing process diagrams versus text, the investigation of how best to represent business processes for risk assessment decision-making is imperative.

This research in progress paper provides the conceptual model of a study on whether a model can help users to better understand the underlying processes to support their risk-related decision-making tasks. Specifically, we aim to study search, recognition, and inference processes when using alternative representations. This study is expected to extend prior research into process model understanding towards the AIS audit domain. We build on the theoretical analysis of representational equivalence [7], the Cognitive Fit theory [15], and the Cognitive Load Theory [16].

The remainder of this paper is organized as follows. The next section provides an overview of the background literature with an emphasis on risk assessment of business processes in assurance practice. Then, the next section explains process model use for audit related judgment and decision-making. Afterwards, we define the research model and the proposed propositions, before concluding the paper.

2 Related Works

In this section, we discuss business process risk analysis and specific applications of process modeling for risk analysis.

2.1 Business Process Risk Analysis

The risk-based audit approach places emphasis on the broader business scope rather than directly focusing on financial misstatement. Risk analysis entails identifying relevant business risks of the underlying business processes (risk identification) as well as controls corresponding to those risks, while making decision based on assessing the magnitude of identified risks for any necessary subsequent tests (risk assessment) [17]. Risk assessment conveys the decisions auditors should make as the

result of the educating risk information. An accurate representation of business processes therefore helps to understand them better in risk identification tasks.

The risk-based audit approach starts by initially determining business risk exposing the current AIS under investigation. Such risks, when not adequately addressed with appropriate internal controls, may lead to unfavorable material misstatement in the reported financial statement. Hence, the first step is to establish a set of standard controls to reduce the likelihood of the risks. Next, existing controls and the set of standard controls are compared, while any deficiencies and solutions are identified. Finally, auditors and managers test these controls to verify if they are performing as documented [18]. Against this elaboration, risk-driven audit approach thus requires identifying and documenting business processes and controls associated with financial reporting as prerequisites for risk assessment. The increasing usage of information systems automating business processes also adds to the complexity of the business risks applicable to the process of provisioning accounting information [4].

Risks attributed to these processes thus need to be carefully captured and analyzed. One example is placing a purchase order which is the subset of the procure-to-pay business process. A company bears risks of having unauthorized purchase requisition or and paying for a not existing supplier which violates an occurrence or existence assertion. This can be addressed by defining a control objective: that purchase orders are placed only for approved requisitions and existing suppliers. In line with this explanation, the International Standard on Auditing (ISA) 315 § A84 emphasizes the importance to understand information system and business processes [4]:

“Obtaining an understanding of the entity’s business processes, which include how transactions are originated, assists the auditor to obtain an understanding of the entity’s information system relevant to financial reporting in a manner that is appropriate to the entity’s circumstances.”

System applications have built-in controls to ensure information integrity of the related business process. Some of these programmed controls may be critical to the evaluation of internal control over financial reporting. It is therefore essential that auditors acquire sufficient knowledge of all automation technologies of business process execution to evaluate the risk exposures and internal control efficacies.

2.2 Business Process Modeling for Risk Analysis

Previous studies have investigated the importance of representation for analysis tasks. Many of these works compare external representation alternatives in an attempt to identify the most effective format for judgment and decision-making tasks [6]. Performance differences have been studied between different representations such as tables versus graphs [19,20], different text groupings [21,22], and between graphs [10, 23]. Some works postulate a superiority of using diagram for externalizing problem [7,11], while others find no clear superiority [12,24]. Notwithstanding the mixture of these studies, to the best of our knowledge, little attention has been paid on two contrasting alternatives, namely diagrams and text. Such a comparison is highly relevant as risk analysis practice works with the format that is provided by the client.

The theoretical analysis developed by Larkin and Simon [7] emphasizes that diagrams might be superior to text due to their geometrical and topological characteristics. Text representations arguably do not acquire such characteristics. These characteristics are believed to evoke computational efficiency because data structure, programs and attention management system of a production (diagram) enable users to use search, recognition and inference processes to solve problems [7]. From an empirical perspective, an experimental work was performed comparing performance differences in terms of accuracy, time, and user perception between entity relationship (ER) model and Backus-Naur-Form (BNF) language grammar [11]. In that study, ER models were found to be superior in terms of time, but no differences found for accuracy measures. Another research identifies characteristics from literature that are relevant to the situation of when a diagram appears to be superior over text format [24].

The business process modeling literature focuses on the process model as a visual representation of a process [25]. Research in audit risks and controls typically concentrate on procedural aspects such as methodology, documents, or higher-level requirement [see 26,27], while leaving information extraction less explored and open. For instance, how information is represented to facilitate user understanding on business processes receives hardly any attention.

Prior works take two approaches for understanding business processes. The first group can be labeled design-oriented. Design-oriented approaches look at notational aspects of risks and controls that should be introduced in a new, or embedded in an existing model. For instance, Carnaghan [28] compares different process models based on their capacity to represent internal controls in a process level risks assessment. She concludes that current models do not sufficiently address the representational requirements. Furthermore, ontological deficits are discussed for flowcharts and data-flow diagrams in this context [31]; extending ER diagrams with risks and controls [29]; complementing EPCs with risks models [30]; or by mapping out REA and DFD diagrams to identify internal control [18]. None of the aforementioned works draws attention to the merit of process models over text.

The second groups, labeled as behavioral-oriented, typically concentrate on the relationship between graphical notations, user characteristics and decision-making tasks. Research method that is commonly adopted for this stream is empirical work. The works included in this group are [8, 10, 11, 12, 32]. Dunn and Grabski [8] examine the effects of the format (REA vs DCA) for decision-making and found that when there is a high degree of localization, the influence of user experience is decreased. The assessment of performance across four different models in an AIS setting indicates that diagrams are best suited for process oriented tasks [10].

Among the relatively few papers in diagram versus text for risks assessment, it appears that no strong conclusion can be derived whether a diagram surpasses text in decision-making tasks. Boritz et al. [12] report that no difference was found in risk assessment based on either a business process diagrams or a narrative, while an experiment comparing conceptual models with text partially shows the superiority of diagrams over narrative [11]. Interestingly, information arranged around the business processes is proved to be more effective than arranging information cues in other category of groupings such as based on control objectives or transactional codes [21,22]. This may indicate that users might benefit from models since information

cues are easily located, thereby enabling process search, recognition and inference [7]. Again, given this mixed conclusion, the question whether business process model does have the influence on risk assessment remains open.

3 Theoretical Foundations and Hypotheses

This section discusses theoretical foundations and the research model of the work.

3.1 Theoretical Background

In the context of our research problem, at least three theoretical perspectives are relevant. The first relates to the question of comparability, which is discussed by the Theory of Equivalence of Representations [7]. When two representation alternatives are equally inferable, they are informationally equivalent. One representation (diagram) may outperform another one (textual) if it is informationally equivalent, and additionally can facilitate inference in an easier way than another representation, indicating the existence of a computational advantage [7]. A cognitive computational advantage depends upon the orchestration quality between the representation form, the mental programs, and the attention management system, in which the programs the search, recognition and inference are processed. All the three are relevant in a risk analysis setting. Search uses the attention management system to locate relevant elements in a data structure. Recognition involves matching information from the representation with the problem [11]. This is likely to be highly dependent upon representation. Inference is rather a task dependent process, in that it requires a user's domain knowledge to combine information deduced from problem tasks with relevant information stored in the user existing knowledge.

The next relevant theory in this context is Cognitive Fit Theory [15]. Cognitive fit theory states that a correspondence between tasks and information representation leads to superior task performance. Since its introduction, the theories' external validity has been supported through various empirical works involving enhancement in contexts, constructs involved, and modification. General findings consistently state that different kind of representations may or may not fit well with certain tasks [20,34,35,36]. The basic formulation of Cognitive Fit Theory describes processes which are initially operating with respect to the problem representation and to the problem-solving task, to produce the mental representation which then produces a problem solution. Cognitive fit occurs when information type emphasized in both representation and task elements match, resulting to a consistent mental representation for facilitating problem-solving process. When the information type emphasized in both representation and elements do not match, the problem solver must exert additional cognitive effort to either transform the problem representation to better match the task or transform their decision processes to better match better the problem representation, which will hinder performance [6].

The third theory, Cognitive Load Theory (CLT) defines the cognitive constraints associated with humans [9]. Humans as problem solver have a limited number of information chunks to process in their short-term memory, and "...any problem that

requires a large number of items to be stored in short-term memory may contribute to an excessive cognitive load” [16]. Following the theory, there are three sources of cognitive load: intrinsic load, extraneous load and germane load [16]. While intrinsic load is inherently attached to the task complexity (determined by the elements interactivity and the processing procedure), an unfavorable effect on learning is more attributed to extraneous load when the task and problem information presented force a learner to spend more mental efforts than what the working memory can handle. Appropriate manipulation of information representation should reduce extraneous load and instead promote the germane load, which contributes to schema construction, therefore facilitating learners learning.

3.2 Research Model

Against the theoretical background elaborated above, we develop a research model as the framework for structuring our research, and accordingly set out propositions pertinent to which representation is best to facilitate business process understanding for risk assessment. Research models operationalization set up in [9,14] is adopted and synchronized with the current study. Figure 1 shows our research model.

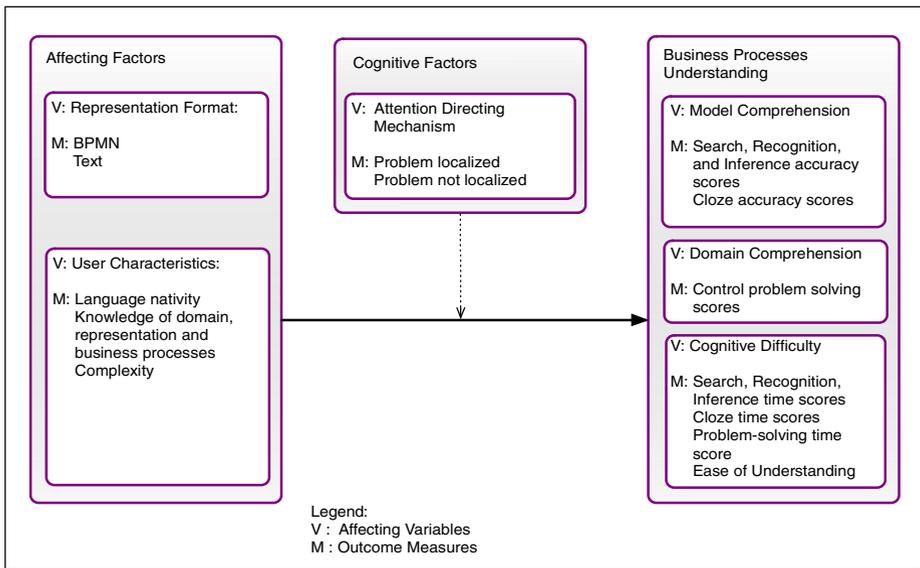


Fig. 1. Research Model

As theorized in [7], we expect that adopting diagrams would better facilitate business process understanding compared to using textual representation. The advantage appears to be observable through an examination on search, recognition and to some degrees, inference processes run by program on the available data structure supported by attention directing mechanism. Given the varied findings on BPM-narrative comparison, careful investigation of how BPM would lever risk

analysis is warranted. We aim to use the Business Process Model and Notation (BPMN) as a typical process notation [37] and text narratives as the other end. We choose BPMN as the alternative model because it is the widely accepted process modeling standard. BPMN is intended be readily understandable by business analysts, system engineers and general business people [39].

The theory of cognitive fit is then revisited to provide the rationale for setting up the necessary propositions. As suggested by the theory, when the form of problem representation matches with the problem tasks, users are expected to have a consistent mental model which further enables them to enhance performance quality. One factor that is an important element of the matching process is the capability to localize a problem in specific groupings on an internal level (cognitive). This localization is an important element of the attention directing mechanism as suggested by [7] and has been elaborated by [8] for REA-DCA tasks comparison. According to [7], diagrams may be advantageous in attention management as opposed to narratives. When one can localize a specific area in a problem representation, the process of matching with problem tasks is enhanced without cognitive load of mental transformation processes.

With this reasoning, we argue that using BPMN would enable users to direct attention better on specific areas of a problem when searching pieces of information, recognizing the relation upon the task, and ultimately inferring better conclusions for particular tasks. In accordance with our research model above, the following propositions are suggested, followed by our proposed hypotheses operationalization:

- P1: A representation that better supports the localization of risk and control problems leads to better performance.

Table 1. Effects of Process Representation Alternatives and Cognitive Fit Situation

Analysis of Effects Type of Representation		Model Understanding	Problem-Solving Understanding	Cognitive Difficulty	
		Accuracy	Accuracy	Time	Ease of Understanding
Narrative	Attention directing mechanism is weak since control issues are hard to localize: <ul style="list-style-type: none"> • Cognitive Fit does not exist. • Requires transformation. 	Lower	Lower	More	Lower
BPMN	Attention directing mechanism is strong since control issues are easy to localize: <ul style="list-style-type: none"> • Cognitive Fit exists. • Requires less transformation, if any. 	Higher	Higher	Less	Higher

Table 1 summarizes the development of the effects of alternative representations to the dimensions of business process understanding. For giving better clarity, specific naming for tasks – search, recognition, inference, cloze – is removed. Statement in proposition 1 is then translated further into the following hypotheses:

- H1a: More control issues are identified using BPMN than narrative for search tasks.
- H1b: More control issues are identified using BPMN than narrative for recognition tasks.
- H1c: More control issues are identified using BPMN than narrative for inference tasks.
- H1d: Higher scores are obtained using BPMN than narrative for cloze tests.
- H1e: Higher scores are obtained using BPMN than narrative for problem-solving tasks.

Accordingly, diagrammatic business process representation will provide users with greater computational efficiency than the equivalent text-based counterpart.

The existence of computational efficiency may also lead to a favorable decrease in efforts spent for understanding a model. This means that users might find equivalent number of risk and control cues, but one user is able to do a task relatively faster than others. According to cognitive load theory, this occurrence denotes a reduction in cognitive load, preferably the extraneous load element. The load reduction is reasonably associated with attention directing mechanism that works better to localize information stored in diagrammatic representations than narrative representations. Therefore we have:

- H1f: Users using BPMN will identify control issues when performing search tasks faster than narrative.
- H1g: Users using BPMN will identify control issues when performing recognition task faster than narrative.
- H1h: Users using BPMN will identify control issues when performing inference tasks faster than narrative.
- H1i: Users using BPMN will perform faster when performing cloze tests than narrative.
- H1j: Users using BPMN will perform faster when performing problem-solving tests than narrative.

Task performance is contingent to whether a fit is present between the knowledge emphasized in presentation format and the type of knowledge required to solve the task, hence the cognitive fit. Prior research has shown that organizing information around business process enables users to find more risk and control factors than users who used materials organized around financial statement categories [21,22]. We see that diagrammatic representations arguably have a closer fit with the risk assessment tasks that provide better attention directing mechanism than narratives, although both formats emphasize process flow. We then propose the following hypothesis:

- H1k: The presence of attention directing mechanism is positively associated with the higher control scores, higher efficacy and faster time for all tasks.

Prior accounting and information system research has demonstrated that user characteristics, and or environmental characteristics all contribute to performance [38]. Therefore, we need to take user characteristics into account as influencing factors for business process understanding. Involvement of user characteristics in the research model contributes to answer the pragmatic dimensions of the study such as user knowledge and exposure to both business process modeling and auditing. Putting user characteristics into the analysis, the following proposition is stated:

- P2: User characteristics to process representation will affect users' tasks performances.

The proposition is elaborated more into several hypotheses. First hypotheses predict the effect of the use of English as a second language. This is reasonable since the study incorporates a broad set of diverse participant nationality. [9] advises that English as a second language is one potential impediment in process understanding. By the same token, user perception might be considered as factor that slows down the understanding. The more complex a problem case, in absence of experience, would correspond to an inverse of accuracy and time:

- H2a: The use of English as a second language and perceived complexity will have a negative effect on model understanding accuracy scores.
- H2b: The use of English as a second language and perceived complexity will have a negative effect on domain understanding accuracy scores.
- H2c: The use of English as a second language and perceived complexity will have a negative effect on model understanding completion time.
- H2d: The use of English as a second language and perceived complexity will have a negative effect on domain understanding completion time.

Other potential user characteristics worth considering are knowledge of representation, knowledge of business the case presented in the experiment, and knowledge of the business processes and auditing domain. For simplification purpose, we combine these aspects as the following hypotheses:

- H2e: Higher knowledge in representation, case, and domain will be positively associated with model understanding accuracy scores.
- H2f: Higher knowledge in representation, case, and domain will be positively associated with domain understanding accuracy scores.
- H2g: Higher knowledge in representation, case, and domain will be positively associated with model understanding completion time.
- H2h: Higher knowledge in representation, case, and domain will be positively associated with domain understanding completion time.

Furthermore, different information presentation formats would also affect the perception of ease of understanding. This perception (perceived ease of understanding) indicates the cognitive load users have to bear to complete the task given to them within the specified time frame. [40] suggests using this measure to

reflect perception of ease of understanding with different term, perceived difficulty. Therefore, the following proposition is stated:

- P3: Business processes representation that can localize risks and controls problems or provide attention-directing mechanism in particular task representation is perceived to be easier than one that does not.

The corresponding hypothesis is:

- H3: Users perceive BPMN to be easier to understand than text narratives.

The derived hypotheses provide the basis for an empirical research program on studying the influence of process representation on risk analysis performance. Such a program is highly timely given the rather ad-hoc utilization of process-related documentation when analyzing risks in practice. The insights brought forward by this research program are deemed to have strong implications for risk analysis research and practice. Most notably, they might spark efforts to standardize visual representations in the accounting information systems domain.

4 Conclusion

In this paper, we have considered different representational options to support risk analysis in the context of business processes. This research is motivated by increasing risk analysis requirements and regulations, an ad-hoc usage of representations in practice, and contradicting findings on preference for a particular representation format in general research on conceptual models. We have discussed relevant theoretical foundations including information equivalence, cognitive load and cognitive fit in order to establish a research model. This research model and its theoretical foundation provide us with the basis to formulate an extensive set of hypotheses, which together form a research program to study the phenomenon.

The next stage of this work is to conduct various experiments. Careful consideration must be taken in terms of execution control and measurement control. Beside that, its cost with regards to investigation and its ease of replication are high [41]. A challenge in this context will be a balanced involvement of populations that are easy to reach like graduate business students and the group of practitioners that are difficult to reach. We aim for a web-based experiment in order to achieve a better access for the latter group.

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