An Exploratory Study of Process Modeling Practice with BPMN

Jan Recker[1], Marta Indulska[2], Michael Rosemann[1], Peter Green[2]

[1] Faculty of Information Technology
Queensland University of Technology
{j.recker, m.rosemann}@qut.edu.au

[2] UQ Business School
The University of Queensland
{m.indulska, p.green}@business.uq.edu.au

ABSTRACT

This paper is a contribution towards a theory-driven, exploratory empirical investigation of process modeling practice with the industry standard BPMN. We perform a representational analysis of BPMN using an ontological representation theory. Furthermore, we discuss a series of semi-structured interviews with BPMN adopters in order to explore the use of this technique empirically. We identify several representational issues related to the practice of modeling with BPMN, for example, the capture of business rules and the specification of process decompositions. Our study uncovers five contextual factors that impact on the use of process modeling techniques, such as tool support and modeling conventions. We discuss implications for research and practice. In particular, we highlight the need for consideration of representational issues and contextual factors in decisions relating to BPMN adoption in organizations.

Keywords: *Process Modeling, Usage Behavior, Representation Theory*

INTRODUCTION

Over recent years, chief information executives have realized the importance of information technology in 'making the difference' by changing business processes [15]. Hence, building process capabilities is of major interest to organizational decision making now and in the future. Process modeling – the act of capturing and graphically describing the processes in an organization – is an essential means in this endeavor. In fact, process modeling is widely used within organizations as a method to increase awareness and knowledge of business processes, to deconstruct organizational complexity and to aid the analysis and design of process-aware information systems [1].

In managing process modeling initiatives, the type of technique to be used for process modeling is an important consideration [30]. Generally, the decision for a particular process modeling technique is associated with related investments in tool purchases, training, conventions and methodologies. Furthermore, this decision has significant implications not only for the outcomes and success of modeling initiatives but also for the investment decisions required to establish a productive modeling environment. For instance, a large Australian bank estimated that its decision to introduce and use the ARIS approach [33] for its process modeling initiatives resulted in costs of $3.5M approximately. Similarly, Palmer [27] reports that organizations spend from $100,000 to over $5 million on investment in process modeling training and methods and similar amounts for related software acquisitions.

Nowadays, the process modeling technique of choice appears to be the recently released Business Process Modeling Notation (BPMN) [6]. BPMN was developed by an industry consortium whose constituents represent a wide range of process modeling tool vendors. They envisaged BPMN to be applicable in many areas, from process documentation and improvement scenarios to technical applications of process modeling such as workflow engineering, simulation or web service composition.

While work on BPMN commenced roughly around 2003, it was only in 2006 that BPMN was released as an Object Management Group (OMG) standard [6]. In spite of this recent release, BPMN has enjoyed significant uptake. The official BPMN web site (www.bpmn.org) already lists more than 40 vendors of process tools that support BPMN, and a fast growing number of organizations in all industries have made BPMN their process modeling technique of choice.

The adoption decisions made in respect to BPMN, however, have so far not been made on basis of a critical analysis of the actual capabilities and deficiencies of BPMN, nor by an examination of related usage patterns and behaviors. In fact, overall, very little is known about process modeling practice [1, 23]. The knowledge of representational capabilities and general process modeling practice, however, is instrumental in facilitating well-founded decisions relating to BPMN adoption in organizations, and the associated investments in appropriate tool purchases, training and methodologies.

Accordingly, the *aim of this paper* is to provide a deeper understanding of the potential and actual issues of process modeling with the emerging process modeling standard, BPMN and to explore the contextual settings in which process modeling occurs. The research presented in this paper uses a theory of representation [e.g., 39, 40, 41], in conjunction with qualitative, semi-structured interviews, to guide an empirical investigation into process modeling practice with BPMN. The three *research questions* of this paper are:

- What are the *theoretical issues of process modeling with* BPMN in light of representation theory?
- Which of these theoretically identified issues are perceived as *actual process modeling issues* by BPMN users?
- Which *contextual factors* affect the use of a process modeling technique such as BPMN?

We proceed as follows. The next section provides an introduction to process modeling with BPMN and introduces the theoretical background of our research. Section three discusses our research design before section four summarizes the outcomes of our theoretical analysis of BPMN. In section five, we discuss findings from a series of qualitative, explorative BPMN-user interviews and develop a contextualized model of process modeling technique use. The final section summarizes the contributions of this paper and discusses implications and limitations of the presented research.

II. Background & Theory

Process Modeling with BPMN

For executive decision makers to develop an informed opinion about the impact and business change of information technology, they require a deep and transparent understanding of operational and managerial processes running in their organizations. Process modeling is an approach for describing how businesses conduct their processes and operations. Process models typically include graphical depictions of at least the activities, events/states, and control flow logic that constitute a business process [10]. Additionally, process models may also include information regarding the involved data, organizational/IT resources and potentially other artifacts such as external stakeholders and performance metrics to name just a few [e.g., 33].

Process models are designed using so-called process modeling techniques (also called languages or notations), i.e., sets of graphical constructs and rules how to combine these constructs. Over time, a wide range of such process modeling techniques has been made available, and used, in organizations, covering intuitive graphical techniques such as the Event-driven Process Chain (EPC) [33] as well as more advanced techniques such as YAWL [38] that are founded on mathematical, rigorous paradigms.

Counteracting the inflation of techniques and the resulting market fragmentation, recent industry moves have seen the emergence of a *de facto* standard, BPMN, that has enjoyed significant uptake and widespread adoption in industry. BPMN was developed by an industry consortium in a standardization process that took more than four years and 140 meetings, both physical and virtual. The outcome of this development effort is a specification document [6] that differentiates BPMN into a set of core graphical elements and an extended specialized set. The core set was envisaged to suffice for depicting the essence of business processes in intuitive graphical models, while the complete set provides additional constructs to support advanced process modeling concepts such as process orchestration and choreography, workflow specification, event-based decision making and exception handling. Overall, the complete BPMN 1.0 specification defines 38 constructs plus attributes, grouped into four basic categories of elements, viz., Flow Objects, Connecting Objects, Swimlanes and Artefacts. *Flow Objects*, such as events, activities and gateways, are the most basic elements used to create BPMN models. *Connecting Objects* are used to inter-connect Flow Objects through different types of arrows. *Swimlanes* are used to group activities into separate categories for different functional capabilities or responsibilities (e.g., different roles or organizational departments). *Artefacts* may be added to a model where appropriate in order to display further related information such as processed data or other comments. Figure 1 gives the example of a BPMN model of a payment process. For further information on BPMN refer to [6].

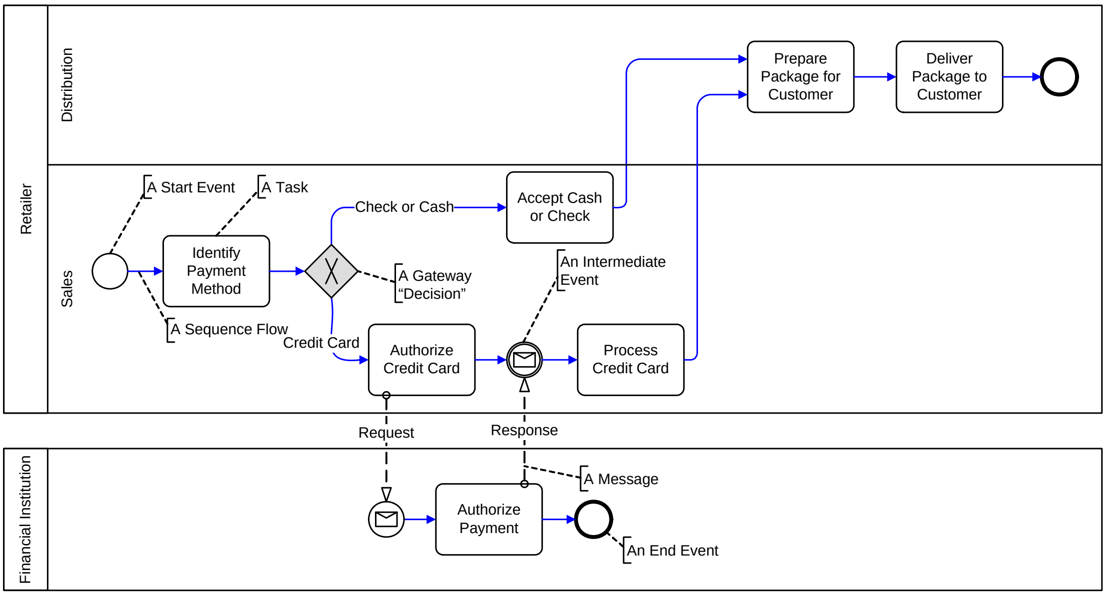

Figure 1: BPMN Example 'Payment Process'

In light of this development, both for scholars studying BPMN and for the wider community of BPM practitioners, three questions emerge that wait to be answered [47]:

1. How can BPMN be used (i.e., what is theoretically possible)?
2. How should BPMN be used (i.e., what is recommended for practice)?
3. How is BPMN being used (i.e., what do people actually do with it)?

A growing body of research has been, and is being, conducted on questions one and two. For instance, research has been published that examines BPMN's capacity to support workflow technology and domain representations [29], to facilitate semantic script analysis [13], and to provide software code generation [26] from BPMN. Likewise, training programs and online debates have emerged that discuss how to ‘best’ use BPMN. The fundamental questions of how BPMN is *actually* being used in practice, and which factors influence such usage, however, have not yet been fully examined. This question, and the potential to improve decisions on BPMN adoption and use, motivates our research.

Theoretical Foundation

The choice of the type of technique to be used for process modeling is an important investment decision [30]. Investments costs related to training, tool support, and methodologies are dependent on the selection of an appropriate technique. Also, different modeling techniques tend to emphasize diverse aspects of processes, such as activity sequencing, resource allocation, communication, or organizational responsibilities [36]. In other words, the Petri net model of a business domain looks considerably different from a data flow diagram or BPMN model of the same domain.

We are interested in establishing why this situation would be the case. In other words, our objective in this study is to investigate empirically the modeling issues associated with the capabilities and deficiencies of BPMN for process modeling. To that end, we turn to a theory of representation [39, 40, 41] to facilitate an examination of this particular process modeling technique.

Representation theory is based on the observation that models of business domains and information systems are essentially models of real-world systems. Real-world systems, in turn, can be explained and described using ontology – the study of the nature of the world and what exists in reality - in terms of the properties of, the structure of, and the interactions between, real-world things [7, pp. 3-6]. Hence, Wand and Weber [39, 40, 41] developed a theory of representation theory from the adaptation of an ontology proposed by Bunge [7]. This theory suggests a model of representation, known as the Bunge-Wand-Weber (BWW) representation model [39, 40, 41], as a benchmark for the evaluation of the representational capabilities of modeling techniques. In this paper we employ this model and the associated principles of representational analysis [e.g., 32] as a theoretical basis to guide our empirical investigation of process modeling practice with BPMN.

The BWW representation model specifies a set of constructs that is deemed necessary to provide faithful representations of Information Systems, including their properties and interactions, and which therefore should be included in any conceptual modeling technique (refer to [43] for a detailed description).

The process of using the BWW representation model as a reference benchmark for the evaluation of the representational capabilities of a modeling technique forms the core of the method of *representational analysis* [e.g., 32]. Representational analysis can be used to make predictions on the modeling strengths and weaknesses of a modeling technique, viz., its capabilities to provide *complete* and *clear* descriptions of the domain being modeled. In this process, the constructs of the BWW representation model (e.g., thing, event, transformation) are compared with the graphical constructs of the modeling technique (e.g., event, activity, actor) in a bi-directional mapping. The basic assumption is that any deviation from a 1-1 relationship between the corresponding constructs in the representation model and the modeling technique leads to representational deficiency in the use of the technique, which potentially causes confusion to its users. These undesirable situations can be further categorized into four sub-types (see Figure 2), resulting in two main evaluation criteria that may be studied according to the BWW model [43]: *ontological completeness* and *ontological clarity*. Ontological completeness indicates whether users of a modeling technique are able to articulate all relevant real-world aspects they want to have represented in a model. Ontological completeness is measured by the degree of construct deficit (a 1:0 mapping relationship), i.e., the extent to which a process modeling technique covers completely the constructs proposed in the BWW representation model. On the other hand, ontological clarity indicates how unambiguously users can articulate relevant real-world aspects in a model, i.e., how much effort is required to model. Ontological clarity is constituted by the degrees of construct overload (a m:1 mapping relationship), being the extent to which single technique constructs cover several BWW constructs, construct redundancy (a 1:m mapping relationship), i.e., the extent to which a single BWW construct maps to several technique constructs, and construct excess (a 0:1 mapping relationship), being the extent of technique constructs that do not map to any BWW construct.

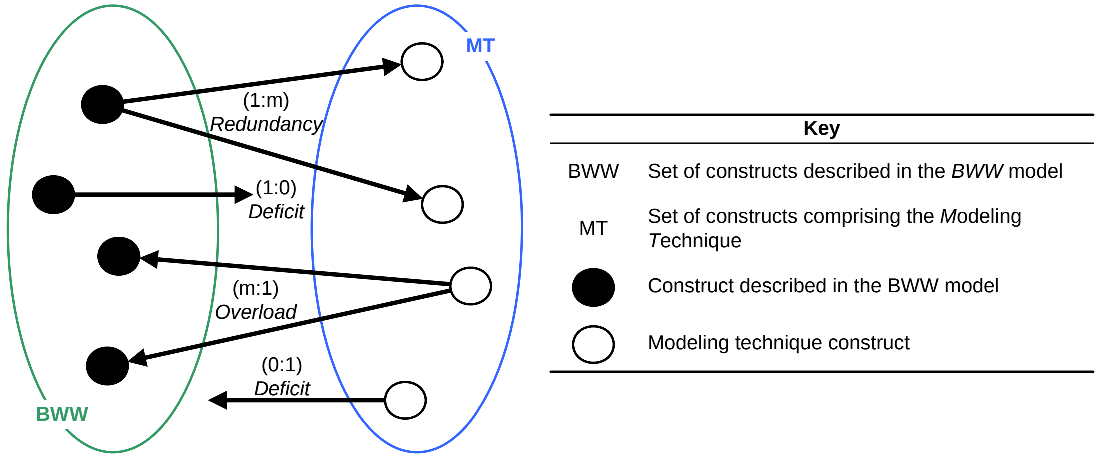

Figure 2: Types of potential representational deficit and non-clarity

Over the last fifteen years, the BWW model has reached a significant level of maturity, adoption and dissemination, and has been used in a wide range of research projects to evaluate different modeling techniques. The evaluated techniques cover a wide spectrum of modeling areas including data, schema, object-oriented, business, and reference modeling. An overview is provided in [20]. The model also has a growing track record in the area of process modeling, with contributions coming from various researchers [18, 21, 28, 37].

Some criticism has been leveled over the years at the use of the BWW representation model, *viz.*, limited empirical testing [45] and a lack of understandability of the BWW constructs [31]. The work to date has attempted to mitigate these criticisms. For instance, a number of authors have undertaken empirical tests of the "validity" of the predictions stemming from representation theory [e.g., 3, 4, 8, 16, 19, 35]. These studies found that the premises offered by representation theory indeed inform researchers about conceptual modeling activities, outcomes and success. Likewise, efforts were undertaken to provide procedural guidelines for the application of the theory [32], which we followed in our investigation.

III. Research Design

Before we provide an overview of the outcomes of our representation theory-based evaluation of BPMN, it is necessary to appreciate the overall research model that underlies our study.

The first stage of our study is to perform a representation mapping of technique constructs specified in the BPMN technique against the set of essential representation constructs specified in the BWW representation model. In stage two, based on the final mapping, propositions can be derived that suggest implications when BPMN users attempt to model real-world scenarios. From the derivation of the (theoretical) propositions, stage 4 involves the design and conduct of an empirical study to evaluate the proposed implications (stage three) and to explore contextual influences in the settings in which BPMN is being put to use by practitioners. Section IV discusses this theoretical analysis. Empirically evaluating the theoretically identified representational issues requires access to sources of evidence. Given that our research objective is to *explore* the use of BPMN in process modeling practice, we deemed qualitative, semi-structured interviews an appropriate empirical research method. Section V evaluates and discusses the design, conduct and results of these interviews.

IV. Theoretical Analysis

Representation Mapping

To follow a rigorous approach towards the bi-directional mapping of BPMN constructs to BWW constructs, we followed an extended methodology that allows to maximize the objectivity and internal validity of such work [32]. Specifically, our analysis was conducted in three steps. First, two of the authors separately read the BPMN specification and mapped the BPMN constructs against BWW constructs in order to create individual first analysis drafts. Second, the researchers met to discuss and defend their mapping results. Third, the jointly agreed second draft was discussed and refined in several meetings with all four authors. By reaching a consensus at the end of this entire process, we achieved maximal objectivity and rigor in this type of research.

In order to display inter-judge reliability in the mappings, a raw percentage agreement [24] and Cohen's Kappa [9] were used to measure the agreement between the mapping researchers. Raw percentage agreement for the representation mapping of BPMN was calculated to be 69 percent in the first round and 87 percent in the second round while a Cohen's Kappa statistic was calculated to be .616 in the first round and .832 in the second round. Both measures exceed generally recommended

Kappa levels of .6 [24]. In the third round, the mapping was discussed and refined until a 100 percent agreement across the complete research team was obtained.

Table 1 summarizes the outcomes of the final agreed mapping and also displays a brief reasoning behind the mappings of BWW constructs to/from BPMN constructs. Stemming from this analysis, the discussion of the proposed representational implications for BPMN is presented in the following section.

Table 1. BPMN representation mapping results

BWW Construct	BPMN Construct	Reasoning behind mapping
THING	Lane, Pool	Both a Pool and a Lane can represent specific participants (organizational units or persons) in a BPD.
PROPERTY		
IN GENERAL	Attributes of Pools, Attributes of Lanes	Both the Pool and the Lane construct in BPMN have Attributes that capture the properties in general of the thing they represent. An example of this is the Name of a Lane (which can, for instance, be instantiated with the name of a stakeholder involved in a business process), the parent organizational structure in which the stakeholder works (parentPool) or the name of the super-ordinate organizational entity (Participant). The Attributes concept provided in BPMN, however, must be instantiated for every Pool and Lane in a BPD.
IN PARTICULAR	N/A	
HEREDITARY	N/A	
EMERGENT	N/A	
INTRINSIC	N/A	
MUTUAL: NON-BINDING	N/A	
MUTUAL: BINDING	N/A	
ATTRIBUTES	N/A	
CLASS	Lane, Data Object	A Data Object represents a document that is used as input or created as output during the course of a process. This can be an invoice, for example. However, the Data Object does not represent a specific object or thing but rather a type of document that can be instantiated in a specific instance of a process (e.g., invoice no. 4711). The BPMN construct Lane can be nested, in which case Lanes share a common property (i.e., parentLane). When used in this manner, a Lane can be used to represent a group (i.e., class) of things such as departments or people (e.g., managers).
KIND	Lane	A Lane can be nested within another Lane that, as per definition, belongs to a Pool. Such a Lane would then have two properties common to other Lanes (i.e., parentLane and parentPool), which in turn makes it a kind of a thing, i.e., a specific sub-type of the concept Lane.
STATE	N/A	
CONCEIVABLE STATE SPACE	N/A	
STATE LAW	N/A	

BWW Construct	BPMN Construct	Reasoning behind mapping
LAWFUL STATE SPACE	N/A	
EVENT	Start Event, Intermediate Event, End Event Message, Timer, Error, Cancel, Compensation, Terminate	The BPMN constructs Start Event, Intermediate Event and End Event allow for the modeling of certain triggers for a certain action to follow in a BPD. A Message can either be a start or an end message. In both cases this denotes a concept that evokes a transition between states of a thing. For instance, an arriving message could cause a process to cancel. Similarly, a message detailing a change request would lead to a change in an invoice document. A Timer is an event that, at a given point of time, triggers a certain action (such as, for instance, sending a follow-up note to a customer or canceling an order due to missing payment). Likewise, an Error is an event that may arise and that requires a particular action to be taken (namely, to cancel a process and to perform a rollback of related transactions if necessary). Cancel, Compensation and Terminate are all considered events that can arise in a thing given a particular action of a thing (here, a cancel request, a termination request, or a compensation request for a particular process scenario).
CONCEIVABLE EVENT SPACE	N/A	
LAWFUL EVENT SPACE	N/A	
TRANSFORMATION	Activity, Task, Collapsed Sub-Process, Expanded Sub-Process, Nested Sub-Process, Transaction	Each of Activity, Task, Transaction, Collapsed Sub-Process, Expanded Sub-Process, Nested Sub-Process are constructs that allow for the representation of a mapping of a thing from one state to another. For instance a refund sub-process will take a thing (e.g., a person) from one state to another (e.g., from a state of being poor to a state of being wealthy). An Activity is the same as a Task, both are concepts used to express how to perform certain action that lead to state changes (e.g., the task "approve credit card application" leads to changes in the status of the application, such as, for instance, from "in progress" to "rejected".) A Transaction is simply a special type of activity as it specifies those actions that are controlled through a transaction protocol (such as BTP or WS-transaction).
LAWFUL TRANSFORMATION	Default Flow, Uncontrolled Flow, Exception Flow	The BPMN constructs Default Flow, Uncontrolled Flow and Exception Flow are directed arcs that show the order of activities that will be performed in a process. They explicitly dictate what task is allowed after a certain action has occurred. They specify the legal order of tasks that can be performed at any given point and in turn the events that are lawful to occur subsequent to a given action in a process.
STABILITY CONDITION	Rule Conditional flow	The BPMN constructs Rule and Conditional Flow both embody the specification of a transformation by means of a condition expression that is to be evaluated. A Rule is basically an expression that evaluates some process data at runtime to determine whether a Sequence Flow is being activated or not. A Conditional Flow is basically a Sequence Flow with an extra condition expression that is evaluated at runtime to determine whether or not the flow will be used.
CORRECTIVE ACTION	'exception task', compensation activity	The 'Exception Task' in BPMN is a task that is linked to the Exception Flow mechanism and specifies what to do when the Exception Flow is triggered. Both this Exception Task and the Compensation Activity construct in BPMN

BWW Construct	BPMN Construct	Reasoning behind mapping
		represent types of lawful transformation and express behavior linked to a certain execution condition.
HISTORY	N/A	
ACTS ON	Message Flow	The Message Flow construct in BPMN depicts the interactions between participants of a process and indicates the direction of the interaction (e.g., from a supplier to a vendor).
COUPLING	Message Flow	The Message Flow construct in BPMN further contains association attributes connecting source and target object in a relationship. Thereby, it affords the representation of Coupling.
SYSTEM	Pool, Lane	The BPMN construct Pool describes different participants and their processes within a given process. A Lane may be nested or defined in a matrix. In these cases the Lane construct represent a set of things between which couplings exist.
SYSTEM COMPOSITION	Pool, Lane	A Pool is composed of Lanes that define all participants within a Pool, which corresponds to defining all things within a system. As a Lane may be nested it may further have things in its own composition.
SYSTEM ENVIRONMENT	Pool, Lane	Within one BPD, it is possible to make use of several Pools (e.g., to model business-to-business interactions). Within such a BPD, a Pool outside of another Pool would depict the things not in the system of the other Pool. Along similar lines, different nested Lanes within a Pool or Lane can represent different sets of process participants (e.g., different departments), so one Lane would mark the environment of the other Lane or of another Pool.
SYSTEM STRUCTURE	N/A	
SUBSYSTEM	Pool, Lane	Given that multiple Pools and Lanes are allowed in a BPD, each Pool that represents a process partner or participant (e.g., one of several organizations participating in an inter-organizational process scenario) in a multi-pool BPD is in its essence a subsystem of the super-ordinate system represented by the BPD. A Lane is by definition a subset of a parent Pool.
SYSTEM DECOMPOSITION	Pool, Lane	A Pool in a multi-pool BPD defines a system within an (inter-organizational) system, thereby graphically articulating the decomposition of the system. The same holds by definition for Lanes used in Pools.
LEVEL STRUCTURE	Pool, Lane	Different Pools in a BPD define the sub-structure of an inter-organizational process and allow for differentiation between the hierarchy of these participants (for instance, by using a black box versus a white box approach). Lanes can be nested, which in turn allows for the explicit graphical specification of the hierarchical structure of the systems expressed by the Lanes.
STABLE STATE	N/A	
UNSTABLE STATE	N/A	
EXTERNAL EVENT	Start Event, Intermediate Event, End Event, Message, Timer, Error, Cancel, Compensation	All of the Event subtypes (Start, Intermediate, End) can be external or internal, depending on the context of their use. A Message, for instance, may be an environmental component when sent by a customer outside the considered system (i.e., the process) or internal when sent from another process participant contained in the process description. Along similar lines, an Error, Cancel or Compensation event may arise due action external to the considered process or internal to the process (e.g., a compensation or cancel
INTERNAL EVENT	Start Event, Intermediate Event, End Event,	

BWW Construct	BPMN Construct	Reasoning behind mapping
	Message, Error, Cancel, Compensation, Terminate	request from the customer on the one hand and from an internal department or process stakeholder within the organization on the other hand). A Timer is an external event as it denotes a concept to visualize how a change of state is incurred due to virtue of time (which, per definition, is a concept external to all systems). A Terminate event, on the other hand, is a form of internal event as it denotes a visualization concept to demarcate how a process can be stopped (without consideration of consequences) by virtue of action of internal stakeholders (e.g., process owners or process managers) but not by environmental components or stakeholders.
WELL-DEFINED EVENT	Compensation, End Event	In BPMN, the Compensation construct (in connection with a Compensation Association) is used to indicate that compensation is necessary. It triggers a defined sub-process with a specified transformation leading to a certain defined state (i.e., it specifies exactly how transaction that occurred during the course of a process have to be roll-backed in order to arrive at the state of the process prior to enactment of the transaction that have been requested to be compensated). Similarly, an End Event is an indication of the completion of a process. As such, it marks a point where the state of a thing is changed to its final state. Hence, the state of any thing after the occurrence of this event can always be predicted (simply because it remains unchanged within this particular process).
POORLY-DEFINED EVENT	Message, Timer, Error, Cancel, Terminate, Start Event, Intermediate Event	A (part of a) process that relies on a Message to arrive cannot be predicted in its behavior due to the uncertainty of the actual content of the message. For instance, it is impossible to predict whether a customer note details a request to cancel a purchase order or to add another item to the order. The same holds in principle for the uncertainty of occurrence of an Error, Cancel or Terminate. In all of those cases the definition of the subsequent state is indeterminate as it is impossible to uniquely ascertain the occurrence of these types of event. Start Event and Intermediate Event are in their essence event subtypes that may resemble any specific event. Thereby, they are per definition poorly-defined as subsequent transformations and states cannot be predicted due to lack of information.
ONTOLOGICAL EXCESS	Link, Off-Page Connector, Gateway Types, Association Flow, Text Annotation, Group, Activity Looping, Multiple Instances, Normal Flow, Event (super type), Gateway (super type)	The Link and Off-Page Connector constructs in BPMN are graphical mechanisms for connecting processes that cross the boundaries of one or several documents. At most, they specify details required for implementing processes in workflow settings. Yet, they do not bear any representational meaning. The constructs Association Flow, Text Annotation and Group are mechanisms to further annotate any object in a BPD with additional information. Activity Looping and Multiple Instances are graphical representations that depict a composed series of transformations but not a transformation as such. The BPMN Gateway sub types are merely graphical elements. All required conditions as to the branching and merging of processes have to be specified in the following Sequence Flows but not in the Gateway itself. Normal Flow, Event (super type), and Gateway (super type) are classes of constructs that are in the specification subdivided into different modeling constructs with specific

BWW Construct	BPMN Construct	Reasoning behind mapping
		semantics and therefore do not have specific significance in a process model as they are not supposed to be used.

Proposition Building

Based on the representation theory analysis of BPMN, nine propositions were derived to investigate the implications of the lack of ontological completeness and clarity for the use of the technique. To establish rigor, validity and reliability of our research, we followed a procedure similar to the one proposed in representational analysis [e.g., 32].

The first three propositions (P1-P3) stem from the notion of construct deficit. That is, the lack of a mapping of a BWW construct to a BPMN construct indicates the lack of means for users to describe particular real-world phenomena. Such a situation drives users to modify existing constructs, employ new constructs, or adopt constructs from other modeling techniques to compensate for the deficit. From the perspective of construct redundancy (P4-P6), we identify examples of BWW constructs to which more than one BPMN construct is mapped. Such cases are undesirable as they lead to confusion as to which real-world concept can best be represented by a particular language construct. From the perspective of construct excess (P7), we identified the BPMN constructs that appear to have no real-world meaning as per the BWW model. Accordingly, users will get confused when using these constructs and, hence, they will need mechanisms for further clarification.

From the perspective of construct overload (P8-P9), we can identify examples of BPMN constructs to which more than one BWW construct has been mapped. Such cases require the user to bring to bear extra-model knowledge in order to understand the capacity in which a given construct is used in a particular scenario. The propositions are summarized in Table 2.

Table 2. Propositions derived from the representational analysis of BPMN

No	Proposition and Rationale
Construct deficit	
P1	There is no BPMN representation for *state*, *stable state*, *unstable state*, *conceivable state space*, *state law*, *lawful state space*, *conceivable event space*, and *lawful event space*. Due to the lack of support for state-based concepts, **BPMN users will lack means for the specification of business rules in process models.**
P2	The lack of BPMN representation for *history* can cause significant problems related to recovery and reliability of interacting entities, such as inter-organizational systems. Accordingly, **BPMN users will lack means for the specification of a log of state changes in process models.**
P3	Because there is no representation for *system structure*, there is no thorough demarcation of the

	process system and the objects within. Accordingly, **BPMN users will lack means for the specification of the process structure and decomposition in process models.**
Construct redundancy	
P4	The BPMN Pool and Lane constructs share a capacity to represent a *thing*. Accordingly, **BPMN users will have difficulty understanding which of these constructs to use for modeling process-related objects in process models.**
P5	A *transformation* can be represented by the BPMN constructs Activity, Task, Collapsed Sub-Process, Expanded Sub-Process, Nested Sub-Process, and Transaction. Accordingly, **BPMN users will have difficulty understanding which of these constructs to use for the graphical articulation of transformations in process models.**
P6	An *event* can be represented by nine BPMN constructs, *viz.*, Start Event, Intermediate Event, End Event, Message, Timer, Error, Cancel, Compensation, and Terminate. Accordingly, **BPMN users will have difficulty understanding which of these construct to use for the graphical articulation of events in process models.**
Construct excess	
P7	The BPMN constructs Link, Off-Page-Connector, Association Flow, Text Annotation, Group, Activity Looping, Multiple Instances, Normal Flow, Event (super type), and Gateway (including all Gateway Types) carry no real-world meaning. Accordingly, **BPMN users will have difficulty specifying exactly the meaning and purpose of these constructs in a process model.**
Construct overload	
P8	The BPMN construct Lane maps to the BWW constructs *thing*, *class*, *kind*, *system*, *subsystem*, *system composition*, *system environment*, *system decomposition*, and *level structure*. Accordingly, **BPMN users will have difficulty specifying exactly which real-world phenomenon is being graphically articulated by the Lane construct in a process model.**
P9	The BPMN construct Pool maps to the BWW constructs *thing*, *system*, *subsystem*, *system composition*, *system environment*, *system decomposition*, and *level structure*. Accordingly, **BPMN users will have difficulty specifying exactly which real-world phenomenon is being graphically articulated by the Pool construct in a process model.**

V. Empirical Analysis

Research Rationale and Interview Design

Representational analyses can suggest whether one modeling technique is more clear or expressive than another technique. However, a representational disadvantage does not necessarily imply a practically observable disadvantage or issue [16]. In particular, it is not clear that conclusions derived from a representational analysis accurately reflect the way that people employ the technique under observation in real-life modeling scenarios. Rather, analysis of how people employ and use process modeling techniques in real-life modeling scenarios requires empirical investigations.

In designing our empirical study, we sought not to restrict ourselves to *measuring* purely the theorized shortcomings of BPMN but rather to be able to *explore* the context in which certain representational deficiencies may or may not occur and why that would be so. We deemed semi-structured in-depth interviews [2] to be the most appropriate empirical research strategy, mainly because they allowed us to carry out research in an area in which few previous studies exist and to examine our phenomenon of interest from the user perspective [25]. Semi-structured interviews are predominantly of qualitative nature and guidelines for their design and conduct have been described extensively in the literature [e.g., 22, 25]. Semi-structured interviews in the context of representational analysis have briefly been introduced in [19]. These guidelines have in this study been followed and extended.

In terms of reliability and validity of our empirical study, we followed the guidelines of Yin [46] for qualitative research. To build construct validity into the research model, we maintained an evidence database to provide opportunities to reconstruct data collection and analysis procedures. As generally recommended [14], validity of the evaluation findings was ensured by using a two-person research team with pre-defined interviewing roles (interview moderator and note taker) to strengthen the validity of the findings and results drawn from the interviews.

A semi-structured interview protocol was developed to strengthen the reliability of the data gathered. The process of designing the protocol encouraged us to consider both what is being measured and the most appropriate means of measuring it. All interviews were conducted with the use of the protocol and were also recorded and transcribed. The transcriptions were analyzed using a thematic coding process [5]. Thematic analysis attempts to uncover a range of concepts or themes within textual or verbal communications or statements, and to quantify and analyze the presence or strengths of these concepts. In our study, this approach is helpful to uncover issues in the use of the BPMN modeling technique and to relate these back to our theoretical propositions. To that end, the interview transcriptions were cross-referenced and examined using a data analysis tool.

External validity was strengthened with the use of replication logic. In this research, we used the BWW representation theory and the propositions drawn from our theoretical analysis to build a semi-structured interview protocol to guide our empirical study across all interview settings. The protocol was developed on the basis of the nine propositions introduced in the previous section (a copy of the interview protocol is available from the authors on request). The protocol consists of two main sections – a section that collects demographic information (Section A) and a section composed of questions related to the propositions (Section B).

To guide our empirical investigation following our theoretical analysis, we developed classification schemes to consistently and comprehensively classify participant responses to Section B questions.

This work is based on, and further extends, protocols that were previously used by Green and Rosemann [19] and Davies et al. [11]. One classification scheme each for construct deficit, redundancy, excess and overload, was developed for this study (see Figure 3). Our pilot tests, as well as prior work using initial versions of the classification scheme [e.g., 11], showed these classifications to be appropriate.

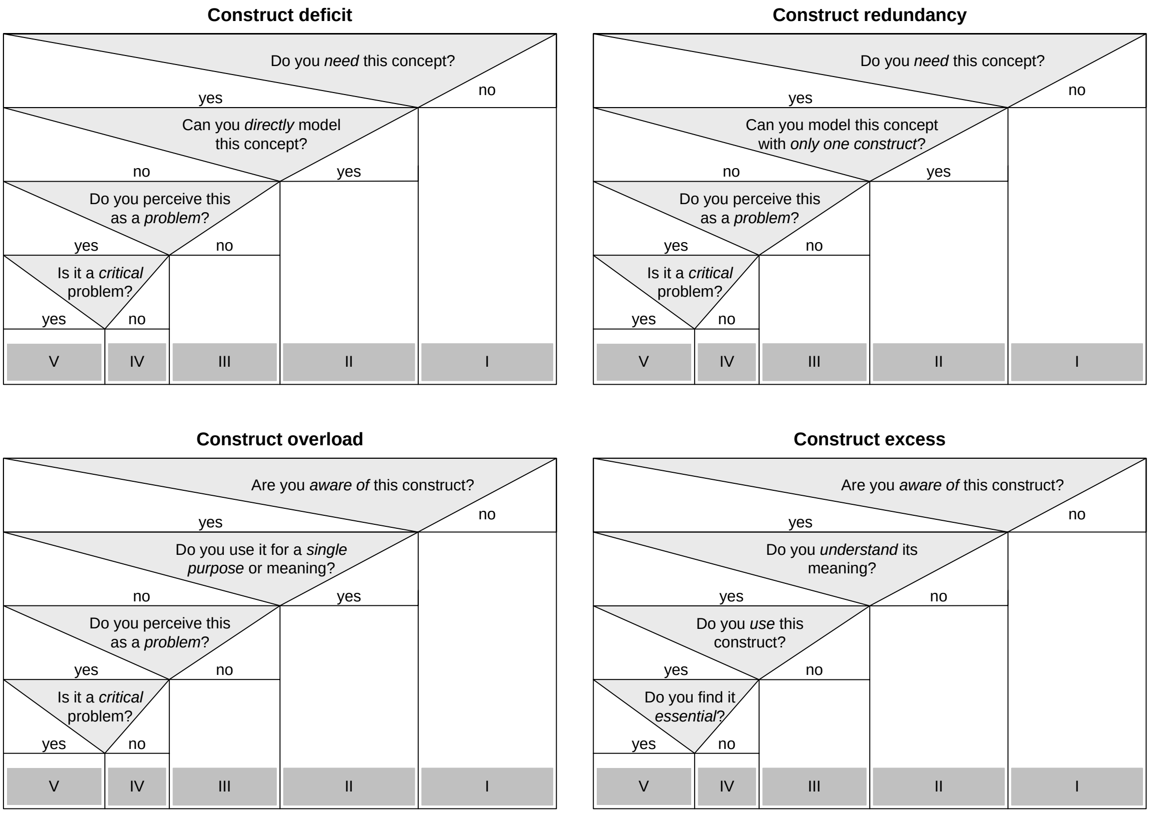

Figure 3. Response classification schemes

As an example, we consider the construct deficit classification scheme (see Figure 3). Under this scheme, the first question asked of the participant is that of need for a particular modeling concept, e.g., "have you ever had the need to graphically represent business rules?" If the response is negative, it is classified as a type I response. If the answer is positive, a further question regarding the ability to model directly the concept is asked, e.g., "can you explicitly graphically represent business rules using BPMN constructs?" This response can be classified as a type II response if the participant can directly model the concept in question. Otherwise, they are asked to indicate if they perceive this inability to be a problem. If not, then a type III response is recorded, otherwise a type IV or V response is recorded, depending on the criticality of the problem. Type V responses can be seen as the strongest form of support for a proposition.

We perused the four classification schemes to direct our interview strategy and to code appropriately the different responses received. The coding, in turn, assisted in our qualitative examination by adding quantified information to our response analysis.

Interview Results and Discussion

In our study, six Australian-based organizations across four Australian states participated as research cases, and a total of nineteen practitioners of these six organizations, incorporating various roles in their respective business environments, (*e.g.*, business analyst, technical analyst, modeling team leader), were interviewed. The case sites visited varied in organizational size, with one organization employing less than 1,000 employees, two organizations employing between 1,000 and 5,000 employees, and the remaining three organizations employing more than 5,000. The participants within these organizations ranged in terms of the type of training they received in BPMN, with 31% having accomplished a formal training course on BPMN, 15% having embarked on an organization-internal course and the remaining 54% having learned BPMN on the job and by reading the specification themselves, respectively.

In discussing the findings from the interviews, we follow the four types of representational deficiency suggested by Weber [43] and complement these with a discussion of contextual factors and themes that emerged during our data analysis. The next subsections present the findings from our thematic analysis of the responses.

Dealing with Representational Deficit

Proposition P1 has apparent support based on the participants' comments. Questioning about the need for modeling business rules uncovered that 63 percent of participants (12 responses out of 19) had a need for representing business rules in their process models. Some of the reasons given by the remaining seven participants were that their process models are intended for representatives from the lines of business who may not have the experience to read more complicated diagrams, and that the organization wanted to start with simpler diagrams in order to facilitate process understanding. Of the twelve participants that had a need for business rule specification, 75 percent (9 responses out of 12) stated they could not directly model business rules in BPMN. This finding represents 33 percent of participants (4 responses out of 12) who found workarounds and therefore do not consider this aspect to be a modeling issue, and 42 percent of participants (5 responses out of 12) who consider the inability to directly integrate business rules into a process description to be a problem. While BPMN was not intended to support formal rule specification, some comments indicated that having an explicit representation would indeed be preferable:

> *"[…] A symbol that says something specifically is a business rule so that you know in future to look at it, mightn't be bad."* (interview transcription data)

This situation suggests that users have trouble identifying the interface between process modeling and business rule modeling techniques, and expect better support in the identification of appropriate interfaces between process logic and business rule logic in a process model. Some of the workarounds used when integration of business rules is not supported (as with BPMN) included narrative descriptions of rules and conditions, using spreadsheets and external tables, and using additional tools that allow users to create hyperlinks to documents, meta-tags and attribute fields. Our evidence, however, suggests that these workarounds are deemed problematic in practice due to the representational separation of the modeled rules and the process model they are of relevance to. Indeed, users perceive a need for representational support in process modeling techniques to assist in the identification and specification of interfaces between process models and the business rules that govern the execution of these processes.

Regarding proposition P2, 37 percent of participants (7 responses out of 19) have a need to model the history of state changes. Some of the remaining respondents indicated that there is a need for such modeling but that it has not yet been done in their organization or that they have not yet figured out how to do this task. Another suggested reason for not requiring such direct modeling was the fact that, in this particular organization, process models were predominantly used to convey and communicate business procedures, and history of state changes would be a logical software design state:

"[…] business process modelling is the way I look, see what the business does. Change of state is when you start looking at your data changing and not with your processes, and your entry life cycle, so it's analysing what the business does." (interview transcription data)

Of the seven participants that indicated a need for modeling the history of state changes, over 71 percent (5 responses out of 7) indicated that while they had no way of modeling this construct directly, it did not prove to be a problem. Some workarounds involved simply having multiple activities on the diagram with names that implied state changes of things.

Representing the structure of process systems was expected to be one of the weaknesses of BPMN. Proposition P3 was found to have apparent support. Of the nineteen responses, 89 percent (17 responses out of 19) indicated a need for capturing the process structure and decomposition explicitly in a model. Of these, seventeen participants, 29 percent (5 responses out of 17), indicated that they model process system structures with BPMN directly with the use of pools, lanes, and start/end events while 71 percent (12 responses out of 17) indicated that they lacked direct modeling capabilities in BPMN and had to rely on free form texts, links implemented in the tool to other diagrams (such as IDEF0 models) and further hyperlink functionality provided. Three participants classified the lack of direct modeling capabilities as a minor problem, with another three participants classifying it as a major problem, in fact, a major deficiency. Others indicated that the need for a more explicit graphical representation for process structure and decomposition should indeed be on the agenda for a revision of BPMN:

„[…] I think if the standard allows for a large amount of decomposition, my understanding is that it doesn't at the moment, but if, the people see it as that's the way they want to use it, we definitely need something to link the two […]. Because it's designed the way it is, we're not supposed to use it that much, but I know some people have that need." (interview transcription data)

Dealing with Representational Redundancy

Regarding the modeling of process-related objects (proposition P4), results indicated that 21 percent of participants (4 responses out of 19) had no limitations in modeling objects with BPMN. These users predominantly used either Pools or Lanes, as predicted by representation theory. However, over 35% of participants (7 responses out of 19) indicated that they encountered problems when trying to directly model such objects with BPMN. Of these seven respondents, 71 percent (5 responses out of 7) indicated that this situation was not a problem, mainly due to the use of tools or textual annotation:

> *„[…] no, I don't think it's a problem, it does work. I mean, I'm fairly visually oriented but you know, I would have a problem with other people if I said well, yeah you know, if you have, you know use this sort of rectangle represents this, this and this, [inaudible] outline of rectangle represents another unit, that might be accepted."* (interview transcription data)

Some of the more experienced participants who indicated the issue not to be a problem admitted that it would indeed be a problem if they did not have additional tools into which BPMN was incorporated in their organization, i.e., if they were using BPMN in isolation.

Proposition P5 concerned redundancy in the modeling of state transformations. Unlike this proposition, our results indicate that over 94 percent of participants (18 responses out of 19) indicated their ability to directly model transformations with no confusion. Only one participant indicated a problem and he/she classified it as a major problem. It is interesting to note that some of the respondents even used additional workarounds (such as color-coding of activity symbols) to allow a more refined differentiation of transformations, e.g., between automated and manual tasks. Also, methodologies and guidelines for process modeling were in place and they included templates that reduced any confusion over which BPMN construct to use in which scenarios. One would expect that without these additions confusions over BPMN redundancy would manifest itself more severely, as indicated by one respondent:

> *„[…] well we just use a main one, activity. Certainly naming, naming is one of our horrible, horrible challenges. We just try and make them short enough but meaningful enough and what level of detail you put in the name or what level do you attach to documentation, so that's*

> *something. […] everything, every naming of our processes we've got a formal naming convention that we have."* (interview transcription data)

A similar situation was found regarding the redundancy of event types in BPMN, with 74 percent of the interviewees (14 responses out of 19) stating that they did not experience any limitations in using BPMN for the modeling of events. In fact, some interviewees stated that the event specializations provided in the specification comprehensively and rigorously allow for the depiction of different events that may impact business operations:

> *"[…] and that's where BPMN is really good, you know, all the options you can think of, no one's said, we could really need another type. You know, you've got the timer event and then you've got a message arriving, all sorts of things."* (interview transcription data)

However, out of the 26 percent of responses (5 responses out of 19) indicating that they encounter limitations in capturing events, 80 percent (4 responses out of 5) categorized this limitation as a problem (minor or major). Our empirical data furthermore suggests that modelers using the core BPMN set (that does not contain event specializations) encounter more difficulty in capturing business events. Only 50 percent of the six core set users (3 responses out of 6) stated that they have no limitations in modeling events, and 67 percent out of the remaining core set users (2 responses out of 3) classified this issue as a (minor) problem. This finding is contradictory to our theoretical proposition, which predicts that confusion would arise when using the full specification set. Core set users often responded that the limited set of constructs is not explicit enough and needs to be extended to capture comprehensively different events. Other interviewees stated that the usage of the core set forced them to complement their BPMN diagrams with additional documents further refining the events sketched in the model. While this situation was not perceived to be a major problem due to this workaround, responses nevertheless indicated that the event specializations in BPMN are perceived as a helpful feature. This finding suggests that the different event sub-types provided in BPMN assist modelers in articulating 'how' events are being undertaken in business domains, rather than providing additional real-world information.

Dealing with Representational Excess

We predicted in proposition P7 that users would avoid some BPMN constructs in order to limit confusion over their meaning when interpreting the model. For this proposition, we found varying levels of support, ranging from apparent support for two constructs, to limited support for four constructs and not apparent support for six constructs. The constructs Off-page connector, Group, and Multiple Instances were classified by over 50 percent of interviewees as being ‘not in use’ (63 percent, 58 percent, 63 percent, respectively). Some other proposed excess constructs, however, were rated as essential for process modeling activities. Examples include the constructs Normal flow, Event and Link. The responses indicate that while some constructs (such as Link) may have no real-world semantics, they are nonetheless perceived as important for process modeling as they allow for better demarcation and linking of large-scale process models. The same case holds, for instance, for Text Annotation and Association Flow. From a representational viewpoint, such constructs may be regarded as ‘support constructs’ that may be helpful for the act of modeling but have no real-world meaning per se. However, in modeling practice, they seem to be very useful for complementing the graphical models with extra information, for instance additional textual descriptions that help inexperienced model readers to better understand the process specifications:

> *„[…] I think they’re useful. They are essential, you need some form of clarification. Maybe not in future when everyone’s used to these maps, but at the moment it’s very limited.”* (interview transcription data)

As expected, support constructs such as Text Annotations were more often perceived as essential by the practitioners that used the core BPMN set only (67 percent) than amongst extended set users (46 percent). In these cases, Text Annotations provide the benefit of adding process details to a model without having an explicit graphical representation.

Dealing with Representational Overload

The interview responses clearly indicate ambiguities in the specification of the BPMN Lane and Pool constructs. This situation indicates apparent support for propositions P8 and P9. Of all respondents, only 5 percent (1 response out of 19) and 26 percent (5 responses out of 19) of the interviewees stated they do not use the Lane and the Pool construct respectively. This situation was mostly because in these cases the organizational boundaries of a process were self-evident and need not be captured in a model. Conversely, 56 percent and 64 percent of the responses, respectively, used the Pool and Lane constructs for two or more distinct purposes or meanings, with 29 percent of the interviewees (4 responses out of 14) using the Pool construct even for three distinct purposes or meanings. The types of purposes used for the Lane construct included, *inter alia,* roles (used by 61 percent of interviewees), organizational units and business areas (39 percent), scoping (22 percent) and grouping (17 percent). In terms of the Pool construct, purposes included external organizational units and business areas (64 percent), internal organization (50 percent), scoping (29 percent), and grouping (21 percent). Some of the interviewees explicitly mentioned the flexible specification of the constructs as a rationale for inconsistent use:

> *"[…] we sometimes use it* [the Pool symbol] *at an organizational level. Sometimes we use it as a business level, sometimes we use it as sector level, it's not really consistent, because of the nature of the symbol."* (interview transcription data)

In fact, one interviewee, when asked about the usage of the Pool construct, responded that it was a nice concept but difficult to grasp and the reason they did not use it was to keep the models simple and understandable. These findings suggest that end users tend to struggle with the additional usage complexity that comes with flexible technique specification and interpretation. Instead, they would appear to be more receptive towards more rigid construct definition and guidance.

Emerging Contextual Factors Affecting Process Modeling Technique Use

The semi-structured interviews allowed us to gather user feedback on the propositions derived from our theoretical analysis. However, we also sought to gather deeper insights into contextual factors that may have remained undiscovered by the representational analysis but are key to understanding process modeling technique use.

To that end, the two-person interviewing team used probing questions in addition to the interview questions pertaining to the classification scheme (see Figure 3) to explore contextual factors that may provide a rationale for the explanatory insights obtained. We conducted a thematic coding analysis [44] on the transcribed interview data to uncover central, recurring concepts across the responses.

Overall, our study uncovered five contextual factors that appear to influence the usage of BPMN and the perceived criticality of its suggested representational issues, *viz*. use of modeling tools, use of modeling conventions, modeler experience, the modeling role and the modeling purpose. In identifying and describing these factors, we refer to existing theoretical conceptualizations of conceptual modeling practice [42] and process modeling practice [1], both of which distinguish individual factors such as role and experience from socio-organizational factors such as conventions and mandates, purpose/requirements, and employed methods. In the following sections, we examine each of the identified factors in more detail.

Modeling Tools

Process modeling techniques are often implemented, and used, in a modeling tool or even a business process management system [e.g., 12]. These tools provide extended functionality to support the way techniques can be deployed. For instance, some tools provide model repositories in which models can be stored and linked on different levels of abstraction. Moreover, most tools offer a variety of techniques for process modeling, which, in turn, enable users to complement a technique with constructs from another technique if they encounter deficits in the original technique [17]. In our study, we found that the modeling tool, in which BPMN is implemented, influences the way users perceive the representational deficiencies (i.e., completeness and clarity) of BPMN. Some of the deficiencies that exist in BPMN were overcome by means of tool functionality (model repository, meta-tags and links to other documents and techniques, for instance). As one of the interviewees stated:

“[…] well, if you can’t afford a good tool, it could be a problem because just the basic set doesn’t have it, so that’s [inaudible] a problem. From my personal perspective.“ (interview transcription data)

Hence it would appear that a tool can be used to mask and/or mitigate deficiencies that, *prima facie*, exist in modeling techniques. These findings suggest that, when a technique is not implemented in a tool with additional modeling functionality, i.e., if BPMN is used in isolation, its deficiencies would manifest more strongly. For example, 75 percent of the interviewees who indicated a need to capture business rules were not able to do so with BPMN. However, some respondents did not consider this situation to be a major problem *only because* they overcame the deficit in BPMN with tool-based workarounds that included narrative descriptions of rules and conditions, spreadsheets, or hyperlinks to external tables and meta-tags. Table 3 summarizes tool functionality that our interview results suggest to have an impact on how BPMN users would perceive a predicted deficiency of the technique.

Table 3. Tool functionality influencing technique usage perceptions

Tool functionality	**Impact**
Integrated repository	An integrated model repository stores all models within a central database and facilitates navigation between process models on different levels of conceptual abstraction. Thereby, it may overcome deficiencies within a process modeling technique related to process decomposition and scoping.
Navigation capacity	Navigation capacity allows users to link and access process models from within other process models through hyperlinks. Thereby, it may mask deficiencies within a process modeling technique related to process decomposition and scoping.
Additional attribute fields	Additional attribute fields and meta-tags for language constructs used within a process models allows a user to depict additional information about the context in which a technique construct is used. Thereby, clarifying information can be annotated to a technique construct, which potentially rectifies concerns about the real-world meaning of the construct.
Access to other modeling techniques	Integrated modeling tools such as System Architect or ARIS allow users to link process models with other conceptual models and to combine different models. Thereby, potential deficits within a technique can be overcome by allowing the user to employ additional techniques to depict the real-world phenomena that could not be articulated with the original technique. For instance, some interviewed BPMN users reported that they used UML state chart models to depict business rules.
Access to new technique constructs	In advanced modeling tools, the user is allowed to define new or additional technique constructs to be used in addition to an existing technique. In the present study, some interviewees reported that they used new constructs in addition to regular BPMN constructs to explicitly describe IT system-supported tasks in a process model.
Hyperlinks to documentation	In some modeling tools, hyperlinks can be created within process models that provide access to additional documentation in the form of spreadsheets or documents. In the present study, for instance, this was often done to document business rules that could not be depicted with BPMN.

Tool functionality	Impact
Method filter	A method filter restricts the set of technique constructs, or even a set of techniques, to be used by process modelers. It reduces the apparent complexity of a technique by limiting the user to a reduced set of constructs. While this may induce construct deficit in the modeling task, it may also reduce construct redundancy, overload or excess within a technique.

Modeling Conventions

In modeling practice, users often do not employ the modeling technique in its original or full version. Indeed, a recent study by zur Muehlen and Recker [48], which analyzed over 120 BPMN models for frequency of construct use, deduced a core set ("common core") of just six BPMN constructs and an extended set ("extended core") of just six more BPMN constructs.

In practice, organizations often follow a set of modeling conventions that restrict the set of technique constructs to be used. And indeed, of the six organizations studied, four were using specific modeling conventions. Modeling conventions can be seen as an organization-internal standardization of a technique. These conventions specify the way the technique is implemented and put to use for modeling. Two types of impact of the conventions can be differentiated. First, in some cases, modeling conventions *restricted* the use of BPMN to a reduced set of technique constructs, which sometimes influenced the way BPMN modelers perceived some of the proposed deficiencies in BPMN, as indicated in the following response that shows that the respondent deemed the organizationally restricted set of technique constructs as problematic:

> *"[…] minor, because you just create the descriptions and they'll read it from there, but sometimes you know, when you're in a meeting with high level managers the last thing they want to do is read descriptions. They want to look at it and understand it and walk away, so I'm definitely for more BPMN figures."* (interview transcription data)

Second, in some cases modeling conventions *amended* the BPMN specification. For instance, some organizations found deficits in BPMN for differentiating manual from IT system-supported tasks and introduced color-coding as a means to graphically articulate these two types of tasks:

> *"[…] we also used colors to shade the boxes to differentiate between the two, because some people didn't think that certain steps could be performed manually and certain*

steps can be performed on the system and they wanted to differentiate between both, so we used shading to show one versus the other." (interview transcription data)

Modeler Experience, Role and Purpose

Experience and role of the modeler, together with the purpose for which modeling is being conducted, also appear to impact the usage of BPMN as well as the perception of its issues. Different individual abilities and different requirements towards modeling influence how BPMN constructs are used, and which constructs are used. An expert data modeler, for instance, exhibits higher degrees of innovation and adaptability in conceptual modeling [34]. As such, he or she is able, for instance, to revert to a repertoire of modeling "workarounds" when encountering modeling problems that stem from a technique deficiency. Similarly, an expert process modeler is more likely to have created many process models and he/she would have used a larger set of constructs. Hence, such an expert modeler is more likely to be aware of any weaknesses in their use. A novice modeler, on the other hand, may not have had to model a large variety of processes, may not have had the need to use all technique constructs, and hence may be unaware of the weaknesses or may not have enough experience to recognize them as such.

The differences in process modeling expertise and the impact of these experience levels on the usage of BPMN were clearly evident in the interviews. On some of the propositions, several of the interviewees commented that, at the present stage of their modeling experience, they could only see minor consequences of the weakness for practical use, that is, "a nice feature to have." Others explicitly stated that they were not yet at a level of modeling knowledge that would allow them to use BPMN in the way it was intended. As one interviewee stated:

> *"[…] I haven't done enough with it. […] because sometimes you don't have this start and end, because you need start and end to have these, you know, it sort of looks nice but then you have this, dependency between activities, so I don't really know how to do that."* (interview transcription data)

In conclusion, it appears that the level of modeling expertise indeed impacts the way process modeling tasks are performed and how users perceive, and use, a process modeling technique.

A second important individual difference factor would appear to be the modeling role (for example, business analyst, systems analyst), that a user occupies in a modeling initiative. Interviewees coming from different backgrounds (i.e., systems analysts versus business analysts) often reacted differently to the same set of propositions. Some of the modelers with technical background explicitly mentioned the divergence between their own background and the more business-oriented way that BPMN was used in the organization:

> *"[…] it's a broad change in terms of the way that you're thinking with BPMN, because it's very high level. It's pretty much [inaudible] what the business processes are, I'm working in sort of like, a semi-technical business area. I'm used to writing use cases a lot so, at first I'm so used to detail stuff and I have to change my mindset into writing it in more, higher level."* (interview transcription data)

Other interviewees conceded that they have not yet made use of certain BPMN constructs because their role in the modeling initiative was business-oriented and in that role they have not encountered a need for using some of the constructs:

> *"[…] I haven't really, I suppose because I don't go down into the software, the actual software development side of describing the processes. I stop with just describing the business and the business' requirements, I haven't had a need to describe anything other than actual people, in the business area."* (interview transcription data)

In terms of process modeling purpose, it was found in our study that modelers who create BPMN models for the purpose of communicating with business users were likely to use a smaller set of constructs than modelers using BPMN modeling in technical application areas, e.g., process execution or simulation (indicated in Figure 4 through the differentiation of 'core set uses' versus 'extended set uses').

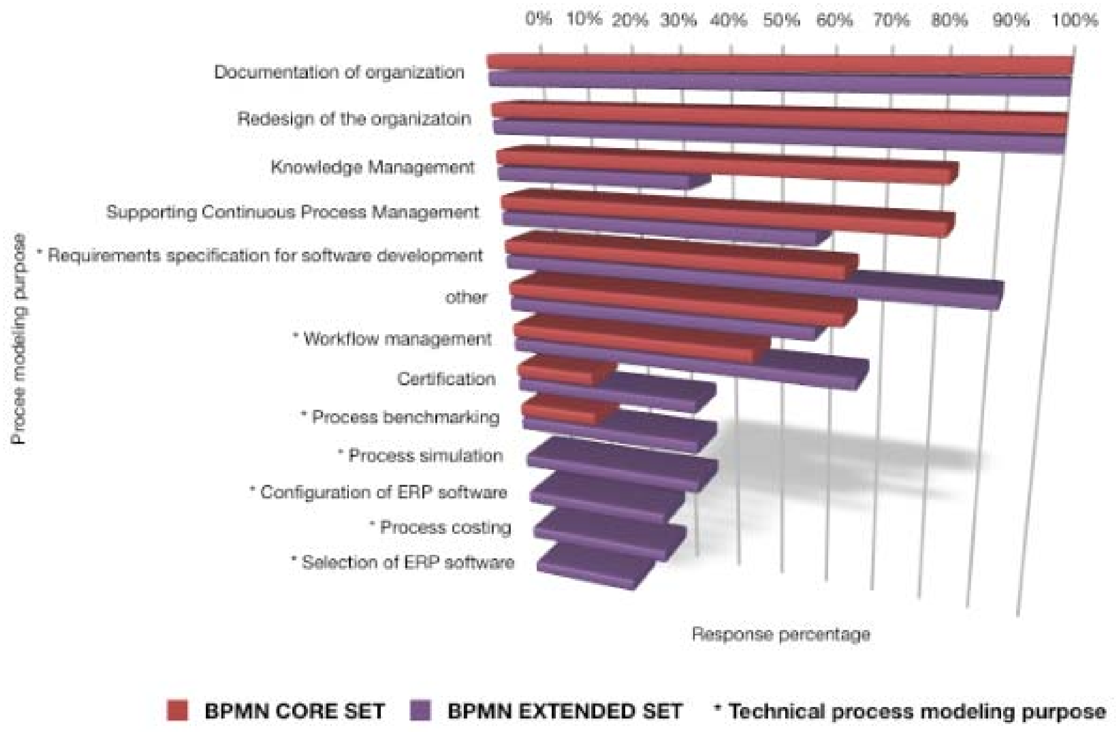

Figure 4. Extent of BPMN use by process modeling purpose

Figure 4 shows how the extent of BPMN construct usage varied in the case organizations in accordance to the purpose of the process modeling. The data suggests that for typical business modeling purposes (e.g., organizational redesign, process documentation, continuous process management or knowledge management), the BPMN core element set was often deemed sufficient by the organizations in terms of providing an adequate set of BPMN constructs for process modeling. In contrast, in terms of more IT-oriented purposes (marked with an '*' in Figure 4) such as workflow management, selection and configuration of ERP software, process simulation or systems requirements specification, Figure 4 indicates that organizations tended to use more frequently, if not exclusively, an extended or complete set of BPMN constructs so as to add expressiveness to the process models.

VII. Conclusions

Discussion

This paper presented a comprehensive analysis of BPMN that incorporates both a theoretical model for evaluation and semi-structured interviews to gain insights on the generated propositions and to contextualize the results. Our theoretical analysis resulted in nine different propositions regarding perceived issues in the application of BPMN for process modeling. Our empirical investigation revealed that some but not all of these predictions constitute critical issues in process modeling practice (see the summary provided in Table 4). Note that the three identified levels of support (un apparent, limited, apparent) used throughout this paper and summarized in Table 4 have not been established by means of mathematical or statistical evaluation. Rather, the evaluation of each proposition is based on the interpretive judgment of the research team on the basis of the content analysis of the interview data.

Table 4. Summary of interview results: Levels of proposition support

Deficiency type	No	Proposition	Level of support
Construct deficit	P1	Capturing business rules	Apparent
	P2	Capturing state histories	Limited
	P3	Supporting process decomposition	Apparent
Construct redundancy	P4	Articulating real-world objects	Limited
	P5	Articulating state transformations	Not apparent
	P6	Articulating events	Not apparent
Construct excess	P7	Providing superfluous modeling constructs	Apparent (2 of 12) Limited (4 of 12) Not apparent (6 of 12)
Construct overload	P8	Specifying the ‘Lane’ construct	Apparent
	P9	Specifying the ‘Pool’ construct	Apparent

More specifically, our findings suggest that end users miss capability in BPMN needed for the articulation of business rules that govern organizational processes, as well as for the specification of process structure and decomposition. These deficits motivate users to employ additional means for their modeling, thereby increasing complexity and decreasing consistency of their modeling. Also, end users struggle with the ambiguities of some BPMN constructs, viz., Lane and Pool, and look for more guidance in the use of these constructs. We further found that end users manage redundancy in

BPMN rather well and are able to cope with different constructs that share similar meanings. We further found interesting usage patterns relating to a number of support modeling constructs, such as text annotations and grouping constructs, which are used in organizations to further enhance the process specifications on an informal level.

In our study we also uncovered, and examined, a range of personal, organizational and situational factors that impact process modeling practice and the way graphical techniques are used for process modeling. Through our interview analysis we uncovered the presence of five factors that inform a contextualized model of the use of graphical techniques for process modeling. First, modelers with different levels of *process modeling experience* range in terms of how many modeling scenarios they have encountered and also in their portfolio of modeling workarounds. This experience, in turn, affects how these modelers perceive strengths and weaknesses of a technique and also affects how the modelers go on about employing a technique for process modeling. Second, the individual backgrounds of the process modelers determine their *role in a modeling initiative* and ultimately their view of a process model – in accordance to their set of skills, their training background and their cognitive abilities. Third, the *purpose* for which a process model is to be used determines the set of real-world phenomena that is relevant to be modeled and thereby the way a technique is being used to model real-world domains. How good or bad a technique is used, hence, depends largely on the application area for which the models to be created are being used. Fourth, the act of process modeling is typically supported through a *modeling tool* that offers a set of advanced and extended features. The functionality of the tool can assist a process modeler in overcoming deficiencies existing in a technique, which would prevent the modeler from perceiving them as problematic. Fifth, *modeling conventions* specify the way in which a technique is being put to use and standardize organization-wide the semantics of the technique. Thereby, certain deficiencies may not manifest due to amendments to the original specification of the technique.

In conclusion, our study provides theoretical and empirical evidence on the strengths and weaknesses of using BPMN for process modeling, and also discusses a range of contextual factors that impact the use of BPMN. This information is vital to establishing an information opinion about adoption and use of BPMN, and can guide executive decision makers in their investment decisions when choosing to implement a process modeling initiative in an organization.

Implications for Research

From our investigation we draw several implications for research. First, representation theory provides a fruitful basis from which insights into potential and actual issues with the use of a process modeling technique can be obtained. However, there is a need to consciously explore the setting in which a process modeling technique is put to use and in which potential issues with the technique may (or may not) become apparent. Representation theory offers an explanatory framework to guide these investigations (the premises of which can be tested using quantitative data). The use of empirical (preferably qualitative) data further increases the scope of the theory in that it provides evidence and contextual information about the insights that can be gained from the theory. Hence, combining representation theory-based analysis with qualitative inquiry provides an even more fruitful avenue for research into modeling technique use. More precisely, this study illustrated how the organizational context of process modeling can be examined in detail by using the explanatory framework offered by representation theory together with the use of qualitative data collection and thematic analysis. By doing so, this study provides a comprehensive example of how to further increase the explanatory power of investigations into conceptual modeling practice by combining representation theory-based analysis with qualitative inquiry.

Second, we believe that our work serves both as motivation and input to the extension of process modeling research. Some of the conjectures we derived from our exploratory examination (e.g., the dynamics between technique-related modeling issues and task- and user-based intervening factors) call for appropriate empirical research strategies that further operationalise and test these propositions. At present, only little is known about process modeling practice and process modeling technique usage overall. Our endeavor is to consider a contextualized, rich model of the domain in which process modeling is situated. The work presented in this paper explores a range of situational factors that frame the contextual setting in which process modeling techniques are being put to use. Thereby, our work can be leveraged in the development and testing of research models aimed at explaining process modeling technique adoption, usage, and eventually success.

Third, our work identifies a need for further research into the nature and capabilities of process modeling techniques. Indeed, the uncovered representational issues can trigger a number of related design science efforts to improve and extend current process modeling techniques such as BPMN. Aside from the representational issues pertaining to overloaded, redundant and excessive construct specifications, we would like to point out the need for more research on the relationship of process modeling and business rule representations, and the integration between the two approaches. Our study shows that while BPMN was not intended to include formal business rule specification, it is evident that users would prefer to be able to describe representationally in their process models where and how business rules affect the depicted processes, and they have trouble with identifying the interface between process modeling and business rule modeling.

Implications for Practice

We identify five general benefits for the practitioner community of process modelers and their ecosystems. First, the results can provide guidance to executive decision makers in organizations concerned with adopting BPMN by providing validated evidence of BPMN modeling issues of which modelers should be aware. For example, knowing that BPMN exhibits a limitation in the modeling of business rules, an organization may put in place additional tools together with a set of business rule modeling conventions or it may adopt a business rule modeling technique. Such a move would help ensure consistent modeling and prevent correcting the models at a later stage. Second, decision makers should consciously explore the organizational setting they establish for process modeling activities. For instance, the level of expertise of the process modelers as well as the existence of modeling conventions impact the way a process modeling technique is put to use, and, *ceteris paribus*, thereby influence the quality of the models produced. Third, from a managerial perspective, the resulting contextualized model of process modeling technique usage can guide the design of effective intervention capacities for introducing new process modeling techniques or extensions to existing ones. On the basis of the research findings, management can make an informed decision regarding the procedures that prepare for the introduction, as well as the uptake and use, of a process modeling technique. Fourth, by highlighting the modeling issues in BPMN, the process modeling community can raise awareness for these issues and can be guided in developing workarounds and other means for masking deficiencies, or even extirpating some of them. Fifth, by showing empirically which issues exist in a technique and how these issues impact user evaluations, designers can be guided in their efforts to develop techniques that allow end users to fully and effortlessly create descriptions of the real-world domains with which they are concerned. This situation will ultimately warrant not only popularity of the technique but also instrumentality and productivity for process modeling.

Limitations

While this research provides valuable insights into both theoretical capabilities of BPMN and BPMN's perceived modeling issues, it has some limitations. First, while a focus on representational capabilities has been found to be useful to guide studies on modeling techniques [20], further criteria, such as BPMN's perceived understandability, have to be considered for a more comprehensive analysis of BPMN. Second, all of our interview participants are based in Australia. However, while we lack evidence for it, we see no indications why Australian modelers would not be representative of process modelers in other settings and so, why our findings could not be extended beyond the limited regional scope. Third, the moderating ability of tools, modeling conventions, as well as modeler experience, role and purpose, were seen to have an impact on the results of this study by diluting, in some cases, the criticality of the modeling issues perceived by the BPMN users. The study presented in this paper is clearly at an explorative, formative stage, and our findings remain to be tested empirically on a larger scale to warrant generalizability. However, we strongly believe that our exploratory study has uncovered a rich and comprehensive first explanation of process modeling technique use that can stimulate and guide further empirical research in this emerging relevant domain of IS practice.

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