Do Process Modelling Techniques Get Better? A Comparative Ontological Analysis of BPMN

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Abstract

Current initiatives in the field of Business Process Management (BPM) strive for the development of a BPM standard notation by pushing the Business Process Modeling Notation (BPMN). However, such a proposed standard notation needs to be carefully examined. Ontological analysis is an established theoretical approach to evaluating modelling techniques. This paper reports on the outcomes of an ontological analysis of BPMN and explores identified issues by reporting on interviews conducted with BPMN users in Australia. Complementing this analysis we consolidate our findings with previous ontological analyses of process modelling notations to deliver a comprehensive assessment of BPMN.

Keywords

Business Process Management, BWW ontology, Business Process Modelling, BPMN

INTRODUCTION

Business Process Management (BPM) has been identified as the number one business priority, and building Business Process Capability is seen as a major challenge for senior executives in the coming years (Gartner Group, 2005). The interest in BPM has, among others, triggered substantial academic and commercial work aiming towards advanced business process modelling solutions. One of the most recent proposals for a new business modelling technique is the Business Process Modeling Notation (BPMN) 1.0, which was released in May 2004. Though BPMN is not yet an official standard, there is a clear intention to take it to a level at which it will become a standard. This intention is backed up by the popularity and the increased industry interest in BPMN. Among others, BPMN is the organisation-wide modelling standard within Queensland Government.

This paper evaluates BPMN 1.0 from the viewpoint of an established ontology – the Bunge-Wand-Weber (BWW) ontology (Wand and Weber, 1990, 1993, 1995). We selected the BWW ontology for this study for three reasons. First, unlike other ontologies, the BWW ontology has been derived with the Information Systems discipline in mind. Second, the BWW ontology is an upper ontology. Its foundational character and comprehensive scope allows for wide applicability. Third, there is an established track record and demonstrated usefulness of ontological analyses of modelling techniques using BWW.

The *aim of this paper* is to identify ontological shortcomings of BPMN in an early phase of its development and application. Thereby, both developers and users may be able to pinpoint and scrutinize possible shortcomings of the current specification to derive a more sophisticated, revised specification that may then become a standard. To address this objective we conducted an ontological analysis of the BPMN notation, developed propositions based on the identified ontological shortcomings, and tested them in interviews with representatives of the BPMN user community in Australia. In order to obtain further insights on the eligibility of BPMN as a standard for Business Process Modelling, we consolidated our findings with previous ontological analyses of eleven other competing process modelling notations in order to comprehensively assess BPMN not only from an ontological viewpoint but also from a historical and comparative perspective.

The remainder of our paper is structured as follows. The next section gives an overview of the BWW approach and related work. The findings from the ontological analysis and our derived propositions are presented next. In the section that follows we present the results of the empirical study related to the testing of these propositions. Next, we discuss the findings from the comparison of our analytical work with previous ontological analyses of process modelling notations. We conclude by discussing the results and limitations of our research, as well as future work in this area.

THE BWW ONTOLOGY AND RELATED WORK

The BWW Ontology

Over the last few decades numerous conceptual modelling techniques, used to define requirements for building information systems, have emerged with no consistent theoretical foundation underlying their conception. Concerned that this situation would result in the development of information systems that were unable to completely capture important aspects of the real world, Wand and Weber (1989; 1990; 1993; 1995) developed and refined a set of models for the evaluation of modelling techniques and the scripts prepared using such techniques. These models are based on an ontology defined by Bunge (1977) and are referred to as the BWW models. *Ontology* studies the nature of the world and attempts to organise and describe what exists in reality, in terms of the properties of, the structure of, and the interactions between real-world things (Shanks *et al*., 2003). As computerised information systems are representations of real world systems, Wand and Weber suggest that ontology can be used to help define and build information systems that contain the necessary representations of real world constructs. The BWW representation model is one of three theoretical models defined by Wand and Weber (1995) that make up the BWW models. Its application to information systems foundations has been referred to by a number of researchers (Green and Rosemann, 2004) and is now often referred to as simply “the BWW model”. The key constructs of the BWW model can be grouped into four clusters: things including properties and types of things; states assumed by things; events and transformations occurring on things; and systems structured around things (Green and Rosemann, 2005). For a complete definition and description of ontological constructs please refer to, for example, (Weber, 1997).

Weber (1997) suggests that the BWW model can be used to analyse a particular modelling technique in order to make predictions on the modelling strengths and weaknesses of the technique. He clarifies two main evaluation criteria that may be studied according to the BWW model: *Ontological Completeness* and *Ontological Clarity*.

Related Work

The BWW representation model has been used in over twenty-five research projects for the evaluation of different modelling techniques (see (Green *et al*., 2005a) for an overview). In this section, we briefly summarise those studies that focus specifically on process modelling techniques.

Keen and Lakos (1996) determined essential features for a process modelling scheme by evaluating six process modelling techniques in a historical sequence by using the BWW representation model. Among the modelling techniques evaluated were: ANSI flowcharts, Data Flow Diagrams (DFD) and the IDEF Method 3 Process Description Capture Method. The evaluation is restricted to the assessment of the ontological completeness of each technique. From the analysis the authors concluded that, in general, the BWW ontology facilitates the interpretation and comparison of process modelling techniques. The authors did not, however, empirically verify their findings on the features of process modelling schemes.

Green and Rosemann (2000) analysed the EPC notation with the help of the BWW ontology, assessing both ontological completeness and clarity. Their findings have been empirically validated through interviews and surveys (Green and Rosemann, 2002). Confirmed shortcomings were found in the EPC notation with regard to the representation of real world objects and business rules, and in the thorough demarcation of the analysed system.

Green *et al*. (2005a; 2005b) compared different modelling standards for enterprise system interoperability, including Business Process Execution Language for Web Services v1.1 (BPEL4WS), Business Process Modeling Language v1.0 (BPML), Web Service Choreography Interface v1.0 (WSCI), and ebXML Business Process Specification Schema (ebXML BPSS) v1.1. All these standards, which proclaim to allow for specification of intra- and inter-organisational business processes, have been analysed in terms of their ontological completeness. The study found that ebXML provides a wider range of language constructs for specification requirements, indicated through its comparatively high degree of ontological completeness. In addition, a minimal ontological overlap (MOO) analysis (Wand and Weber, 1995; Weber, 1997) was conducted in order to determine the set of modelling standards with a minimum number of overlapping constructs but with maximal ontological completeness (MOC), i.e. maximum expressiveness. The study identified two sets of standards that together allow for the most expressive power with the least overlap of constructs, viz., ebXML and BPEL4WS, and, ebXML and WSCI. At the present point in time, this analysis too, has not yet been empirically validated.

Overall, the conducted research has mostly been of a purely theoretical nature. Most of the evaluations lack, at the time of writing, empirical verification of the theoretical findings. Overcoming this shortcoming of previous ontological analyses, our foremost research objective was to conduct a comprehensive study on BPMN that included the empirical testing of our findings. Furthermore, we wanted to put the results of our ontological analysis in the context of previous studies in order to understand if process modelling techniques are actually improving in terms of their representation capabilities, *i.e.* their ontological completeness.

SUMMARY OF THE ONTOLOGICAL ANALYSIS OF BPMN

BPMN Background

The development of the Business Process Modeling Notation (BPMI.org, 2004) was based on the revision of other notations including UML Activity Diagram, UML EDOC Business Process, IDEF, ebXML BPSS, Activity-Decision Flow Diagrams, RosettaNet, LOVeM, and Event-driven Process Chains. BPMN is designed to be a graphical visualisation for business processes, which can be mapped to the process execution language BPEL4WS. Although this gives BPMN a technical focus, its specification is targeted at both technical and business users. The specification document differentiates the BPMN constructs into a set of core graphical elements and a more specialised and extended set. For the purpose of this research we investigated both sets.

BPMN is a very recent modelling technique and, consequently, there is so far only limited research that critically evaluates BPMN. Wahl and Sindre (2005) report on an analytical evaluation of BPMN using the Semiotic Quality Framework (Krogstie and Sølvberg, 2003). They explore the following criteria: domain appropriateness, participant language knowledge appropriateness, knowledge externalisability appropriateness, comprehensibility appropriateness, and technical actor interpretation appropriateness. They conclude that BPMN particularly excels in terms of comprehensibility appropriateness due to its construct specialisations and type aggregations, and is overall well-suited for the domain of business process modelling. Interestingly, they also see the need for, and potential of, an ontological analysis. Similarly, Nysetvold and Krogstie (2005) compared BPMN to UML Activity Diagrams and EEML using the same semiotic quality framework, finding that BPMN achieves the highest score in all categories except for domain appropriateness. The ranking of the languages, however, is based on a simplistic weighting scheme which has not been reasoned as to its objectivity and is thus considered to be a subjective evaluation. White (2004) compared the BPMN specification to UML activity diagrams, with respect paid to their capability of supporting the workflow patterns as introduced by van der Aalst *et al.* (2003). He concludes from his investigation that BPMN is adequate to cater for all of the 21 patterns, and that, from his viewpoint, BPMN is more intuitive than UML.

Ontological Analysis of BPMN: Findings and Propositions

In order to follow a rigorous, objective approach towards evaluation, we followed the methodology for ontological analysis as proposed by Rosemann *et al.* (2004). Our ontological analysis was conducted in three steps. First, two researchers separately read the BPMN specification and mapped the BPMN constructs against ontology constructs to create individual first analysis drafts. Second, the researchers met to discuss and defend their mapping results, resulting in a jointly agreed second draft. Third, the joint draft was presented, discussed and refined in several meetings with the entire research team, leading to the consensual final mapping result. Thereby, we feel that we have significantly increased objectivity and rigor in our research. Table 1 summarises the final, agreed outcomes of our ontological analysis of BPMN.

Based on the findings from the ontological analysis of BPMN, we derived propositions in order to demonstrate how the lack of ontological completeness and clarity can lead to problems with the use of the notation. The first three propositions stem from the notion of ontological completeness of BPMN: 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 deficiency drives users to modify existing constructs or employ additional constructs (e.g. create new constructs or adopt constructs from other modelling techniques) in order to compensate for the deficit.

- P1. Because there is no representation for state, stable state, unstable state, conceivable state space, state law, lawful state space, conceivable event space, and lawful event space, state modelling will lack definability and focus, and thus, the depiction of business rules that rely on state laws and transformation laws will be unclear. Also, users will be unable to determine which events and states can be expected to occur in the system and which events and states can occur but should not be allowed to.
- P2. Because there is no representation for history, the need for a log of state changes in important entities will not be met. Such a situation can cause significant problems related to recovery and reliability of interacting entities, such as inter-organisational systems.

P3. Because there is no representation for system structure, there is no thorough demarcation of the system and the things within the system. This deficiency can lead to difficulties in the use of BPMN for modelling inter-organisational business processes. Also, in large modelling projects, problems can arise regarding how to structure process models into constituent models. Due to the inability to break down the system coherently, the understandability of models captured with BPMN will be undermined.

From the perspective of construct excess, we identified the BPMN constructs that appear to have no real-world meaning according to the BWW ontology. Accordingly, users will get confused when using these constructs.

P4. Because 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) appear to have no real-world meaning, their use will cause understandability problems. Users will have to bring extra knowledge to make sense of these constructs. Specifically, BPMN provides certain super types (such as Event, Gateway, Normal Flow) that are further specialised in the notation and thus appear to be redundant from the perspective of the ontology.

Ontological Construct	BPMN Construct
THING	Lane, Pool
PROPERTY	*N/A*
In General	Attributes of Pools Attributes of Lanes
In Particular	
Hereditary	
Emergent	
Intrinsic	
Mutual: Non-binding	
Emergent	
Mutual: Binding	
Attributes	
CLASS	Lane, Data Object
KIND	Lane
STATE	
CONCEIVABLE STATE SPACE	
STATE LAW	
LAWFUL STATE SPACE	
EVENT	Start Event, Intermediate Event, End Event, Message, Timer, Error, Cancel, Compensation, Terminate
CONCEIVABLE EVENT SPACE	
LAWFUL EVENT SPACE	
TRANSFORMATION	Activity, Task, Collapsed Sub-Process, Expanded Sub-Process, Nested Sub-Process, Transaction
LAWFUL TRANSFORMATION	Default Flow, Uncontrolled Flow, Exception Flow
Stability Condition	Rule, Conditional Flow
Corrective Action	'Exception Task', Compensation Activity
HISTORY	
ACTS ON	Message Flow
COUPLING	Message Flow
SYSTEM	Pool, Lane
SYSTEM COMPOSITION	Pool, Lane
SYSTEM ENVIRONMENT	Pool, Lane
SYSTEM STRUCTURE	
SUBSYSTEM	Pool, Lane
SYSTEM DECOMPOSITION	Pool, Lane
LEVEL STRUCTURE	Pool, Lane
STABLE STATE	
UNSTABLE STATE	
EXTERNAL EVENT	Start Event, Intermediate Event, End Event, Message, Timer, Error, Cancel, Compensation
INTERNAL EVENT	Start Event, Intermediate Event, End Event, Message, Error, Cancel, Compensation, Terminate
WELL-DEFINED EVENT	Compensation, End Event
POORLY-DEFINED EVENT	Message, Timer, Error, Cancel, Terminate, Start Event, Intermediate Event
Construct excess	Link, Off-Page Connector, Gateway Types, Association Flow, Text Annotation, Group, Activity, Looping, Multiple Instances, Normal Flow, Event (super type), Gateway (super type)

Table 1: Representation mapping results

From the perspective of construct overload, we can identify examples of constructs in the BPMN specification to which more than one ontological construct has been mapped. Such cases require the user to bring extra-model knowledge in order to understand the capacity in which a given construct is used in a particular scenario.

P5. Because the BPMN construct Lane maps to the BWW constructs Thing, Class, Kind, System, Subsystem, System Composition, System Environment, System Decomposition, and Level Structure, users will be required to bring to bare extra model knowledge in order to understand which real-world concept is being modelled by the Lane construct. Consider, for example, a question whether a Lane in a BPMN model represents a specific organisational entity, an application system, or a set of entities.

P6. Because the BPMN construct Pool maps to the BWW constructs Thing, System, System Composition, System Environment, Subsystem, System Decomposition and Level Structure, users will be required to bring to bare extra model knowledge in order to understand which real-world concept is being modelled by the Pool construct. Specifically, it is unclear whether a Pool stands for a single organisational entity, whether it is part of a super-ordinate entity, or whether it might be external to a modelled system.

From the perspective of construct redundancy, we can identify examples of ontological constructs to which more than one BPMN construct can be mapped. Such cases are undesirable since they lead to user confusion as to how to understand which real-world concept can best be represented by a particular language construct.

P7. Because a Thing can be represented by either a Pool or a Lane, users will have difficulty understanding which of these constructs should be used. Specifically, users will confront problems when modelling organisational entities, e.g. whether to use a Lane or a Pool for representing an organisational department.

P8. Because a Transformation can be represented by the BPMN constructs Activity, Task, Collapsed Sub-Process, Expanded Sub-Process, Nested Sub-Process, and Transaction, users will get confused as to which construct is to be used when representing a transformation. The BPMN constructs differ in terms of visualisation but apparently no significant semantic differentiation can be stated in terms of their use.

P9. Because an Event can be represented by any of the BPMN constructs Start Event, Intermediate Event, End Event, Message, Timer, Error, Cancel, Compensation, and Terminate, users will encounter confusion regarding the differentiation of these constructs from each other.

TESTING THE PROPOSITIONS

Rationale for Semi-Structured Interviews

As we are concerned with analysing the expressiveness and applicability of BPMN in process modelling contexts to evaluate its feasibility as a new standard we needed to develop a sound methodological basis to empirically test the derived propositions. The need for such a comprehensive approach stems from our belief that theoretical analysis alone does not necessarily report on the user's perception of modelling techniques, and that empirical observations alone do not suffice to explain a technique's efficacy. For theoretical guidance we adopted the recommendations of Gemino and Wand (2003) for grammar-based evaluation approaches. We chose to evaluate the effectiveness of the use of BPMN through empirical verification of the theoretical predictions. We selected semi-structured interviews as an appropriate means and designed an interview protocol[1] in order to approach BPMN practitioners. Through the interviews we are able test the findings from our theoretical evaluation of BPMN (i.e. verify or falsify the propositions), and discover further issues with the BPMN notation that may have remained undiscovered by the ontological analysis. Thus, the interviews allow us to obtain richer feedback and extended reasoning from the practitioners. Specifically, in our research context, we sought to understand the modellers' motivation to use BPMN and their experience with BPMN within their respective organisational contexts. Two researchers participated in the interviews, which were conducted over a two week period. The obtained data was then codified and analysed.

Questionnaire Design

The interview protocol is structured in two sections. Section A captures the demographic information about the interviewees while Section B captures their experiences with BPMN. Section B was developed by modifying the tested design proposed by Davies *et al*. (2004), which follows a top-down structure for identifying issues and their severity (see Figure 1).

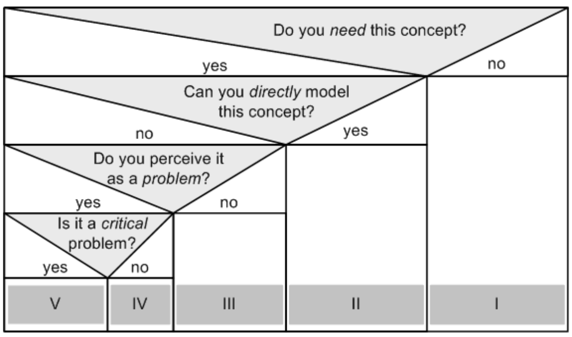

Figure 1: Questionnaire structure and response classification

Section B begins with questions that aim to determine the need of the BPMN modeller to model a certain phenomenon (concept). For example, whether a business analyst needs to directly model business rules in a given situation or not. If such a demand exists, a follow-up question seeks to capture how the practitioner models this concept with the use of BPMN constructs. If it is found that the practitioner feels that the present set of BPMN constructs is either unavailable or insufficient for modelling a certain concept, the next question captures whether the practitioner feels that this unavailability or insufficiency is a problem. This structure helps to classify the identified theoretical propositions into five different categories, which differ in the perceived severity of the identified shortcoming.

1 A copy of the interview protocol is available from the authors on request.

Participants

The semi-structured interviews were conducted and audio-recorded with eleven BPMN practitioners from four Australian organisations (three public sector institutions and one private consulting company). We have not been able to conduct more interviews from different industry sectors or from different organisations. This is due to the recency of the BPMN standard which has not yet experienced wide-spread adoption levels. Further identified interviewees were from the same demographic background in terms of experience with business process modelling and their purposes for modelling, and would not add further insight. The participants varied in levels of experience in both process modelling and usage of BPMN for modelling purposes (see Figure 2).

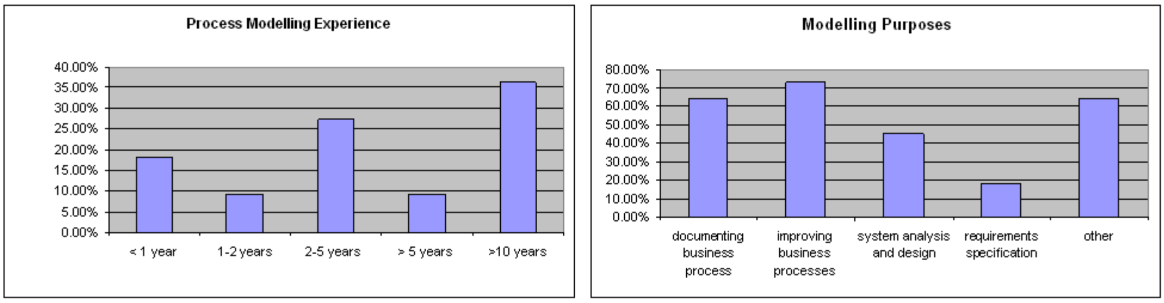

Figure 2: Sample participant demographics

Interview Results

The recorded interviews were analysed in order to determine if the set of nine propositions held in practice. Based on the responses of the interviewees, apparent support (in varying degrees) has been identified for propositions P2, P4, P5, P6, and P7, while no apparent support (or an insignificant level of support) was shown for propositions P1, P3, P8 and P9.

Questions regarding proposition P1 uncovered that over sixty percent of the interviewed users did not have any need at all for modelling all possible or allowable states. The remainder did so with workarounds but did not consider the need for workarounds to be a problem. Only one respondent (equiv. 9%) indicated that this limitation is a problem of medium severity but conceded that the ability to represent all possible or allowable states was not required at the current level of modelling within his/her organisation, therefore was not a problem at this stage.

Proposition P2 was considered to have weak apparent support. Thirty-six percent of the interviewees expressed the need to capture the history of state changes of a thing. This capture is done with additional BPMN diagrams or with textual additions. These workarounds were not considered to be major problems; however, they would be of significant severity if BPMN were being used in isolation rather than with tool support or other means.

No apparent support was found for proposition P3 – lack of representation of system structure. Over eighty-five percent of interviewees stated that they had no limitations in representing the structure of the system, while the remainder indicated that they had no need to graphically do so.

Limited apparent support was found for proposition P4 – only some of the constructs (for example, Group, Multiple Instances, and Gateway Types) were found to be not used by practitioners while many of the constructs that were predicted to cause understandability problems have been found to be successfully used in practice (see Figure 3). However, follow-up questions revealed that the Group and Multiple Instances constructs were not understood by twenty-seven and eighteen percent of interviewees respectively. Additionally, while over sixty-three percent of interviewed practitioners had used the Gateway super type construct, over seventy percent of interviewees indicated that they understood the Gateway specialization constructs but avoided using them.

The interview responses clearly indicate ambiguities in the specification of the BPMN Lane and Pool constructs (propositions P5, P6, and P7). Throughout the interview we persistently found that the definition of these constructs constituted a problem for the interviewees, an indication that the specification of these constructs lacks clarity and rigor, and that both constructs are being used to model things, classes of things and also partly systems structured around things. Hence our analysis clearly identified a shortcoming of the current specification that needs reconsideration and revision.

No apparent support was found for propositions P8 and P9, with 100% of the interviewed practitioners indicating that they did not experience any limitations with modelling events or transformations. Some practitioners commented, however, that they avoided using the event specialisations so as to not introduce the potential for model misrepresentation. However, the users did not consider this situation to be a problem.

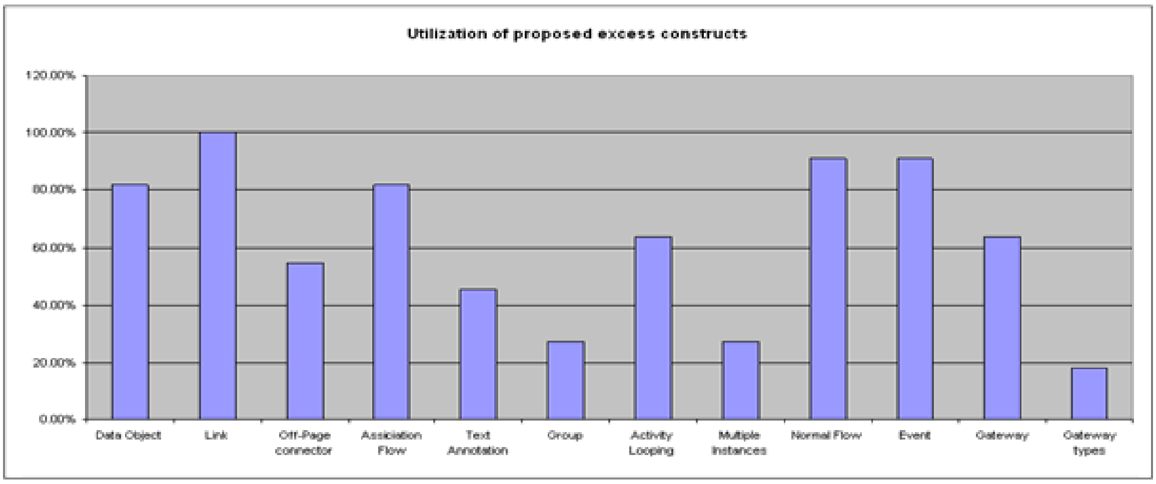

Figure 3: Sample interview results: BPMN excess constructs

It is important to note that many of BPMN's proposed limitations with respect to modelling various business process concepts were perceived to be of minor or no relevance by the participants due to the use of additional modelling tools. For example, in terms of directly modelling business rules (see proposition P1), 63% of the interviewees experiencing limitations reported that they use *other* modelling tools in addition to BPMN to allow for the depiction of business rules, for example, through spreadsheets, documents or models. None of them classified this shortcoming of the BPMN specification as a major problem. We would therefore expect that if BPMN were treated in isolation these problems would be amplified.

BPMN AND THE PROCESS MODELLING DISCIPLINE – SIGNS OF MATURITY?

Research Design

In addition to the individual ontological analysis of BPMN and the related empirical testing, we sought to position the BPMN technique amongst other popular process modelling techniques. Referring back to the related work, we assessed the outcomes of ten previous ontological analyses of process modelling techniques and complemented them with our own analysis of BPMN. Furthermore we conducted our own ontological analysis of *Petri nets* in its original and most basic form (Petri, 1962), as we perceive it to be the intellectual birthplace of more rigorous and disciplined process modelling.

For comparison purposes the focus of this study was *ontological completeness* only. We placed special emphasis on ensuring comparability of the analyses. As the prior analyses were independently conducted by four different research groups (see Related Work section), and as the ontological analyses referred to varied research purposes, significant effort was put into making the individual analyses comparable. We did neither question nor review the mapping results as proposed by the different research groups interpretation-wise. However, due to varying sets of BWW representation model constructs included in the analyses, we had to generalise the following specialised constructs of the BWW model.

- As some research groups did not entirely differentiate between property types we generalised all property-related sub-types to the super-type *property*.
- As some research groups did not consider the constructs of *stability condition* and *corrective action* in the context of the *lawful transformation* construct, we generalised any mapping of these two constructs to a mapping of *lawful transformation*.
- As the ontological construct *process* used in (Green and Rosemann, 2000) has not been specified in the representation model as defined in (Wand and Weber, 1993, 1995; Weber, 1997), we did not consider it in our comparison.

Findings and Discussion

The results of our comparison are illustrated in Table 2. Each tick indicates that the specified ontological construct can be represented by the analysed technique. The ontological constructs are arranged in a way that corresponds to the BWW model clusters.

The consolidation of previous ontological analyses with our own analyses of Petri nets and BPMN leads to several interesting results. A longitudinal study of the ontological completeness of the analysed techniques shows an obvious increase in the coverage of the ontological constructs, peaking in a high degree (76%) of ontological completeness of the ebXML technique and high ontological coverage of BPMN (66%). The high level of ontological completeness of BPMN can perhaps partly be explained by the fact that previous approaches including Event-driven Process Chains and Petri nets heavily influenced the development of the BPMN specification.

Language / Version / Year Ontological Construct	Petri net 1962	ANSI Flow-charts 1970	DFD 1979	ISO TC87 1982	Merise 1992	EPC 1992	$IDEF_3$ 1995	ebXML 1.01 2001	BPML 1.0 2002	WSCI 1.0 2002	BPEL4WS 1.1 2003	BPMN 1.0 2004
Things including Properties and Types of Things												
THING	✓			✓	✓		✓					✓
CLASS	✓							✓	✓	✓	✓	✓
KIND												✓
PROPERTY			✓			✓	✓	✓	✓	✓	✓	✓
States assumed by Things												
STATE	✓					✓	✓	✓	✓	✓	✓	
CONCEIVABLE STATE SPACE								✓				
STATE LAW	✓			✓	✓	✓		✓				
LAWFUL STATE SPACE	✓							✓				
STABLE STATE						✓		✓				
UNSTABLE STATE	✓							✓				
HISTORY								✓				
Events and Transformations occurring on Things												
EVENT	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
CONCEIVABLE EVENT SPACE								✓				
LAWFUL EVENT SPACE								✓				
EXTERNAL EVENT				✓	✓	✓		✓	✓	✓	✓	✓
INTERNAL EVENT	✓			✓	✓	✓		✓	✓	✓	✓	✓
WELL-DEFINED EVENT	✓					✓		✓	✓	✓	✓	✓
POORLY DEFINED EVENT								✓	✓	✓	✓	✓
TRANSFORMATION	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAWFUL TRANSFORMATION	✓			✓	✓	✓		✓	✓	✓	✓	✓
ACTS ON	✓							✓		✓	✓	✓
COUPLING		✓	✓		✓		✓	✓		✓	✓	✓
Systems structured around Things												
SYSTEM			✓		✓		✓	✓		✓	✓	✓
SYSTEM COMPOSITION			✓		✓		✓			✓	✓	✓
SYSTEM ENVIRONMENT			✓									✓
SYSTEM STRUCTURE					✓		✓			✓	✓	
SUBSYSTEM								✓				✓
SYSTEM DECOMPOSITION			✓				✓					✓
LEVEL STRUCTURE			✓			✓	✓					✓

Table 2: Comparison of analyses of ontological completeness of process modelling techniques

Looking at the results from a cluster-based perspective reveals that only BPMN is able to cover all aspects of *things*, including properties and types of things (highlighted in light grey in Table 2). In this aspect, BPMN appears to denote a considerable improvement compared to other techniques. For example, the popular EPC performs poorly (highlighted in light grey in Table 2).

From the perspective of states assumed by things, however, BPMN achieves a very low degree of ontological completeness (0%), as do most techniques, except for ebXML (100% – highlighted in dark grey in Table 2) and Petri nets. This situation suggests that the Petri net specification, although being composed of only seven language constructs, denotes a relatively flexible notation, especially in terms of business rule modelling, which itself is heavily dependant on rigorous state and state law specification. The formal mathematical specification of Petri nets seems to be advantageous when it comes to state and state law modelling. The situation also indicates that it may be advantageous to use ebXML *in addition to* BPMN models as it would allow for better specification of some real-world concepts since it provides coverage for most of the ontological deficits of BPMN (see highlighted dark grey area in Table 2), especially in terms of *state*, *state law*, and *event* space modelling. Since BPMN is a graphical notation also designed for business modelling, it may hence be desirable to supplement BPMN models with ebXML specifications (rather than textual notes), especially when the process models are to be used for system and executable process specifications. Table 2 suggests that these two techniques provide maximum ontological completeness (MOC) with minimum ontological overlap (MOO)

(Wand and Weber, 1995; Weber, 1997). This proposition, however, needs to be further tested by a thorough ontological overlap analysis, as for example performed in (Green and Rosemann, 2004).

BPMN is claimed to be directly translatable into BPEL4WS specifications (BPMI.org, 2004). From an ontological viewpoint this claim can only be supported to a certain degree. Table 2 indicates that, especially in terms of systems structured around things, BPEL4WS lacks ontological expressiveness compared to BPMN (highlighted in light grey in Table 2). Thus, a BPMN specification of the system to be developed, especially the demarcation from its environment and its decomposition into subsystems, might not be unambiguously translatable into executable BPEL4WS specifications and may thus require extra modelling and specification effort to avoid misinterpretations of the resulting BPEL4WS models.

CONCLUSIONS, LIMITATIONS AND FUTURE WORK

BPMN is the most recent proposal for a process modelling notation, which claims to support the process-oriented specification of business and system requirements. As a potential standard, BPMN attracts significant attention in academic and practice communities. Our ontological analysis of BPMN confirmed the relatively high maturity of BPMN. Still, a few potential shortcomings have been identified. An empirical study with BPMN users was able to confirm that BPMN contains some ambiguous elements in its specification, for example the Pool and the Lane constructs. However, as most of the ontological issues proposed were found to have no or only weak support, we conclude that a) the theoretical shortcomings are only of minor practical relevance at this early stage of BPMN use in Australia and b) the notation, although being quite recent, has already gained support from practitioners. Another factor that appears to impact practitioners' identification of BPMN's shortcomings is the set of tools available to supplement the use of BPMN in their workplace. It seems that if the practitioners have used these tools prior to starting use of BPMN, they tend not to classify their use as a supplement to BPMN as a problem.

This paper has some limitations. First, its empirical base is rather limited as we were able to collect evidence from only eleven participants. However, we believe that even this small sample size provides valuable first insights. Second, our comparison was based on the outcomes of independent theoretical studies. Though we made some minor modifications in order to increase the comparability, we are aware that the ontological analyses might not be fully consistent with each other. Third, our comparison focused on ontological completeness only. This analysis alone led to interesting findings, but we believe that analysing the ontological clarity of process modelling notations will lead to further insights into the process modelling discipline.

In our future work we plan to extend the sample size for this empirical study. We also plan to extend our analysis of BPMN, and the comparison with previous ontological analyses, to include ontological clarity. Finally, we want to consolidate the comparative findings from all ontological analyses in the area of process modelling techniques in order to derive from the BWW model an ontology focused on business processes in order to develop a more appropriate benchmark for ontological analyses in the domain of Business Process Management.

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