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"Modeling with Tools is Easier, Believe Me"
The Effects of Tool Functionality on Modeling Grammar Usage Beliefs

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Abstract. *Increasingly, studies are reported that examine how conceptual modeling is conducted in practice. Yet, typically the studies to date have examined in isolation how modeling grammars can be, or are, used to develop models of information systems or organizational processes, without considering that such modeling is typically done be mans of a modeling tool that extends the modeling functionality offered by a grammar through complementary features. This paper extends the literature by examining how the use of seven different features of modeling tools affects usage beliefs users develop when using modeling grammars for process modeling. We show that five distinct tool features positively affect usefulness, ease of use and satisfaction beliefs of users. We offer a number of interpretations about the findings. We also describe how the results inform decisions of relevance to developers of modeling tools as well as managers in charge for making modeling-related investment decisions.*

Keywords: conceptual modeling, perception measurement, usage beliefs, tool functionality.

1 Introduction

Information systems (IS) analysts and designers need to have an understanding about the domain in which the system is meant to operate, and the functions it has to perform [43]. To address this task, they often create conceptual models of the relevant business domains the information system is intended to support. These models are created using semi-formal, diagrammatic conceptual modeling grammars that provide graphical constructs and rules how to combine these constructs [68].

Conceptual modeling is an active research area in Information Systems [11]. Related research has examined, for instance, how conceptual modeling grammars are capable of creating models that provide a faithful representation of some real world domain [62], how a specific conceptual model provides a faithful representation of a real world domain [51], or, more generally, how the quality of conceptual models can be managed [47].

Recently, research has started to examine how conceptual modeling grammars are used in practice. It was shown, for instance, that direct utility beliefs (such as ease of use, usefulness and satisfaction) are key determinants of users' decisions to continue to use a modeling grammar [54]. It was also shown that perceived usefulness and perceived ease of use of a modeling grammar are dependent on their ontological properties; viz., their levels of construct deficit, redundancy, overload and excess [61]. Other studies have examined, for example, different usage patterns of conceptual modeling grammars [20, 72].

Our interest in this paper is to extend the current body of knowledge about grammar usage beliefs in conceptual modeling. Research to date has examined how models are created using grammars or methods [e.g., 67], how the models are understood [51] or used in a variety of settings [1, 50]. Yet, the usage of these modeling artifacts has typically been studied *in isolation*, i.e., decoupled from the modeling environment in which modeling is conducted.

Specifically, most studies that examined the use of modeling grammars have not explicitly considered that these grammars are typically implemented, and used, within a modeling tool. These tools have become very sophisticated and provide extended functionality to support the way grammars can be deployed. For instance, some tools provide model repositories in which models can be stored and cross-linked on different levels of conceptual abstraction [41]. Also, most tools offer a variety of grammars to use for conceptual modeling, which, in turn, enables users to overcome any type of deficiency they might encountered in any given grammar [31]. Finally, more recently, tools have emerged that provide collaboration support for modeling, for instance, through advanced visualization features [7].

Our primary conjecture is, therefore, that modeling tools impact the way that modeling grammars are used by analysts. *How* exactly modeling tools affect usage of modeling grammars, however, is still unclear. Moreover, it remains unclear which modeling tool functionality specifically affects the way that grammars are used.

In this paper, therefore, we report on research we undertook to examine the effects of seven types of tool functionality on three key grammar usage beliefs. We draw on data collected as part of a large field study [54-56] of users of the Business Process Modeling (BPMN) grammar [6], the current industry standard in process-aware modeling of information systems; and examine the data collected with a specific focus on the reported tool functionality in use by BPMN modelers. We proceed as follows. We review relevant literature about modeling tools and previous findings about key grammar usage beliefs. Then, we report on our data collection efforts, before presenting the results of our study. We provide a discussion of implications of the findings, and conclude the paper with a summary of its contributions and limitations.

2 Background

2.1 Prior Work

In deciding how to model a real-world domain, the decision of the type of grammar to be used for conceptual modeling is an important consideration. The offset of modeling constructs and the related grammar rules define the world view of that grammar and thus specifies the limits of what can be modeled with a given grammar [33]. The type of grammar used for conceptual modeling (e.g., data-oriented, object-oriented, or process-oriented) defines the language and its grammatical rules that can be used to articulate and communicate details about the real-world domain, and thus determines the outcomes of the modeling process, i.e., the type and quality of the model produced. There is a need, consequently, to understand the modeling capabilities, and limits thereof, of a modeling grammar, and the implications these limits have on the actual usage of the grammar. This understanding is of equal importance for the developers of modeling grammars, their end users as well as the developers and adopters of modeling tools.

Aside from research that studies the final *product* of using modeling grammars, i.e., the model produced [e.g., 51, 65], recently, research has been conducted to understand the *process* of using grammars for conceptual modeling. Initial studies in this vein of research examined how well grammars, in theory, support the modeling of real-world phenomena [29] or how principles of modeling could be formulated [37]. Since then, increasingly, empirical work has been carried out to understand the process of modeling with grammars. For instance, Davies et al. [13] and Fettke [23] report on surveys on the usage of conceptual modeling in practice. Dobing and Parsons [20] report on a study of how UML is used. Zur Muehlen and Recker [72] define usage patterns of the BPMN grammar. In [54], a theoretical model was developed and empirically tested that describes important grammar usage beliefs and how they lead to continued usage of a modeling grammar. This study was the first to inform a body of knowledge about the grammar usage experience as perceived by the modeler. Finally, in [61], a study is reported on the ontological characteristics of conceptual modeling grammars that determine the important grammar usage beliefs perceived usefulness and perceived ease of use.

2.2 Grammar Usage and Tool Functionality

The studies reviewed above have arguably advanced our knowledge about how grammars are used in the process of conceptual modeling. Still, grammars are not the only modeling artifact relevant to this process. For instance, most organizations define organization-internal modeling conventions – norms that prescribe modeling guidelines, layout conventions and other standards [e.g., 63]. In this context, some studies have been conducted of late to define best practices, for instance, for naming conventions to be used in conceptual modeling [45].

Similarly, a decision for or against the use of a conceptual modeling grammar is typically associated with investments in a modeling tool to support and enact the modeling [35]. Such investments decisions are important to the effectiveness and efficiency of modeling projects [2] and are associated with significant costs. For instance, a large Australian bank estimated that its decision to introduce and use the ARIS toolset [64] for its process modeling initiatives resulted in costs of $3.5M approximately.

Aside from being an important factor in the investment decision about process modeling, the modeling tools also impact the way modeling itself is conducted. State-of-the-art modeling tools provide a graphical editor to build or read conceptual models and complement this editor with advanced functionalities to support the act of modeling as well as the utilization of the model produced. Currently, several research efforts are underway to develop advanced tool support for conceptual modeling through advanced repositories [41], advanced visualization support [7] or with advanced collaboration features [16].

Turning to modeling tool features that are widespread in industry at current, Table 1 describes the most common tool functionality in use, based on the studies in [14, 30, 57, 58], which discuss, to some extent, how tools are used in conjunction with grammars in modeling initiatives. Table 1 further describes briefly how the tool functionality can be used to offset grammar deficiencies or other modeling challenges.

Table 1. Commonly Used Modeling Tool Functionality

ID	Name	Description
TF1	Integrated repository	An integrated model repository stores all models within a central database and facilitates navigation between models on different levels of conceptual abstraction. This functionality can alleviate problems about model querying and cross-referencing [41].
TF2	Navigation capacity	Navigation capacity allows users to link and access models from within other models through hyperlinks. This feature may be helpful in constructing, and accessing, decomposed models of information systems [9].
TF3	Additional attribute fields	Additional attribute fields and meta-tags for grammar constructs used within a model allow a user to depict additional information about the context in which grammar constructs are used in a model. Thereby, clarifying information can be annotated, which potentially rectifies concerns about the real-world semantics of the construct [26].
TF4	Access to other modeling grammars	Integrated modeling tools such as System Architect or ARIS allow users to link models with other conceptual models and to combine different models. Thereby, potential deficiencies within a grammar can be overcome by allowing the user to employ additional grammars to depict the real-world phenomena that could not be articulated with the original grammar [28].
TF5	Access to new grammar constructs	In some modeling tools, the user is allowed to define new or additional grammar constructs to be used in addition to an existing grammar. This allows users to specify additional semantics in cases where a grammar may have a deficit of representation constructs [58].
TF6	Hyperlinks to documentation	In some modeling tools, hyperlinks can be created within models that provide access to additional documentation in the form of spreadsheets or documents.
TF7	Method filter	A method filter restricts the set of grammar constructs, or even a set of grammars, to be used by modelers. It reduces the apparent complexity of a grammar or set of grammars by limiting the user to a reduced, potentially less cumbersome or easier to use set of constructs [14].

Clearly, tool functionalities such as the ones described in Table 1 influence the way that modeling is conducted, and thereby impact both the process and outcomes of conceptual modeling. Consider the following example: In our overarching study on the use of the BPMN grammar [54-58, 61], we found that the modeling tool in which the BPMN grammar was implemented and used, influenced the way users perceived deficiencies of the BPMN for process modeling to manifest. Fig. 1 gives the excerpt of the transcription of an interview with a member of a modeling team in large Australian organization.

I1:	[…] when you model business processes with BPMN do you ever want to decompose or break up the model into smaller, more detailed models.
U:	yes.
I1:	and how do you do that?
U:	um, okay, so within Casewise it allows you to explode an activity box, so you'd right click and basically select explode and then it'll allow you to create a level […] yeah, so it'll allow you to decompose it, so it's either a decomposition or a, or a flow.
I1:	so you're relying on Casewise to do this?
U:	that's right.
I1:	are you aware of anything in BPMN that would actually allow you to decompose a model?
U:	no.

Fig. 1. Excerpt from interview transcriptions in the study described in [57, 58]

Inspecting the conversation displayed in Fig. 1, it becomes evident how the interviewed modeler relied on functionality provided by the CaseWise Corporate Modeler toolset to mitigate deficiencies in the BPMN grammar related to the decomposition of a model. This anecdotal evidence, in turn, suggests the key relevance of modeling tools on the way that modelers perceive their modeling experience.

2.3 Proposition Development

We believe that the evidence to date indicates that modeling tool functionality will impact the process of using a conceptual modeling grammar. In turn, this impact should become evident in the beliefs users develop about the conceptual modeling grammar in the process of working with the grammar. Given that lack of grammar characteristics such as ontological completeness or clarity decrease perceptions of usefulness and ease of use [61], we conjecture that appropriate tool functionality can mitigate these and other deficiencies and in turn alleviate concerns about grammar usage. Before the background of these findings and arguments, our primary proposition in this study is therefore:

> The tool functionality offered by a modeling tool will positively impact grammar usage beliefs that users develop when working with modeling grammars.

Our argument is that modeling tool functionality that provides features to enhance the expressiveness of a modeling grammar, or reduce the complexity of a grammar, will influence the perceptions that users have about the usage of these grammars, for example, whether users find these grammars more useful, easy to use, or satisfactory for conceptual modeling.

Note the tentative formulation of our research proposition. Our interest in this study is not to suggest a specific theoretical model about *why* certain functionality impacts modeling grammar usage beliefs, but rather to formulate a proposition to guide an empirical study that explores *how* tool functionality usage is associated with grammar usage beliefs. Our study, therefore, is exploratory rather than confirmatory in nature.

To operationalize this proposition further, we collated the most common tool functionalities in use for modeling, as shown in Table 1.

To examine which beliefs modelers have about the grammar they use when engaging in conceptual modeling, we turn to the study by Davies et al. [13], who report that perceived usefulness and perceived ease of use (measured as complexity) are two key usage beliefs influencing the decision to continue using conceptual modeling in practice. And indeed, Recker [54] showed that *perceived usefulness* (PU), *perceived ease of use* (PEOU) as well as *satisfaction with grammar use* (SAT) are the three strongest drivers influencing intentions to continue using a modeling grammar. This research demonstrates that PU, PEOU and SAT are three key beliefs users have about a modeling grammar when they use the grammar for modeling real-world business domains.

Examining the meaning of these usage beliefs, PU captures performance beliefs (for instance, whether or not using a grammar improves the quality of the modeling outcome or the overall success of the initiative), and reflects expected effectiveness and efficiency gains that can manifest from the use of a modeling grammar. PEOU captures attitudes and beliefs about the effort that is needed to apply a grammar. Finally, SAT captures the extent to which modeling grammar use implies a realization of expected benefits from grammar use (such as assistance in meeting modeling objectives, provision of all constructs required to depict desired real-world phenomena and so forth) [54].

The importance of these usage beliefs stems from the fact that behavioral beliefs (what we believe about how the use of an artifact assists us in performing a behavioral activity such as conceptual modeling) are instrumental to defining how we actually behave (i.e., how we perform conceptual modeling) [21].

PU, PEOU and SAT have in common that they are three key usage beliefs pertaining to the direct utility of the grammar at hand [52]. Direct utility beliefs capture perceptions stemming from a first-hand experience, and are therefore distinct from beliefs about facilitating conditions such as expectation-confirmation or social norms. Indeed, it has been shown that, over time, direct utility beliefs dominate usage decisions over externally motivated beliefs [21], thereby warranting our interest in these beliefs specifically.

Accordingly, in the following we describe an empirical study set out to measure how the three usage beliefs PU, PEOU and SAT associated with a modeling grammar are affected by the use of different types of tool functionality.

3 Method

3.1 Research Approach

To gather data to examine the relative influence of tool functionality on modeling grammar usage beliefs, we consider empirical data gathered through a survey as part of a large field study of adopters of the process modeling grammar BPMN [6]. We selected the survey research method because it facilitates rigorous hypothesis testing through a sample size bigger than, for example, case studies [25]. Also, survey research has the potential to produce generalizable results that can be applied to populations other than the sample tested [40]. This can be of benefit to the present study to draw conclusions about conceptual modeling grammar users in general.

Data was collected globally from BPMN grammar users via a web-based instrument during 2007 and 2008. We selected the BPMN grammar as a target grammar to study for several reasons. BPMN has been ratified as an official industry standard through the standards body Object Management Group, which also brought forward the UML standard. Since its release in 2006, BPMN has quickly become a widely adopted standard for the design of process-oriented software systems [49], web services [17] and service-oriented architectures [53]. It has significant uptake in the community of system, business and process analysts, and it is used for typical IS application areas such as business analysis, workflow specification, requirements analysis and systems configuration [56].

The target population for this study included business and technical analysts engaged in modeling initiatives that had knowledge of, and usage experience with, the BPMN grammar specifically. Users were invited globally to participate in the online survey through advertisements made in online forums and blogs (e.g., WordPress, BPM-research.com, Column2), through modeling tool vendor announcements (e.g., itp-Commerce, IDS Scheer, Casewise, Tibco, Intalio) and through practitioner magazines and communities (e.g., BPTrends.com, ABPMP, BPM-Netzwerk). Participants were informed about type and nature of the study and were offered incentives for participations, including a summary of the results and the chance to win a free textbook.

3.2 Design and Measures

Four constructs were measured in this study: perceived usefulness (PU), perceived ease of use (PEOU), satisfaction with grammar use (SAT), and seven types of tool functionality (TF).

To measure the latent constructs PU, PEOU and SAT, we used multi-item scales to reduce potential measurement error and interpretation bias. To that end, we adapted the scales for the constructs PU, PEOU and SAT from pre-validated measures in IS usage and acceptance research [15, 48, 52]. The scale development process we used is described in [60]. Scale items were reworded to relate specifically to the context of BPMN grammar use.

Specifically, PU was measured using one item (PU1) to provide an overall judgment of usefulness while the remaining two items assess usefulness (in the sense of effectiveness) in explicit relation to the domain substrata conceptual modeling purpose (PU2) and objective (PU3).

PEOU measurement featured one item to measure the effort of applying a conceptual modeling grammar for a specific conceptual modeling purpose (PEOU1), one item to measure the effort of learning how to apply a conceptual modeling grammar (PEOU2), and one item to measure the effort of performing conceptual modeling tasks with the grammar, i.e., the effort of building conceptual models (PEOU3).

The SAT scale captured respondents' satisfaction levels (both in intensity and direction) along three semantic dimensions, these being contention (SAT1), satisfaction (SAT2) and delightedness (SAT3).

To collect data on tool functionality used, we asked respondents which of the seven tool functionalities summarized in Table 1 they are using when creating models with the BPMN grammar. We further queried respondents about key organizational and individual demographics, such as experience with modeling, size of organization and modeling team, and name of modeling tool in use. Finally, participants were invited to comment textually on their use of the BPMN modeling grammar. The comments allowed us to examine qualitative data about the use of the grammar. Appendix 1 lists all questionnaire items of the survey.

3.3 Validity and Reliability of Measures

Scale reliability and validity for the three considered latent constructs was assessed via confirmatory factor analysis implemented in SPSS Version 16.0. All scale items were modeled as reflective indicators of their hypothesized latent constructs. All constructs were allowed to co-vary in the measurement model. Table 2 gives the scale validation results. Construct correlations were PU-PEOU = 0.44, PU-SAT = 0.58, and PEOU-SAT = 0.54.

Regarding uni-dimensionality and internal consistency reliability of scales, we found that Cronbach's α for all constructs exceed 0.7 [66]. Further, the composite reliability measure ρc exceed 0.7 [38] for all constructs.

Regarding convergent validity [24], we note that all indicator factor loadings are significant and exceed 0.6, all construct composite reliabilities ρc exceed 0.7, and the average variance extracted (AVE) for each construct exceeds the variance due to measurement error for that construct (i.e., AVE each exceeds 0.5).

Finally, regarding discriminant validity, we note that the largest squared correlation between any pair of constructs s 0.34 (between PU and SAT), while the smallest obtained AVE value is 0.90 (PEOU), thereby meeting Fornell and Larcker's test [24].

Table 2. Scale Validation Results

Construct	Item	Mean	St. Dev.	Item loading	Sig.	α	ρc	AVE
PU	PU1	6.04	1.02	0.85	0.00	0.87	0.83	0.91
	PU2	5.94	1.03	0.88	0.00			
	PU3	5.50	1.58	0.83	0.00			
PEOU	PEOU1	5.17	1.29	0.78	0.00	0.87	0.81	0.90
	PEOU2	5.10	1.33	0.87	0.00			
	PEOU3	5.10	1.31	0.88	0.00			
SAT	SAT1	5.22	1.24	0.85	0.00	0.93	0.88	0.94
	SAT2	5.12	1.27	0.88	0.00			
	SAT3	4.79	1.45	0.86	0.00			

4 Results

4.1 Descriptive Statistics

After data inspection and cleansing, we obtained 528 usable responses in total. The geographic distribution of respondents mirrored the general distribution of process practitioners worldwide [71]. Almost 60% of respondents worked for private sector companies, with more than 40% of respondents working in large organizations with more than 1000 employees, and 22.7% and 26.8% of respondents working for mid-sized and small-sized organizations, respectively. The size of the process modeling team, in which respondents worked as process modelers, ranges from less than 10 members (64.4% of respondents) to more than 50 members (3.8% of respondents). The reported average amount of experience in process modeling was 6.4 years. Experience in modeling with BPMN specifically ranged from 15 days to 5 years (with an average of 9 months and a median of 4 months). The lower experience with the BPMN grammar is likely due to the timing of the data collection roughly three years after the official release of the BPMN standard through OMG.

Table 3 shows the most commonly reported modeling tools in use; and also summarizes descriptive statistics about the relative usage of the seven tool functionalities identified and queried.

Table 3. Descriptive Statistics about Modeling Tool and Functionality Usage

Tool	**Tool Usage**	**TF1**	**TF2**	**TF3**	**TF4**	**TF5**	**TF6**	**TF7**
ActiveModeler Avantage	*0.5%*	✓	✓	✓			✓	
Appian BPM Suite	*1.4%*	✓	✓	✓	✓	✓	✓	✓
BEA AquaLogic BPM Suite	*0.5%*	✓	✓					
Binner IMS Sycat	*0.5%*	✓		✓			✓	
BOC Adonis	*0.5%*	✓	✓	✓	✓	✓	✓	✓
Borland Together	*0.5%*	✓	✓	✓	✓		✓	
Casewise Corporate Modeler	*3.3%*	✓	✓	✓	✓	✓	✓	✓
COSA Process Designer	*0.5%*	✓	✓	✓	✓			
eClarus Business Process Modeler	*0.9%*	✓	✓	✓				
Eclipse	*0.9%*	✓	✓			✓	✓	
Fuego BPM Enterprise Server	*0.5%*				✓			
Holocentric Modeler	*2.8%*	✓	✓	✓	✓	✓	✓	✓
IDS Scheer ARIS	*3.3%*	✓	✓	✓	✓	✓	✓	✓
iGrafx FlowCharter	*2.3%*	✓	✓	✓	✓	✓	✓	
ILOG Jviews	*3.8%*	✓	✓	✓		✓	✓	✓
Intalio BPMS	*4.9%*	✓	✓	✓	✓	✓	✓	✓
itp-Commerce Process Modeler	*7.7%*	✓	✓	✓		✓	✓	✓
Lombardi Teamworks	*0.7%*	✓	✓	✓		✓	✓	
MagicDraw	*1.9%*	✓	✓	✓	✓	✓	✓	✓
MessageXchange	*0.5%*	✓		✓	✓		✓	
Microsoft Visio	*18.1%*		✓	✓	✓	✓	✓	
Mindjet MindManager	*0.5%*	✓	✓		✓		✓	✓
Pega BPM Suite	*0.5%*	✓	✓			✓		
Proforma ProVision	*0.9%*	✓	✓	✓	✓	✓	✓	✓
Ramco - Business Process Platform	*0.5%*	✓		✓	✓	✓		
Savvion Process Modeler	*1.4%*	✓	✓	✓	✓	✓	✓	
Seeburger Process Designer	*0.5%*		✓	✓		✓		✓
SparxSystems Enterprise Architect	*6.8%*	✓	✓	✓	✓	✓	✓	✓
SunGard EXP CARNOT	*0.5%*	✓	✓		✓		✓	
Telelogic System Architect	*5.9%*	✓	✓	✓	✓	✓	✓	✓
Tibco BusinessStudio	*1.4%*	✓	✓	✓	✓		✓	✓
Troux Metis	*0.9%*	✓	✓		✓	✓	✓	✓
Ultimus BPM	*0.5%*	✓						
Unisys IT Modeler	*0.5%*		✓	✓	✓		✓	
Visual Paradigm Visual Architect	*6.1%*	✓	✓	✓	✓	✓	✓	✓
WebMethods Modeler	*0.5%*				✓	✓		
Other	*16.6%*	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Functionality available		*81.6%*	*78.9%*	*71.1%*	*65.8%*	*60.5%*	*71.1%*	*44.7%*
Functionality in use		*46.2%*	*56.1%*	*42.4%*	*31.4%*	*26.1%*	*41.7%*	*21.2%*

Based on Table 3, we can identify the most frequently reported tools in use. Microsoft Visio denotes by far the most popular way to model BPMN (18.2 %), followed by itp-commerce's Process Modeler solution (7.7%), which is in a Visio plug-in that extends the modeling capacities of Visio with a BPMN simulation engine, additional attributes and analysis options. Several large scale Business Process Management suites with in-built modeling environments were also frequently reported (e.g., SparxSystems, Telelogic, Intalio, IDS Scheer and Casewise).

Perusal of Table 3 further suggests that end-users indeed make use of extended tool functionality if available. The data suggests a frequent use of model browsers with navigation capacities (56.1%), integrated model repositories (46.2 %) and additional attribute fields (42.4 %).

Finally, Table 3 summarizes data on the type of functionality offered by the most frequently reported tools; based on cross-tabulated responses about tool type and tool functionalities in use (note that in-house solutions and unnamed tool data are not included and that some respondents were using multiple tools, each providing several functionalities). Specifically, the data in Table 3 shows that some tools, such as Ultimus BPM, only provided limited extended functionality (an integrated modeling repository), while several solutions (such as Visual Paradigm Visual Architect, Intalio BPMS, Holocentric Modeler, Casewise Corporate Modeler, IDS Scheer ARIS and others) offer all seven functionalities considered. The most frequently available functionality appears to be an integrated modeling repository (available in over 80% of the tools named by respondents), while a method filter was only available in 44.7% of the tools named.

4.2 Data Analysis

Recall, our proposition in this study was that the use of certain tool functionality positively impacts usage beliefs that users develop about the use of a modeling grammar. To examine this proposition, we examined the survey data in three ways, as described in the following.

4.2.1 Structural Equation Modeling

In a first step, we examined the associations between the three usage beliefs considered. To that end, we used structural equation modeling (SEM) implemented in LISREL Version 8.80 [38]. Each indicator was modeled in a reflective manner (as in the measurement model), and the theoretical constructs were linked as hypothesized [54]. Results of our examinations of the links between the three usage beliefs are presented in Fig. 2. Goodness of fit statistics (GFI = 0.96, NFI = 0.98, NNFI = 0.98, CFI = 0.98, SRMR = 0.04, RMSEA = 0.07, χ^2 = 106.16, df = 24, χ^2/df = 4.42) for the model suggest adequate fit of the model to the data [34].

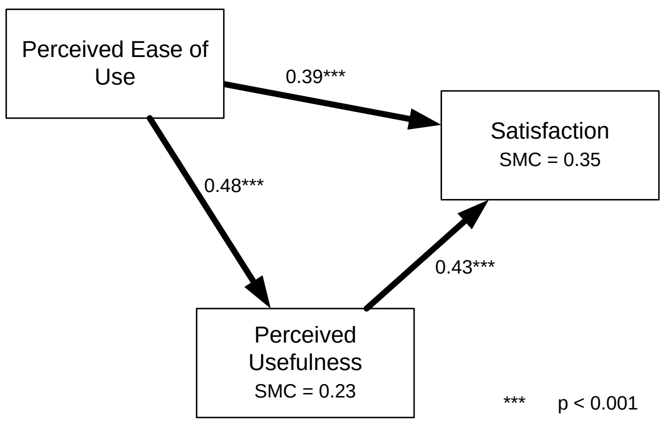

Fig. 2. Summary of model results

The results obtained and displayed in Fig. 2 are consistent with previous studies involving these usage beliefs [e.g., 4, 54] and show that ease of use perceptions of a modeling grammar strongly influence perceptions about the usefulness (β = 0.48, p < 0.001), and the satisfaction with grammar use (β = 0.39, p < 0.001). Also, satisfaction with grammar use is impacted positively by usefulness perceptions ($\gamma = 0.43$, $p < 0.001$). The results imply that perceptions about the process of modeling with a particular modeling grammar (as measured by satisfaction with grammar use) is dependent on perceptions of utility (perceived usefulness) and complexity (perceived ease of use) of the grammar.

4.2.2 Analysis of Variance

In a second step, we then examined *whether* and *how* tool functionality affects the three considered usage beliefs PU, PEOU and SAT. We were interested in ascertaining how the levels of usefulness, ease of use and satisfaction vary when modelers use – or do not use – complementary functionality offered by the modeling tools they use. To that end, we used a multiple analysis of variance (MANOVA) technique implemented in SPSS Version 16.0 [8].

As dependent measures, we used the average total factor scores for each of the three-item constructs PU, PEOU and SAT. As independent factors, we used a binary (yes/no) measure for each of the seven tool functionalities considered. This measure captures whether or not that particular feature is being used by a process modeling grammar user. We ran a MANOVA for each of the tool functionalities separately.

We first checked whether the data met the assumption of equal variances in the dependent measures across groups. Levene's tests were insignificant for all analyses, indicating that the data met this assumption. Table 4 gives the results from the MANOVA analyses.

Table 4. MANOVA Results

ID	Tool functionality	Use	PU		PEOU		SAT	
			Mean (St. Dev.)	F (Sig.)	Mean (St. Dev.)	F (Sig.)	Mean (St. Dev.)	F (Sig.)
TF1	Integrated repository	No	5.86 (1.07)	0.94 (0.33)	5.05 (1.14)	3.31 (0.12)	5.05 (1.22)	0.06 (0.94)
		Yes	5.77 (1.13)		5.21 (1.21)		5.04 (1.26)	
TF2	Navigation capacity	No	5.76 (1.13)	1.56 (0.25)	5.00 (1.23)	**4.71 (0.03)**	4.88 (1.27)	**7.56 (0.01)**
		Yes	5.87 (1.07)		5.22 (1.12)		5.17 (1.21)	
TF3	Additional attribute fields	No	5.60 (1.25)	**16.83 (0.00)**	5.18 (1.09)	1.56 (0.21)	5.04 (1.24)	0.00 (0.98)
		Yes	5.99 (0.94)		5.05 (1.28)		5.04 (1.24)	
TF4	Access to other modeling grammars	No	5.65 (1.02)	**3.79 (0.05)**	5.17 (1.11)	1.51 (0.22)	5.03 (1.39)	0.02 (0.89)
		Yes	5.88 (1.24)		5.03 (1.29)		5.05 (1.16)	
TF5	Access to new grammar constructs	No	5.82 (1.12)	0.01 (0.93)	5.14 (1.15)	0.11 (0.74)	5.03 (1.27)	0.24 (0.63)
		Yes	5.83 (1.03)		5.10 (1.25)		5.09 (1.16)	
TF6	Hyperlinks to documentation	No	5.85 (1.08)	0.39 (0.53)	5.11 (1.21)	0.15 (0.70)	4.95 (1.31)	**3.97 (0.05)**
		Yes	5.79 (1.21)		5.15 (1.13)		5.17 (1.12)	
TF7	Method filter	No	5.81 (1.06)	0.39 (0.53)	5.11 (1.21)	0.73 (0.47)	4.98 (1.25)	**5.77 (0.02)**
		Yes	5.88 (1.24)		5.20 (1.06)		5.30 (1.17)	

Inspection of Table 4 leads to several interesting observations. First, when considering the usage beliefs, we note that for six of the seven tool features considered (all but TF1, the use of an integrated repository), grammar usefulness perceptions increase when the tool functionality was in use. In two of these six cases, the increase is significant, for TF3 – the use of additional attribute fields ($p = 0.00$) and TF4 – the use of access to other modeling grammars ($p = 0.05$). Similar, we note that satisfaction with grammar use is positively associated with tool functionality in all but one case (again, TF1), with three of these associations being significant (TF2 – the use of model navigation capacity: $p = 0.01$; TF6 – the use of hyperlinks to documentation: $p = 0.05$; and TF7 – the use of a method filter: $p = 0.02$). Regarding ease of use perceptions, the use of tool functionality increased ease of use beliefs in four out of seven cases (TF1, TF2, TF6, TF7). One of these increases (TF2) we found to be significant ($p = 0.03$).

Considering tool functionality, we note that two tool features (TF1 – integrated repository – and TF5 – access to new grammar constructs) failed to show a significant effect on any of the three usage beliefs considered. TF3 and TF4 each showed a significant positive association with grammar usefulness perceptions, while TF6 and TF7 each showed a significant positive association with grammar use satisfaction perceptions. TF2 stands out as the single tool functionality influencing both ease of use ($p = 0.03$) and satisfaction perceptions ($p = 0.01$).

4.2.3 Qualitative Analysis

In a third step, we complemented the quantitative analysis with an analysis of the qualitative data we collected, by examining the survey comments received from respondents. Recall, we asked participants to comment freely on their use of the BPMN grammars and any issues associated with their usage experience. Overall, 134 comments (25.4%) were received as part of the survey.

We inspected the textual data received with a specific focus on comments made about the use of BPMN in conjunction with a tool or specific tool functionality. In examining this data, we perused 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.

Perusing thematic coding, we first categorized the comments received into seven broad themes, as summarized in Table 5 in relative order of frequency of occurrence in the comments.

Table 5. Thematic Coding of Survey Comments

Theme	Frequency of occurrence	Description
Tool support	24.3%	Comments that focused on the use of BPMN within a tool environment, the use of tool functionality in conjunction with BPMN, or the expression of demand of tool support for modeling with BPMN.
Survey	23.5%	Comments that concerned the conduct or focus of the BPMN usage survey itself (e.g., wording of questions, follow up questions or expression of interest in results).
Adoption	16.4%	Comments that illustrated processes, barriers, enablers or outcomes of individual or organizational adoption of BPMN as a modeling standard in organizational or systems design projects.
Documentation/training	11.9%	Comments that addressed the availability, content, focus, breadth or depth of the available documentation or training at the time of the survey during 2007/2008.
Methodology	11.9%	Comments that relate to components or issues of a modeling methodology that relates to BPMN use, including descriptions of modeling objectives, symbol selection, model mapping and model decomposition.
Grammatical rules	7.5%	Comments that discuss the syntax or semantics of BPMN modeling constructs or construct associations (such as the use of gateways, lanes or off-page connectors).
Other	4.5%	Comments not falling into the categories above (such as general research questions or BPMN-unrelated inquiries).

As summarized in Table 5, the thematic coding process resulted in the identification of five categories of issues related to the use of the BPMN grammar, viz., tool support, adoption, documentation and training, modeling methodology and grammatical rules. The theme "survey" pertained to the design and execution of the study rather than the grammar itself. These broad themes of issues largely align with general issues in process modeling as identified in a recent Delphi study [36], which identified, for instance, adoption, training and methodology to be among the top ten issues of process modeling by practitioners and vendors, respectively. We further note that several of the issue noted in the 2007/2008 survey of BPMN grammar use have since then become topics of interest to the academic community. For instance, theories have emerged that explain BPMN adoption in industry [54, 55]. Similarly, documentation [69] and training material around BPMN [59] has been made available. The grammar syntax and semantics of BPMN have been scrutinized [19] and work on the methodology of process modeling has been conducted [44]. The issues around tool support; however, have largely been neglected to date, which, in turn, highlights the contribution of the analysis reported in this paper.

Based on the categorization of themes in Table 5, we then examined specifically the comments pertaining to the theme "tool support", and further coded the data for specific concepts relevant to this theme. Perusing a similar thematic coding process as before, we coded the tool support comments in terms of *tool functionality in focus*, *ascribed impact on grammar use*, and *resulting consequences*. Table 6 summarizes the results from the coding process and also displays exemplary codes from the data.

Table 6. Summary of Results From In-depth Coding of Tool Support Comments

Tool functionality in focus	Ascribed impact on grammar use	Suggested resulting consequence	Exemplary quotes
Integrated repository / access to other modeling grammars	Positive	Easier integration of models into overarching enterprise architecture	*"[…] I have also used BPMN in a combination with IDEF0 to capture (particularly) processes' and tasks' resource footprints. This is possible by using Metis and the MEAF template."*
Method filter / access to (new) grammar constructs	Negative	Increase in complexity of modeling due to tool representation of grammar. Lack of tool representation for complete set of BPMN constructs, in turn decreasing perceived usefulness.	*"I should have stuck to using MS Visio […]. At least in the System Architect tool I find it cumbersome, non-intuitive, restrictive, poor at conveying flowchart style sequences and loops and more complex nuances."* *"Uptake is being limited by the degree of tool representation of BPMN symbols in the tool library."* *"I like the extended set of symbols. Unfortunately, the tool that I am using is limited to the basic set, so it is not as useful as I would like."*
Availability of tools in general	Negative	Lack of adequate functionality	*"The only problem with BPMN is the lack of adequate software to draw. Each software has significant flaws."*
Access to other modeling grammars	Negative	Lack of model transformation for workflow design/execution	*"Personally, i have found issues when i am trying to model the interaction of the underlying workflow engine/background computer interaction"* *"I miss a further link between BPMN and BPEL with possibility to export models."*
Availability of additional, complementary functionality	Positive	Access to model-based analysis techniques (e.g., critical path network analysis, activity-based costing)	*"Modeling with BPMN is very easy and friendly. What would make it a more valuable tool, would be the inclusion of calculation techniques. Once I use BPMN to show a process, I have to redo the work by using other methods to calculate best paths, optimize, such as PERT-CPM, linear programming, lines calculations and other methods. I'd like to find a tool to do it all at once"*
Access to other modeling grammars	Positive	Combination with other modeling/analysis techniques	*"I am using BPMN […] after "softer" analysis using a modeling method that includes Diamond Mandala Matrix, Data Flow Diagram and Work Flow Architecture […]."*
Availability of additional, complementary functionality / access to other modeling grammars	Ambivalent	Provision of simulation capability through tool; lack of functionality for reporting and stakeholder presentation	*"Overall, BPMN is a powerful tool, especially when coupled with simulation. […] I am currently limited with the reporting capabilities of Process Modeler and find it hard to present the process models in attractive ways to the stakeholders."*
Access to new grammar constructs	Positive	Use of extended construct vocabulary	*"The only extension to the specification we have made is the use of BPML join/split bars to represent joining/splitting processes as opposed to the BPMN use of decision points for such representations"*

The qualitative analysis results summarized in Table 6 largely lend further support to our quantitative results, and also allow us to further contextualize the results. Three key findings emerge:

First, in general we note that comments on the use of the BPMN grammar are often made in association with the tool that is in use. The fact that most respondents did not clearly separate tool use from grammar use points to the important impact that a tool environment has on the modeling grammar use, and in turn on the modeling process overall.

Second, we note that the focus of comments received largely aligns with the types of tool functionality we inspected in our quantitative analysis. Most of the comments received focus on the availability of access to other modeling grammars (such as IDEF, BPML or BPEL), the availability of other or new grammar constructs (for representing specific aspects of business processes such as convergence or divergence), or the integration of the repository with other modeling artifacts in an overall enterprise architecture. Still, we also note that the comments received points to further, complementary functionality that we did not consider in our quantitative study. Notably, several comments indicate the importance of model-based analysis functionality in modeling tools (for instance, to support simulation, reporting, or process performance analysis). This data hints at the importance of providing functionality not to support the modeling process itself but to support ongoing work with the resulting artifact (the model itself).

Third, our qualitative analysis suggests that the impact of tool functionality on modeling grammar use can be both negative and positive, depending on the way the functionality is implemented and made available to the user. For instance, availability of other or new modeling grammar constructs was at times perceived to be positive (in that it allowed a more complex representation of process phenomena) and sometimes to be negative (in that it further increased the complexity of modeling). Similarly, the availability of access to other modeling grammars was often noted as a positive feature, while its absence was often commented to be negatively influencing the modeling experience.

5 Discussion

We believe the results obtained from our quantitative and qualitative analysis permit a number of interesting interpretations. Table 7 summarizes our insights from our quantitative analysis and displays the directionality (Dir. – positive or negative) and significance (Sig.) of effects of the use of the seven types of tool functionality (TF1-7) considered on the dependent variables (DV) of interest (PU, PEOU and SAT).

Table 7. Summary of Quantitative Analysis Results

TF/ DV	**TF1**		**TF2**		**TF3**		**TF4**		**TF5**		**TF6**		**TF7**	
	Dir.	Sig.	Dir.	Sig.	Dir.	Sig.	Dir.	Sig.	Dir.	Sig.	Dir.	Sig.	Dir.	Sig.
PU	-	ns	+	ns	+	**0.00**	+	**0.05**	+	ns	-	ns	+	ns
PEOU	+	ns	+	**0.03**	-	ns	-	ns	-	ns	+	ns	+	ns
SAT	-	ns	+	**0.01**	-	ns	+	ns	+	ns	+	**0.05**	+	**0.02**

Based on these results, in general, it would appear that tool functionality can positively contribute to usefulness and ease of use perceptions as well as general satisfaction with modeling grammar use. Still, we cannot assert this finding to be generalizable across all functionalities or beliefs. Consider tool functionality TF1 (integrated repository), which decreases usefulness and satisfaction perceptions but enhances ease of use perceptions. The fact that all these deviations (positive and negative) are not statistically significant suggests that an integrated repository denotes a hygiene but not a motivator factor [32], i.e., a tool feature that is regarded as a mandatory, required functionality but not one that strongly enables or motivates elevated usage perceptions. This interpretation would classify integrated model repositories as a commodity feature.

We further note inconsistent effects of tool functionality on ease of use perceptions. We can interpret our findings as suggesting that tool functionality either impacts ease of use (e.g., TF2) or usefulness (e.g., TF3) but rarely both. Indeed, only for TF2 and TF7 do we note positive associations with both PU and PEOU – yet, the associations are non-significant in three out of four cases. These results suggest that tool functionality either adds to effectiveness and productivity of a modeling grammar usage experience, or it decreases the perceived complexity (and hence increases the efficiency) of the modeling task. This interpretation is further supported by the fact that both significant PU associations in the data (in the cases of TF3 and TF4) show negative albeit insignificant associations to PEOU.

Next, we consider the findings about the tool functionalities in more detail, focusing on those functionalities that show significant associations to the considered usage beliefs:

TF2 (Navigation capacity). Navigation capacity stands out as the one tool functionality positively impacting two usage beliefs, viz., PEOU and SAT but not PU. Navigation capacity allows users to decompose and cross-reference conceptual models with each other, which is instrumental for allowing modelers to break down complex systems and processes into more manageable sub-systems [10] or sub-processes [3]. The decomposition functionality, therefore, reduces the complexity of the modeling task, thereby elevating ease of use perceptions. The positive effect on satisfaction, on the other hand, can be explained through the system quality perspective suggested by DeLone and McLean [18]. Navigation capacity corresponds to a system providing *integration* and *accessibility* functionality to aid the task at hand, which, as stipulated in [18], manifests in increased usage satisfaction.

TF3 (Additional attribute fields). Additional attribute fields can be used to specify additional information and add further real-world semantics to a conceptual model. Prior studies [31, 58] have shown that such a tool feature can be used to rectify issues in a modeling grammar related to its expressive power, i.e., its capability to provide complete representations of important real-world concepts sought to be articulated. Expressiveness of a modeling grammar is a key determinant of a grammar's usefulness [61]. Our results therefore suggest that additional tool features can be used to mitigate grammar expressiveness deficiencies, which is manifested in elevated usefulness perceptions.

TF4 (Access to other grammars). Similar to the additional attribute fields, tool access to other modeling grammars can be used to offset any limitations in expressiveness exhibited by a modeling grammar. Theoretically, combining multiple grammars increases maximum ontological completeness – the ability to provide more complete representations of real-world domains [31]. Again, we therefore interpret our results as suggesting that tool functionality can be used to increase the expressive power of a modeling grammar, which then leads to increased usefulness perceptions.

TF6 (Documentation hyperlinks). Documentation hyperlinks provide support for the act of modeling. The fact that this functionality shows no significant association with PU or PEOU but instead to SAT suggests that the elevated satisfaction must be determined by factors other than increased grammar utility. Again, we turn to DeLone and McLean [18] and their work on information and system quality as important antecedents to usage satisfaction. We may view documentation hyperlinks as a system feature providing *integration* (the tool allows data to be integrated from various sources), *accessibility* (information can be easily extracted from the tool), and *timeliness* (the tool allows for timely responses to information requests). In light of this interpretation, our findings would lend further support to earlier studies confirming significant direct associations between system quality and satisfaction [e.g., 70].

TF7 (Method filter). We note a situation similar to that of TF6. A method filter appears to provide a feature not directly related to a modeling task at hand (hence not influencing grammar usefulness or ease of use beliefs) but instead facilitating efficient and effective modeling by providing appropriate and relevant views on the modeling environment. Using the DeLone and McLean [18] framework, this situation suggests that a method filter provides *flexibility* (the tools adapts to different user demands) as well as *accessibility* – two important dimensions of system quality, which, in turn, explains the noted positive association to grammar use satisfaction.

6 Implications

Our qualitative and quantitative analyses of tool features in the process of using a process modeling grammar suggest a rich set of implications that pertain directly to process modeling practice. On the forefront, our research is the first to explore and statistically confirm the impact of modeling tools and their functionalities on the process of creating models by using dedicated process modeling grammars. The relevance of tools to modeling processes has been a well-known but hitherto largely un-reflected fact, and our research is the first contribution to untangle the contribution of tools to the process of modeling. In turn, we believe that the findings from our study have important practical implications for at least three key components in the wider process modeling ecosystem, viz., the process of using process modeling grammars, the making of tool investment decisions to support modeling, and the setup of appropriate modeling environments. We discuss key implications for these components, in turn.

6.1 Using Process Modeling Grammars

First, our study results inform tool developers about key tool features that warrant positive experiences by users about the process of using process modeling grammars. By dissecting which tool features increase usefulness or ease of use perceptions of process modeling grammars, tool developers are informed in their efforts to (re-) design tools in a way that process modeling grammars can be improved, either by increasing effectiveness and usefulness or by decreasing complexity.

One specific finding to note is the lack of positive influence on usage beliefs shown by the tool feature "access to new grammar constructs." This finding suggests that tool-based grammar extensions do not positively contribute to the usage experience. Indeed, the results suggest that modeling will become more complex even (as suggested by the noted, albeit insignificant, decrease in ease of use perceptions from 5.14 to 5.10).

Second, we found an important role to be played by the tool functionality 'method filter'. The purpose of this functionality is to define and restrict the availability and use of process modeling grammar constructs. Through such a mechanism, the process of using a grammar for modeling can be managed by defining and maintaining a trade-off between expressiveness (and hence usefulness) versus complexity (and hence ease of use). Our results show that the use of a method filter can increase ease of use, usefulness as well as overall satisfaction perceptions (albeit not in all cases significantly), thus contributing positively overall to the modeling experience.

A third finding to note is the role of additional attribute fields. The use of this functionality we found to be negatively associated with usage perceptions. This might imply that the use of additional meta tags increases the complexity of the modeling process because additional information needs to be captured and specified, without this additional information being explicitly represented graphically in the diagram. From the viewpoint of modeling, therefore, our findings suggest that additional attributes are inhibiting the effective and efficient execution of the process of modeling rather than supporting it. Of course, this interpretation is speculative and should be considered before the background of potential tradeoffs with information requirements for model application tasks.

6.2 Making Modeling Tool Investment Decisions

Aside from implications for the practice of modeling, we believe that our study results are also of interest to managers in charge of the process of making tool investment decisions. We showed that specific tool functionality (for instance, navigation capacity, documentation hyperlinks, method filters) can improve the modeling grammar usage experience by the end users. In turn, we believe that the availability of certain tool functionality should be taken into explicit account when selecting and adopting modeling tools. Specifically, we believe we can identify three types of tool features relevant to the tool investment decision:

1. **Commodity functionality**: A commodity feature denotes functionality that is required and expected from a state-of-the art tool. Its presence will not significantly increase the usefulness or ease of use of the process of using modeling grammars; but its absence will be noted critically. In our analysis, we note an *integrated model repository* and access to *new grammar constructs* to be functionality that is deemed mandatory but does not significantly evaluate usage perceptions when present. For a tool investment decision, therefore, such functionality should be categorized as 'must have' criteria.
2. **Hygiene functionality**: a hygiene feature denotes functionality that is not necessarily regarded as mandatory but will significantly enhance the usage experience if present. In our analysis we note *navigation capacity* and *method filter* to be two tool features that fit this description. Both features, when in use, positively and significantly impacted the grammar usage experience in terms of usefulness, ease of use or satisfaction. In turn, such functionality should be categorized as 'should have' criteria.
3. **Surplus functionality**: a surplus feature denotes functionality that, if available and in use, actually worsens the process modeling grammar usage experience. A likely reason, as discussed above, is that such functionality provides overhead functionality that increases the complexity and effort of modeling without providing an appropriate surplus of benefits (e.g., in terms of effectiveness or efficiency gains). Our results indicate that *additional attribute fields* and *access to other modeling grammars* appear to fall in this category. Albeit not all effects were significant, the use of these features negatively impacted perceptions of usefulness, ease of use or satisfaction. For a tool investment decision, therefore, such functionality should be categorized as 'need not have' criteria.

6.3 Managing the Modeling Environment

Last, the findings from our study have practical implications for managers in charge of modeling projects. This is because the results that specific tool functionality can improve the modeling grammar usage experience by the end users not only identified relevant tool investment decision criteria but also informs managers in charge of modeling conventions how to set up a tool environment in which end users can work productively and with ease. Our qualitative analysis of the respondent feedback further suggests that not only the question of availability of a tool feature is of relevance to a positive grammar usage experience, but also the question of how the functionality is implemented specifically.

We note two specific key findings. First, we note the trade-off between offering new, additional grammar constructs versus the restriction of a grammar construct set (via functionality such as *access to new grammar constructs* and *method filter*). Our quantitative analysis suggests that additional grammar constructs enhance usefulness perceptions but decrease ease of use perceptions (see Table 7). Similarly, our qualitative analysis suggests that the availability of additional constructs was at times to be perceived as positive, as some tools were found to be restricting the expressiveness of the modeling. At the same time, we found that a method filter (that restricts the use of modeling grammar constructs) had strong positive influence on usage satisfaction. In turn, these findings suggest that managers in charge of modeling conventions should carefully consider whether and how they restrict and/or extend the modeling vocabulary before the tradeoff of expressiveness gains versus complexity increase.

Second, our qualitative analysis also hints at the relevance of integrating models created with one specific grammar (such as BPMN) with other models (e.g., data models) as part of an overall model architecture. There is tool functionality available (e.g., integrated repository, navigation capacity and access to other modeling grammars) to support this task; yet, the key underlying issue appears to be of a methodological form. Our findings thus suggest that an effective modeling environment needs to consider grammar- and tool-related issues in close connection to other elements such as modeling methodology, overall modeling architecture and modeling governance. And indeed, the frequent occurrence of grammar usage issues that are independent from modeling tools (viz., adoption, methodology, grammatical rules and documentation/training) shows that issues pertaining to model management, methodology and governance are important elements of the modeling environment that managers in charge need to address. And indeed, this finding is strongly aligned with the result that model management, modelling level of detail, methodology and governance are four of the top ten issues of process modelling [36]. Our study, in turn, informs managers about how to include relevant tool functionality in the setup of an effective modeling environment, however, we acknowledge that the study does not fully inform all important elements of this important task.

7 Conclusions

7.1 Contributions

In this paper we reported on an empirical study carried out to examine how the use of functionality offered by state-of-the art process modeling tools influences key usage beliefs about the grammars analysts employ for modeling. Our work presents an important extension of existing literature about grammar usage beliefs [61] and continued usage intentions [54] by demonstrating how features of a tool environment influence grammar usage beliefs. We showed that specific tool functionality can positively contribute to usefulness perceptions as well as general satisfaction with modeling grammar use. We offered a number of theoretical interpretations about these results. In turn, aside from its practical merits, our research also informs the current research agenda on conceptual modeling. A logical step from the research presented in this paper, for instance, is to extend our exploratory insights into a theoretical model to explain *why* tool functionality shows positive associations with grammar usage beliefs. Suitable reference theories to extend our work in this direction could be models of technology appropriation [12] or task-technology fit [27]. Further, we note an important direction for future research to be the examination of *how* and *why* tool functionality use affects not only the *process* but also the *product* of conceptual modeling, for instance, the quality of the model produced. Such research could link to, and significantly extend, the present body of knowledge on not only the measurement of but also the determination of conceptual modeling quality [39, 42, 46].

7.2 Limitations

The results of our study must be interpreted in light of its limitations. For instance, we consider usage beliefs instead of actual usage measures. Still, perceptual beliefs have been shown to be adequate determinants of actual usage behaviors [22], thereby justifying our interest in these measures.

Furthermore, our study considered a limited set of usage beliefs and tool functionalities, based on prior research [14, 30, 54, 57, 58]. We contend that other important usage beliefs (e.g., expectation of confirmation, hedonistic motives, or perceived performance beliefs) exist that relate to the grammar usage experience, and also that other tool functionalities may have been considered. Also, we contend that our selection of modeling tool features may be limited. Even though we based our selection of seven features on studies reporting the use of these features in modeling practice, other modeling tools may offer additional functionality that we didn't investigate.

Finally, we caution the reader about the subjective interpretation bias that may be present in our qualitative analysis. Still, we followed methodological guidelines for analyzing our data to mitigate interpretation risks [5], and we note how the results are largely in line with the quantitative results obtained. Nevertheless, we regard the results from the qualitative analysis as tentative findings that may guide speculative reasoning but that will require further, preferably quantitative research, for final confirmation.

These limitations, therefore describes important boundary conditions for the results obtained and all conclusions derived from our work should be interpreted accordingly.

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Appendix – Survey Items

Organizational demographics

Type of organization *[private/public]*
Size of organization *[less than 100, between 100 and 1000, over 1000]*
Size of modeling team *[less than 10, between 10 and 50, more than 50]*

Personal demographics

Country of origin *[drop down list]*
Type of training received in BPMN *[drop down list]*

Prior modeling experience

Over your working life, roughly, how many years experience do you have in process modeling overall? *[number of years]*
Over your working life, roughly, how many months experience do you have with BPMN overall? *[number of months]*

Over your working life, roughly, how many process models do you think you have created with BPMN? *[number of models created]*

Perceived Usefulness

PU1. Overall, I find BPMN useful for modeling processes. *[7-point Likert scale]*
PU2. I find BPMN useful for achieving the purpose of my process modeling. *[7-point Likert scale]*
PU3. I find BPMN helps me in meeting my process modeling objectives. *[7-point Likert scale]*

Perceived Ease of Use

PEOU1. I find it easy to model processes in the way I intended using BPMN. *[7-point Likert scale]*
PEOU2. I find learning BPMN for process modeling is easy. *[7-point Likert scale]*
PEOU3. I find creating process models using BPMN is easy. *[7-point Likert scale]*

Perceived Satisfaction with Grammar Use

TF1. I feel extremely contented about my overall experience of using BPMN for process modeling. *[7-point Likert scale]*
TF2. I feel extremely satisfied about my overall experience of using BPMN for process modeling. *[7-point Likert scale]*
TF3. I feel extremely delighted about my overall experience of using BPMN for process modeling. *[7-point Likert scale]*

Tool Functionality
Which of the following tool functionality are you using when creating models with BPMN?
Please select as many answers as required.

TF1. Integrated repository for all models.
TF2. Navigation between models on different levels.
TF3. Additional attribute fields for symbols.
TF4. Access to other notations and modeling techniques.
TF5. Access to new symbols in addition to BPMN symbols.
TF6. Access or hyperlinks to other documentation from within the models.
TF7. Method filter for restricting and specifying the set of symbols to be used.

Comments
If you would like to make a statement about other potential issues or experiences you have encountered with BPMN, please feel free to leave us a message by including your comment in the following textbox.