

# Extending different Business Process Modeling Languages with Domain Specific Concepts: The Case of Internal Controls in EPC and BPMN

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**Abstract:** Conceptual models of business processes and related business process modeling languages play a crucial role in today's information systems research and practice. Common BPMLs such as BPMN 2.0 or EPC are widely accepted and applied in various domains. However, such BPMLs provide a set of generic process modeling elements but do not allow for modeling domain specific concepts. This also holds true for control means as one of the key concepts for process audits. To address this gap, this paper presents an empirically grounded extension of the EPC with modeling concepts for process-integrated control means. The results of a laboratory experiment with 58 participants demonstrate that the extension facilitates a comprehensive enactment of process audits. In conclusion, the results of this research project are contrasted with a previously designed BPMN 2.0 extension in order to present insights we gain from extending two different BPMLs with the same domain concept.

**Keywords:** Process Modeling Language Extension, EPC Extension, Process Audits

## 1 Introduction

Business process management (BPM) with related business process modeling languages (BPML<sup>3</sup>) is a well-established research area with high relevance for practical applications [Da06]. Existing BPML like the Business Process Model and Notation (BPMN) and the Event-driven Process Chain (EPC) are accepted in academia and practice. Such BPMLs provide a set of generic modeling constructs for typical elements of a business process (e.g. control flow, data, resource) which makes them applicable in various domains [RRF08]. However, with this broad focus these languages do not provide appropriate modeling elements for domain specific concepts. For comprehensively covering a particular domain these general-purpose BPMLs need to be extended with additional modeling elements. Doing so, specific requirements of a domain and stakeholder perspectives can be addressed more precisely. Such language extensions facilitate model understanding and foster communication among experts of a particular domain.

This also applies to the audit domain. Regulatory requirements directly impact the design and enactment of business processes in and across today's organizations. Accordingly, BPM practitioners and researchers have paid greater attention to compliance and

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<sup>3</sup> In this paper we use the acronym "BPML" to refer to common business process modeling languages.

audit aspects in recent years [LMX07]. In current audit practice the main focus is set on business processes. This approach is based on the assumption that well controlled processes lead to a compliant state of an organization e.g. in terms of fairly presented financial statements [Ru06]. When it comes to auditing a business process, auditors mainly review the design and enactment of control means that are embedded in the process flow. Empirical research results indicate that auditors benefit from an integrated representation of business process models and embedded control means [BHT09]. However, surveys among auditors show that BPMLs are not widely used in current process audit practice [BJJ07, SM14]. This signifies that common BPMLs do not sufficiently meet auditors' requirements for presenting audit-relevant concepts in process models [Ca06, Sa11]. This appraisal complies to the results of previous literature reviews which identify methods for annotating, and enhancing business process models with compliance/audit modeling elements as one of the main open issues on the research agenda for the compliance and audit domain [ASI10, Sa11]. To address this gap, this paper presents an approach for extending the EPC as a wide-spread BPML with modeling elements for control means. An existing EPC meta-model is extended and notation elements are introduced to provide appropriate concepts for enriching process models with control means. A laboratory experiment with 58 participants is used to evaluate the utility of the designed extension. This research project marks a further step in a larger research endeavor. The proposed extension is based on thorough empirical research work in the audit domain, especially focusing on auditors' conceptualization and representation of control means in the context of process audits [SR14]. In previous research work we have extended the BPMN 2.0 to provide modeling elements for process-integrated control means. Against this background, the contribution of this paper is twofold: 1) we propose an extension of the EPC for control means; and 2) discuss insights that we gained from extending two separate BPMLs with the same domain concept.

The remainder of this paper is structured as follows. The next section elaborates on related research regarding the EPC, the extension of BPMLs and relevant concepts in the audit domain. Section 3 outlines the applied research approach and presents the proposed extension for the abstract and concrete syntax of the EPC and a corresponding XML-based interchange format. An example demonstrates the applicability of the extension. The results of the evaluation are summarized in section 4. In section 5 the insights we gain from extending two different BPMLs with the same domain specific concept are comprehensively discussed. The paper closes with a conclusion along with implications for future research work in section 6.

## 2 Related Research

BPMLs as basis for conceptual models of business processes are a research topic with a long tradition and ongoing attention in information systems research and practice [LS07]. Most common example for BPML are Petri Nets [Pe62], IDEF [MM98], Unified Modeling Language (UML) Activity Diagrams [OMG11], BPMN 2.0 [ISO13] and

EPC [KNS92]. The latter two are well-established semi-formal BPMLs which find widespread use in the BPM domain. The EPC was introduced by Keller et al. as a modeling language to represent temporal and logical dependencies in business processes [KNS92]. It became popular as a BPML in the context of reference modeling (e.g. the SAP reference model [CK97]) and is used in common business software (i.e. Microsoft Visio) as well as open-source tools (e.g. bflow\* tool box [Bo10]). The ‘Architecture of Integrated Information Systems’ (ARIS) utilizes the EPC as a central method to conceptually integrate functional, organizational, data, and output perspectives in process modeling and information systems design [STA05]. To enable interchangeability of EPC models, Mendling and Nuettgens [MN06] complement the EPC with an XML-based interchange format termed as EPC markup language (EPML). Several approaches added domain specific concepts to EPC, e.g. for performance measures [Ko08], risk-oriented concepts [RW08], inter-organizational process modeling [SV05], and financial statements [MN14]. BPMN 2.0 is a broadly accepted BPML with standardized meta-model, notation elements, and XML-based interchange format. It is –in contrast to the EPC– defined as ISO standard and provides an extensibility mechanism that enables the integration of new concepts while ensuring validity of BPMN 2.0 core elements [ISO13]. A recent literature review lists not less than 30 domain specific BPMN 2.0 extensions [BE14].

In this context, in a previous research project we proposed a BPMN 2.0 extension that provides modeling concepts for process-integrated control means [SR14]. The design of this extension is based on empirical research results that we acquire with a multi-method research approach (expert interviews, online survey). Aim was to rigorously derive all relevant concepts and their attributes as well as modeling requirements for process audits [SMN12]. In total, 12 modeling concepts and their relations were identified. These results were transformed to an empirically grounded conceptual model that describes all relevant concepts of the process audit domain and their relations to business processes [Sc13]. This conceptual model was used for designing the BPMN 2.0 extension and also lays the basis for the EPC extension outlined in this paper.

One key concept is “control means” which constitute recommended courses of action to ensure that a desired state of a process (control objective) is achieved [SHF11]. They are either directly integrated in a process (e.g. invoice approval) or are independently performed from a particular process (e.g. internal audit) [ISA12]. Our empirical analyses reveal that auditors conceptualize control means mainly as process-integrated measures respectively as ‘special’ process activity [SMN12]. Essential attributes for control means are timing (preventive or detective), nature (manual or automated), and frequency (time period a control means has to occur, e.g. daily, monthly).

On a general level, there is an ongoing debate on appropriate methods for supporting domain aspects in conceptual modeling. There are two options: 1) developing a new domain specific modeling language (DSML) [Fr10]; or 2) extending existing general-purpose modeling languages. We opt for the later approach as a large number of concepts that have been identified as relevant for process audits are already well-considered in existing BPMLs [RRF08]. The approach also enables reuse of well-known modeling

concepts, benefits from advantages of established BPMLs (standardization, tool support, practical relevance), and avoids costly development of a new DSML [BE14]. Against this background, several researchers recently paid increased attention to the extensibility of BPMLs in general. Atkinson et al. [AGF13] identify three different strategies for supporting the extension of modeling languages: 1) *In-built*: Mechanisms enable changes to the meta-model without changing the core elements; 2) *Meta-model Customization*: The meta-model is directly changed as the language does not provide appropriate mechanisms for extensions; and 3) *Model annotation*: An extension is defined in a separate language and instances of the extension are linked to instances of the language core elements via model weaving. As stated earlier, BPMN 2.0 provides an extensibility mechanism (In-built) whereas EPC lacks of such mechanisms and requires direct changes of the meta-model to enable domain specific extensions (Meta-Model Customization). Braun and Esswein [BE15] propose a generic framework for meta-model modifications which systematizes operations (add, delete, alter) for changing components of a modeling language (abstract syntax, concrete syntax, semantics). With this paper we want to contribute to this research stream on domain specific BPML extensions.

### 3 Extension for Internal Controls – EPC+C

#### 3.1 Research Approach

The research presented in this paper follows the design science research approach [He04]. The designed artifact is an extension to the EPC and the corresponding XML-based interchange format EPML. The relevance of the artifact stems from the fact that methods for annotating process models with compliance modeling elements are still lacking [Sa11]. The applied research method is conceptual modeling. A BPML consists of an abstract syntax (meta-model), concrete syntax (notation), and semantics [HR04, Pa06]. Accordingly, the proposed artifact extends the EPC meta-model and notation to provide a complete language extension for control means.

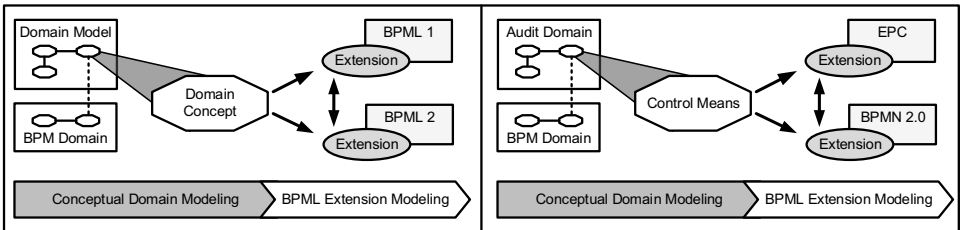


Fig. 1: General concept of Inter-BPML extensions and an instantiation

For the evaluation of the EPC extension we choose a 1 x 2 between-group laboratory experiment with participants from the audit domain. With this experiment design we focus on the stakeholders' perception of the EPC extension regarding understandability

and appropriateness [Fr07]. A discussion of insights we gain from extending two different BPMLs with the same domain concept complements the contribution of this paper. Fig. 1 illustrates the approach we denote as ‘*Inter-BPML extension*’.

### 3.2 Abstract and Concrete Syntax of the EPC Extension

Although the EPC was developed in a research project, there is still no standardized, commonly accepted meta-model available. Existing approaches for EPC extensions solve this problem by defining own meta-models [Ko08, RW08]. For our extension subsequently named as ‘EPC+C’, we use the meta-model proposed by Korherr [Ko08] which was already applied for other EPC extensions [MN14]. Fig. 2 outlines our proposed conceptual domain model for the extension as a UML-class diagram. For the reason of clarity, the classes of our extension are highlighted in grey.

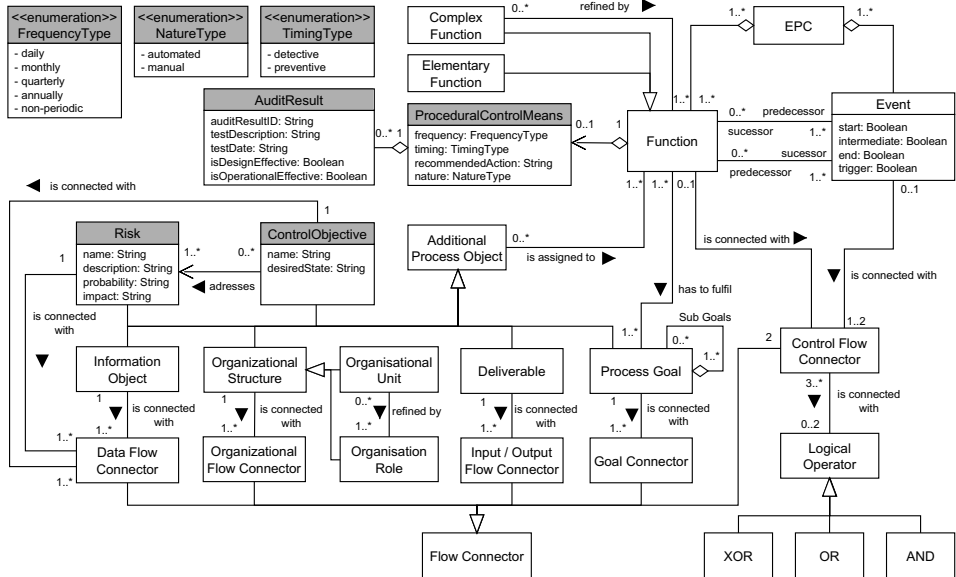


Fig. 2: Conceptual model for the EPC extension ‘EPC+C’

Our extension comprises the classes *ProceduralControlMeans*, *AuditResult*, *Risk*, and *ControlObjective* which represent all relevant control means-related domain concepts. The core element of this extension is the class *ProceduralControlMeans*. It provides a set of attributes that represent relevant characteristics of control means. These attributes are *frequency*, *timing* (preventive, detective), and *nature* (manual, automated) which are further specified by corresponding enumerations. The attribute *recommendedAction* defines an action that should be performed to enact the control means. The class *ProceduralControlMeans* is linked to the EPC core element *Function* which represents a process activity in an EPC model. This linkage is in line with auditors’ conceptualization of

control means as ‘special’ process activity (cf. section 2). By means of this composition, an EPC *Function* inherits attributes of *ProceduralControlMeans* and is thereby extended. The classes *AuditResult*, *Risk*, and *ControlObjective* are further elements of the audit domain. They are solely considered from the control means perspective (e.g. risk is also associated to other BPM concepts). The classes *Risk* and *ControlObjective* are linked to the EPC element *DataFlowConnector* and inherit from the *AdditionalProcessObject* class. Two constraints have to be defined for these elements: 1) A *Risk* may only be connected to a *ControlObjective* 2) A control objective may only be attached to a function, which is extended by the *ProceduralControlMeans* class.

The interchange format for the BPMN 2.0 extension was defined with the help of a dedicated method and model transformations [SCV11]. In the case of EPC and EPML such a method is not available. However, extensibility was one design principle for constructing the EPML XML schema [MN06]. EPML provides several possibilities for domain specific extensions. We use the extension point in the XML complex type *tEpcElement*. Our EPML extension leverages the results of the BPMN 2.0 extension as the generated XML complex types are reused for constructing an extended EPML XML schema.

For visualizing the EPC+C elements, we propose an extension of the EPC notation. The notation extension should not alter core EPC notation elements and should be as close as possible to it (look and feel). Accordingly, our design considers the EPC notation elements and existing approaches for EPC extensions. The prior described *ProceduralControlMeans* enhances the EPC function. For the attribute *timing* a marker is required to distinguish detective and preventive control means. The marker concept is inspired by the EPC extension of Rieke and Winkelmann [RW08]. A single lens denotes detective control means whereas a lens encircled by a shield indicates a preventive control. A similar design for both icons facilitates the perceptibility of control means in a process model. Likewise, a marker is used to separate risks and control objectives from EPC information objects. A checkbox icon denotes a *ControlObjective* and an exclamation mark a *Risk*. Fig. 3 depicts all notation elements of our EPC extension.

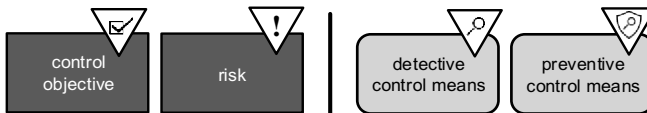


Fig. 3: Notation Elements for the EPC+C Extension

### 3.3 Application Example for the EPC extension

As an application example, Fig. 4 portrays an EPC model for a simple purchase-to-pay process fragment (left part) and the corresponding section of the EPML document (right part). Such an EPC process model is also used in the laboratory experiment to introduce the extension of the EPC notation to the participants. The process starts with the event ‘Purchase Requisition created’. The purchase requisition is processed by the function

‘Order Goods’. After the order goods are received (event ‘Goods received’) the goods receipt is reconciled with the corresponding purchase order. The EPC function ‘Reconcile received Goods with Order’ is extended with all attributes from class *Procedural-ControlMeans* (*frequency*, *nature*, *timing*, and *recommendedAction*) which transforms a common EPC function to an detective control means. The EPC process model also includes the EPC+C notation elements for the concepts *ControlObjective* and *Risk*. The EPML document in Fig. 4 shows that the control means is related to an audit result and refers to a control objective which is linked to a specific risk. Details for these concepts are given as additional XML elements of the EPC node (not the function node). In Fig. 4 the extended parts of the EPML document are highlighted in grey boxes.

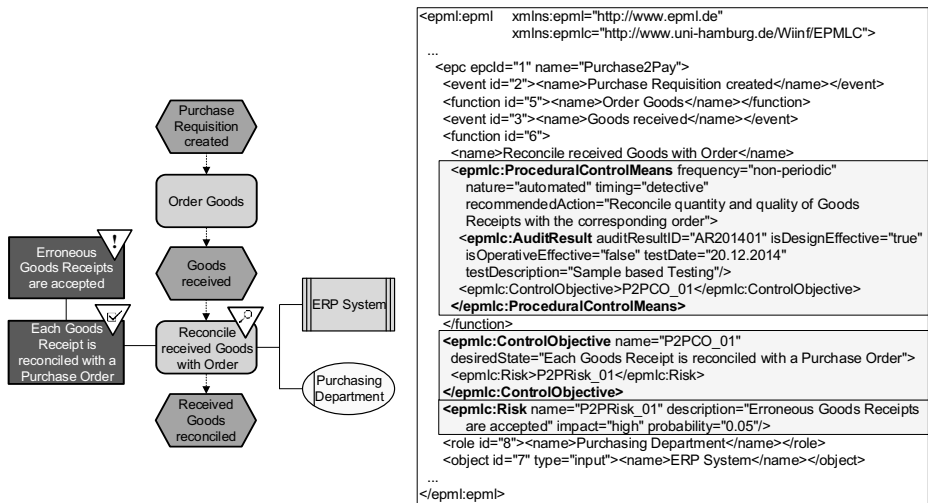


Fig. 4: Sample Process as EPC Model (left) and EMPL description (right)

## 4 Evaluation

### 4.1 Experimental Design<sup>4</sup>

The evaluation in a design science research project tries to measure how well the designed artifact supports a solution for the addressed problem [Pe07]. In this project, a 1x2 between-group experiment is used for evaluating the concrete syntax of the EPC extension. The two groups receive the same information on a purchase-to-pay process (process model) and embedded control means (controls matrix). For one group the process model is extended with EPC+C. However, a transformation of one presentation into

<sup>4</sup> This section is based on the published results of the BPMN extension as the experiment for both extensions are equivalently designed [SR14].

the other is possible without loss of information [He14]. In process audits, the main task for process auditors is to interpret existing models. For evaluating the quality of model interpretation two perspectives are discussed in academia: *interpretational fidelity* (how faithfully does the interpretation of the model supports the reader to comprehend the domain semantics included in the model?) and *interpretational efficiency* (what resources are required for interpreting the model?) [BM06, Re13]. In similar studies interpretational fidelity is measured by using comprehension tasks to test how well a model user understands the content of a given model (comprehension task performance) [MSR12, Re13]. To operationalize interpretational efficiency, usually the time is measured a model user needs to complete these comprehension tasks (comprehension task efficiency) [He14, MSR12, Re13]. In our experiment following hypotheses are tested: Comprehension task performance (H1) and Comprehension task efficiency (H2) are positively affected by using the EPC extension. The experiment is implemented as an online accessible test using Qualtrics research suite [Qu13]. As participants internal and external auditors as well as process analysts are recruited by utilizing business networks (e.g. XING) and large audit associations (e.g. DIIR, ISACA). After answering questions about demographic characteristics, process and audit knowledge, the participants are randomly assigned to one of the groups (EPC, EPC+C). The experiment comprises three process models with increasing complexity. As first task for each model, the participants are asked to identify control means by clicking them in the model. As second task, multiple choice questions have to be answered, which refer to the process control flow and embedded control means (model 1: 4 questions, model 2: 7, model 3: 15).

## 4.2 Results of the Experiment

In total 58 participants passed the experiment (EPC = 28 and EPC+C = 30). Chi-square tests confirm that in terms of demographic characteristics (age, education, employment status, working experience, self-reported process modeling knowledge and self-reported audit knowledge) the participants are equally represented in both groups. Only for the characteristic “gender” there is an unequal distribution (in total: 45 male/13 female, EPC: 19/9, EPC+C: 26/4). However, we noticed no significant differences for the measured variables for male and female participants. In order to test our hypothesis we conduct a Mann-Whitney-U-Test (MWU) [BD95] as non-parametric test for small sample sizes ( $n < 30$ ) to compare the means of both groups (EPC, EPC+C) regarding five variables. For comprehension task efficiency the time is measured (in seconds) the participants need to conduct the controls identification task for the first control means (*Duration – First Identification*), the identification of all control means (*Duration - Controls Identification*), and to answer the comprehension questions (*Duration – Comprehension Questions*). Comprehension task performance is operationalized by the number of correctly identified control means (*Correctly identified Controls*) and correctly answered questions (*Correct Answers*). All variables are added up for all three models.

Tab. 1 summarizes the results of the MWU tests. The results demonstrate that both groups significantly differ in the variables for duration of answering the comprehension



questions, duration of full control means identification and the number correctly identified control means. The mean rank of correctly identified control means for EPC+C (34.15) in comparison to EPC (24.52) indicates significantly more correct identified control means in the EPC+C group which supports the hypothesis H1. For comprehension task efficiency, the results indicate contradictory findings. The mean rank of variable Duration – Controls Identification for the EPC+C group (17.12) is significantly lower than for the EPC group (33.21) which indicates a significantly faster perception of the control means in the EPC+C group. However, regarding the duration for the comprehension questions, the mean ranks for EPC group (18.81) and EPC+C group (27.44) indicate, that the participants in the EPC group answered the questions much faster. Accordingly, regarding H2 (comprehension task efficiency) the experimental results are inconclusive. It can be assumed that the extension supports perception of control means, but does not significantly facilitate the understanding of the whole process model.

	Mean		Mean Rank		MWU <sup>[1]</sup>	Z <sup>[2]</sup>	AS <sup>[3]</sup>
	EPC	EPC+C	EPC	EPC+C			
<b>Comprehension Task Performance</b>							
Correctly identified Controls (0-7)	6.54	6.90	24.52	34.15	280.50	-2.854	<b>0.004</b>
Correct Answers (0-26)	20.57	20.80	28.13	30.78	381.50	-0.603	0.547
<b>Comprehension Task Efficiency</b>							
Duration – Controls Identification (sec)	91.98	50.99	33.21	17.12	103.00	-3.940	<b>0.000</b>
Duration – First Identification (sec)	40.77	31.71	29.33	19.69	161.00	-2.397	0.170
Duration – Comprehension Questions (sec)	449.43	537.58	18.81	27.44	164.00	-2.172	<b>0.030</b>

<sup>[1]</sup> Mann-Whitney-U Value <sup>[2]</sup> Empirical Z Value (asymptotic probability of error for n<30), <sup>[3]</sup> Asymptotic significance

Tab. 1: Means & M-W-U Results for the Groups EPC (n=28) and EPC+C (n=30)

These results are in line with the comparable experiment for our BPMN 2.0 extension. In the BPMN experiment, also the duration of control means identification was significantly improved by the extension. Accordingly, both experiments indicate a positive effect on *interpretational efficiency*. One possible interpretation is that the integrated documentation of control means and process control flow reduces the cognitive load for process model and control matrix interpretation. However, the EPC experiment reveals a negative effect on the duration for answering the comprehension questions. This might indicate that the additional information in the process model hampers model understanding or forces the participants to investigate the process model more deeply. In contrast to the BPMN extension, the results of the EPC+C experiment show a positive effect on *interpretational fidelity*. These results are potentially caused by the different extension designs in both BPMLs. For BPMN only markers were used whereas for EPC also the additional elements (e.g. risk) are represented as separate notational elements.

## 5 Discussion

With accumulated experiences from the design of two BPML extensions, in the following we discuss general aspects of the design process, domain modeling, reusability of

BPML core elements, and BPML extensibility mechanisms in general.

**BPML-independent Domain Modeling:** The first step for the design of a domain specific extension should be a comprehensive domain analysis that results in a complete conceptual model of the application domain. This modeling step should be conducted independently from a specific BPML in order to avoid adverse effects to clarity and accuracy of the domain model. This recommendation complies with related methods for domain specific BPML extensions [Br14, SCV11]. Such a profound domain model facilitates a consistent design of extensions for different BPMLs. It ensures that the domain specific concepts are consistently interpreted for each BPML when considering BPML specific capabilities and restrictions. The results of our two BPML extensions demonstrate that in regard to the domain specific concepts the designed extensions for both BPMLs are quite similar. For instance, the extension of the XML-based interchange format of BPMN could be reused for EPML with only slight changes.

**Conceptual Link of Domain Concept & BPM Domain:** As a second step, we recommend relating the constructed domain model with a generic, BPML independent conceptual model for business processes to explicitly outline all relevant relations between a process model and the domain specific concepts. In our research projects the established conceptual link between BPM and the application domain facilitates identifying BPML concepts that lent themselves for reuse in the design of the BPML extension [Sc13]. This recommendation supports the idea of an equivalence check to evaluate conceptual and semantic links in an early design stage [Br14]. In addition, this link should guide the subsequent development of BPML specific extensions to ensure consistent semantics and conceptualizations of domain concepts across several BPMLs. For instance, control means should be consistently conceptualized as an activity in different BPMLs.

**BPML Extension Mechanisms:** In our research projects we propose an extension for a BPML with a built-in extension mechanism (BPMN 2.0) and a BPML without specifications for extensibility (EPC). The advantage of the latter is obviously the design freedom for the construction of the BPML extension. Drawbacks are uncontrolled changes to the meta-model and violations of the separation of concerns design principle which may adversely affect the understandability of the BPML extension [AGF13]. It also permits different extension approaches which lead to different non-comparable and non-interoperable BPML extensions. Furthermore, tool support for such extensions is not ensured which restricts its practical relevance. However, an in-built extension mechanism does not solve all these problems. The extension mechanism first of all ensures the consistency of the BPML meta-model. For instance, the BPMN 2.0 extension mechanism does not support a semantic link for extended elements. In particular, the added elements and attributes can be attached to any BPMN 2.0 core element and not only to an activity as it is intended in our case. This restriction can only be accomplished by adding further rules to an extension in textual language or by conceptual domain specific extension models including the link of domain concepts to BPML elements. Furthermore, such an extension mechanism does not provide methodological support for the design of an extension. Designed extensions that comply with the extension mechanism can indeed

be interchanged between modeling tools but not all tools necessarily support such extensions since it is not required as the standard allows different levels of compliance [ISO13]. Hence, an interchange of a process model can lead to a loss of extended concepts. In summary, we conclude that the extension mechanism is only a protection for the abstract syntax but does not appropriately guide the design of an extension.

**Reuse of Existing BPML Concepts:** For our BPML extensions we focus on the reuse of core BPML modeling elements. For example, we use the BPMN marker concept to represent the control means attribute *timing* and the task concept for specifying the attribute *nature*. In contrast, the EPC extension uses the *additional process element* concept to represent *Risk* and *ControlObjective* as own notation elements. This approach complies with ARIS which integrates elements from different modeling perspectives i.e. organizational units from an organizational model. Our extension may refer to an ‘audit perspective’ in which separate domain models can be defined. However, the native modeling concepts of the EPC do not allow representing all domain specific concepts. In fact, we apply a marker concept which was proposed by another EPC extension [RW08] to represent the control means attribute *timing*. In case of BPMN, the risk and control objective are not integrated in the concrete syntax. This is a design decision we made, as the focus of the BPMN extension is set to control means. To cover the complete semantics of e.g. the concept risk a separate extension is required to include all relevant risk related aspects. Such a comprehensive augmentation of a BPML can lead to a language ‘defacement’ as stated by Braun and Esswein [BE15]. Alternatively, the concepts *ControlObjective* and *Risk* could be added by using BPMN 2.0 annotations. However, annotations are not directly connected to the process flow and do not meet the complex semantic of these two concepts. In conclusion, it can be stated that BPML core elements may support domain concepts differently. Measures and methods to evaluate the degree of fitting between domain concepts and BPML core elements would facilitate the design of effective BPML extensions.

## 6 Conclusion and Further Research

The design of dedicated modeling languages for an application domain is an important research topic for conceptual modelers. This also applies to the audit domain. Accordingly, in recent years researchers have been paying more attention to a comprehensive modeling support for audits. Nevertheless, recent research results show that methods for annotating, and enhancing business process models with audit modeling elements are still lacking [Sa11]. To address this gap, the paper presented an extension to the EPC. This extension enables an integrated representation of business processes and control means to support the enactment of process audits. A laboratory experiment with 58 participants demonstrated that the extension increases auditors’ interpretational efficiency compared to a separated documentation of process models and control means. A comparison with a similar extension for BPMN 2.0 revealed essential design aspects when it comes to extending general-purpose BPMLs with domain specific concepts. We identi-

fied a BPML-independent domain modeling and the construction of a conceptual link between the domain model and a generic conceptual model of a process as crucial steps in the design process for a BPML extension. Furthermore, we discussed the reuse of existing modeling concepts as well as implications and shortcomings of BPML extension mechanisms and a methodology for the design of a BPML extension.

The results of the evaluation and especially the discussion on BPML extensions point to several opportunities for fruitful research directions. The case of EPC demonstrates that the design of an extension requires a standardized meta-model to facilitate the design of additional domain specific extensions. Such a commonly accepted meta-model for EPC should be established in the EPC research community to increase its dissemination. On a more abstract level, our discussion reveals several shortcomings regarding extension mechanisms and methodical support for extending BPMLs in general. Both aspects should be considered more intensely by the BPM research community. In this regard, general principles for designing effective BPML extensions that foster interoperability between various extensions from potentially different domains and the design of an extension repository would be further valuable research contributions. These artifacts would facilitate reuse and combination of existing research results in terms of cumulative design science research and would lay a basis for methods to evaluate the completeness and effectiveness of BPML extensions. These topics remain on our research agenda.

## References

- [AGF13] Atkinson, C.; Gerbig, R.; Fritzsche, M.: Modeling Language Extension in the Enterprise Systems Domain. IEEE, Vancouver, 2013; pp. 49–58.
- [ASI10] Abdullah, N.S.; Sadiq, S.; Indulska, M.: Information Systems Research: Aligning to Industry Challenges in Management of Regulatory Compliance. PACIS 2010 Proceedings, 2010.
- [BD95] Bortz, J.; Döring, N.: Forschungsmethoden und Evaluation. Springer Berlin Heidelberg, Berlin, Heidelberg, 1995.
- [BE14] Braun, R.; Esswein, W.: Classification of Domain-Specific BPMN Extensions. In (Frank, U.; Loucopoulos, P.; Pastor, Ó.; Petrounias, I. eds): The Practice of Enterprise Modeling. Springer Berlin Heidelberg, 2014; pp. 42–57.
- [BE15] Braun, R.; Esswein, W.: A Generic Framework for Modifying and Extending Enterprise Modeling Languages. 2015.
- [BHT09] Bierstaker, J.L.; Hunton, J.E.; Thibodeau, J.C.: Do Client-Prepared Internal Control Documentation and Business Process Flowcharts Help or Hinder an Auditor's Ability to Identify Missing Controls? In: AUDITING: A Journal of Practice & Theory Vol. 28, No. 1, 2009; pp. 79–94.
- [BJJ07] Bierstaker, J.; Janvrin, D.; Jordan Lowe, D.: An Examination of Factors Associated with the Type and Number of Internal Control Documentation Formats. In: Advances in Accounting Vol. 23, No. 2007; pp. 31–48.
- [BM06] Burton-Jones, A.; Meso, P.: The Effects of Decomposition Quality and Multiple Forms of Information on Novices' Understanding of a Domain from a Conceptual Model. In: Journal of the Association for Information Systems Vol. 9, No. 12, 2008;

- pp. 748–802.
- [Bo10] Böhme, C.; Hartmann, J.; Kern, H.; et al.: bflow\* Toolbox - an Open-Source Modeling Tool. Business Process Management Demonstration Track 2010.
- [Br14] Braun, R.; Schlieter, H.; Burwitz, M.; Esswein, W.: BPMN4CP: Design and implementation of a BPMN extension for clinical pathways. 2014 IEEE International Conference on Bioinformatics and Biomedicine (BIBM). 2014; pp. 9–16.
- [Ca06] Carnaghan, C.: Business process modeling approaches in the context of process level audit risk assessment: An analysis and comparison. In: *International Journal of Accounting Information Systems* Vol. 7, No. 2, 2006; pp. 170–204.
- [CK97] Curran, T.; Keller, G.: SAP R/3 Business Blueprint: Understanding the Business Process Reference Model. 1997.
- [Da06] Davies, I.; Green, P.; Rosemann, M.; et al.: How do practitioners use conceptual modeling in practice? In: *Data & Knowledge Engineering* Vol. 58, No. 3, 2006; pp. 358–380.
- [Fr07] Frank, U.: Evaluation of Reference Models. In (Fettke, P.; Loos, P. eds): *Reference Modeling for Business Systems Analysis*. IGI Global, Hershey, USA, 2007; pp. 118–140.
- [Fr10] Frank, U.: Outline of a method for designing domain-specific modelling languages. ICB-Research Report, 2010.
- [He04] Hevner, A.R.; March, S.T.; Park, J.; Ram, S.: Design science in information systems research. In: *MIS Quarterly* Vol. 28, No. 1, 2004; pp. 75–105.
- [He14] van der Heijden, H.: Effects of diagram format and user numeracy on understanding cash flow data. 37th Annual Congress of the European Accounting Association. Tallinn, 2014.
- [HR04] Harel, D.; Rumpe, B.: Meaningful modeling: what’s the semantics of “semantics”? In: *Computer* Vol. 37, No. 10, 2004; pp. 64–72.
- [ISA12] International Federation of Accountants: ISA 315 (Revised), Identifying and Assessing the Risks of Material Misstatement through Understanding the Entity and Its Environment. 2012.
- [ISO13] ISO: ISO/IEC 19510:2013 - Information technology – Object Management Group - Business Process Model and Notation 2.0. 2013.
- [KNS92] Keller, G.; Nüttgens, M.; Scheer, A.-W.: *Semantische Prozeßmodellierung auf der Grundlage “Ereignisgesteuerter Prozessketten (EPK).”* Veröffentlichungen des Instituts für Wirtschaftsinformatik (IWi), Universität des Saarlandes, 1992.
- [Ko08] Korherr, B.: *Business Process Modelling - Languages, Goals and Variabilities*. Vienna University of Technology
- [LMX07] Liu, Y.; Muller, S.; Xu, K.: A static compliance-checking framework for business process models. In: *IBM Systems Journal* Vol. 46, No. 2, 2007; pp. 335–361.
- [LS07] Lu, R.; Sadiq, S.: A Survey of Comparative Business Process Modeling Approaches. In *Business Information Systems*. Springer Berlin Heidelberg, 2007; pp. 82–94.
- [MM98] Menzel, C.; Mayer, R.J.: The IDEF Family of Languages. In (Bernus, A.P.D.P.; Mertins, P.D.K.; Schmidt, P.D.G. eds): *Handbook on Architectures of Information Systems*. Springer Berlin Heidelberg, 1998; pp. 215–249.
- [MN06] Mending, J.; Nüttgens, M.: EPC markup language (EPML): an XML-based interchange format for event-driven process chains (EPC). In: *Information Systems and e-Business Management* Vol. 4, No. 3, 2006; pp. 245–263.
- [MN14] Müller-Wickop, N.; Nüttgens, M.: Conceptual Model of Accounts Closing the Gap between Financial Statements and Business Process Modeling. Proceedings of the Modellierung 2014. Wien, Austria, 2014.

- [MSR12] Mendling, J.; Strembeck, M.; Recker, J.: Factors of process model comprehension— Findings from a series of experiments. In: *Decision Support Systems* Vol. 53, No. 1, 2012; pp. 195–206.
- [OMG11] OMG: Unified Modeling Language Infrastructure 2.4.1. 2011.
- [Pa06] Patig, S.: *Die Evolution von Modellierungssprachen*. Frank u. Timme, 2006.
- [Pe07] Peffers, K.; Tuunanen, T.; Rothenberger, M.A.; Chatterjee, S.: A Design Science Research Methodology for Information Systems Research. In: *Journal of Management Information Systems* Vol. 24, No. 3, 2007; pp. 45–77.
- [Pe62] Petri, C.A.: *Kommunikation mit Automaten*. Rhein.-Westfäl. Inst. f. Instrumentelle Mathematik an der Univ. Bonn, 1962.
- [Qu13] Qualtrics: *Qualtrics Research Suite*. Provo, Utah, USA, 2013.
- [Re13] Recker, J.: Empirical investigation of the usefulness of Gateway constructs in process models. In: *Eur J Inf Syst* Vol. 22, No. 6, 2013; pp. 673–689.
- [RRF08] Rosemann, M.; Recker, J.; Flender, C.: Contextualisation of business processes. In: *International Journal of Business Process Integration and Management* Vol. 3, No. 1, 2008; pp. 47–60.
- [Ru06] Ruhnke, K.: Business Risk Audits: State of the Art und Entwicklungsperspektiven. In: *Journal für Betriebswirtschaft* Vol. 56, No. 4, 2006; pp. 189–218.
- [RW08] Rieke, T.; Winkelmann, A.: Modellierung und Management von Risiken. Ein prozessorientierter Risikomanagement-Ansatz zur Identifikation und Behandlung von Risiken in Geschäftsprozessen. In: *Wirtschaftsinformatik* Vol. 50, No. 5, 2008; pp. 346–356.
- [Sa11] Sadiq, S.: A Roadmap for Research in Business Process Compliance. In (Abramowicz, W.; Maciaszek, L.; Węcel, K. eds): *Business Information Systems Workshops*. Springer Berlin Heidelberg, 2011; pp. 1–4.
- [Sc13] Schultz, M.: Towards an Empirically Grounded Conceptual Model for Business Process Compliance. In (Ng, W.; Storey, V.C.; Trujillo, J.C. eds): *Conceptual Modeling*. Springer Berlin Heidelberg, 2013; pp. 138–145.
- [SCV11] Stroppi, L.J.R.; Chiotti, O.; Villarreal, P.D.: Extending BPMN 2.0 : Method and Tool Support. Third International Workshop, BPMN 2011, Lucerne, Switzerland, November 21–22, 2011. 2011; pp. 59–73.
- [SHF11] Strecker, S.; Heise, D.; Frank, U.: Prolegomena of a modelling method in support of audit risk assessment. In: *Enterprise Modelling and Information Systems Architectures* Vol. 6, No. 3, 2011; pp. 5–24.
- [SM14] Schultz, M.; Mueller-Wickop, N.: *Towards Auditors’ Preferences on Documentation Formats in Business Process Audits*. Modellierung 2014. Vienna, Austria, 2014.
- [SMN12] Schultz, M.; Mueller-Wickop, N.; Nuettgens, M.: Key Information Requirements for Process Audits – an Expert Perspective. Proceedings of the 5th International Workshop on Enterprise Modelling and Information Systems Architectures (EMISA). Vienna, Austria, 2012; pp. 137–150.
- [SR14] Schultz, M.; Radloff, M.: Modeling Concepts for Internal Controls in Business Processes – An Empirically Grounded Extension of BPMN. In (Sadiq, S.; Soffer, P.; Völzer, H. eds): *Business Process Management*. Springer International Publishing, Cham, 2014; pp. 184–199.
- [STA05] Scheer, A.-W.; Thomas, O.; Adam, O.: *Process modeling using event-driven process chains*. *Process-Aware Information Systems: Bridging People and Software Through Process Technology*. Wiley Publishing, 2005; pp. 119–146.
- [SV05] Seel, C.; Vanderhaeghen, D.: Meta-Model based Extensions of the EPC for Interorganisational Process Modelling. In (Nüttgens, M.; Rump, F.J. eds): *Proceedings 4th GI-Workshop EPK 2005 - Geschäftsprozessmanagement*. 2005; pp. 117–136.