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Rafika Thabet, Elyes Lamine, Amine Boufaied, Dominik Bork, Ouajdi KORBAA

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Rafika Thabet
Toulouse University, INPT, rafika.thabet@gmail.com

Elyes Lamine
University of Toulouse, IMT Mines Albi, elyes.lamine@univ-jfc.fr

Amine Boufaied
University of Sousse, ISITCom, boufaied.amine@gmail.com

Dominik Bork
University of Vienna, Faculty of Computer Science, dominik.bork@univie.ac.at

Ouajdi KORBAA
University of Sousse, ISITCom, ouajdi.korbaa@centraliens-lille.org

See next page for additional authors

Presenter Information

Rafika Thabet, Elyes Lamine, Amine Boufaied, Dominik Bork, Ouajdi KORBAA, and Hervé Pingaud

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Completed Research

Rafika Thabet
University of Sousse, ISITCom, MARS Research Lab, Tunisia
University of Toulouse, INP, CNRS, LGC, Toulouse, France
rafika.thabet@inp-toulouse.fr

Elyes Lamine
University of Toulouse, ISIS, Castres, France
University of Toulouse, IMT Mines, Albi, France
elyes.lamine@univ-jfc.fr

Amine Boufaied
University of Sousse, ISITCom, MARS Research Lab, Tunisia
boufaied.amine@gmail.com

Dominik Bork
University of Vienna, Faculty of Computer Science, Vienna, Austria
dominik.bork@univie.ac.at

Ouajdi Korbaa
University of Sousse, ISITCom, MARS Research Lab, Tunisia
ouajdi.Korbaa@centraliens-lille.org

Hervé Pingaud
University of Toulouse, INP, CNRS, LGC, Toulouse, France
herve.pingaud@univ-jfc.fr

Abstract

Modeling is one of the fundamental aspects of Risk-aware Business Process Management. The conceptualization of new modeling approaches needs to integrate all abstraction layers of risk and business process concepts and requires a highly specialized knowledge in conceptual modeling foundations and formal specification of meta-models. This paper introduces a risk-aware business process modeling approach based on the BPRIM method. In order to comprehensively and unambiguously specify the proposed approach, we revert to the FDMM formalism. Furthermore, a corresponding software prototype called AdoBPRIM has been implemented using the ADOxx meta-modeling platform to assess the technical feasibility of the approach. The usability of the tool has been empirically evaluated and a healthcare process-based example is presented as a proof-of-concept. We show that the AdoBPRIM approach enables Risk-aware Business Process Management with an excellent usability. In summary, this paper constitutes a best-practice for formally specifying, technically implementing, and empirically evaluating modeling method conceptualizations.

Keywords

Modeling Method, Risk-aware Business Process Management, BPRIM, Formalization, ADOxx.

Introduction

Nowadays, risk consideration in business process management is a growing concern since the business environment is becoming more and more competitive, complex, and unpredictable. To face this concern, a paradigm named Risk-aware Business Process Management (R-BPM) has recently emerged. R-BPM has been investigated by several research groups and has launched many challenges. Most of these challenges are concerned with introducing either a pure modeling approach or a pure management approach for R-BPM. Being one of the fundamental aspects of R-BPM, this paper focuses on the second major research line. For supporting the management in R-BPM, tool support becomes inevitable. However, recent research shows, that specifications of modeling approaches often lack formality, resulting in an increased effort for the realization of tooling (Bork et al. 2018, 2020).

According to literature, a considerable proportion of R-BPM modeling approaches do not provide a precise formal specification of meta-models integrating risk and business process concepts. In this context, some formalizations for meta-modeling approaches were introduced such as EMOF (OMG 2011), EMF (McNeill 2008), and KM3 (Jouault and Bézivin 2006). However, these approaches concentrate on the specification of software structures (Fill et al. 2012), which complicates their use in our context. The same holds true for the Object Constraint Language (OCL) (OMG 2014) which focuses on UML in particular (Johannsen and Fill 2015). In contrast, the FDMM (Formalism for Describing ADOxx Meta Models and Models) represents an easy-to-use formalism which enables the formalized specification of meta-models for different application domains without requiring specialized mathematical knowledge apart from set theory and first-order-logic (Fill et al. 2012). Utility of FDMM in formally and precisely specifying ADOxx meta-models and models has been shown in several applications, see e.g., (Fill et al. 2012).

This paper introduces a risk-aware business modeling approach integrating all abstraction layers of risk and business process concepts. The contribution extends our previous works that introduced a management approach called Business Process-Risk management - Integrated Method (BPRIM) (Lamine et al. 2020; Sienou 2009; Thabet et al. 2018, 2020). In this paper, we strengthen the formal foundation and the empirical evaluation of BPRIM by introducing: 1) a precise formal specification of the BPRIM meta-models using FDMM, 2) a free modeling tool using the open meta-modeling platform ADOxx called AdoBPRIM, and 3) an empirical evaluation to assess the usability of AdoBPRIM.

The rest of the paper is structured as follows. First, the theoretical background and a short overview of the related works on R-BPM are introduced. In the following section, the main steps of the modeling approach conceptualization are presented. Afterwards, an evaluation of the usability of the AdoBPRIM modeling tool is given. In the following section, a case study from the healthcare domain illustrates the application of the modeling approach. Finally, the paper is closed with a conclusion and some directions for future work.

Background and Related Work

In this section, we introduce the necessary theoretical foundations of modeling method and the FDMM formalism before giving a brief synopsis of the relevant R-BPM literature.

Modeling Method Concept

According to (Karagiannis and Kühn 2002), a comprehensive modeling method comprises three main components: (1) a modeling *language*, which forms the core building block of a modeling method, which itself consists of syntactic elements (abstract syntax), their graphical representation (concrete syntax or notation), and their meaning (semantics), (2) a *modeling procedure*, which describes the steps applying the modeling language to create valid models, and (3) *mechanisms & algorithms*, which provide functionalities (e.g., simulation, transformation) to use and evaluate models.

FDMM Formalism

In order to comprehensively and unambiguously specify a modeling method, e.g., to support software developers in realizing a modeling tool, conventional specification techniques like meta-models need to be enriched with more formal approaches in order to derive a comprehensive and precise specification (Bork et al. 2018, 2020). In the following, we introduce the core concepts of the FDMM formalism as described in (Fill et al. 2012).

Equation (1) specifies the basic constituents of a meta-model MM which comprises model types MT[1], an ordering relation $\leq$ and $domain, range,$ and $cardinality$ functions.

$$MM = \langle MT, \leq, domain, range, card \rangle \quad (1)$$

Where MT is the set of all model types:

[1] A model type refers to the technical realization of a diagram in ADOxx.

$$MT = \{MT_1, MT_2, \ldots, MT_m\} \quad (2)$$

Each model type MT_i is then specified by the object types O^T representing object types and relation types, data types D^T, and attributes A:

$$MT_i = \langle O_i^T,\ D_i^T,\ A_i \rangle \quad (3)$$

The relation ≤ orders object types according to their inheritance. For example, $o_1^t \leq o_2^t$ can be interpreted as such: o_1^t is a subset of o_2^t, i.e., o_1^t is inheriting from o_2^t.

The domain function (Equation 4) enables the specification of a mapping between attributes and the power set of object types. It is furthermore particularly used for the specification of relation type endpoints and for inter-model-references (INTERREFs in short).

$$domain : A \rightarrow P\left(\bigcup_j O_j^T\right) \quad (4)$$

The range function maps an attribute to the power set of all pairs of object types and model types, all data types, and all model types. It furthermore enables the specification of allowed attribute values.

$$range : A \rightarrow P\left(\bigcup_j \left(O_j^T \times \{MT_j\}\right) \cup D^T \cup MT\right) \quad (5)$$

The cardinality function $card$ further constrains how many instances of a certain attribute the value can have. This enables e.g., the specification of an enumeration of attribute values.

$$card : O^T \times A \rightarrow P(N_0 \times (N_0 \cup \{\infty\})) \quad (6)$$

Current R-BPM approaches

For several years, researchers aim for integrating the two traditionally separated fields of risk management and business process management into a common concept referred to as Risk-aware Business Process Management (R-BPM) (Neiger et al. 2006; Suriadi et al. 2014). R-BPM promotes risks consideration in all stages of Business Process Management (BPM) and enables robust and efficient process management within an uncertain environment. The importance of this integration has been confirmed by the research community (Lamine et al. 2020; Neiger et al. 2006; Suriadi et al. 2014) and by industry guidelines (Coso 2004). Furthermore, this integration is a strategic objective of the European Network and Information Security Agency and the European Commission in ICT Trust and Security (Varela-Vaca 2016).

(Altuhhov et al. 2013) propose an extension of the Business Process Model and Notation (BPMN) standard for the IS Security Risk Management. Their approach expresses assets, risks, and risk treatment regarding asset confidentiality, integrity and availability in one BPMN-extended model. Their proposal allows to design security requirements to secure important assets defined through business processes. (Bock and Frank 2016) propose RiskM, a modeling method for IT risks which is based on the Multi-Perspective Enterprise Modeling method (MEMO). RiskM allows to model processes, IT assets, strategies, and goals. High-level requirements and key concepts of RiskM are also defined and implemented. (Varela-Vaca 2016) proposes OPBUS (OPtimization of BUsiness process Security), a risk-aware framework for security-quality requirements in business processes management. OPBUS focuses on including security issues from design to execution stage of the BPM lifecycle. A tool supporting the OPBUS framework is proposed.

All presented approaches either don't formally specify requirements or don't comprehensively define meta-models integrating risk and business process concepts. Furthermore, few of them propose a supporting modeling tool and neither provide an empirical tool evaluation.

Consequently, this paper addresses the identified shortcomings by introducing a modeling approach integrating all abstraction layers of risk and business process concepts. For this purpose, instead of starting from scratch, we build our contribution on top of our previous works on BPRIM. In these works, we introduced an integrated management approach, called Business Process-Risk management - Integrated Method (BPRIM) (Lamine et al. 2020; Thabet et al. 2018, 2020). BPRIM focusses on how risk management should be considered during the business process management lifecycle. BPRIM suggests an integrative approach with three components: (a) a conceptual unification of risk and business process based on the coupling between the ISO/DIS 19440 conceptual model and a new conceptual model for risk, (b) a common modeling language of risk and business process extending the Event-driven Process Chains (EPC) notation, and (c) a synchronized lifecycle of business process design and risk management. Considering information exchanged between the stages of the lifecycle, a set of diagrams was identified (e.g. Process Landscape, Organizational chart, Context, Business Process (BP), Risk Taxonomy, Risk-Extended BP, Risk Analysis, Risk, Risks Relationship, Risks Treatment and Risks Mapping).

Conceptualization Procedure of the AdoBPRIM Modeling Approach

This paper follows a five-step procedure (as presented in Figure 1) which is based on the generic Design Science Research paradigm (Von Alan et al. 2004). The procedure comprises steps to purposefully conduct the conceptualization of a modeling approach integrating all abstraction layers of risk and business process concepts. The steps of the procedure enable smooth transitions from informal requirements toward semi-formal definition (e.g., meta-models) toward formal (e.g., FDMM) specification to implementation of a modeling tool.

In a first step, AdoBPRIM requirements are defined. Afterwards, the meta-model based on the BPRIM method is represented by a UML class diagram. In a third step, the meta-model is formalized using the FDMM formalism to prepare the ground for its implementation as a modeling tool using the ADOxx meta-modeling platform. Finally, the modeling tool is subject to evaluation to assess its validity. In the following sections, each step of the procedure will be explained in greater detail.

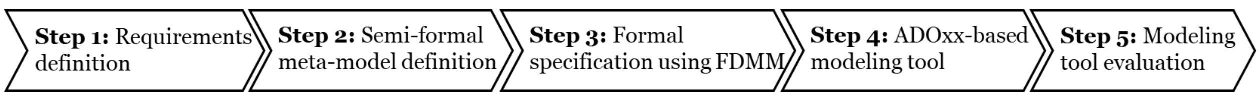


Figure 1. Conceptualization procedure of the AdoBPRIM modeling approach

Step1: Requirements definition

A proper understanding of the system under study requirements has a high impact in the successful development of software products (Alencar et al. 2009).In a first step of our procedure, requirements to conceptualize the AdoBPRIM modeling tool are defined along the modeling method components defined by (Karagiannis and Kühn 2002). In total, five high-level requirements were defined (see Table 1). First, the modeling approach should support the modeling language and manage the diagrams provided by the BPRIM management method (Rq1). Second, the modeling approach should support all stages of the BPRIM lifecycle (Rq2). Third, the modeling approach should provide the diagrams functionalities, e.g., "High understandability", "learnability" and "autonomy", and "Flexible handling" (Rq3 and Rq4). Additionally, each diagram is supposed to generate a particular result which is meant to be taken up and further processed by other diagrams (Rq5).

Requirements (Rq)	**Description**
Rq1: Manageable set of BPRIM diagrams using the BPRIM modeling language	AdoBPRIM support the BPRIM modeling language and should provide a set of BPRIM diagrams.
Rq2: Support of all stages of the BPRIM lifecycle	The modeling approach should consider all stages of the BPRIM lifecycle.
Rq3: High understandability, learnability and autonomy of BPRIM diagrams	The diagrams provided by AdoBPRIM must be easy to learn and directly usable, without extra training.
Rq4: Flexible handling	The diagrams should be adaptable for specific user groups.
Rq5: Successive sequencing of diagrams	A clear order of diagrams should be given by the modeling tool.

Table 1. Requirements toward the conceptualization of the AdoBPRIM modeling approach

Step2: Semi-formal meta-model definition

In a second step of our procedure, the semi-formal meta-model of the BPRIM modeling language is represented by a UML class diagram (see Figure 2-(a)). The latter has a semi-formal nature, i.e., it lacks formal specifications (Bork and Fill 2014). With this representation, it is not ensured that all details are specified unambiguously and all information is consistent, which is necessary for a subsequent technical implementation.

Step3: Formal specification using FDMM

In a third step, a formal specification of the BPRIM meta-model is defined using the FDMM formalism. This will enable a more direct and unproblematic implementation of the meta-model on the ADOxx platform. The formal specification covers only certain aspects of BPRIM in order to illustrate the feasibility and benefit of using FDMM. We selected five core diagrams of the BPRIM meta-model and some attributes that play a central role in the integration of the different diagrams.

Equation (7) specifies the basic constituents of the AdoBPRIM meta-model:

$$MM_{AdoBPRIM} = \langle MT_{AdoBPRIM}, \leq, domain, range, card \rangle \tag{7}$$

As outlined in previous section, AdoBPRIM is composed of a large number of diagrams that are all tightly interconnected. Each diagram is realized as a model type in ADOxx. Equation (8) specifies that AdoBPRIM comprises the model types Business Process diagram MT_{BP}, Risk Taxonomy diagram MT_{RT}, Risk-extended Business Process diagram MT_{R-BP}, Risk Analysis diagram MT_{RA}, and Risk diagram MT_{R} :

$$MT_{AdoBPRIM} = \{MT_{BP},\ MT_{RT},\ MT_{R-BP},\ MT_{RA},\ MT_{R}\} \tag{8}$$

In the following, we will further constrain our focus by exemplifying the FDMM-based specification of the Risk-extended Business Process diagram MT_{R-BP}.

$$MT_{R-EPC} = \langle O^{T}_{R-BP},\ D^{T}_{R-BP},\ A_{R-BP} \rangle \tag{9}$$

The available object types of MT_{R-BP} *are specified as shown in Equation (10):*

$$O^{T}_{R-BP} = \left\{ \begin{matrix} Activity, Resource, Product, Event, Risk, Process\ Interface, Operational\ Role, \\ Performance\ Indicator, Capability, Objective, Risk\ Factor, Risk\ Situation, influences, \\ activates, supports, affects, assigned\_to, leads\_to, has\_Input, has\_Output, evaluated\_by \end{matrix} \right\} \tag{10}$$

Next, we define the data types for MT_{R-BP} by:

$$D^{T}_{R-BP} = \{String, Integer, Enum_{L}, Enum_{S},\ Expression, InterRef\} \tag{11}$$

Thereby, the Enumerations $Enum_{L}$ and $Enum_{S}$ are used to represent the ADOxx enumeration attribute types for the Likelihood (Equation12) and the Severity (Equation 13) of a Risk with pre-defined values, respectively.

$$Enum_{L} = \left\{ \begin{matrix} \text{L0. Not defined, L1. Very improbable, L2. Very unlikely, L3. Unlikely,} \\ \text{L4. Possible/Likely, L5. Very likely tocertan} \end{matrix} \right\} \tag{12}$$

$$Enum_{S} = \{\text{S0. Not defined, S1. Minor, S2. Significant, S3. Major, S4. Critical, S5. Catastrophic}\} \tag{13}$$

The set of attributes for the object types are then specified as follows:

$$A_{R-BP} = \left\{ \begin{matrix} Name, Id, Risk\_Ref, Process\_Interface\_Ref, Type, Likelihood, Severity, \\ criticality, Risk\_Ref\_MT, Risk\_Ref\_Obj \end{matrix} \right\} \tag{14}$$

Finally, we can conclude the formal specification by adding domain, range, and cardinality definitions for the attributes. Again, we selected some of the attributes and object types defined above to illustrate this. Equation (15) specifies domain, range, and cardinality for the attribute $Likelihood$ of the object types $Risk$, $Risk\ Factor$, and $Risk\ Situation$. Equation (15) also shows, how the enumeration $Enum_{L}$ specified in Equation (12) is used for specifying the range of the Likelihood.

$$domain\ (Likelihood) = \{Risk, RiskFactor, RiskSituation\}$$
$$range\ (Likelihood) = \{Enum_L\}$$
$$card\ (Risk, Likelihood) = \langle 1,1 \rangle$$
$$card\ (RiskFactor, Likelihood) = \langle 1,1 \rangle$$
$$card\ (RiskSituation, Likelihood) = \langle 1,1 \rangle \tag{15}$$

Similarly, Equation (16) shows the specification of the $Severity$ attribute which uses the enumeration $Enum_S$ as specified in Equation (13).

$$\text{domain}\ (Severity) = \{Risk\}$$
$$range\ (Severity) = \{Enum_S\}$$
$$card\ (Risk, Severity) = \langle 1,1 \rangle \tag{16}$$

Step4: ADOxx-based Modeling Tool

In a fourth step, the AdoBPRIM modeling tool is realized respecting requirements (Rq1-5). We have chosen the ADOxx meta-modeling platform (ADOxx.org 2020). ADOxx is a multi-user platform that provides a repository based on a relational database for meta-models and models. To introduce meta-models to ADOxx, no advanced knowledge of a programming language is required - in contrast to the use of e.g., EMF which requires a deep knowledge of the Java programming language. In addition, the ADOxx platform provides functionality which facilitates the management of models in the created modeling tool. For instance, ADOxx provides components and modules to analyze, simulate, and evaluate models. Besides, ADOxx has been widely used in industry and academia. In the past twenty years, tool support for more than 50 domain-specific modeling languages has been successfully realized with ADOxx (see (Karagiannis et al. 2016) for an overview).

The upper left side of Figure 2 shows the conceptual architecture of ADOxx-based tool development which comprises models on four abstraction levels: On the highest level, the ADOxx Meta^2 Model introduces generic concepts like modeling and relation class, and attribute. The ADOxx Meta Model instantiates these generic concepts to provide two abstract modeling languages, one for graph-based dynamic structures and one for hierarchical static structures. As an AdoBPRIM tool developer one then instantiates from this ADOxx meta-model in order to introduce his/her specific meta-model, in our case the BPRIM meta-model - excerpts are visualized in Figure 2-(a). Afterwards, the tool environment is set-up for AdoBPRIM tool users to create AdoBPRIM models.

Step5: Modeling Tool Evaluation

Finally, the usability of the AdoBPRIM modeling tool was empirically evaluated. According to literature, usability can be conceived as the "ease-of-use" of a software product and its ability to be applied for the intended purpose (Bevan 1995). Therefore, a, experiment was conducted with 20 students of the fourth year undergraduate studies at the university of the first author. All students were attending a course dealing with the fundamentals of business process management. The material of the experiment was based on a case study that was designed against the background of the Medication Use Process (MUP) of a patient within a healthcare facility. In the following, first the case study will be shortly introduced before the results of the evaluation will be presented.

A Use Case for the AdoBPRIM Modeling Tool

According to (Vest et al. 2019), the Medication Use Process can be defined as "the fundamental system that provides the basis for safe medication use within the healthcare environment". Thus, ensuring medications are used and secured in the most appropriate manner and across all settings. MUP consists of a complex and multidisciplinary process, involving numerous practitioners and four major steps: (i) prescribing/transcribing - entering and processing prescriptions for patient care; (ii) dispensing - preparing medications from a prescription for patient; (iii) administration -- administering and documenting administration of a medication; and (iv) monitoring - monitoring patients for adverse events and therapeutic effectiveness.

The complexity of this process causes an occurrence risk of Medication Errors (ME), which can involve serious clinical consequences on the patients. Indeed, in 2015, the French National Authority for Health (FNAH) (HAS 2013) considers that 40% of the serious adverse events are of medication origin. For this reason, the safety of this process is in the heart of the concerns of the guardianships and the healthcare facilities (HAS 2013). Indeed, this process safety needs in particular the implementation of a risk management approach. Therefore, we suggest studying the potential of the BPRIM management approach and the AdoBPRIM modeling tool to manage the ME risks related to Medication use process.

Figure 2 illustrates some instantiated diagrams using our modeling tool for the management of the ME risks related to the MUP. We present, in Figure 2-(b), the ME risks taxonomy by using the Risk taxonomy diagram. The MUP extended to ME risks is presented in Figure 2-(c) using the Business Process diagram extended to risks. For each ME risk related to the MUP a corresponding risk analysis diagram must be created. In Figure 2- (d), we have taken the Overdosage risk as an example and we have described its corresponding analysis diagram. At diagram's level, some specific algorithms are available for checking validity of the diagram, qualitatively analyzing and evaluating the modeled risk. These analysis and evaluation algorithms are specific to our application domain of the Medication Use Process exposed to risk of ME. Figure 2-(e) presents a two-dimensional risk matrix showing the criticality level of each analyzed MEs risk.

Evaluation results

To collect the users' perceptions of the usability of the tool, the SUMI (Software Usability Measurement Inventory) questionnaire was used (Kirakowski and Corbett 1993). The SUMI questionnaire was developed by the Human Factors Research Group (HFRG) at the University College Cork and is an established approach for testing software usability (Mansor et al. 2012). The questionnaire builds on 50 standardized items that allow assessing the satisfaction of software users according to the scales "efficiency", "affect", "helpfulness", "control", and "learnability". Additionally, a "global scale" provides a single construct for the "perceived quality of use" building on 25 selected items providing information on a software's general usability. The major strength of the SUMI approach is that a normative database (comprising approx. 150 software applications) is used for analyzing and interpreting the results gained by applying the SUMI questionnaire (Sauro and Lewis 2016).

In the experiment, the students were handed out the case study together with the SUMI questionnaire to rate the perceived usability of the modeling tool. As SUMI requires the users to have some experience with the tool to be evaluated, the students attending the experiment also received an introduction to the prototype. The questionnaires were anonymized to mitigate participants' concerns about negative consequences resulting from a poor rating of the tool. The data from the questionnaires was entered into the SUMI online form and the results of the usability study were made available by the HFRG. A summary of the results is given in Figure 3.

Following the SUMI database, the global usability of a software has an average value of "50" considering a normal distribution whereas the standard deviation is "10" and the maximum score amounts to "74" (Kirakowski and Corbett 1993). It turned out that all scales of AdoBPRIM were above average and thus a positive quality perception from the user side could be confirmed. This suggested that the participants judged the tool to be helpful for working on the case study (efficiency) and largely self-explanatory (helpfulness). In that context, a large majority of the participants stated that they would recommend the software. Users generally felt to be in control of the software (control). According to the feedback received, the software did not behave in an unexpected manner when working on the case study. Users' emotional reaction to the software was average (affect). However, the participants agreed that there was a lot of reading to be done before they were actually able to work with the tool. All in all, the usability study provided promising results. The global usability of the tool was perceived to be above average and its ability to support users in risk-aware business process modeling was confirmed.

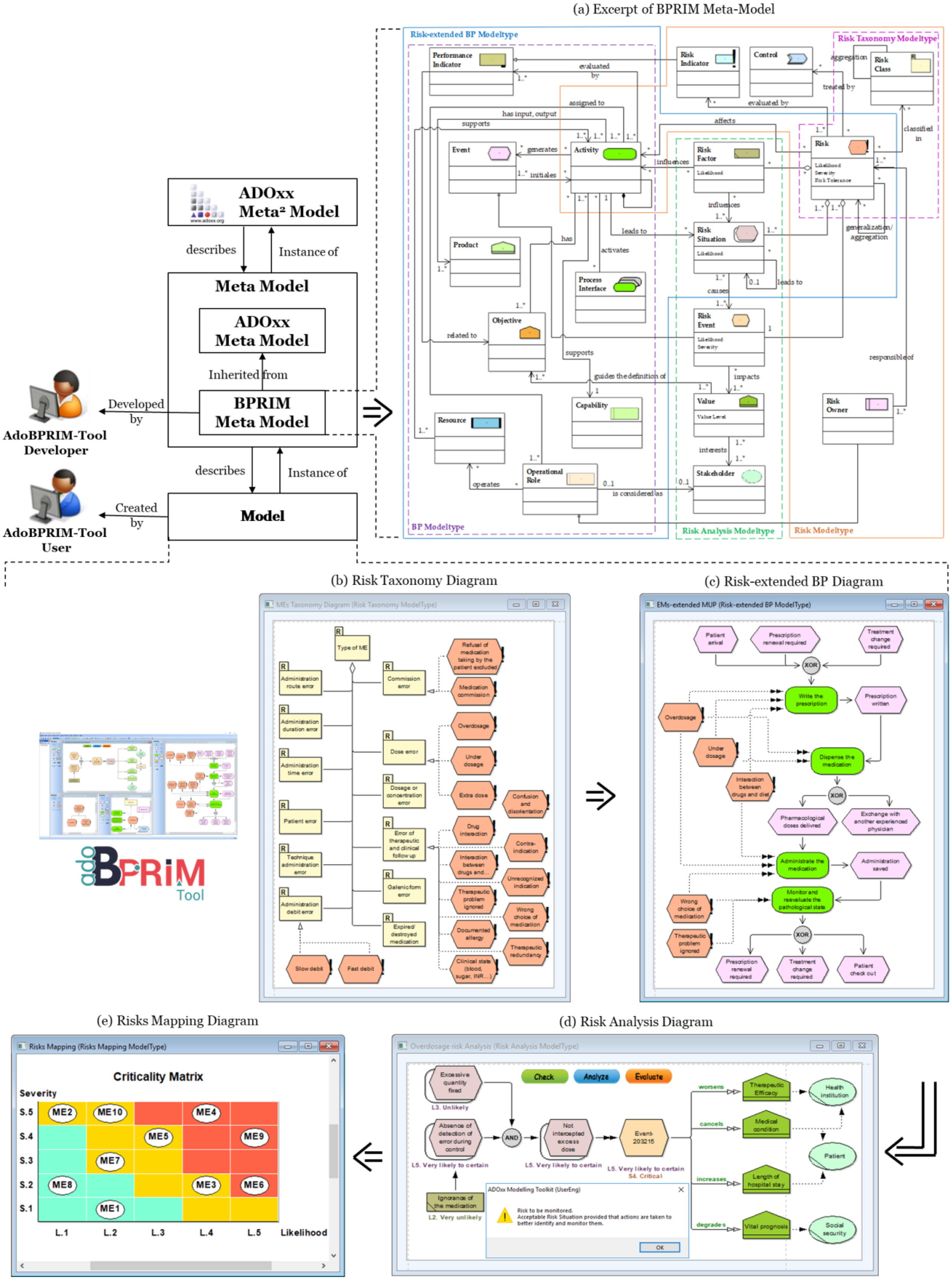
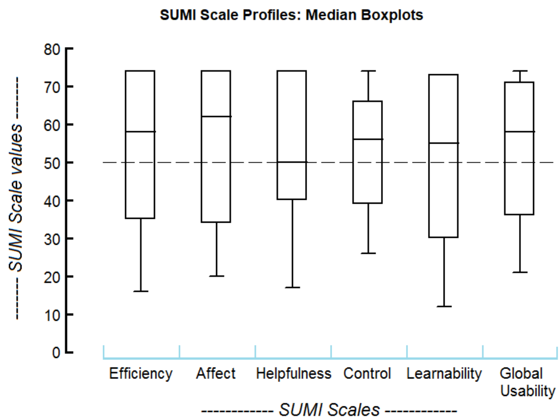


Figure 2. Overview of the AdoBPRIM modeling approach

Potentials for improvement were also provided from the experiment, in particular, integration of additional functionalities for risk management. In that context, some participants stated that they would like to have in the software more risk assessment methods to analyze and evaluate the impact of risks on business process activities and to have more intuitive risks mapping methods to evaluate risks criticality over time. To overcome these shortcomings, we are currently working on a new version of AdoBPRIM, which will integrate new mechanisms and algorithms for risk assessment and mapping.



Summary Statistics

SUMI Scales	**Mean**	**St Dev**	**Median**	**Min**	**Max**
Global Usability	52.72	18.51	58.5	21	74
Efficiency	52.94	20.52	58.0	16	74
Affect	55.06	20.41	62.5	20	74
Helpfulness	53.61	18.05	50.0	17	74
Control	53.39	14.58	56.5	26	74
Learnability	51.06	21.60	55.0	12	73

Figure 3. Results summary of the AdoBPRIM usability study according to the SUMI scales

Conclusion

The integration of BPM and risk management disciplines is an innovative research topic that has launched many challenges in the BPM field. This research aims to address some of the challenges by introducing an open risk-aware business process modeling approach based on our management approach, the Business Process-Risk management - Integrated Method (BPRIM) (Lamine et al. 2020). To derive a comprehensive and precise specification of the approach, we revert to the FDMM formalism. The dedicated modeling tool, called AdoBPRIM, is then realized using the ADOxx meta-modelling platform. The modeling tool is available through a project within the Open Models Laboratory (Karagiannis et al. 2016), a worldwide community of modelers and modeling method developers. Finally, the evaluation results show the relevance of the AdoBPRIM modeling tool and verify the validity and the correct formulation of the constructs and the diagrams proposed in the BPRIM management approach. All this motivates us to pursue the improvement of our modeling approach by integrating additional mechanisms and algorithms, expanding the number of users, and studying the potential of applying AdoBPRIM in healthcare processes in our future research.

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