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AN APPROACH FOR ANALYZING THE EFFECTS OF RISKS ON BUSINESS PROCESSES USING SEMANTIC ANNOTATIONS

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Abstract

The management of risks has gained a lot of attention in the last years. Among the current challenges in this domain are the integration of risk management in the strategic planning and performance management across business units and organizational structures, the assessment of a company's risk bearing capacity, and the improvement of the methods of risk measurement. In order to support the elicitation of risks in business processes, measure their impact on a company's return and provide reports for regulatory authorities, it can be reverted to technology-oriented knowledge management. In this context we propose an approach that uses semantically annotated models to represent the influence of risks on business activities based on the concepts provided by a risk knowledge base. By transferring the annotated model information to the knowledge base, inference rules can be applied to analyze the effects of risks on the business processes during subsequent capacity simulations. For a first evaluation the approach has been implemented using the ADOxx meta modeling platform, the Protégé ontology management toolkit and the Jess rule engine. Finally, the use of the implementation is shortly illustrated by reverting to a sample business process from the domain of banking.

Keywords: Risk management, Conceptual modeling, Semantic annotation, Knowledge elicitation.

1 Introduction

According to a biennial survey of executives by Accenture, risk management is today not only regarded as a necessity to comply with regulations but is increasingly viewed as a source of competitive advantage (Accenture, 2011). This view is supported by the academic literature that relates these advantages to an increased risk awareness to facilitate better strategic and operational decision making, the realization of synergies through an integrated management of risks as well as improved information about a firm's risk profile for all stakeholders (Hoyt and Liebenberg, 2011). In order to enhance risk management practices, Alhawari et al. recently proposed to apply concepts from the area of knowledge management to facilitate the identification of risks, their analysis, examination and evaluation, the planning of responses, and the support for the handling and monitoring of risks (Alhawari et al., 2011). In particular the aspect of examining and evaluating risks using explicit organizational knowledge will be taken up in the following.

In this paper we therefore focus on the support of risk management using concepts from technology-oriented knowledge management, where the explicit modeling of computer-understandable knowledge has been traditionally considered as an important stream within knowledge management (cf. Maier, 2004 p.214ff). For this purpose we first revert to approaches from the area of business process-related risk management where a number of approaches have been developed for modeling process-specific knowledge. These include the representation and handling of risks in process modeling languages e.g. (Zur Muehlen and Rosemann, 2005; Lambert et al., 2006; Strecker et al., 2011), the analysis of process-related risks using simulations e.g. (Jallow et al., 2007; Tjoa et al., 2011) and the use of semantic schemata for describing threats to process resources (Ekelhart et al., 2009). What is missing so far is the contribution of such process-related risk approaches to the generation of data for the corporate-wide measurement of an organization's risk and return position in a flexible and organization-specific way (Faisst and Buhl, 2005; Fill et al., 2007). Such measurements are however essential to determine the overall risk profile of an organization and support corresponding decisions on the strategic and operational level through quantitative figures. The knowledge contained in the processes and the according risk representations thus has to be processed in a way that permits the provision of such data. In addition, the application of risk-oriented process modeling languages so far requires either the re-creation of existing models in the new language or presupposes the use of a specific type of modeling language. Due to thousands of models that are already stored in some organizations' repositories in various modeling languages cf. (Rosemann, 2006), it is thus necessary to develop a more flexible approach that can be applied to existing models and does not depend on a specific modeling language.

The approach we will present in the following takes up this challenge by using semantic annotations of business process and organizational models for representing risks. In this way, information about risks from either existing generic or organization-specific risk knowledge bases can be assigned and made machine-processable without the need to modify an existing modeling language. Through the transfer of this annotated information and the application of inference rules, it can then be specified how the occurrence of risks modifies the behavior of a business process in terms of the properties of its activities and the availability of its resources. Through the execution of the rules, these modifications can be applied to the business process and organization models. Finally, the modified models can be fed into an existing capacity simulation algorithm to create the data for measuring the effects of the process-related risks on the return and risk position of a particular business segment.

The remainder of the paper is structured as follows: In section 2 we will review related approaches from the areas of business process-related risk management and semantic annotation of business processes to lay the foundations for our approach. Section 3 describes how the semantic annotations of business process and organizational models are realized using a meta modeling approach as well as the structure of the underlying ontology and the necessary rules. In section 4 the implementation of the approach is illustrated by using the ADOxx meta modeling platform, the Protégé ontology management toolkit and the Jess rule engine. It is then applied to a use case from the domain of banking for a first evaluation of its feasibility.

2 Related Work

In the following we will provide an overview of existing approaches in the areas of process-related risk management, semantic annotations for business process models as well as applications of semantic annotations and semantic technologies for process-related risk management.

One of the first sources that discusses the integration of risk aspects in business process models is the work by (Zur Muehlen and Rosemann, 2005). They propose the extension of event driven process chains (EPCs) with risk aspects and the addition of three specific risk model types. For the extension of EPCs they attach risk elements to functions which are detailed by the following model types: a risk structure model to define hierarchical relationships between risks, a risk goal model to determine the impact of risks on business goals, and a risk state model to define the causal relationships between risks and their consequences. A similar approach for extending EPCs is taken by (Rieke and Winkelmann, 2008) who define an additional set of constructs for representing risks and their handling within the boundaries of an EPC model. The integration of risk aspects has also been discussed for other common process modeling languages: (Lambert et al., 2006) present extensions for the integrated definition of function (IDEF) modeling language to describe risk sources in a business process and (Karagiannis et al., 2007) and (Fill et al., 2007) describe extensions of Adonis business process models to relate risks and controls, respectively to depict the influence of risks on certain attributes in business process activities.

Apart from extensions of process modeling languages also new modeling languages have been designed that specifically focus on the representation and handling of risks in business processes. In this context (Sienou et al., 2008) describe a risk modeling method to realize a multi-layer integration of business process and risk management. For this purpose they define a modeling language based on a unified meta model, an integrated lifecycle and a set of rules. Another particular risk modeling method has been proposed recently by (Strecker et al., 2011) for the purpose of IT risk assessment. Their approach is based on the Multi-Perspective Enterprise Modeling Method (MEMO). In this way their newly created risk modeling language RiskML references business process, software, goal, cost, organizational and information system concepts in existing MEMO meta models. In addition to the risk modeling language they describe a risk process model to support the three risk assessment phases of risk identification, risk analysis and risk prioritization. A general reference model for reducing the complexity of the relationships between business processes, IT applications and IT infrastructure, vulnerabilities and threats has been proposed by (Sackmann, 2008). This reference model is meant as a basis for the formal modeling of relations between the causes of IT risks and their effects on the business processes and a company's returns. These relations are then formally expressed by four matrices.

For the actual calculation of the impacts of risks on business processes it is typically reverted to simulations. This is necessary as the distribution of the probability and impact of risks is usually uncertain and either has to be estimated based on existing data about past incidents or through expert judgment (Denk and Exner-Merkelt, 2005, p.195). In the approach described by (Jallow et al., 2007) expert judgments for the probability of risk factors and cost impacts on business process activities are used. Thereby, experts are required to specify a probability figure for each factor and a lower, medium and upper limit of a triangular distribution for the according impact. These figures are then used for a Monte-Carlo simulation that generates forecast and sensitivity charts of the expected cost impact for the process. However, the control flow of the process is not considered in their approach. A similar approach for risk-aware business process analysis is described by (Tjoa et al., 2011). As a basis for their simulation algorithm they define a formal model that represents business process elements, the behavior and effects of threats and safeguards, the availability and integrity of an activity's attributes and the relation between the attributes of activities and resources. Again, the control flow of the process is not considered in these models.

Semantic annotations of process models can today be regarded as state-of-the-art in the academic literature on process modeling. Among the large number of approaches that have been elaborated for this purpose are: the semantic reverse engineering for analyzing productive ERP systems (Celino et al., 2007; Oppitz et al., 2009), semantic model comparisons (Ehrig et al., 2007), semantic validations to determine the semantic consistency of tasks and during process executions (Weber et al., 2008; Ly et al., 2009), the support of cross-organizational business processes and interoperability (Höfferer, 2007) or the dynamic binding of web services to processes during process execution (Stein et al., 2009). In addition, a number of semantic schemata have been made available that can be applied using annotations. These include ontologies for the representation of key performance indicators (Wetzstein et al., 2008), the Core Ontology for Business Process Analysis (COBRA) (Pedrinaci et al., 2008), the business process management ontology (BPMO) (Jenz&Partner, 2006) or the business process ontology (BPO) by (Markovic and Pereira, 2007). Although these schemata provide guidance on the formal representation of business process concepts, they currently do not contain risk management related concepts.

More specifically, in the context of risk management semantic annotations have been used to check the compliance of business processes with legal regulations. For this purpose Governatori et al. reverted to temporal logic statements to annotate a business process and then check whether certain compliance rules are fulfilled (Governatori et al. 2008). Namiri and Stojanovic presented a formal rule-based approach for expressing control strategies for risks during the execution of business processes and thus enable compliance checking (Namiri and Stojanovic, 2007). In (Ly et al., 2009) the use of semantic constraints for compliance checking is made available both for the design time and the run time of business processes. Another approach that also links business processes and semantic schemata is described by (Ekelhart et al., 2009) in the domain of information security risk management. In this work a toolkit is presented that permits to gain an integrated view on business process models and concepts from a common security risk ontology. Thereby security threats can be linked to the elements of a process.

Summarizing these findings it can be stated that the following research results have been achieved: representation of risks in various business process modeling languages; specific modeling languages for representing risks and their handling; simulation of impacts on business process activities; semantic annotation of business processes; and the checking of semantic rules and constraints for business processes. Despite the substantial contribution of these approaches to process-related risk management and semantic analyses, several aspects have not been considered so far: this includes the availability of an approach for representing risks in process models that can be used for different modeling languages; the integration of such an approach with an organization-specific and consistent definition of risk parameters in a machine-processable format; and the generation of risk and return data from process models including their control flow to contribute to the measurement of a company's overall risk profile.

3 Representing and Analyzing Risks in Business Processes Using Semantic Annotations

In this section we introduce our novel approach for representing risks in business process and organization models using semantic annotations. These annotations will establish the basis for determining the impact of risks on a particular business segment based on a capacity simulation.

In figure 1 the conceptual foundations of the approach are depicted: The starting points are an existing business process and an organization model that characterize a business segment. It is assumed that these two models contain all necessary information to apply standard capacity simulation algorithms[1].

[1] For a detailed discussion of the algorithms for capacity simulations we refer the interested reader to (Herbst et al., 1997).

This includes in particular (Herbst et al., 1997): the control flow and the information flow of a business process, temporal attributes for all process activities such as waiting, execution, resting and transport times, cost attributes, the mapping of activities to actors and resources in the organizational model, the quantification of the number of processes in a given time period, and the distributions for the probabilities of all branches. Based on a given quantity of process executions per time period, a capacity simulation typically generates estimates for the occurrence of activities, the overall execution time and the required resources for this time period. From this the expected return of the process and the variance of the returns, i.e. the risk in a financial sense can be derived based on the occurrence of return-generating activities, e.g. the actual selling of a product.

The models are then used as input for the annotation with concepts from a risk knowledge base. The risk knowledge base contains information about the conceptual structure of risks, the specification of distributions for the impact and probabilities of risks and instances of risks including the concrete impact and probability estimates and affected process or resource attributes. The information about the risks can thus be stored separately from the information about the processes and the organizational structure and offers a consistent representation of the risks throughout an organization or even between different organizations. The annotation links elements in the business process and organization model to concrete instances of risks. Thereby it will for example be expressed that an activity "Check customer data using IT-system A" is affected by the risk "Failure of IT system A" that is an instance of an "IT failure risk" and has - in the context of the considered organization - an annual estimated probability of 0.01 and can be characterized by a normally distributed impact value on the execution time with a mean value of 20 minutes and a variance of 5 minutes.

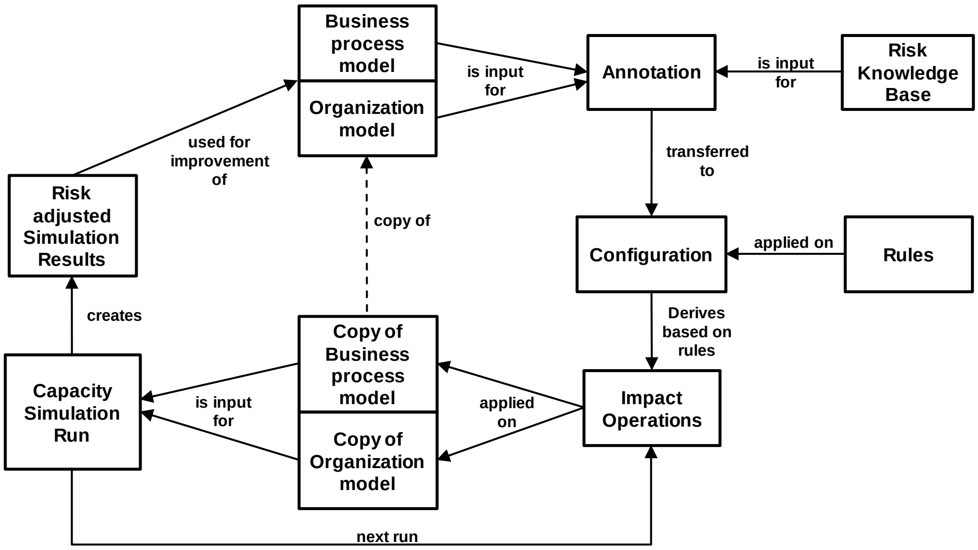

Figure 1: Conceptual relationships of the approach

The information expressed by the annotations is then transferred into a "configuration": Thereby data about the annotated elements and the risks is made available in a machine-processable format that permits the application of inference rules - we will illustrate in detail below how this is achieved. In order to determine the effects of the assigned risks on the contents of the business process and organization model, a number of antecedent-consequent rules are added to determine which and how certain types of risks affect the contents of the models. The output of these rules is a set of impact operations that conduct the actual modifications of the models. Following the example from above, such a rule could state that "for every instance of an IT failure risk that affects the execution time, the execution time of the annotated element is extended with the given probability for an impact value which is determined by a random value drawn from the given normal distribution". The impact operations, i.e. the consequents of the rules, are then applied on copies of the original business process and organizational models. In this way the necessary data for the execution of the simulation are provided. After the execution of the first run of the simulation, the impact operations are again applied on the original values to create a new set of random values for the distributions. This cycle is repeated until the simulation produces stable results that are used to determine the expected return and variance for the particular business process. In this way a *risk-adjusted capacity simulation* can be realized.

In order to make the approach universally applicable for different modeling languages we use a meta modeling approach for the semantic annotations that has been developed in the course of the SeMFIS project (Fill, 2011). The core idea of this approach is to provide two model types for representing semantic annotations and elements of an ontology. Ontologies in this context are viewed as shared, computer-usable definitions of the common words, concepts and relations among them, which are used to describe and represent an area of knowledge (Obrst, 2003). Through the integration of the annotation and the ontology information in a common modeling environment, a user centered design with a single point of entry user interface for the annotations can be easily realized (Fill, 2011). This is regarded as essential for a successful use of annotations in the context of knowledge management as all analyses can be conducted in a uniform way by accessing the models cf. (Uren et al., 2006).

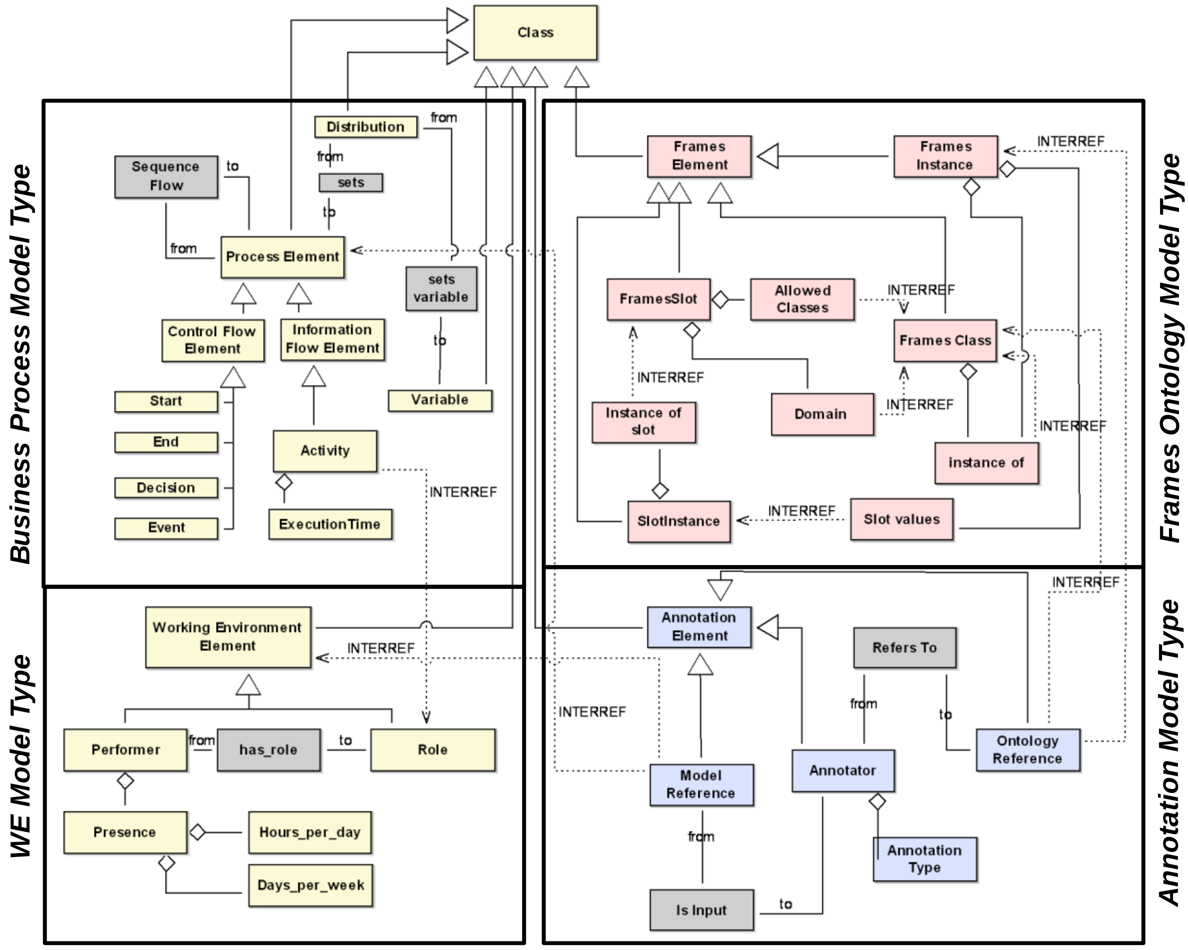

Figure 2: Excerpt of the Meta Model Used for the Annotation Approach

For our purposes we chose the Protégé frames ontology implementation of the OKBC Knowledge Model as described in (Wang et al., 2006) for the definition of the ontology meta model. The advantage of this type of ontology, in contrast for example to OWL, is that it is based on the unique-name assumption, i.e. if two objects have different names they are assumed to be different, and the closed-world-assumption, i.e. for all information a specific template has to be specified and everything is prohibited until it is permitted (Wang et al., 2006). This greatly simplifies the entering of data: for example for the specification of a hierarchy of risk types, it is inherently assumed that all entered types are different from each other and need not be explicitly defined as being disjoint. In addition, powerful implementations both for handling frames ontologies using the Protégé ontology management toolkit and for applying rules on these ontologies via the Jess rule engine are available (Eriksson, 2003).

Figure 2 illustrates the core relationships between business process, organization, semantic annotation and frames ontology models in detail: As an example we selected the Adonis business process modeling language that provides a business process model type – shown in the top left corner – and an organization model – denoted as working environment model shown in the bottom left corner. However, also another business process modeling language that is capable of supporting simulations could be used. For the realization of the annotations the semantic annotation model type is added – as shown in the bottom right corner. It references elements in the business process and working environment model types and elements in the frames ontology model type – as shown in the upper right corner.

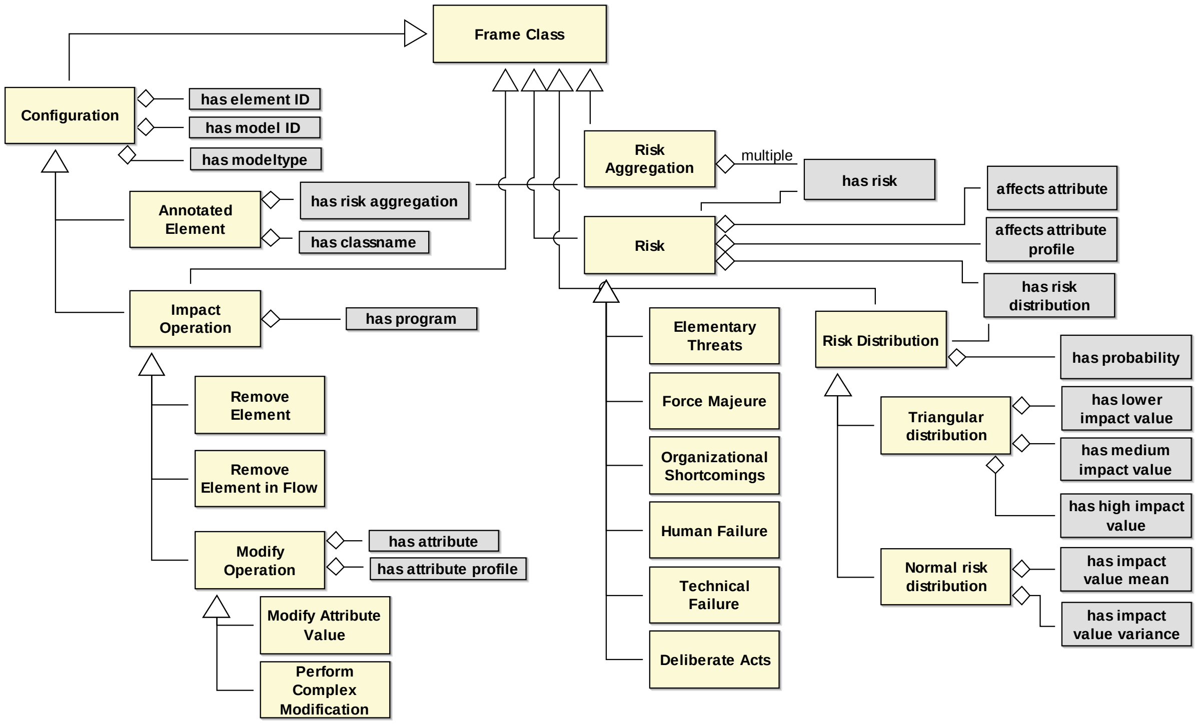

Figure 3: Overview of the Used Frames Ontology Showing its Classes and Slots

For the realization of the risk knowledge base and the specification of configurations we set up a frames ontology as shown in figure 3. Thereby the risk knowledge base is integrated as follows: For the representation of risks we re-used an existing classification that has been successfully applied both in science and industry (Sackmann, 2008). It originates from the so-called "IT-Grundschutz catalogue", which is a document that is provided by the German Federal Office for Information Security (BSI, 2011). This catalogue defines the five basic risk categories "elementary threats", "force majeure", "organizational shortcomings", "human failure", "technical failure", and "deliberate acts". This classification thus establishes a generic way for classifying the different types of risks in the knowledge base. We then added concepts for specifying the risk distributions and the probability of occurrence. Following the approach by (Jallow, 2007) we use a single value for specifying the probability and multiple parameters for distributions for specifying the impact of a risk. Currently, two types of distributions are available: a triangular distribution, which is commonly used in risk management due to easy representation of expert estimates, and a normal distribution that is typically used if detailed data about previous incidents is available cf. (Denk and Exner-Merkelt, 2005). To combine several single types of risks, a risk aggregation concept is available that links to the annotated elements of the configuration. The aggregation thus does not affect the computation or impact of risks but is used for an easier annotation of an element with several risks by a risk analyst or operations manager.

On the side of the configuration part of the ontology, concepts are available to represent the annotated elements and their links to the risk aggregation as well as the impact operations. For the definition of impact operations three sub-types are available: the “remove element” type stands for operations that completely remove an element during a simulation run, the “remove element in flow” type denotes operations that remove an element but re-assign the surrounding connectors to the remaining elements if possible, and the “modify operation” type provides again two sub-types for the modification of attribute values or more complex operations. Each impact operation inherits the attributes of the configuration for determining the affected element as well as a “has program” attribute that specifies the actual operations in the programming or scripting language used to modify the models.

Based on these ontology concepts, the contents of the annotation model are transferred to the ontology and represented as instances of the “annotated element” class. Subsequently, rules can be specified that lead to the generation of instances of the “impact operation” class. An example for an outline of such a rule that creates impact operations for all technical failure risks would then be:

```
Annotated_Element(?x) ∧ has_element_ID (?x, ?e) ∧ Risk_Aggregation(?y)
∧ has_risk_aggregation(?x,?y) ∧ Risk(?z) ∧ has_risk(?y, ?z) ∧
∧ is-a(?z, Technical_Failure) ∧ Triangular_Risk_Distribution(?v) ∧
has_lower_impact_value(?v, ?low) ∧ ...
⇒
Perform_Complex_Modification(?i) ∧ has_program(?i, "TRIANGULAR_MOD " +
"elementID:" + ?e + " low:" + ?low ...)
```

Thereby, the content of the “has_program” slot refers to a function in a scripting language that modifies the element with the specified ID by using the given values for a triangular distribution. After performing the modifications the simulation run can be started.

4 Implementation and Application to a Use Case in Banking

The approach has been implemented by using the following frameworks and technologies. The meta models were implemented on the ADOxx[2] meta modeling platform as it is provided by the Open Models Initiative[3]. This allowed us to easily generate according model editors and re-use the simulation capabilities of the platform for simulating business processes and organizational models (Herbst et al., 1997). In addition, we used the ADOscript language that offers a large variety of functionalities for handling and manipulating information contained in the ADOxx based models. As a basis for the application of rules, we used the Protégé API to represent frames ontologies. By adding the JessTab API (Eriksson, 2003), a link to the Jess rule engine was established that we used for executing the rules on the frames ontologies. For mediating between ADOscript and Protégé we used the Java programming language to define according interfaces.

With these technologies the following operations can be conducted to exchange information as shown in figure 4. Starting from a given business process and working environment model that are available on the ADOxx platform, a new instance of a particular risk and an aggregation are created in the frames ontology model “Risk ontology” that also contains all concepts of the ontology shown in figure 3. In the next step an annotation with this risk aggregation is created by using an annotation model. With this information available on the ADOxx platform, the export and risk processing can be initialized. This is conducted by the Mediator component that transfers the annotation information into the risk ontology model and requests the frames data. The retrieved data is then transformed into a Protégé frames project from where the data is mapped to a Jess knowledge base by using the JessTab API. Next, the Mediator instantiates a pre-defined rule set in JessTab and then sends the execution com-

[2] ADOxx is a registered trademark of BOC AG.
[3] See http://www.openmodels.at for further details last access 26-03-2012.

mand so that the rules are executed in Jess on the knowledge base. Jess creates the new instances of the impact operations in the ontology from where the mediator collects it. Finally, the Mediator performs the impact operations on the models together with the simulation runs. In our implementation the impact operations are realized as ADOscript procedures that receive the details about the distribution of the risk impact, the probability, the affected element and the affected attribute of the element. By executing these procedures, a random value based on the given distribution is calculated and the modification of the referenced attribute value is performed.

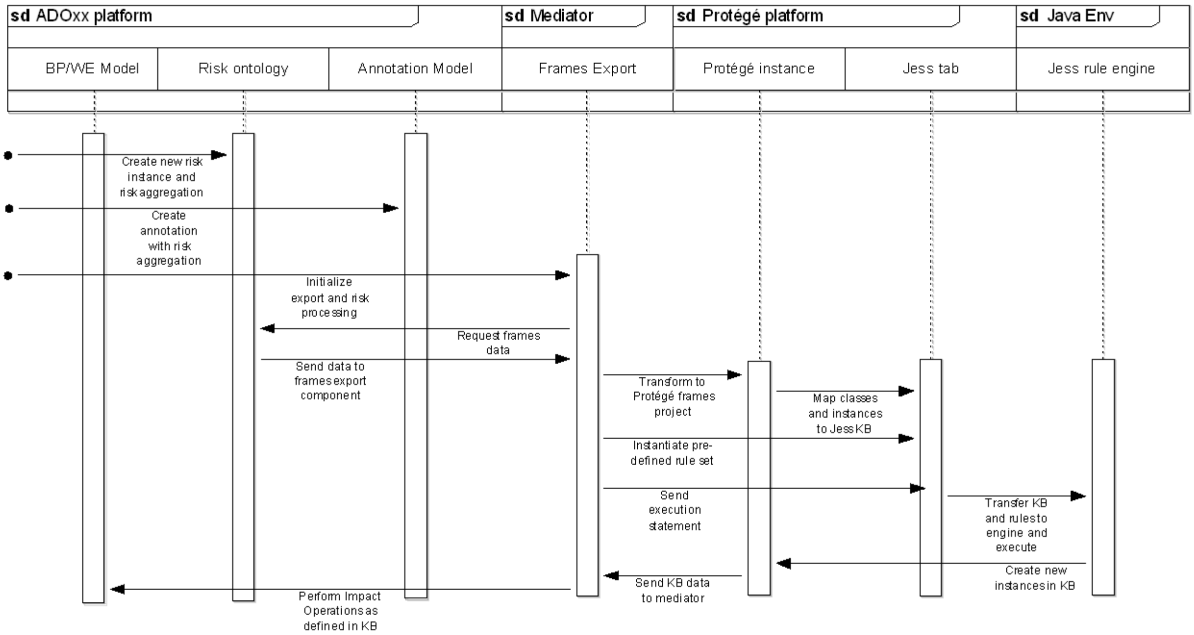

Figure 4: Exchange of Information between the Different Components

Thus, as soon as the meditator has received all derived impact operations from the knowledge base, copies of the models are created. Then, the impact operations are applied and a first run of an ADOxx capacity simulation is started with a given quantity of process executions by using an ADOscript call. Next, the mediator resets the values of the copied models and performs again the impact operations followed by the simulation call. This cycle is repeated in the standard setting for 1000 times to generate useful simulation results but can be adapted based on the complexity of the underlying models and the complexity of the involved risk annotations. In the current implementation the sensitivity and stability of the simulation results are not evaluated for determining the number of simulation runs. It is planned to add this for a future version.

In order to evaluate the feasibility of the approach by using a concrete example, we used the description of an account opening business process of a bank[4]. We complemented it with additional data where necessary, together with a simple working environment model to provide all necessary data for conducting a capacity simulation on ADOxx. We then modeled the process using the described meta models. During the opening of an account, the Finstar system of the bank has to be accessed to create the customer profile – see figure 5. For representing the risks of a server breakdown and a failure of the air condition in the server room, we created an instance of a technical failure risk in the frames ontology model and added the parameters for a triangular risk distribution to affect the execution time of an activity. Both risk instances were then assigned to a risk aggregation which was in turn used in the annotation model to relate it to the activity “Create new customer profile and enter data in the Finstar

[4] The process we used has been elaborated and published by Gerardo Palmisano for the Hypothekarbank Lenzburg on http://www.lernender.ch - last access 03-11-2011

system". We then defined a Jess rule that creates impact operations for all technical failures and made it available for the Mediator component. Finally, the Mediator component was started with a given process quantity of 100 process executions per month which provided us with the end results of the risk-adjusted capacity simulation in the form of 1000 samples for the expected costs and activity occurrences of the process. From this the expected return and risk of the regarded business segment could be calculated based on the expected occurrence and variance of the activity where all signatures for opening the account are received from the customer, together with the average increased costs due to the extension of the execution time.

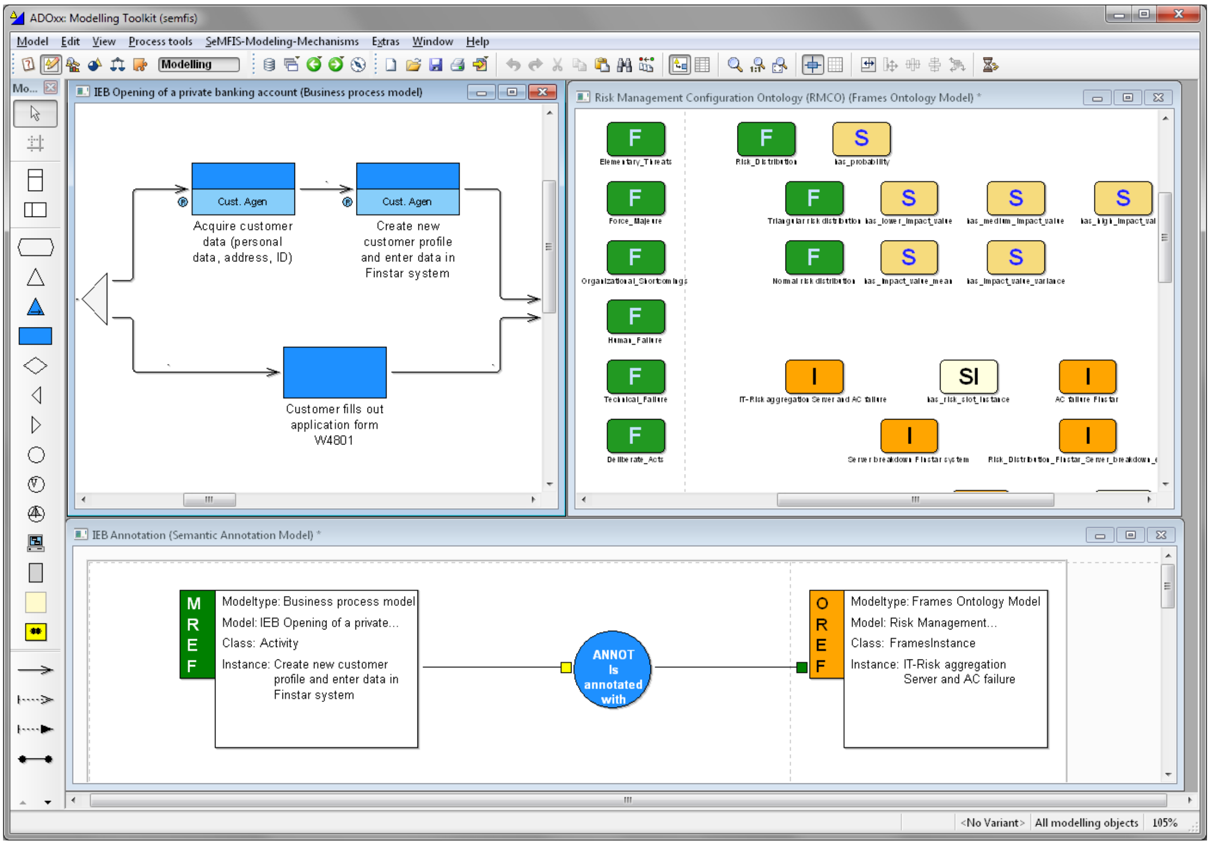

Figure 5: Screenshot of the Account Opening Process Model (upper left), the Frames Ontology Model (upper right) and the Semantic Annotation Model (bottom)

Due to integrated user interface for the business processes, the frames ontology model and the semantic annotation model these tasks could be performed very easily. However, as this is only a first evaluation of the feasibility of the approach, more detailed user studies have to be conducted. This concerns also the suitability of the results of the risk-adjusted simulations for practical purposes as the number of required input data is quite extensive. However, the approach in this form provides a maximum adaptability for analyzing different types of risks based on the flexible definition in the risk knowledge base together with the sets of rules. At the same time it provides a linkage of process-related risks with the risk profile of a particular business segment due to generation of concrete risk and return figures.

5 Conclusion and Outlook

In this paper we have shown how semantic annotation of conceptual business process and organizational models can be used to represent process-related risks. It was further shown how this information can be processed and used as input for the risk-adjusted simulation of business processes. It is planned to further evaluate the approach using a detailed practical example, especially to optimize the user interaction and the suitability of the simulation results for industry-level risk management.

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