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A CONCEPTUAL METAMODEL APPROACH TO ANALYSING RISKS IN BUSINESS PROCESS MODELS

[1]HANANE LHANNAOUI, [2]MOHAMMED ISSAM KABBAJ, [3]ZOHRA BAKKOURY

[1]Ph.D Candidate, AMIPS Research Group, Ecole Mohammadia d'Ingénieur,

Mohammed Vth University, Rabat, Morocco

[2, 3] Professors, AMIPS Research Group, Ecole Mohammadia d'Ingénieur,

Mohammed Vth University, Rabat, Morocco

E-mail: [1]lha.hanane@gmail.com,[2]kabbaj@emi.ac.ma, [3]bakkoury@emi.ac.ma

ABSTRACT

Business processes are performing ineffectively due to different risks. Several methods are proposed for the identification and management of risks in business process environments. In this paper, we propose a technique, for analysing risks in business process models, that originates from the safety domain. This approach initiates the improvement of business process models in an early phase of business process lifecycle by translating risk analysis output to design. Moreover, we introduce a conceptual meta-model for our integrated approach. This will describe specific concepts of business related risk analysis and will facilitate the exploitation of risk analysis output for further process improvement.

Keywords: *UML, HAZOP, Risk Analysis, Business Process Models, Design*

1. INTRODUCTION

The uncertain economic times of the past few years have had a major effect on how companies operate these days. Now, companies have a renewed focus: to manage risk. Risk is the main cause of uncertainty in any organization. Thus, companies increasingly focus more on identifying risks and managing them before they even affect the business. Therefore, the knowledge of the risks organizations are facing will give them various options on how to deal with potential problems even before facing them.

This paper discusses this issue. It suggests an integration of business process management and risk management in the modelling phase. Our work recognizes the risk as an important phenomenon that should be considered in the (re)-design of business processes. It introduces an approach that aims to analyse risk business process models in order to incorporate the analysis result (risk controls) in a later phase. Actually, integrating risk analysis in business process modelling has many advantages, including the ability to:

- Emphasize the importance of risk analysis prior and while process modelling;
- Allow early identification of major risks and program consequent adaptation [1];
- Analyse risks and incorporating risk mitigation strategies in business process model during design time [2] and [3];
- Design business process models with high reliability and quality.

The approach proposed in this paper is based on a conceptual integration of risks and processes. We introduce a conceptual meta-model that provides the fundamental concepts for conducting risk analysis for business process models. The aim is to allow the organizations to produce a risk analysis that help them, in the future, to improve business process model through integrating risk controls by design. Our meta-model is the core for a complete methodological process that enables the mitigation of risk by design through a mechanism that permits to evolve from risk analysis output to a redesign proposal [3].

The remainder of this paper is organized as follows: Section 2 describes the business process modelling with Event-driven Process Chain. Section 3 talks about HAZOP a risk analysis technique whose adaptation is used in the current paper while Section 4 outlines the proposed framework for integrating EPC models and risk

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analysis. Section 5 describes our approach for analysing risks in business process models whose meta-model is represented in section 6. Finally, section 7 concludes the paper.

2. BUSINESS PROCESS MODELLING WITH EVENT-DRIVEN PROCESS CHAINS

2.1 EPC

EPCs (Event-driven Process Chain) are a graphical business process description language introduced by Keller, Nuttgens and Scheer in 1992 [4]. It was developed at the Institute for Information Systems of the University of Saarland, Germany, in collaboration with SAP AG. The EPC is a core part of the ARIS-framework and combines different views towards the description of enterprises and information systems in the control view on the conceptual level [5].

EPCs describe processes on the level of their business logic. The name represents the control flow structure of the process as a chain of events and functions. Actually, the EPC describes processes by the use of alternating functions and events as time-referring state changes. Events and Functions are linked by the control flow as directional edges [5].

An event-driven process chain consists of the following elements:

- Functions: The basic building blocks. Functions are active elements used to describe the tasks or activities of a business process that needs to be executed.
- Events: Passive elements used to describe under which circumstances a process (or a function) works or which state a process (or a function) results in (like pre-/post-conditions).
- Logical connectors: They can be used to connect activities and events. This is the way how the flow of control is specified. There are three types of connectors: AND, XOR (exclusive or) and OR.

The extended EPC includes the elements described below:

- The Organization Unit or Role is responsible for performing an activity or function.
- The Information Objects portray input data serving as the basis for a function, or output data produced by a function.
- The deliverables represent results (services or products) functions produce or input functions require.

In this paper, we will use the extended version of EPC as a modelling language for describing business process.

2.2 The EPC Meta-model

The meta-model of the EPC is described in Figure 1. An EPC consists of functions, events, control flow connectors, logical operators, and additional process objects. Each EPC consists of one or more Functions and two or more Events, as an EPC starts and ends with an event and requires at least one function for describing a process. A function can be either an Elementary Function or a Complex Function, and the latter is refined by at least one function. A function is connected with two Control Flow Connectors and has to fulfill at least one Process Goal. A process goal can be refined by one or more sub goals. Control flows link events with functions, but also events or functions with Logical Operators, which can be either an XOR, OR or AND. It is connected at least with 3 control flows, one or more incoming as well as outgoing connectors.

A Deliverable, an Information Object, an Organizational Structure as well as Process Goals are called additional process objects and are connected with functions. All these types of additional process objects are assigned to one or more functions.

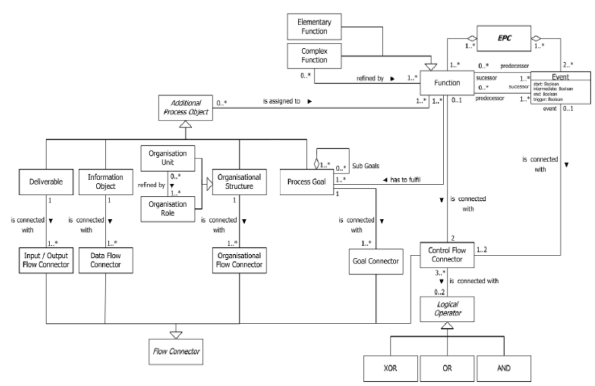

Figure 1: EPC Meta-model

3. ANALYZING RISKS USING HAZOP

3.1 HAZOP

The HAZard and Operability (HAZOP) study was initially developed by the company ICI in 1974 for chemical developing facilities but has later been extended to other types of systems and also to complex operations and to software systems [7]. It is typically conducted by a team consisting of four to eight persons with a detailed knowledge of the analysed system. HAZOP is performed using a set of guidewords and attributes. It is based on a theory

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that assumes risk events are caused by deviations from design or operating intentions.

The purpose of a HAZOP study is to identify what potentially hazardous variations from the design intent could occur in components and in the interactions between components of a system [8]. Consequently, this will permit us to avoid continuing development of designs with potential hazards [8]. The technique uses "guidewords" to promote creative thinking about the ways in which hazardous situations might occur. A guideword is used to express a particular kind of deviation (Table 1).

Table 1: HAZOP Guidewords

Guidewords	Interpretation
No	This is a complete negation of the design intention. No part of the intention is achieved and nothing else happens.
More	This is a quantitative increase.
Less	This is a quantitative increase.
As well as	All the design intention is achieved together with additions.
Part of	Only some of the design intention is achieved.
Reverse	The logical opposite of the intention is achieved.
Other than	Complete substitution, where no part of the original intention is achieved but something quite different happens.
Early	Something happens earlier than expected relative to clock time.
Late	Something happens later than expected relative to clock time.
Before	Something happens before it is expected, relating to order or sequence.
After	Something happens after it is expected, relating to order or sequence.

The International standard BS IEC 61882:2001 itself provides a guide for HAZOP studies of systems utilizing the specific set of guide words previously defined [9]. It also gives guidance on application of the technique and on the HAZOP study procedure, including definition, preparation, examination sessions and resulting documentation and follow-up.

In this paper, we use HAZOP technique for risk analysis since it is:

- A qualitative method. In fact, our approach is based on the study of risk behaviour rather than its appreciation;
- An inductive risk assessment tool, meaning that it is a "bottom-up" risk identification approach where we start from a particular fault to the general effect of the fault;
- Risk-focused. Actually, it concentrates on how the design will cope with abnormal conditions rather on how it will perform under normal conditions;
- Design-oriented because apart from being used for identifying hazards, it proposes recommendations with low-level details on the design.

3.2 HAZOP: A vocabulary for Risk Analysis Modelling

The standard BS IEC 61882:2001 defines terms that characterizes the HAZOP studies as follows itself [9]:

- Characteristic: qualitative or quantitative property of an element
- design intent: designer's desired, or specified range of behaviour for elements and characteristics
- Deviation: departure from the design intent
- Element: constituent of a part which serves to identify the part's essential features

  Elements may depend upon the particular application, but elements can include features such as the material involved, the activity being carried out, the equipment employed, etc.
- Guideword: word or phrase which expresses and defines a specific type of deviation from an element's design intent
- Harm : physical injury or damage to the health of people or damage to property or the environment
- Hazard: potential source of harm
- Part: section of the system which is the subject of immediate study
- Risk: combination of the probability of occurrence of harm and the severity of that harm.

4. AN INTEGRATED FRAMEWORK FOR EPC MODELS AND RISK ANALYSIS

In this section, we first describe our definition of risk and introduce concepts of its environment. Secondly, we provide a vocabulary for risk analysis using an adaptation of HAZOP in business process environment. In synthesis, we unify the two environments for mapping between HAZOP elements on one side and Process and Risk characterizations on the other side.

4.1 HAZOP Adaptation

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This section aims to propose an adaptation of HAZOP for EPC models.
An EPC business process model is composed from a number of elementary fragments. Each fragment can be represented as shown in the figure. The "Function" is the only active element in an EPC fragment.

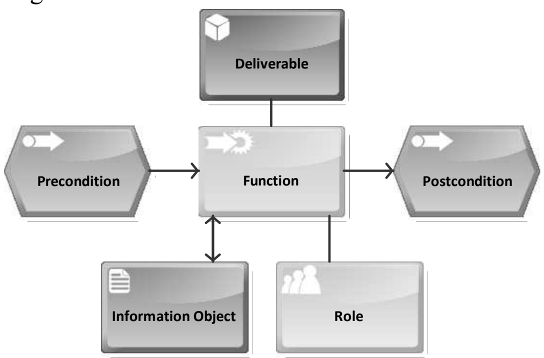

Figure 2: EPC Model Fragment

Accordingly, we simulate, in the following, a function in a business process model to a system whose characteristics are events (precondition and post-condition) and other function's annotations such as the role, the deliverables and Information Objects (Figure 2).
Consequently, any business process model fragment can be considered as a HAZOP part and its EPC elements as HAZOP elements.
We call EPC-based HAZOP the adaptation of HAZOP in business environment. EPC-based HAZOP is based on the re-interpretation of the guidewords of HAZOP in the context of EPC modelling [1], [3] and [11].
The granularity of HAZOP's parts depends on the level of risk. The more the process is risky, the larger the analysed part is. HAZOP is applied on the elements itself [9] or their characteristics.

4.2 A Vocabulary for Risk Modelling

Risk is a concept that is conceived as an Event, a Situation, a metric or a Context [10]. HAZOP defines risk as the "combination of the probability of occurrence of harm and the severity of that harm". This definition is aligned with the majority of research where risk is often characterized by two properties: the frequency and the severity.
In the literature, many concepts are related to risk. Two of them can be coupled with the HAZOP concepts as follows:

- (Risk factor, "Hazard") : Characteristics of the system affecting the probability or the impact of risk;
- (Consequence, "Harm"): it is the damage generated by the risk effect.

4.3 HAZOP Mapping

Through studying the EPC meta-model, we can establish a mapping between the involved elements in EPC-based HAZOP: the risk analysis process and the traditional HAZOP's concepts. The table below summarises the principal elements for this integration.

Table 2: HAZOP, Risk and Modelling Mapping

HAZOP	Process and risk concepts
Characteristic	Event, Role, Deliverables, information objects
Design intent	Process goal
Deviation	----
Element	Function
guide word	---
Harm	Consequence
Hazard	Risk Factor
Part	Process Fragment
Risk	(Probability, Severity) [Harm]

5. A DESIGN-DRIVEN APPROACH FOR ANALYSING RISKS IN BUSINESS PROCESS MODELS

5.1 EPC-Based HAZOP

In this section, we present, in detail, our method that aims to analyse risks in EPC model representing a business process description. Once the EPC model is completed, the EPC-based HAZOP method is applied by selecting model's parts and applying the corresponding guidewords to them.
For that, we propose new definitions of hazard related to guidewords deviations which will suit for applying in the business environment. Table 3 represents then the proposed definitions of the possible deviations that can be detected for the described guidewords and the related parameters.

Once deviations have been identified, possible consequences and causes are analysed. We note that some deviations can be caused by the deviation of other categories ("Characteristics") of elements, such as events, the organization role or unit, the deliverables and the information objects. In those cases, the overall deviation is associated to the function itself and the related characteristics (table 4).

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Table 3: Lists of Deviations

Element	Related parameters	Guideword	Interpretation
Function	Event (Postcondition) , Output (deliverable, Information objects)	Not	The function is not executed and the output is not generated
	Event (Postcondition) , Output (deliverable, Information objects)	More	The function has been executed several times or produced more than intended output
	Event (Postcondition) , Output (deliverable, Information objects)	Less	The function has produced less than the intended output
	Event (Postcondition) , Output (deliverable, Information objects	As well As	The function has generated the intended output but with additional result
	Event (Postcondition) , Output (deliverable, Information objects	Part of	Only part of the intended activity occurs or a part of the output has been generated
	Event(Precondition), Input (Deliverable, Information objects)	Other than	A complete substitution of the activity has been performed
	Event (Precondition)	Early	The function happened earlier than what is intended
	Event(Precondition)	Late	The function happened later than what is intended
	Event(Precondition)	After	The action succeeds something that it should precede
	Event(Precondition)	Before	The action precedes something that it should succeeds

The final outcome of EPC-Based HAZOP analysis consists of a list of recommendations and a list of hazards, together with the possible deviations leading to them. This list of hazards can be linked with a list of risks. In the next section, we propose a new version of the HAZOP output in order to take into account all the variables that are related to business process risks.

Table 4: Correlation of Guidewords and Characteristics

GW	Event		Role	Deliverable		Information objects	
	Precondition	Postcondition		Input	Output	Input	Output
No	+	+	+	+	+	+	+
Less				+	+	+	+
More				+	+	+	+
Part of	+	+		+	+	+	+
As well as		+	+		+		+
Reverse							
Other than		+		+	+	+	+

5.2 EPC-Based HAZOP Analysis Table

In this section, we will introduce EPC-based HAZOP table, an adapted version of HAZOP table (the output of HAZOP) that meets the purpose of our work.

In the literature, Kletz [7] defines 5 principal columns in HAZOP table: guideword, deviation, possible causes, consequences and action required. Other columns can be added to the HAZOP table such as safeguards, comments, responsible for action and severity, which represents a preliminary risk estimation of the impact of the deviation's consequences. We also introduce the severity and frequency which represent respectively, the deviation impact and the occurrence probability of the harm due to it. Those two columns represent the risk valuation.

For the consequences column, generally two levels are represented in the HAZOP table: The use case effect which represents the consequences of the deviation on the HAZOP element and the system effect which associates the deviation to the whole process and gives its effect in the real world. In this paper, we use the term "recommendation" that relates to the new security requirement or the actions required to deal with the related deviation. The recommendation represents changes that should be applied to control risks.

To sum up, the output of the EPC-based HAZOP study is a table with columns for Element, guide word, characteristics (if used), deviation, possible cause, consequence and recommendation for follow-up activities which is composed from action and person responsible.

- Attribute: the EPC element or the characteristic on which the deviation is applied.
- GW: the applied guideword.

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Table 5: EPC-based HAZOP Table

Part :									
Attribute		Guide word	Deviation	Possible causes	Consequences		Severity	Frequency	Recommendation
Element	Characteristic				Use case effect	System effect			

- Description: the deviation resulting from the combination of the attribute and the guideword.
- Causes: possible causes of the deviation that can be resulted from the deviation of any of the parameters predefined.
- Use Case Effect: effect at the use case level.
- System Effect: possible effect in the real world.
- Severity: rating of effect of the worst case scenario.
- Frequency: represents the occurrence probability of the deviation's consequences.
- Recommendation: the actions required to deal with the related deviation.

5.3 Recommendation Structuring

In this work, we adapt for recommendation column the following structuring [3]:

Table 6: Recommendation Structuring

Recommendation					
Re_i	Condition	Action	Responsible	Model element	Recommendation structure
Re_1	Condition (Re_1)	Action (Re_1)	Responsible (Re_1)	Model element in Re_1	Combination of elementary recommendation (Re_i) For example: Re_1 OR ((Re_2 AND Re_3) Then Re_4)
Re_2	Condition (Re_2)	Action (Re_2)	Responsible (Re_2)	Model element in Re_2	
Re_3	Condition (Re_3)	Action (Re_3)	Responsible (Re_3)	Model element in Re_3	
Re_4	Condition (Re_4)	Action (Re_4)	Responsible (Re_4)	Model element in Re_4	

In fact, a recommendation can be elementary or composed from one or more elementary recommendations. Lhannaoui et al. [3] proposes the following written of the composite recommendation using the linking words "or", "and" and "then". That shows the relationships between elementary recommendations;

Concretely, the linking operator "or" is used for scenarios when we have more than one option to treat the risk. For "and", it is used for parallel actions and finally "then" is used to describe a succession of actions. The relationship between elementary recommendations will be expressed using brackets. In case brackets are omitted in the recommendation description, we will use the following operator precedence; "Then" takes precedence over "and" and "and" takes precedence over "or".

A recommendation R can be then written as set of n elementary recommendations Rei, as follows: R=Re1 op1 Re2...Ren where opi is an element that belongs to {"or","and","then"}.

Figure 3: A Composite Recommendation

For each elementary recommendation Rei, lhannaoui et al. distinguishes in [3] four principal elements (Figure 4). Actually, each elementary recommendation has a consequent and a precondition. The precondition is enabled if the deviation occurs. For the consequent, it is defined by the design intent which is the transfer, the mitigation of the consequences impact related to the deviation. The recommendation is also composed, by definition, from the action required to reduce or eliminate the risk and the responsible for this action. Finally, the recommendation may be relating to another element of the process or to the EPC-Based HAZOP attribute itself.

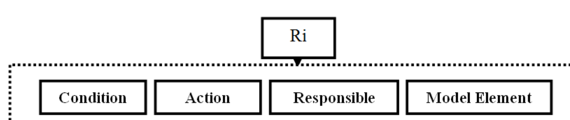

Figure 4: Elementary Recommendation's Composition

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6. A CONCEPTUAL METAMODEL FOR EPC-BASED HAZOP

This paper presents a conceptual method where three disciplines: information modelling, business process modelling and risk analysis (HAZOP) have been combined to investigate improvements of business risk analysis.

In this section, we will use the capabilities of UML in order to capture the dependencies that can affect related risks safety of the model subject to EPC-based HAZOP analysis.

Our main objective here is to get and display the concepts introduced by our method and that can influence the design of the process model. This will help us to automate the exploitation of the results of EPC-based HAZOP and to program consequent adaptations of the design to incorporate risk controls.

We propose to build a meta-model for EPC-based HAZOP as shown in Figure 8.

This meta-model is composed of three interrelated subsystems: (i) the modelled process, (ii) the risk analysis and (iii) the treatment system.

The modelled process

The modelled process is defined as a business process fragment that is affected by a specific risk. The representation of this subsystem as shown in Figure 5 is aligned with the EPC meta-model (Figure 1).

The components have been grouped in the category “Part” which consists of Function, Event or any other Additional process object as described in the EPC meta-model.

To sum up, this package is a true copy of the EPC meta-model with an indication of the relationship between the modelled system and the other packages.

The risk analysis

Figure 6 describes the second part of the meta-model. It shows a representation of risk analysis by EPC-based HAZOP with a focus on the different characteristics of risk as defined in the integrated framework described in Section 4.

A part is composed from elements and potentially characteristics which are related to the element itself. It can have a normal behaviour or may depart from its design. This is called a deviation.

A deviation results from a hazardous situation that can be caused by a specific hazard. This deviation from design or operating intentions leads to the concretization of risk.

Each situation results in damage (Consequence) which can lead to an effect on the system or the use case.

The treatment systems

In order to deal with risks, it is necessary to define a treatment system which aims to drive the situation to a normal and handled state.

ISO/DIS 31000: 2009 [6] enumerates four major categories:

- Avoidance: eliminate the probability of a specific risk before its occurrence;
- Mitigation: reduce the probability of a risk and/or the impact that an occurrence of the risk may bear;
- Transfer: move the impact of a risk (if it occurs) to an external party;
- Acceptance: To accept the consequences (impact) of a risk if it occurs.

Figure 7 describes the whole treatment system in our framework which includes:

- Risk treatment strategy with its four policies: Transfer, Avoidance, Acceptance and mitigation;
- Treatment Action which is related to the Recommendation in the EPC-based HAZOP. Recommendation is either elementary or composite. This latter is composed from a set of elementary recommendation linked with the operators (“Or”, “And” and “Then”) as described previously. Each elementary recommendation is composed from the four elements: Condition, Action, responsible and process element.

7. CONCLUSION AND FUTURE WORK

In order to improve business process, appropriate analysis methods are needed. Effectively, carrying out an appropriate risk analysis in an early phase of the process lifecycle can lead to a review of the business process model.

This paper introduces an integrated approach that combines the strength of risk analysis techniques and business process modelling. This framework is design-oriented and will be considered as a baseline for business process improvement in a post step. Focused on design aspects, our risk analysis methodology is able to generate outcome with elements that permit to improve business process models. Our approach can be used as a foundation for proposing changes in business process which will emphasize the quality and reliability of business process.

Currently, we further investigate on tool for supporting the analysis of the business process risks. In parallel, we are working on the extending of our approach by proposing mechanisms that permit the incorporation of the risk analysis output in business process models in order to improve their reliability.

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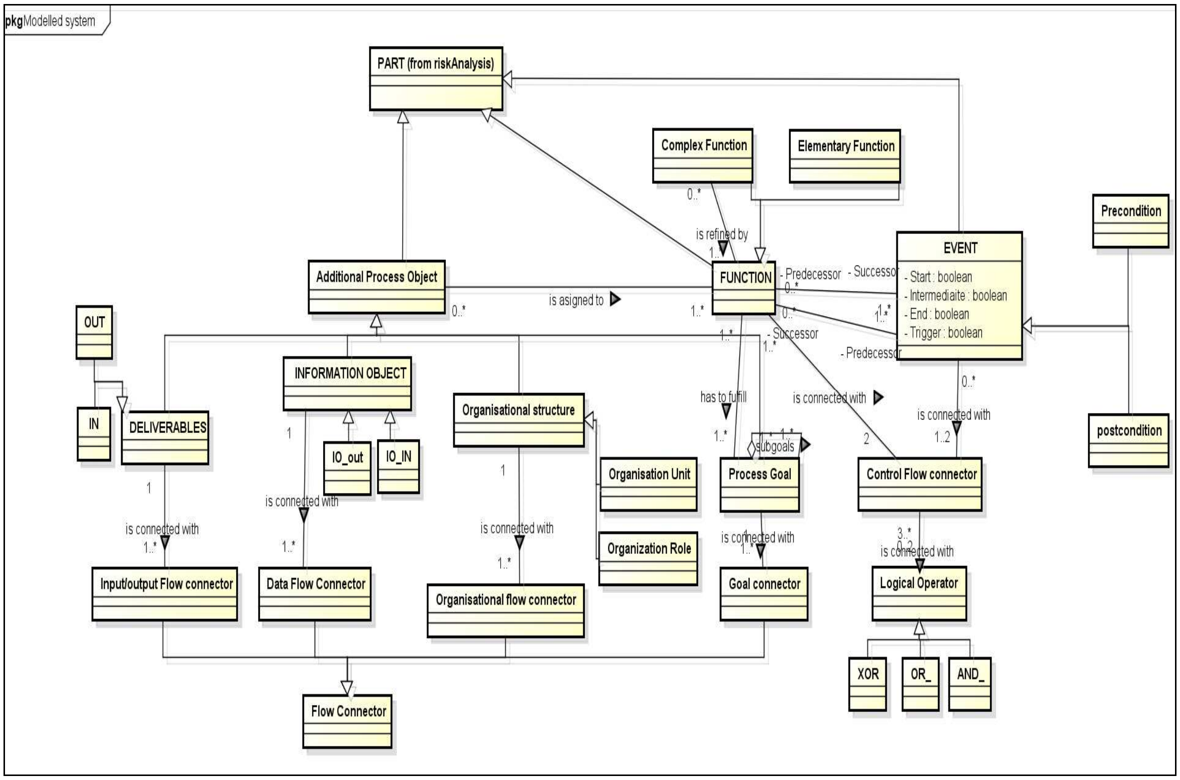

Figure 5: Modelled System

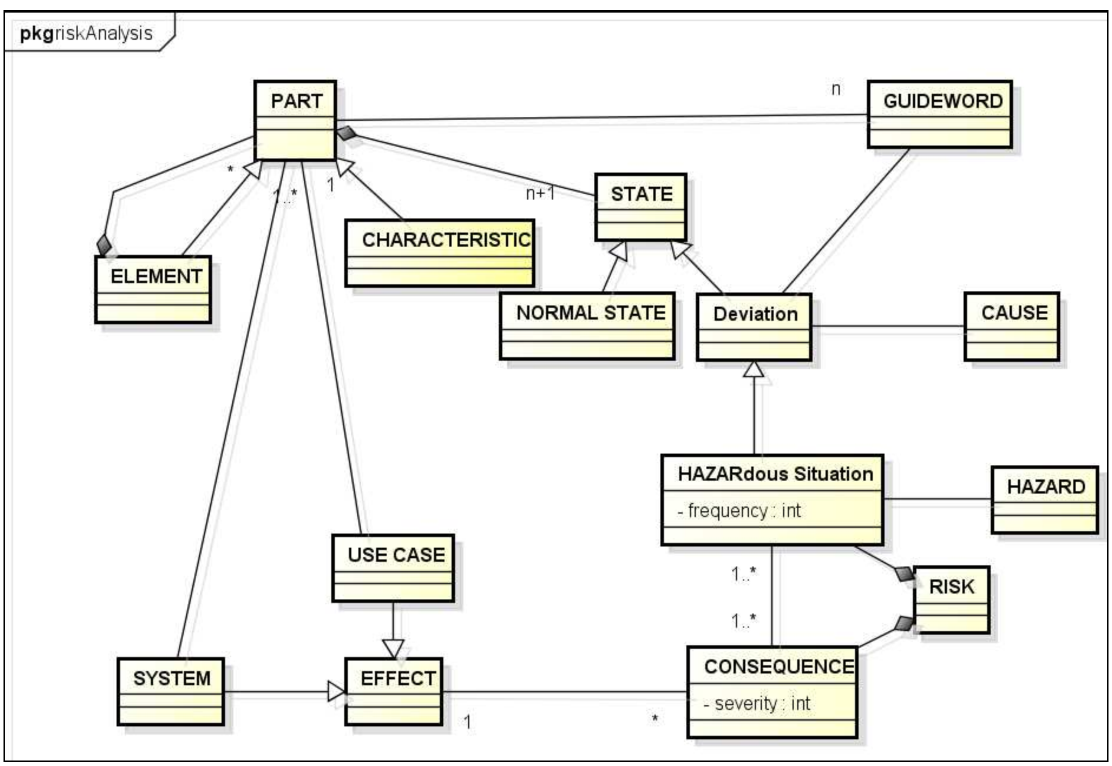

Figure 6: Risk Analysis Package

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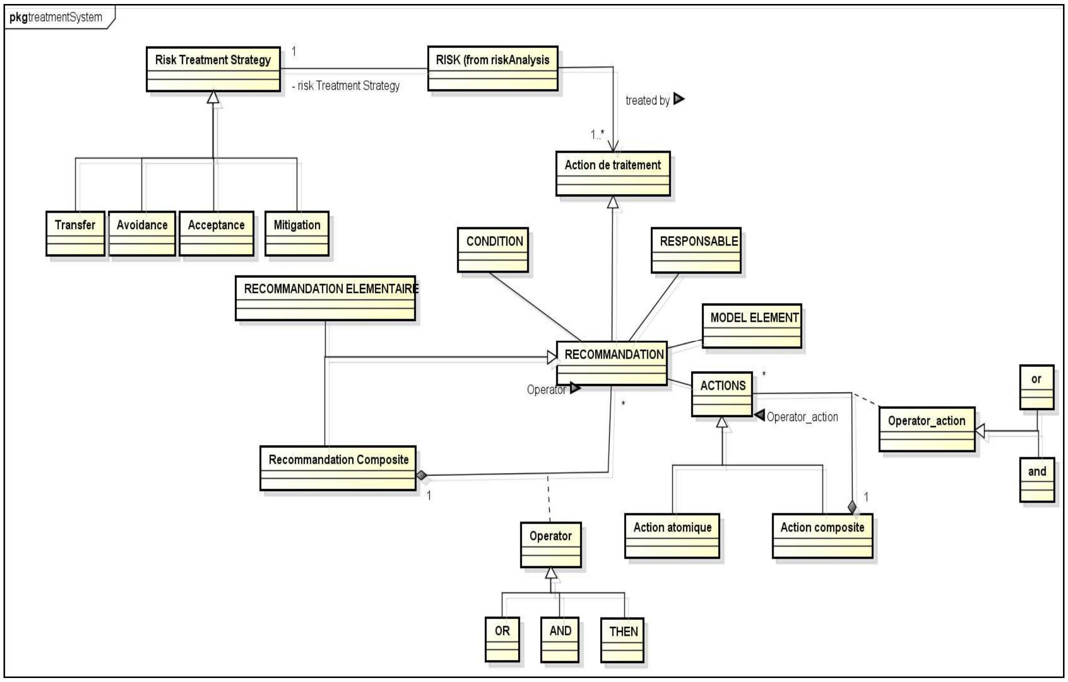

Figure 7: Risk Treatment System

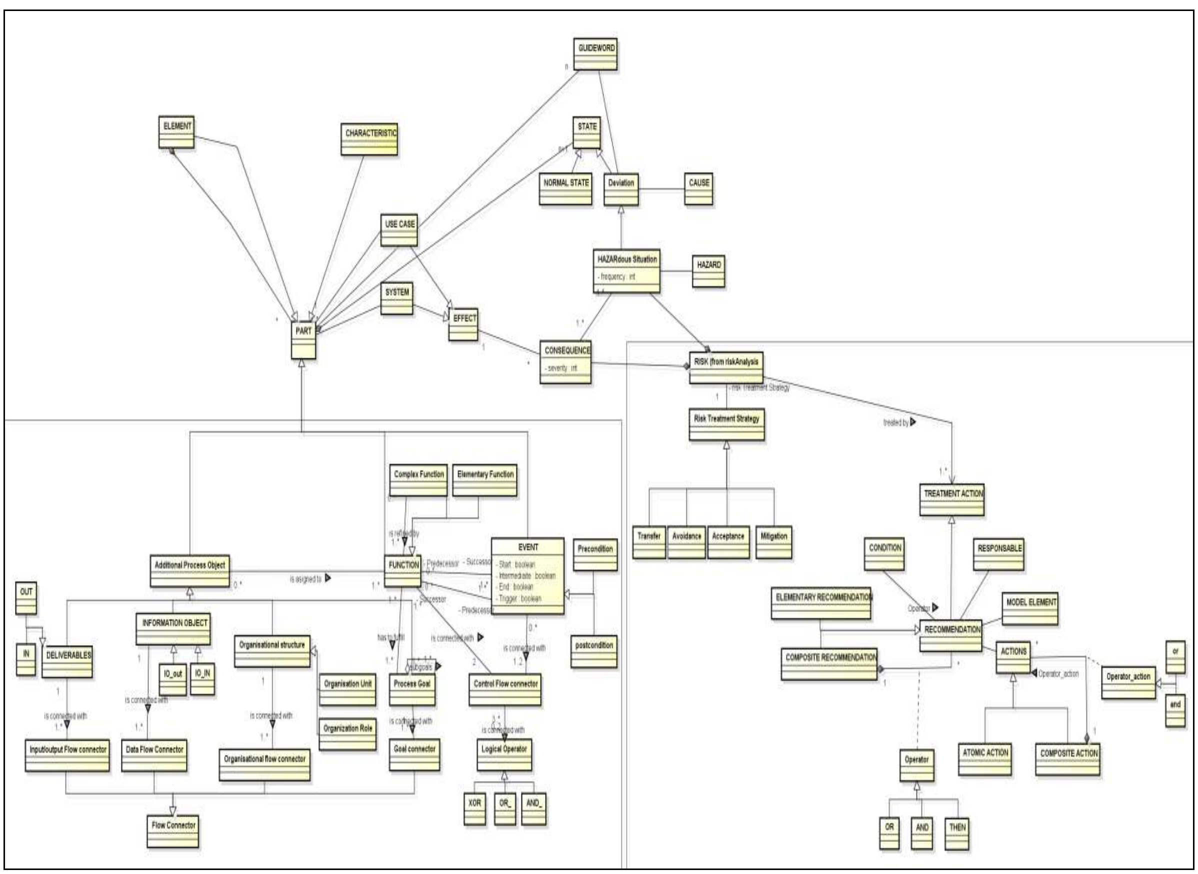

Figure 8: Our Integrated Approach Meta-model