An Ontology for the Identification of the most Appropriate Risk Management Methodology

Silvia Ansaldi[1], Marina Monti[2], Patrizia Agnello[1], and Franca Giannini[2]

[1] INAIL - Centro Ricerche - Via Fontana Candida, 1 - 00040 Monte Porzio Catone (Roma)
{s.ansaldi,p.agnello}@inail.it
[2] CNR - IMATI , Via De Marini, 6 – 16149 Genova
{marina.monti,franca.giannini}@ge.imati.cnr.it

Abstract. Methods and technologies for risk management have been developed and consolidated over time in different sectors and to meet various needs. Recently, ISO organization published a set of documents for risk assessment. These guidelines are not specific to a particular sector, but can be undertaken by any public or private organization and can be applied to any type of risk. This paper presents a research work that aims to realize a knowledge-base for the development of a tool to support the identification of the most appropriate risk management methodology according to the specific characteristics of an organization.

Keywords: risk assessment, domain ontology, standard guidelines.

1 Introduction

Any working activity involves risks and organizations of any type and size have to be able to identify, analyze and evaluate risks at any time during their workflow; the overall process of identification, analysis and evaluation of risks is usually referred as risk assessment. Over the years, institutions and authorities, as well as large industrial groups, have developed many methods for identifying and managing potential sources of risk in order to prevent accidental scenarios and assess the impact they could have on people, the environment and plants' equipment.

Recently, ISO organization published a set of documents for a standard aimed at risk assessment, namely: ISO 31000, that outlines the principles and general guidelines on risk management, ISO 31010, that provides an overview of the techniques of risk assessment and ISO 73, corresponding to a vocabulary of terms for risk management domain. These guidelines are not specific to a particular sector, but can be undertaken by any public or private organization and may be applied throughout the life cycle of an organization and in all its business activities and can be applied to any type of risk, regardless of its nature and its possible consequences. This bench of documents provides the knowledge necessary to identify the most appropriate risk assessment technique for specific organizations and activities. However, accessing the right information and understanding which procedures are the most appropriate for the specific context and configurations might be not straightforward. It is even more

P. Herrero et al. (Eds.): OTM 2012 Workshops, LNCS 7567, pp. 444–453, 2012.
© Springer-Verlag Berlin Heidelberg 2012

problematic for organizations of small size, where the access to the necessary resources is often difficult due to the unavailability of internal experts or time and cost constraints, and where often the definition and implementation of risk management procedure is delegated to external consultants; in this case tools supporting the comprehension of the proposed risk assessment methodology may greatly facilitate the validation and monitoring of the work entrusted to external specialists.

Formalize and exploit the knowledge available in this domain for the creation of tools that can help users to take decisions, considering all factors involved, may represent a progress of the utmost importance. This paper presents a research work aimed to develop a set of ontologies covering the risk management domain. In particular, the paper focuses on the knowledge formalized in two ontologies (OntologyGuide73 and OntologyRATIS - Risk Assessment Techniques Identification Support), used as knowledge-base for tools designed to facilitate the reading and understanding of the guidelines for risk assessment to support the choice of the most suitable for a given context among the available technologies.

The paper is structured as follows: section 2 introduces the domain knowledge, section 3 describes the methodology adopted for the identification and formalization of the domain knowledge in the ontology, section 4 concludes the paper.

2 The Domain Knowledge

Among the attempts to organize the domain knowledge for the risk assessment, Tixier et al. [1] present a review of the methodologies for risk analysis commonly adopted in the process industry, taking into account some general criteria for their classification. The presented 62 methods are described and classified according to four properties: deterministic, probabilistic, qualitative, quantitative. A particularly interesting aspect of this work is that the classifications of the methods are done on the basis of the type of input and output and according to application areas, such as: industrial, transportation of hazardous substances and human factors. A further attempt to classify risk assessment methods can be found in [2], where authors provide a survey that classifies and groups the main methodologies used for risk analysis and those published in scientific journals, applicable to various industrial sectors, such as process plant, process engineering, mechanical engineering, transport, chemistry and medicine. The classification adopted is very simple, the techniques are classified into three groups: qualitative, quantitative and mixed type. In the first group, the risk is considered as a quantity, which can be evaluated and expressed mathematically, even with the aid of recorded data relating to accidents. The paper compares the different methods of analysis and risk assessment based on the advantages and disadvantages, and it also provides interesting insights for future developments. In addition it provides a list of the scientific publications (404) of the last ten years regarding the analysis and assessment of risk, and for each indicates the techniques used, the type of data and the field of application considered.

As mentioned before, a set of standard ISO documents, recently published, aims at providing all the knowledge necessary to identify the most appropriate risk assessment technique for a specific organization and activity. The standard is divided into three different documents [3-5]:

- ISO 31000 (Risk Management - Principles and guidelines)
- ISO 31010 (Risk Management - Risk assessment techniques)
- ISO 73 (Risk Management - Vocabulary)

The document ISO 31000 [3] sets out the principles and general guidelines on risk management, providing a framework for the whole process, as shown schematically in Figure 1.

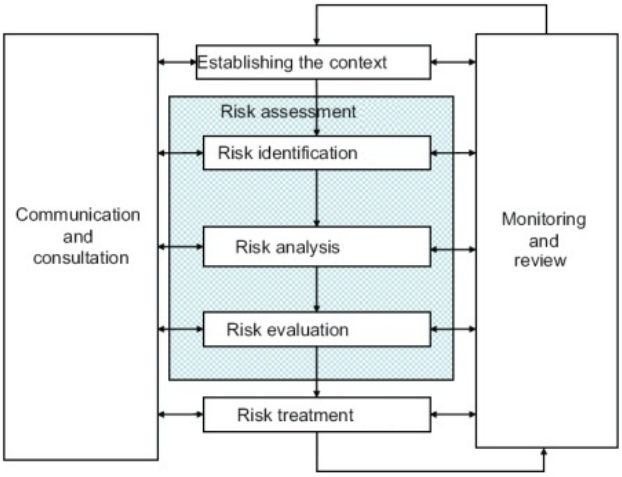

Fig. 1. Risk Management Process (Source: ISO 31000)

Overall, the process includes policies, procedures and organizational choices for managing risk across the entire organization at every level. In particular, it highlights the importance for those who must perform this process, to know: the context and the objectives, the extent and type of risks to be tolerated, how to treat risks considered not tolerable, how risk assessment is integrated in organizational processes, methods and techniques to be used for risk assessment, responsibilities for the process, the available resources, procedures for review and report.

The risk assessment process must provide the information necessary to decide: whether a specified activities has to be undertaken, how to maximize the opportunities, if certain risks should be treated, how to make a choice between different options that involve different risks, how to assign priority to different optional risk treatment, and what is the best strategy to take a risk to an acceptable level. The process includes risk identification, risk analysis and risk evaluation processes.

The risk identification is aimed at identifying situations that may prevent the achievement of objectives. The process includes the identification of causes, sources of risk and events that might have an impact on the objectives.

The risk analysis is mainly aimed to determine the consequences and the probability of the risks identified, taking into account the existing controls and their

effectiveness. The combination of the consequences and the probability of occurrence determines the level of risk. There are several methods of risk analysis, and complex applications may require the combined use of different methods.

Risk evaluation consists of comparing the estimated level of risk with the risk criteria defined simultaneously with the definition of the context, to establish the importance of the level and type of risk. The process uses the understanding gained during the risk analysis to make decisions on possible future actions.

The document ISO 31010 [4] provides an overview of the most commonly used techniques for the identification, analysis and evaluation of risk; it classifies more than 30 different techniques into broad categories based on different points of view. The first classification provided is made on the basis of the applicability of the technique to the process of risk identification and /or risk analysis and/or risk evaluation. As shown in Table 1, for each step of the evaluation process the document specifies the applicability of the method at the different levels.

Table 1. Classification of risk assessment methods based on the applicability to risk identification, analysis and evaluation

Methods	Risk assessment process				
	Risk identification	Risk analysis			Risk evaluation
		Consequences	Probability	Risk level	
Brain-storming	**Strongly applicable**	**Not applicable**	**Not applicable**	**Not applicable**	**Not applicable**
HAZOP	**Strongly applicable**	**Strongly applicable**	**Applicable**	**Applicable**	**Applicable**
……					

The second classification groups the techniques into different macro-categories on the basis of the similarity of the methodological process, specifically: Look-up methods, Support methods, Scenario analysis, Evaluation of controls, Statistical methods, Functional analysis. In addition, for each technique some important characteristics are highlighted according to different points of view: the importance of some factors of influence on the method (resources and capabilities in terms of both budget and human resources, nature and degree of uncertainty, complexity) and whether or not the technique produces a quantitative result. The document illustrates the complexity of the risk assessment process and highlights factors to be considered in deciding the most appropriate strategy.

Finally, the document ISO 73 [5] provides an essential vocabulary to develop a common understanding on the concepts and terminology used in the management of risks across different organizations and different types of applications. The document underlines that when a term is used in the context of a standard it is of fundamental importance that its meaning is not misunderstood or badly used.

3 The Representation of the Domain Knowledge

The ISO documents described in the previous section are well structured and their reading is not particularly difficult. However, the variety of the concepts introduced and their relationships can make the consultation costly. In particular, the choice of the more appropriate risk assessment methodology has to take into account many factors, such as for example the organization and the tasks to consider, the available resources and skills, the objectives and the expected results. Thus, on the one hand, this type of knowledge navigation is demanding and might require very specific skills. On the other hand, risk assessment is one of the activities required by law for health and safety of workers in the workplace.

Ontology is a good means to specify and clarify the concepts employed in a specific domain [6]. In the field of risk management, in the MONITOR project [7], an ontology has been defined to formalize the knowledge necessary to identify the best technology for environmental risk management, in particular for monitoring methods and risk communication. Also in [8] authors propose a tool to support risk analysis based on a set of domain ontologies to support users in the retrieval of relevant information. While Gilmour et al. [9] developed an ontology focused on risk identification methods specific for the process industries.

The knowledge contained in the ISO documents presented in previous section can be exploited to:

- collect common vocabulary and concepts in the risk management domain
- formalise these basic concepts as an ontology in a computer readable format
- exploit this core ontology as a basis for the formalisation in domain ontologies of more complex and structured knowledge concerning specific aspects of the risk management process
- use the resulting ontologies as a knowledge base, for the creation of software tools that can support users in the decision process for the management of risks, allowing them to take into account all the factors involved and the dependency relationships among them.

The design and development of an ontology may follow different methodological approaches; in this research we adopted a top-down method [10], according to which, starting from the domain of interest and the objectives, ontology is developed in various steps up to reach the definition of all the classes, properties and relations:

- Determine the domain and purpose of the ontology,
- Consider the reuse and expansion of existing ontologies,
- Enumerate important terms of ontology and define the classes,
- Define the properties of classes and their relationships

Focusing on the ontology reuse, although we considered several ontologies defined in the course of research projects aimed at supporting the process of risk assessment we decided to develop a new ontology. There are two main reasons which have led to this

choice: the requirement of a knowledge base fully compliant with the ISO 31000 document suite, and the objective to provide an ontology generally applicable to all areas where it is required to perform a risk assessment. In this perspective, to allow future reuse of the ontology, we adopted a layered approach which includes the definition of a core ontology that can be exploited by more specific domain ontologies. In Figure 2 the adopted ontology layered structure is depicted.

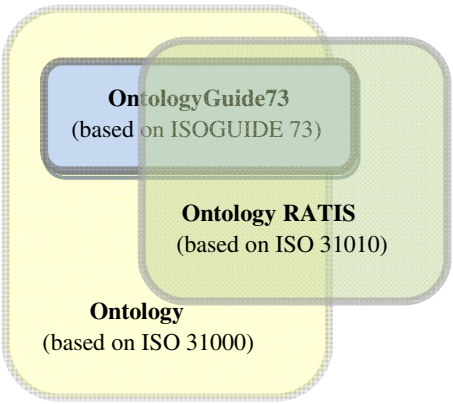

Fig. 2. Layered structure of the defined ontology

OntologyGuide73 is built starting from the content of the document ISO 73, which contains the reference vocabulary of the risk management domain and consequently provides the reference concepts. OntologyGuide73 can be considered the "core ontology" in the domain of risk management on the basis of which other more focused domain ontologies can be defined: for example, ontologies oriented to specific operations, such as maintenance, inspection and service activities, or to different contexts such as industrial environments or civilian complexes.

All the terms defined in the glossary ISO 73 were considered as reference elements (classes) possibly in relation to each other. Furthermore, from the definitions provided by the guide, other concepts have been extracted and modeled in the ontology, that do not have a formal definition in the document, but they have been recognized fundamental for the description of the characteristics of concepts that must be represented, such as the characteristics of the risk assessment technologies formalized in OntologyRATIS. As an example, the term Organization appears very often in the documents, in particular in ISO 73, although it is not explicitly defined; thus it was introduced as a class in the auxiliary OntologyGuide73.

OntologyRATIS, created starting from OntologyGuide73, contains the concepts extracted from the document ISO 31010 that have been identified to provide the technical knowledge necessary to choose the most appropriate risk assessment methodology with respect to the characteristics of a specific organization and of the activities to consider. The analyzed regulations do not provide real taxonomies of risk assessment methodologies, but various types of classification according to different factors that need to be taken into account. Examples of characteristics adopted for the

classification are the applicability of the technique to a specific process of risk assessment (see Table 1) and the type of results produced, whether quantitative or qualitative. These categories are treated in the ontology by defining relations or properties of classes. As for the core ontology, also for ontologyRATIS it has been necessary to introduce concepts that do not have an explicit definition but are required for the completion of the knowledge base.

The ontologies have been defined using the tool Protégé[1], taking into account the guidance provided by the World Wide Web Consortium (W3C). In addition to make the ontology easily accessible to software tools an Application Programmable Interface (API) has been developed using the standard tools SPARQL[2] and Jena[3].

3.1 OntologyGuide73 and OntologyRATIS

At the top level the OntologyGuide73 has four root abstract classes, the first three are corresponding to the elements explicitly listed in the ISO 73 glossary: Terms_Risk, Terms_Risk Management and Terms_Risk_Management_Process, while the fourth class Auxiliary_Resources includes all the concepts not explicitly defined in the glossary and mentioned in some term description, but necessary for the specification of other main concepts. To facilitate the ontology readability, the suffix Terms_ has been added to the name of abstract classes referring the most general concepts. Since abstract classes do not have instances but are used to model common concepts, here their use permits to reflect the terminology structure adopted in the ISO 73 document. For instance, the abstract class Terms_Risk_Management has four sub-classes: Risk_Management_Framework, Risk_Management_Plan, Risk_Management and Risk_Management_Policy. The focus of this research is mainly on the abstract class Terms_Risk_Management_Process, that has, among other sub-classes, the abstract sub-class Terms_Risk_Assessment, that has in turn a sub-class named Risk_Assessment_Method containing all the classes corresponding to each risk assessment method included in ISO 31010. The properties and relationships that can better characterize the specific methods are identified and defined in the ontology. In Figure 3 a partial view of ontologyRATIS including the Risk_Assessment_Method class is depicted: rectangles are classes representing the domain concepts and the enclosed labels indicate the class names. Bold class labels indicate concepts of the OntologyGuide73 (Terms_Risk_Assessment, Risk_Assessment, Risk_Evaluation, Risk_Identification, Risks_Analysis, People). Classes with labels in italic (i.e. Terms_Risk_Assessment, Risk_Assessment, Risk_Assessment_Method) are abstract.

[1] http://protege.stanford.edu/
[2] www.w3.org/TR/rdf-sparql-query
[3] http://jena.apache.org/

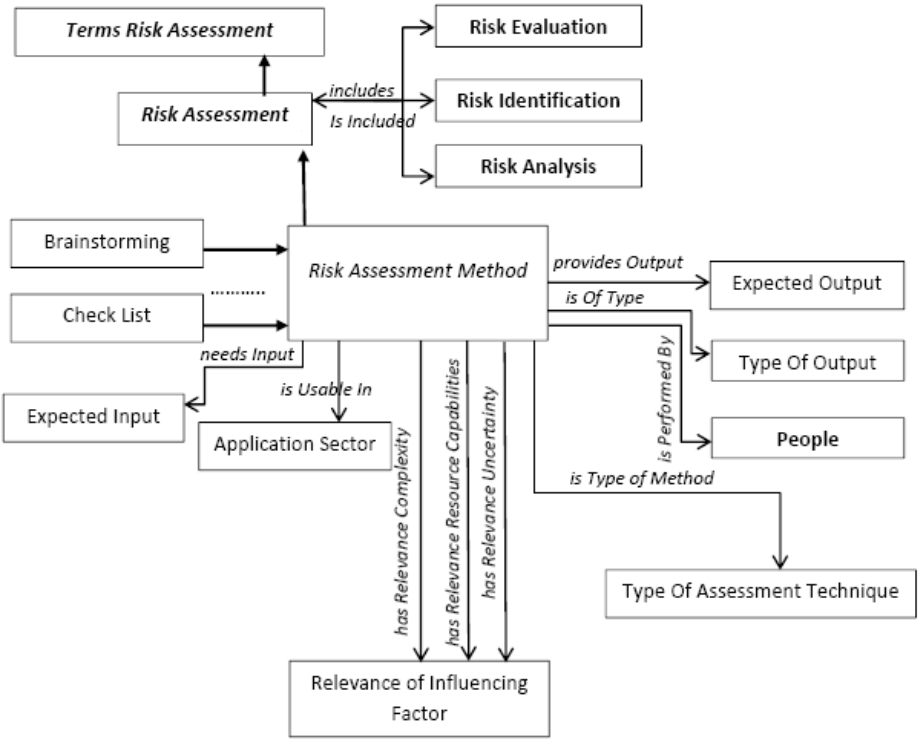

Fig. 3. A partial schema of ontologyRATIS

Unlabelled thick arrows represent the relationship "is-a". For example, Risk_Assessment "is-a" (specific type of) Terms_Risk_Assessment. The relationship "is-a" enables property inheritance among the classes involved, and through this relationship the ontology concepts are classified and organized in taxonomies. Moreover, relationships have a direction, and in this example may have multiple target. For the sake of comprehension, in the picture composite class names are strings with blank spaces. In addition to the taxonomies and the direct relationships, some restrictions have been introduced in order to design most of the concepts included in ISO documents, but explicitly defining only a small set of properties. For example, in ISO 73, Risk_Identification is defined as a "process of finding, recognizing and describing risk. It involves the identification of risk source, events, their causes and their potential consequences". In OntologyGuide73 this concept has been modeled as the restriction applied to Risk_Identification class: "providesOutput some (Risk or Risk_Source or Event)". Risk_Analysis has a similar restriction "providesOutput some (Level_Of_Risk or Consequences or Likelihood)", which models the concept "is a process... to determine the level of risk". These particular restrictions are also used to infer some concepts from the explicit definitions, for instance the classification of the risk assessment techniques. All the methods contained in ISO 31010 are designed as sub-classes of Risk_Assessment_Method class, and their instances are the

specific techniques implemented for each method. On the basis of the type of output which a technique is able to produce, the ontology infers and classifies them into the most suitable type of risk assessment process. In this way, the classification in Table 1 has not been explicitly modeled but has been inferred by the reasoner. Among the advantages of such a design solution, one is that a new risk assessment technique can be introduced directly in the Risk_Assessment_Method, or in some sub-classes, but is automatically classified (through inference) into the appropriate class of methods, such as Risk_Identification, Risk_Analysis or Risk_Evaluation. On the contrary, the relation isOfType in Figure 3 explicitly indicates if a method is able to provide quantitative, semi-quantitative or qualitative results. In future, ontology will be extended to infer also such a classification directly from the type of output which a technique is able to produce .

Finally, each method is mainly described in terms of its target, the expected output data, the required input, the required expertise, and other characteristics, such as in which sector it is applicable, or on which life-cycle phase it can be adopted. The ontology can be queried by general questions, such as for example: “What are the methods used for risk identification? For risk analysis? For the evaluation?, Which methods provide quantitative output? Or qualitative?”. Moreover the questions can be combined to make matters more complex, e.g.: “what kind of qualitative methods can be applied, based on a team of experts during the operating phase of a plant?”.

This reflects the fact that OntologyRATIS has been modeled with the main objective to answer questions aimed at identifying the most suitable risk assessment methods, according to different requirements. In order to fulfill such objectives, the methodology proposed consists of a process which reduces the set of candidates by choosing from time to time some conditions depending on available resources. For example, starting from the expected results (output data), methods can be chosen by discriminating between input required and data available; or vice versa if some input data is available, only risk assessment methods compatible with those data are identified. The other characteristics may be conveniently used to reduce the list of candidates. Of course, each choice increases the complexity of the query, for example the question “Which methods can be used to identify explosive hazards in batch processes industry?” can be described in SPARQL language, as depicted in Figure 4, with the results achieved in the example.

```
select distinct ?a   where  {?a rdf:type ?c.  ?a XX:isUsableInSector ?sec.
?a XX:isApplicableToSituation ?sit.  ?a G73:providesOutput ?out.
Filter ( (?c= XX:Risk_Assessment_Method)  &&  (?sec=XX:Batch_Process) &&
(?sit=XX:Industrial_installations ) &&  (?out=XX:Explosive_Hazard) ).} ORDER BY str(?a)
```

XX: Air_Blust_Index_Method_DL334
XX :Blust_Index_Method_DL334
XX:Dow_Index_Method_DL334
XX:General_Index_Method_DL334

Fig. 4. Example of SPARQL query and achieved results

4 Conclusions

The research presented in this article focuses on the definition of an ontology designed to support the implementation of ISO standards on identification, analysis and risk assessment to facilitate the choice of the risk management techniques most suited to the needs of a specific organization. Ontology formalization includes all concepts defined in the considered ISO documents and in addition those concepts that, although lacking a formal definition in the document, were considered necessary in the description and characterization of risk assessment methods. The design of the presented ontologies tries to minimize the explicit definitions of the identified concepts, exploiting the reasoning facilities offered by the ontology language, in order to infer implicit knowledge as much as possible. A preliminary evaluation of the usefulness of the ontology to meet the users 'requests have been carried out by domain experts.

To make the exploitation of the developed ontologies effective for users, a software tool with an adequate user interface is currently under development, that would facilitate the navigation in the knowledge base, taking into account all the factors involved in the choice of the risk assessment method. Moreover, the application will allow users to directly add instances of risk assessment methods or specify the knowledge required to define new classes of methods.

References

1. Tixier, J., Dusserre, G., Salvi, O., Gaston, D.: Review of 62 risk analysis methodologies of industrial plants. Journal of Loss Prevention in the Process Industries 15(7), 291–303 (2002)
2. Marhavilas, P.K., Koulouriotis, D., Gemeni, V.: Risk analysis and assessment methodologies in the work site: On a review, classification and comparative study of the scientific literature of the period 2000-2009. Journal of Loss Prevention in the Process Industries 24(5), 477–523 (2001)
3. ISO 31000 Risk Management-Principles and Guidelines, ISO/FDIS 31000:2009(E)
4. ISO 31010 Risk Management- Risk Assessment techniques, IEC/ISO 31010
5. ISO GUIDE 73 Risk Management-Vocabulary, ISO GUIDE 73: 2009(E/F)
6. Gruber, T.R.A.: Translation approach to portable ontology specification. Knowledge Acquisition 5, 199–220 (1993)
7. Kollarits, S., Wergles, N.: MONITOR – an ontological basis for risk management, http://www.monitor-cadses.org/documents/MONITOR_BaseOntology_Report_1_0.pdf (accessed July 20, 2011)
8. Assali, A.A., Lenne, D., Debray, B.: Ontology Development for Industrial Risk Analysis, Information and Communication Technologies: From Theory to Applications. In: ICTTA 2008, pp. 1–5 (2008)
9. Gilmour, R.: An Ontology for Hazard Identification in Risk Management, Thesis, Department of Chemical Engineering (2004)
10. Noy, N.F., McGuinnes, D.L.: Ontology Development 101: A Guide to Creating Your First Ontology. Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880 (2001)