View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by I-Revues

On the risk management of construction project: a knowledge-based approach

F.K. KHARTABIL[a], D. BREYSSE [a], F. TAILLANDIER [a]

a. *Université Bordeaux 1, I2M - CNRS 5295, GCE, Avenue des Facultés, Bâtiment B18, 33405, Talence*
f.khartabil@i2m.u-bordeaux1.fr

Abstract:

Risks are inherent in construction projects. Risks can cause delays, cost overruns, and poor performance. Effective risk management is hence necessary in order to mitigate the impact of potential risks and, ultimately, ensure project success. This area of research was not fully appreciated in France until recently, so more powerful tools are still needed. With the increasing importance of knowledge as a competitive asset, this study aims to develop a knowledge-based system for the risk management of construction project. The lack of consistent terminology is a major drawback that can be overcome by developing an ontology. The developed ontology represents a formal shared conceptualization of construction project. The ontology is the semantic framework for the implementation of a knowledge base. The architecture is flexible enough to be the base for three application ontologies that are currently under construction, namely, a building ontology, a tunnel ontology, and a highway ontology.

Keywords: construction project, risk, knowledge, ontology

Résumé :

Les risques sont inhérents aux projets de construction. Les risques peuvent entraîner des retards, des dépassements de coûts, et de mauvaises performances. La gestion des risques est donc nécessaire afin d'empêcher la survenue des aléas et de réduire leur impact afin de maximiser les chances de succès du projet. La communauté française ne s'est impliquée que récemment sur ces questions. Cela souligne la nécessité du développement d'outils plus efficaces pour la maîtrise des risques dans les projets de construction. Les connaissances et l'expérience préalable dans le processus de gestion des risques de projet peuvent fournir un avantage compétitif aux entreprises. L'objectif de cette étude est de développer un système à base de connaissances pour la gestion des risques du projet de construction, en s'appuyant sur une ontologie qui permette de résoudre les questions liées aux imprécisions du vocabulaire. L'ontologie pose le cadre sémantique d'une base de connaissance et permet de formaliser la représentation du projet de construction. La base de connaissance est étendue pour développer trois bases de connaissances relatives aux domaines du bâtiment, des tunnels et des autoroutes.

Mots clefs : projet de construction, risque, connaissance, ontologie

1 Introduction

Many researchers have emphasized the importance of experience and knowledge in the risk management of construction project. In this regard, different tools and systems have been proposed. For instance, checklists or prompt lists of risks have been developed [2]. These lists are generally prepared based on techniques such as questionnaires or interviews with professionals in the construction domain. Construction companies can refer to these lists in order to develop their own specific lists in light of additional information related to their own projects and experience of their members. Risk checklists can be used to identify risks of new projects, instead of starting from the scratch. Other researchers have proposed to classify risks into groups in order to facilitate browsing and scrutinizing the prompt lists of risks [1]. Others have developed Risk Breakdown Structures (RBS) to provide a clearer picture and deal with the large amount of risk information by grouping risks in categories and sub-categories [10, 11]. In addition, risk registers have been developed to enhance the documentation of project risks through the project life cycle [3].

Although the aforementioned tools and systems enhance the knowledge management of construction project risks, they have some drawbacks:

(a) The lack of explicitly representing interrelationships among risks. Actually, risks are never independent, rather, there are cause and effect relationships characterizing them. To this end, some approaches representing interactions among risks have been proposed [6]. These models are based on building networks modeling the interdependencies among risks. These studies have tried to conduct extensive survey of potential construction project risks. However, it is impossible to identify a comprehensive list of possible risks; in new projects, some risks need to be modified or added, others need to be removed. Modifying such networks will imply rebuilding them from the scratch because of their very complex structure;

(b) The absence of representing project and its environment explicitly. The past developed systems focus mainly on representing project risks. However, risks stem from, and also affect, the project its constituents, and its environment. As such, risk management is usually handled separately from other project management functions;

(c) The weak representation of knowledge. The developed systems do not facilitate building a corporate memory that can be used to retrieve stored knowledge and adopt it to the context of the project in-hand and then store the learnt lessons. The lack of consistent vocabulary in describing and representing risks is a major problem.

To address these gaps, we need to develop a flexible knowledge-based system to support construction project risk management. The proposed system is meant to facilitate knowledge capturing, representing, sharing, and reusing. It should enable the common understanding among different project members. It should also foster the interoperability between risk management and other project management functions such as cots, time, quality, and communication management. To achieve this, there is a need to an explicit and formal representation of construction project. This representation will not focus only on construction project risks but also on the project, its constituents, and its environment. This is, however, not an easy task because of the heterogeneity of the sources of construction project knowledge due to its very complex and fragment nature.

Semantic models based on ontologies can provide a powerful means to capture and represent fragmented and dispersed knowledge. Ontology is a branch of metaphysics related to the study of the nature of existence. This term has recently been widely used in the computer science to designate a formal and explicit representation of the concepts of a domain of interest. The key idea is to represent human knowledge by defining concepts and relationships between them in a manner similar to the natural language, but to be understood by the computer. Hence, computer systems can reason and perform complex tasks usually undertaken by humans [4].

2 The Methodology for the development of ontology

This research adopts an approach based on several methodologies for ontology building reported in the literature [8, 9]. This consists of six major phases:

1) Determining the ontology scope and purpose by means of a set of competency questions;
2) Reusing existing ontologies;
3) Building the ontology through the following:
   a) Identifying the basic concepts describing the domain of interest;
   b) Developing the taxonomy (arranging the concepts in super-classes and subclasses);
   c) Defining the axioms describing the interrelationships between the concepts.
4) Validate the ontology according to the previously defined competency questions;
5) Creating individual instances of the defined concepts;
6) Implementing the ontology using an ontology editor.

3 The construction project risk management ontology

The results presented hereinafter have been obtained by following the steps of the methodology presented in the previous section.

3.1 Domain and scope

The scope of the ontology can be defined through a set of competency questions. These questions serve as a validation of the ontology. If the ontology is able to answer the questions, then it fulfills its purpose; otherwise, certain details of representation are still needed. Some examples of competency questions set to define the domain of the developed ontology are as follows:

- What must be done to implement the project?
- How will it be done?
- What are the outputs of the performed work?
- What is needed to do it?
- What can generate risks?
- How to describe the interrelationships between risks?
- What can influence the severity and likelihood of risks?

3.2 Reusing existing ontologies

We have not reused existing ontologies; however, the structure of the developed ontology is similar to some extent to other ontologies developed in the area of construction management [4, 5, 7].

3.3 Building the ontology

3.3.1 The principal concepts

We have defined a set of thirteen principal concepts; the last four ones are related to project risk.

- Project: a temporary endeavor undertaken to construct a building, a tunnel, a highway …
- Actor: a participant involved in the implementation of project.
- Process: a construction process such as, excavate a working shaft, construct a foundation …
- Product: an output/result of a process, such as, working shaft, foundation, column ...
- Product classification: a category to group products, e.g. substructure, superstructure, finishing.
- Activity: a building block in the project that consumes time, cost, and resource. Example: steel fixing of columns.
- Construction method: a means or manner to perform a process. Example, cast-in-place reinforced concrete
- Resource: something needed to perform an activity such as, concrete, loader, and steel-fixer.
- Environment: elements or factors around the project the project that can influence or be influenced by it. Examples: regulations, codes, economic situation.
- Risk factor: an element or situation that has the potential to cause harm to the project.
- Risk event: something that can happen because of one or more risk factors.
- Risk consequence: the outcome of one or more than one risk event.
- Vulnerability/Robustness: a weak or strong point making the project more or less exposed to risk.

3.3.2 Taxonomy building

The taxonomical relationships represent *is-a* relations**.** This means that sub-concepts are specializations of other super-concepts; in other words, a concept B is a sub-concept of a concept A if every individual instance of B is also an instance of A. This enables the computer to raison and generate new knowledge from the existing one. The taxonomy of the developed ontology is shown in figure 1. It defines specializations of the concepts Actor, Resource, and Environment.

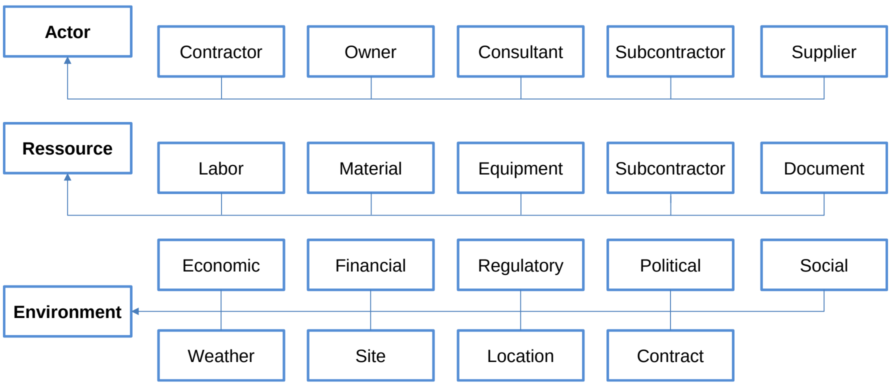

FIG. 1 –The ontology hierarchy

3.3.3 Relationships among classes

Cross-concept relationships represent the relationships between classes that cannot be established through the taxonomy. They link the concepts to further enrich their semantic through the introduction of more details about the concepts definitions.

3.3.3.1 The relations representing the project execution

As can be shown in figure 2, a project is composed of several processes and products. A process is performed according to a construction method and produces a product. A process includes a set of activities that need resources to be realized. An activity precedes other activities.

For instance, « construct a column » (process) can *be implemented by* « cast-in-place reinforced concrete» (construction method), *produces* a « column » that *is classified as* « superstructure » (product classification), and *consists of* « preparing and fixing the framework » (activity), « preparing and fixing the reinforcement » (activity), « pouring the concrete » (activity), and « removing the framework » (activity).

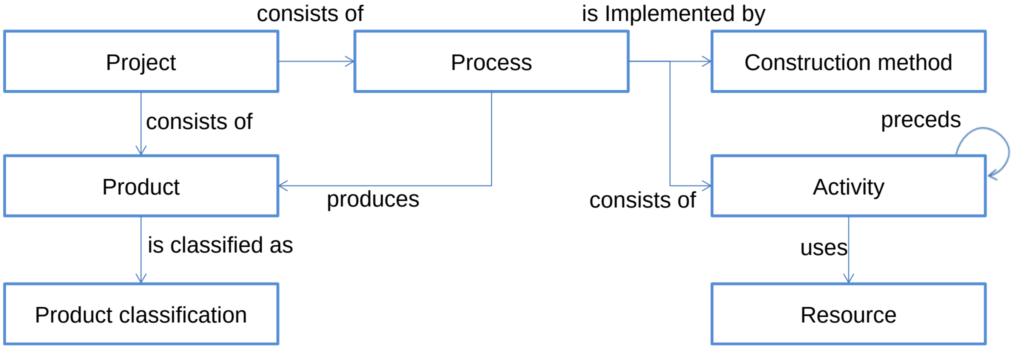

FIG. 2 – Project execution ontological model

3.3.3.2 The relations representing the risks:

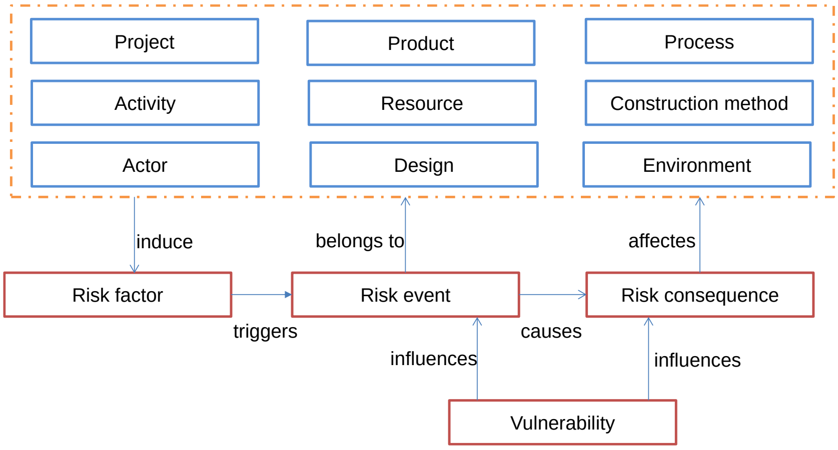

FIG. 3 – Risks ontological model

The upper part of the figure 3 represents the project execution concepts. The lower one represents the risk concepts. The interactions between these two parts are represented explicitly. In the literature, a major issue stems from the difficulty and confusion between risk factors, risk events and consequences, and how these elements are interrelated and interacted with the project, its constituents and its environment. Accordingly, more clarity is needed, which is established through the developed ontology.

The ontology assumes that risk factors are induced by the project, its constituents and its environment, and can lead to one or more risk events. Risk events can be triggered by one or more risk factors; they are associated to the project, its constituents and its environment. Risk consequences are the output of the occurrence of risk events; they affect the project, its constituents and its environment. For instance, « low quality design » (risk factor) can trigger « design change » (risk event), that, in turn, can cause « diminution in productivity » (risk consequence).

Another concept integrated in the ontology is the Vulnerability/Robustness that is a weak or strong point making the project more or less exposed to risk. In the above presented example, if the contractor has « good experience » (Robustness), the likelihood and severity of « design change » will be less. Conversely, « bad coordination between trades» (Vulnerability) will increase the likelihood and severity of « diminution in productivity ».

We add that the interactions between risks is possible and natural, without the need to be explicitly represented: the consequences result in a change of the values of parameters associated with project components "affects", which modifies the risk factors and cause the occurrence of new risk events "*induce*".

3.4 Ontology validation

Going back to the competency identified in the first phase, the developed ontology has been able to answer these questions. Some examples are presented in table 1.

TABLE 1- Ontology validation

Question	**Response**	**Abstraction in the ontology**
What must be done to implement the project?	Construct a foundation Construct deck slab	Process
How will it be done?	cast-in-place reinforced concrete	Construction method
What are the outputs of the performed work?	Fondation Slab	Product
How to describe the interrelationships among risks?	Bad quality design → design change → productivity diminution	Risk factor *triggers* risk event, which *causes* risk consequence

3.5 Creating instances

This research involved an extensive literature review aimed to analyze the most important risks and their causes and consequences, and then represent them according to the developed ontology. The current version of the knowledge base regroups more than 100 instances of risk factors, events, and consequences, and more than 120 relationships among them.

3.6 Ontology implementation

Ontology implementation means coding the ontology in a machine-readable ontology language. In order to implement our ontology, we have reviewed several ontology editors in order to choose a suitable one. Protégé-OWL (version 4.1), an open source freeware developed by Stanford University, has been selected to formally encode the semantic framework presented in the previous section.

4 Building three application ontologies

The developed ontology is a domain ontology. The main goal was to develop it in a flexible way so it can be extended to other application ontologies. In this regard, three application ontologies are currently under construction; namely, a building ontology, a tunnel ontology, and a highway ontology. The figure 4 depicts a part from the tunnel ontology implemented using the Protégé software.

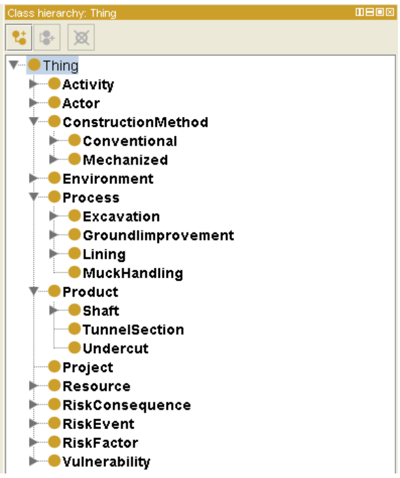

FIG. 4 – Part of the tunnel ontology

5 Conclusion

We have presented a methodology to design and implement a knowledge base for construction project risks. This knowledge base is extended to three specific knowledge bases, namely, a building, a tunnel, and a highway knowledge bases.

This paper is part of ongoing research to develop a knowledge-based system for the risk management of construction project. The system consists in integrating risk management with other project management functions such as time, cost, quality, and communication management. The system is composed of three components:

1) The knowledge bases capitalizing the knowledge and experience related to construction risk management (this part was presented in this paper).
2) Project databases representing repositories of each project data.
3) A project management unit. This is the main unit in the system. It involves managing risks, estimating time and cost and quantifying quality, as well as preparing diverse project reports.

Using the system starts by searching the knowledge base for specific available knowledge. Then, the retrieved knowledge will be adapted to the current project context. Here, the configured information will be saved into the project database. The project management unit will then conduct the activities of risk management and the other activities. According to the dynamic nature of construction project, the knowledge base can be queried in any time to investigate the related situations and to retrieve relevant knowledge. This cycle will be repeated until the end of the project where the lessons learnt will be saved in the knowledge base. Hence, the knowledge bases will grow from a project to another and the management of future project will be enhanced as a result.

Acknowledgment

This work was conducted using the Protégé resource (http://protege.stanford.edu), which is supported by grant GM10331601 from the National Institute of General Medical Sciences of the United States National Institutes of Health.

References

[1] Al-Bahar, J., Crandall, K., Systematic risk management approach for construction projects, *Journal of Construction Engineering and Management,* 1990, 116(3), p. 533-546.

[2] The Construction Industry Institute, Contracting to appropriately allocate risk. University of Texas, 2007.

[3] Dikmen, I., Birgonul M.T., Anac, C., Tah, J.H.M., and Aouad, G., Learning from risks: a tool for post-project risk assessment, *Automation in Construction*, 2008, 18(1), p. 42-50.

[4] El-Gohary N., El-Diraby T., Domain ontology for processes in infrastructure and construction, *Journal of Construction Engineering and Management,* 2010, 131(5), p. 591–603.

[5] El-Diraby, T., Kashif, K., Distributed ontology architecture for knowledge management in highway construction, *Journal of Construction Engineering & Management, ASCE*, 2005, 131(5), p. 591-603.

[6] Eyers, K., Belief Network Analysis of Direct Cost Risk in Building Construction, Master dissertation, University of Toronto, 2001.

[7] Fidan, G., Dikmen, I., Tanyer, A. M., Birgonul, M.T., An ontology for relating risk and vulnerability with cost overrun in international projects, *ASCE Journal of Computing in Civil Engineering*, 2011, 25(4), p. 302-315.

[8] Gruninger M., Fox M.S., Methodology for the design and evaluation of ontologies, *Workshop on Basic Ontological Issues in Knowledge SharingIJCAI-95*, Montréal, Canada, 1995.

[9] Lopez M.F., Gomez-Perez A., Juristo N., METHONTOLOGY: fromontological art to ontological engineering, *Spring Symposium on Ontological Engineering of AAAI*. Université de Stanford, California, 1997, p. 33 –40.

[10] Mehdizadeh, R., Dynamic and multi-perspective risk management of construction projects using tailor-made Risk Breakdown Structures, PhD thesis , Bordeaux 1 University, 2012.

[11] Tah, J. H. M., and Carr, V., "Knowledge-based approach to constructionproject risk management." *Journal of Computing in Civil Engineering*, 2001, 15(3), p.170-177.