THE BASIS OF A DECISION MAKING TOOL FOR RISKS’ EVALUATION BASED ON ONTOLOGIES

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ABSTRACT

In the building and construction sector (AEC) one of the Project Management Knowledge Areas is “Project Risk Management” which describes the processes concerned with identifying, analyzing, and responding to project risk. It consists of risk management planning, risk identification, qualitative and quantitative risk analysis, risk response planning and risk monitoring and control.

This paper exposes the specifications of a decision making tool to evaluate risks, analyzing them in the first stages of a project where the feasibility studies are carried out and also during the execution phase. This application will provide technical solutions and preventive measures for the evaluated risks and it will control and monitor them along the life cycle of the project.

This tool will be based on an ontology whose development is essential for effective web-based concurrent project creation. Ontologies support knowledge management through the use of common taxonomies, axioms and non-taxonomical relationships. Therefore, this paper presents a domain ontology that should act as basis for the specific domains of “Project Risk Management” in the AEC sector.

KEY WORDS

Risks’ evaluation, Project Risk Management, Ontology.

CONSTRUCTION RISK MANAGEMENT

Construction professionals need to know how to balance the contingencies of risk with their specific contractual, financial, operational and organizational requirements. In order to achieve this balance, proper risk identification and risk analysis is required. The risk management process entails identifying construction risks and exposures, and formulating an effective risk management strategy to mitigate the potential for loss.

The construction risks can be broadly grouped under the following categories:

- Technical Risks
  - Incomplete design.
  - Inadequate site investigation.
  - Uncertainty over the source and availability of materials.
  - Appropriateness of specifications.

- Logistical Risks
  - Availability of resources - particularly construction equipments, spare parts, fuel and labor.

- Construction Risks

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- Uncertain productivity of resources.
- Environmental implications
- Safety & Health implications
- Quality implications
- Industrial relations problems.

- Financial Risks
  - Inflation.
  - Availability and fluctuation in foreign exchange.
  - Delay in Payment.
  - Repatriation of funds.
  - Local taxes.

- Political Risks
  - Constraints on the availability and employment of expatriate staff.
  - Customs and import restrictions and procedures.
  - Difficulties in disposing of plant and equipment.
  - Insistence on use of local firms and agents.

Risk is a natural part of any business enterprise; however, the construction industry faces more than its fair share of risk factors. The list of risks is virtually endless and so is the list of risk management strategies that construction owners often deploy - reactively for the most part - during their projects.

On the other hand, construction companies are experimenting great changes in all their aspects, both technologically and in managerial aspects. This means they need to adapt to new situations to maintain their competitiveness.

Currently, there are different management models that companies are adopting to increase their competitiveness. From one side, ISO 9000 (ISO 2000) are a reference point for Quality Management and the basis of the majority of the companies to satisfy customers’ needs.

On the other side, ISO 14000 (ISO 2004) are also the basis of Environmental Management aspects to minimise environmental impacts and are developed following the previous one.

Finally, the new regulation on risk prevention OHSAS 18001 (OHSAS 1999), is inspired on the quality management aspects, continuous improvement and the preventive actions of the business policies.

Quality, Environmental and Safety & Health (QES) management systems are generally considered to be an integration of ISO 9000, ISO 14000 and OHSAS 18001 regulations. They are an approach to doing business that attempts to maximize the competitiveness of an organization through the continual improvement of its products, services, people and environment by emphasizing customer focus (internal and external), long-term commitment, teamwork.


- It only refers to quality and environmental aspects.
- Is limited to documental integration which only means policies, manuals, procedures and registers unification.
The integration line of the management systems should be oriented to the policies unification, manuals, procedures and records and evaluating systems depending on the type of organization.

The benefits for integrating the management systems include an optimized management system, increased competitiveness, better utilization of resources, etc.

Environmental risks are a serious and growing issue for the construction industry. Although many construction firms cling to the belief that environmental exposures are associated only with environmental work, in fact, they exist in every facet of a construction firm’s practice. To succeed in today’s litigious environment, forward-looking contractors are incorporating sound environmental risk management practices throughout their business operations.

Establishing a risk free workplace and reducing environmental pollution are important aspects of the integration. Above all, unity of purpose of employees, and employee involvement and empowerment are vital for a successful program (Koehn E. and Datta N., 2003).

Many construction professionals look at risks individually and do not realize the potential impact that other associated risks may have on their business operations.

Due to the great interest in Construction Risks and basically Environmental and Safety & Health integration, the project we are exposing in this paper deals with the integrated evaluation and analysis of Environmental and Safety & Health Risks with the aim to control safety risk and reduce their impact.

**AIM AND METHODOLOGY**

The aim of this paper is to present a project which is currently being developed to help the construction sector to increase competitively by optimizing management systems resources of the construction companies. The majority of these companies usually use Quality management systems on site; they sometimes apply Safety & Health and Environmental management systems but seldom, if ever, apply integrated management systems. It leads to a waste of money and human resources, which is avoidable by an application of a correct working methodology.

The specific objectives of this project are:

- To develop an ontology to interrelate Environmental and Health and Safety Risks. To do so, different evaluation methods will be analysed.
- To establish the basis of a decision making tool, based on the previous ontology, to integrally analyse Environmental and Health and Safety risks along the life cycle of a construction project and define technical solutions and preventive measures.

Therefore, this project will focus on Environmental and Health and Safety risks being compatible with Quality standards.

**ONTOLOGY DEVELOPMENT**

Recently, ontology engineering has been applied to a wide range of sectors and purposes, including semantic integration of heterogeneous databases, content-based retrieval of product catalogues, and management of corporate memory. In the construction sector, ontologies and other semantic resources (vocabularies, taxonomies, etc.) have been used to facilitate communication and to improve understanding among the various stakeholders operating on a project.

An ontology defines a common vocabulary for researchers who need to share information in a domain. It includes machine-interpretable definitions of basic concepts in the domain and relations among them. The aims to develop an ontology are:
• To share common understanding of the structure of information among people or
  software agents.
• To unify the terminology of a particular domain among people.
• To enable reuse of domain knowledge.
• Although differences exist between ontologies, general agreement exists about several
  issues related with the structure and behaviour of real world objects (Chandrasekaran,
  B. et al, 1999).
• Objects have properties or attributes that can take values, i.e. they can be represented
  as triplets (Object – Attribute – Value).
• Objects can exist in various relations with each other.

This research effort focuses on the use of an ontology to improve the interoperability between
both Environmental and Safety & Health Risks evaluation with the aim to develop a Decision
Making tool.

ONTOGY DOMAIN
It is impossible to develop a single ontology that fully covers a domain or will satisfy the needs
and preferences of each user (Gruber T., 1996). This research attempts to develop an ontology
focused on the Environmental and Safety and Health Risks domain and it allows for future
extension. The starting point in this research was the analysis of different Environmental and
Safety & Health evaluation methods.

COMPETENCY QUESTIONS
This is a very effective and widely used means for validating ontologies (Gruninger M. and
Fox MS., 1995). During the development of the system a set of questions was used to assure
comprehensive and consistent inclusion of all concepts. For example, the following is a partial
listing of the competency questions investigated:
• What Environmental aspects should be taken into account when evaluating
  Environmental risks?
• What Safety & Health aspects should be taken into account when evaluating Safety &
  Health risks?
• What are the common aspects between Environmental and Safety & Health
  evaluations?
• What affect the Environmental valuation?
• What affect the Safety & Health valuation?

The rigorous application of competency questions provides means to assure comprehensive
coverage of concepts.

CONCEPTUAL SCHEMA
The main structure of the proposed ontology is represented in Figure 1 where the important
terms and their relationships that should be included in the ontology can be observed.

This Concept Model is based on a Generic Risk that is related to simultaneously both
Environmental and S&H risk, or if it is not possible, only to one of both. Moreover, these risks
are related to the person who has created them, to the working activity along which they have
been created and to the working place where they have been created in.

On the other hand, Environmental and S&H risks have some properties, such as Severity
and Probability and, from their combination and analysis, the Environmental and S&H
valuation are reached. As a consequence and from the study of these values some prevention
measures are given, tying to solve and reduce both Environmental and S&H risks, and by this
way, the generic risk.

On the other side, this Concept Model and the elements and relationships that it contains
allows the risks classification by the source, the working activity or the working place, what it
means that the risks that a person or machinery create can be identified, as well as which is the most risky working activity or working place.

**Figure 1: Conceptual schema**

**ELEMENTS OF THE ONTOLOGY**

The Concept Model previously exposed defines the concepts that will be considered as classes, subclasses and properties in the ontology.

Classes describe concepts in the domain and subclasses kinds of the already defined classes. In this proposed ontology the classes and their subclasses are:

- **Generic Risk**, composed by all the risks identified along a construction process.
- **Environmental Risk**, composed by the risks identified along a construction process related to environmental aspects.
- **Safety and Health Risk**, composed by the risks identified along a construction process related to safety and health aspects.
- **Prevention measures**, composed by all the prevention measures that should be used to solve the already identified risks.
- **Risk source**, composed by all the stakeholders, machinery, vehicles,… that participate in the construction process and that can produce some risk.
- **Working activity**, composed by all the activities that take place along the construction process of the construction project.
- **Working place**, composed by all the possible different places located in the construction site.
- **Valuation**, composed by the different possible values used in the evaluation of the risk, such as not significant, tolerable,…

On the other hand, to improve the identification of risks the existing relationships between them properties of classes and subclasses are defined. Three kinds of Protégé properties have been used:

- **Object-properties** are used to relate classes and subclasses. *is created by* is used to relate the classes Generic Risk, Environmental Risk and Safety&health Risk to the class Risk source; *is created along* is used to relate the classes Generic Risk, Environmental Risk and Safety&health Risk to the class Working activity; *is created in* is used to relate the classes Generic Risk, Environmental Risk and Safety&health Risk to the class Working place; *is related to* is used to relate the class Generic Risk to the classes Environmental Risk and Safety&Health Risk; and finally *has prevention measures* to
relate the classes Generic Risk, Environmental Risk and Safety & Health Risk to the class Prevention Measures.

- Datatype-properties add information to the classes. Severity and Provability properties are used to valuate the risk in order to select the best prevention measures.
- Annotation-properties would be used to provide multi-lingual names for ontology elements.

**Characteristics of the Decision-Making Tool**

Although the integrated risks management in the construction area is the main objective of construction companies, for the moment the decision-making tool proposed in this paper will only focus on the integration of Environmental and Safety & Health risks. Once this integration is realized and tested, quality, costs and time will also be included.

The ontology defined previously serves as a basis for the development of a Decision Making tool oriented to analyse and evaluate both Environmental and Safety & Health risks along the life cycle of a construction project, with the aim to increase competitiveness by optimizing management systems of a construction company.

Figure 2 shows the general layout of the decision making tool for Environmental and Safety and Health Risks management.

![Figure 2: General layout of the decision making tool for Environmental and Safety and Health Risks management](image)

This tool will facilitate decision-making and continuous improvement with an integrated conception of the whole constructive process.

Depending on the stakeholders (i.e. Client, constructor, designer, etc.), and the specifications of the tool, the life cycle of a project can be adapted to the necessities of each circumstance.

The end users of this decision-making tool are basically contractors who normally receive the memory, drawings, specifications, etc. of a project and should execute it using the best, the cheapest, the shortest, etc. constructive process. Currently, environmental and safety and health aspects are not taken into account until the construction stage. The proposed tool will evaluate these risks in different stages of the project, from the negotiation stage, during the construction stage and at the end of the project taking into account the constructive process.
defined by the contractor. If possible, different constructive processes will be evaluated and the one with fewer impacts will be chosen. For the moment, only environmental and safety and health risks will be taken into account but in the near future time, costs and quality aspects will also be considered when choosing a constructive process.

From the constructors point of view the life cycle of a construction project can be divided into: Study, Planning, Preparation and Production.

For the moment, the Decision Making tool will be oriented to constructors but probably, it can be extended to other stakeholders with the consequent adaptation to the new context.

RISKS EVALUATION
It is planned that in each stage of the life cycle one or many operational controls should be carried out. This means, to analyse the risks in an integrated way. The Decision Making tool will provide an integrated Environmental and Health & Safety analysis to evaluate both risks in conjunction and will be able to extract technical solutions and preventive measures considering both risks.

A construction project is always subjected to changes taking into account costs, time and risks aspects. This Decision Making tool will then help constructors taking risks decisions.

TECHNICAL SOLUTIONS AND PREVENTIVE MEASURE
Once the risks evaluation is carried out, the tool will propose technical solutions and modifications of the constructive process. If it is not possible to modify the process, the tool will provide environmental and safety and health preventive measures.

Then, when the construction stage has started and problems occurred, the tool will provide corrective measures.

REUSABLE KNOWLEDGE
The decision-making tool will also capture all the decisions and situations from each project so as to be able to reuse this information into other projects and/or in other stages of the same project. Therefore, the evaluation method is based on the quality principles of Plan-Do-Check-Act.

DISCUSSION
This Decision Making tool is oriented to constructors to evaluate risks and get technical solutions and preventive measures with the aim to increase competitiveness by optimizing the management systems of the company. This tool will facilitate decision making and continuous improvement with an integrated conception of the whole constructive process.

Using the information of the project the tool evaluates the risks with the aim to decide whether to bid or not, obtaining the main weaknesses of the project in terms of risks. Once the project is accepted, the contractor plans the constructive project (Planning stage) where the tool analyses the project in terms of constructive risks and propose technical solutions and preventive measures. The same happens during the preparation and construction process (Preparation and production stages). Not only at the end of each stage the tool analyses the risks but also between stages of the life cycle (when there are modifications of the project or possible different solutions to carry out) one or many operational controls are carried out to evaluate both risks in conjunction and extract technical solutions and preventive measures considering both risks.

CONCLUSIONS
This research project presented here is developing an ontology based on the analysis of different existing evaluation systems. Its structural issue is the integrated risks evaluation to analyze both environmental and safety risks in a common way.
The issues arisen in integration were basically how to define the risk taking into account both environmental and safety aspects. Then different risks evaluation systems were analysed and a common model was defined based on similar properties of the integrated risk.

This integration of environmental and safety risks management is absolutely objective because it is based on existing systems and only the integration is the difference.

At the first stage, the Decision Making tool is oriented to constructors but probably, it can be extended to other stakeholders with the consequent adaptation to the new context.

For the moment, the tool is still being developed but it is expected that in the near future validation and verification by analyzing different case studies will be carried out.

REFERENCES


