OCCUPATIONAL HEALTH AND SAFETY RISKS: TOWARDS THE INTEGRATION INTO PROJECT MANAGEMENT

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ABSTRACT

Project management in industrial settings in many cases is deficient with respect to integrating OHS risks. This deficiency manifests itself as problems affecting the safety of industrial practices and is explained generally by poor knowledge of OHS within organizations and project teams.

We present, through this paper, a critical review and provide an overview of research and industrial practices aimed at systematic integration of OHS risks into the execution of projects, based on published scientific literature. We thus introduce some of the tools, methods and approaches being developed or adapted to integrate OHS and a general description of the current status of this integration in various fields.

Our focus includes, in fact, laws, management systems, OHS risk management throughout project life cycle and efforts to integrate OHS risk management to industrial safety practices including approaches using historical data and industrial interventions.

We conclude that publications identified are mainly derived from the construction industry and we stress that the objectives, methodologies and results are largely heterogeneous. The integration of OHS risk is not systematic in all industrial fields despite the changing and improving laws and management systems.

In order to complete the overview of OHS integration, we will suggest future reviews and research that specifically investigates other innovative OHS applications and many analyses of recent industrial accidents. Complete synopsis will give opportunities for researchers to use or improve methods and approaches to promote OHS risk management in the manufacturing sector that suffer from lack of knowledge in this area.

Key words

OHS risk management; laws; management systems; project management; industrial safety practices.

1. Introduction

The practice of engineering is called upon increasingly for systematic management that integrates OHS risks with operational risks. This stems directly from article 2.01 of the code of ethics adopted by the Quebec order of professional engineers (OIQ, 2011): "In all aspects of his work, the engineer must respect his obligations towards man and take into account the consequences of the performance of his work on the environment and on the life, health and property of every person".

In Canada, a new era of governance characterized by attitudes and behaviours expected from "a good parent toward a child" (Pérusse and Bernier, 2009) has emerged owing to Criminal Code amendments adopted in March 2004 (Federal Act C-21) and possible consequences resulting from criminal proceedings where measures to protect the health and safety of workers do not exist.

Taking into account the need to eliminate occupational risks contributes to the success of projects (e.g. Gambatese, 2000a; Gambatese, 2000b; Smallwood, 2004; Baril-Gingras et al., 2006; Fung et al., 2010). The elimination of OHS risks is always more beneficial when introduced at the definition stage of a process and during the fine tuning of projects (Charvolin and Duchet, 2006), but also when users remain mindful of it all the way to the completion of a project.

Since the 1980s and in particular the inception of the notion of "integrated prevention" (Claudon et al., 2008), engineers and various stakeholders in OHS have sought to integrate health and safety into the list of tools used in the design of projects. Although numerous software programs and workplace measures have been developed, project designers encounter difficulty using the enormous quantity of data generated as a result and deciding when and where to apply the new information without causing delays and cost increases.

1.1 Problem and objective of the present review

Actually, industry uses rigorous project management, modern and safe facilities and robust rules of occupational health and safety but accidents continue to cause human and social problems (e.g. Shikdar and Sawaqed, 2003; Smallwood, 2004; Li et al., 2009). Several industrial sectors encounter, continuously, serious accidents during all projects phases (e.g. Li et al., 2009) despite their efforts to integrate OHS in project risk management. This situation leads us to examine the current status of the systematic integration of OHS management risks into project management and industrial safety practices.

This paper is organized as follows. Section 2 presents the methodology, including a few definitions related to risk management. Section 3 details the results of the literature identified. The studies are categorized as explained in the methodology. We then summarize the state of OHS integration in industry and we suggest some possible directions for future research in section 4. Finally, the conclusion of the manuscript is provided in section 5.

2. Methodology

2.1 Strategy and research process

To achieve the objective of our research, we have organized our review of the literature as follows: (1) purpose of research; (2) search of the literature; (3) selection of relevant studies; (4) extraction and classification of data obtained from studies; (5) discussion of studies.

Firstly, we survey the recent literature and summarize briefly the extent to which OHS risks are taken into account in the project management and industrial safety practices, with special focus on the construction industry. This work is thus intended to help us in identifying research avenues to address the lack of knowledge noted particularly in the systematic management of OHS risks in the manufacturing sector.

Secondly, we have selected literature and structured our examination of the question surrounding the integration of OHS risks into project management and industrial practices. We queried Compendex, Inspec, IEEE Xplore, Eureka.cc and NIOSHTIC-2 using keywords such as risk, elements of risk, risk factors, risk management, project management, project lifecycle, risk assessment, risk analysis, method, occupational health and safety (OHS), risk management standards, OHS assessment, OHS performance, OHS measurement, OHS intervention, quantitative assessment, qualitative assessment, safety procedures, safety programs, systematic approach, design, ergonomics, safety culture, organization, construction, industry, laws, hazard, causal, model, tools, framework. We also identified books published recently, along with a large number of research reports, by consulting the Internet sites of INRS[1] and IRSST[2]. The search strategy combined two sets of keywords using “AND” or “OR” strategies.

Thirdly, relevant studies were assessed for methodological quality and clarity of their objectives. We analyzed titles, keywords and abstracts of peer-reviewed publications, standards of management and pertinent book chapters. It should be noted that we have analyzed more than 70 peer-reviewed publications for over five months. Peer-reviewed publications are from around the world (in English and French) and published between 1997 and today.

Fourthly, how to integrate the management of OHS risks in industry differs greatly from one sector to another. In part, these differences are mainly due to risk acceptability, development of laws and standards, maturity of project management standards and use of management systems.

We attempted to conduct an interdisciplinary review of literature. We stress that the objectives, methodologies and results of relevant studies identified are largely heterogeneous. In the purpose of trying to classify these publications, we used the mutual influences between the categories we've identified. These mutual influences are inspired from influence diagrams used in engineering. An influence diagram traces links between elements of a system adapted to the context of study (Alexandru, 2009).

If we take the construction sector as an example, the development of laws has helped in changing and improved project management standards (Gambatese, 2000b). This development of project management standards has also enabled the creation and the implementation of several tools and methods that improved project management. The efforts of researchers followed law developments and have stimulated developments of best practices (e.g. Zachariassen and Knudsen, 2002; Saurin et al., 2004; Hare et al., 2006).

For this reason we tried to organize the results based on these identified links of influence. These outcome categories (gray rectangles) and links of influences (arrows) are detailed in the Fig. 1.

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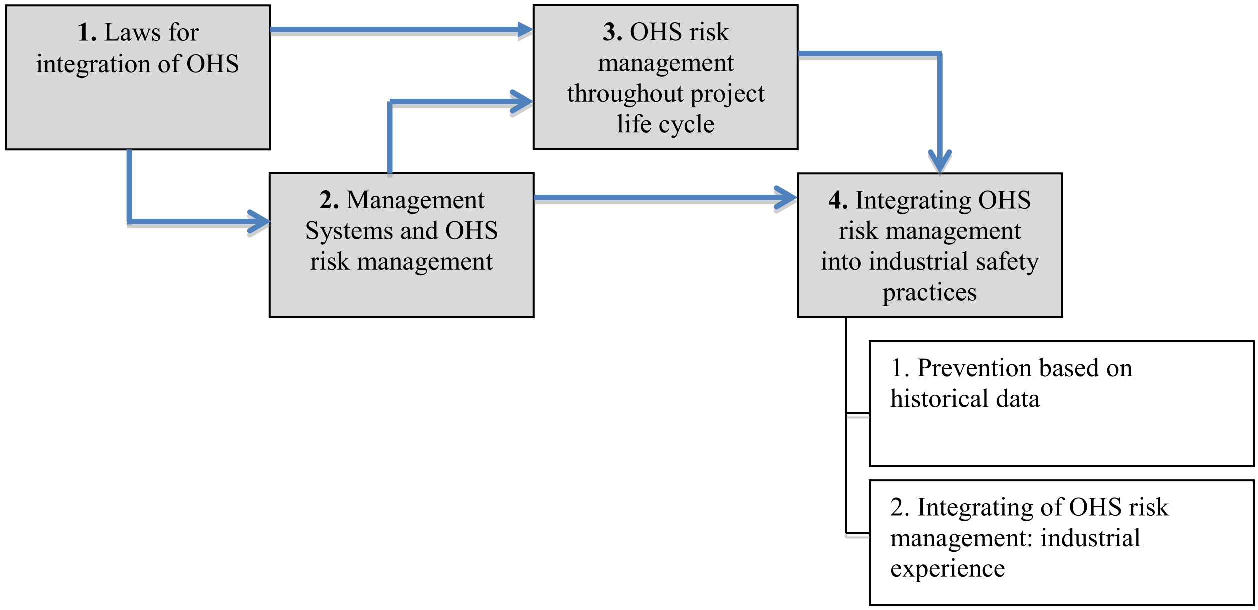

***Fig.1.** Data classification from literature with influences links (Section 3)*

Finally, we discuss results of literature while following categories and links of influences detailed above. In section 4, we summarize the state of the OHS integration in industry, limitations of the review and recommendations.

2.2 Risk and risk management: definitions

The Project Management Body of Knowledge (PMBOK® Guide[3], 2008a) states that project management is the application of knowledge, skills, tools and techniques to project activities in response to needs of the project. The management of a project spans five groups of processes: commitment, planning, execution, control and closure. In chapter 3 of the Construction Extension to the PMBOK® Guide (2008b), PMI® gave an overview of the project safety management processes. This process includes "all activities of the project sponsor/ owner and the performing organization which determine safety policies, objectives, and, responsibilities so the project is planned and executed in a manner that prevents accidents, which cause, or have the potential to cause, personal injury, fatalities, or property damage". In this extension, PMI® defined the term safety management by both safety management and health management. It's important to note that project safety management interacts with all aspects of project management. These

[3] Project Management Body of Knowledge: a reference work on project management, edited by the Project Management Institute (PMI®).

interactions are based essentially on communication between all stakeholders (PMBOK® Guide, 2008b).

Risk is defined as the influence of uncertainty on the attainment of goals (ISO 31000, 2009). It is defined also as inherent in the activities of man and all enterprises. Risk is a combination of the probability and the consequences of the occurrence of a specified dangerous event (OHSAS 18001, 2007). “OHS Risk” is the significance of a hazard, in terms of the probability, and severity of an injury or illness occurring as a result of the hazard. In this paper, we mean by “Risk” the other forms of risk that must be managed by an organization: contract management, construction cost, planning and statistics, human resources and logistics, etc. (Mi and Nie, 2008).

“Project Risk Management includes the processes of conducting risk management planning, identification, analysis, response planning, and monitoring and control on a project” (PMBOK® Guide, 2008a). In the risk management process, risks identification step is the foundation (Liu and Guo, 2009) and it presents challenges (Hagigi and Sivakumar; 2009). This definition stresses the goal of reducing a risk by lowering its likelihood (prevention) or its severity (consequence) (OHSAS 18001, 2007). The guide ISO 73-X 50-251 (Risk Management –Vocabulary) offers definitions of the key elements often used to identify and analyze risks:

- The event is the occurrence of a particular set of circumstances;
- The consequence is the result of an event;
- The probability is the degree of likelihood that an event will occur;
- The source is the element or activity having some potential consequences.

The Software Engineering Institute (SEI) identifies two risk management strategies used in handling risk (Dorofee et al., 1996). The first strategy is to engage actions that reduce the probability of occurrence. The second strategy employs actions to reduce the negative impact on the project if the risk condition is activated. These two strategies are also used to reduce OHS risks (OHSAS 18001, 2007). The SEI has neglected other strategies often used in project risk management and are well detailed by Aubert and Bernard (2004):

- Mitigation, which focuses on steps taken to reduce the probability that an undesirable event will occur;

- Deflection, which consists of modifying the direction of the impact of the occurrence of an undesirable event;
- Establishment of a contingency plan consisting of measures to reduce the impact of an undesirable result;
- Avoidance or refusal to assume risk;
- Retention or acceptance of risk.

Executing actions to mitigate risks requires the dedication of resources, such as time and money (Kutsch and Hall, 2010). For this reason, the commitment of management to this aspect of project execution must be strong (e.g. Gambatese, 2000b).

3. Results

The strategy and research process were applied to select relevant publications. Table1 shows details about the selected publications. In the same table, we have a summary of each publication which shows the industrial sector, the country, the classification performed (Fig. 1) and some tools, methods and approaches developed (30% of studies) or adapted (70% of studies) in each study. This summary helps the reader to identify quickly the information about the OHS integration in various industrial projects.

The results confirm the existence of many publications in order to integrate OHS risks in construction management projects (60% of selected publications). Given the critical nature of the industrial sector and the significant number of accidents occurring at the workplace, several scientifics and experts in this field have proposed some management tools to identify the various OHS risks. It is important to note that the most identified research in construction is generalizable to manufacturing.

Table 1. Summary of the relevant publications selected

Authors (year of publication)	Industrial sector	Country	Outcome categories* (Section 3)						Some of the tools, methods and approaches being developed or adapted
			1	2	3	4.1	4.2	5	
Aubert and Bernard (2004) (book)	--	--						X	Risk factors approach
Baril-Gingras et al. (2006)	OHS sector-based associations	Canada						X	Advisory interventions
Charvolin and Duchet (2006)	Construction	France						X	Multidisciplinary and participatory design; ergonomics and hygiene
Ciribini and Rigamonti (1999)	Construction	Italy						X	Time-space charts
Dassens et al. (2007)	All industries	France				X			MADS and MOSAR methods
Dionne-Peroulx et al. (2003)	Manufacturing	Canada		X					Case study; interviews
Fung et al. (2010)	Construction	Hong Kong	X			X			Historical accident data; accident analysis; Risk Assessment Model (RAM); case study
Gambatese (2000a)	Construction	US			X				Constructability Concepts File
Gambatese (2000b)	Construction	US			X				Project planning and design; owner safety program; best practices database
Gegic (2008)	Metallurgical	Serbia		X					OHSAS standard
Gey and Courdeau (2005) (book)	--	--		X					OHSAS standard
Gibb et al. (2006)	Construction	UK	X		X	X			Construction accident causality; ergonomic approach
Hare et al. (2006)	Construction	UK			X				Interviews with steering groups and expert panels; focus group methods; risk management workshops; control lists; responsibility and assessment charters; audits
Kartam (1997)	Construction	Kuwait	X		X				Critical Path Method (CPM) scheduling software; IKIS Safety
Khodabocus and Constant (2010)	Printing	Reduit, Mauritius		X					OHSAS standard, concept of continual improvement; OHS programs; risk assessments; case study

Kutsch and Hall (2010)	Engineering	UK				X			Qualitative study; interviews
Lamonde et al. (2002)	Construction	Canada					X		Ergonomic intervention; case study
Li et al. (2009)	Construction	China						X	Open life-cycle processes
Lingard et al. (2009)	Construction	Australia			X				Project management; model client framework
Molenaar et al. (2009)	Construction	US				X			Structural equation model (SEM); individual questionnaire
Ponting (2009)	OHSAS standard	UK		X					OHSAS standard
Rivas and Ruskin (2004)	Manufacturing	Australia	X						Codes of safety practices; Australian Standards
Saurin et al. (2008)	Construction	Brazil						X	Cognitive systems engineering (CSE); safety management practices
Saurin et al. (2004)	Construction	Brazil			X				Safety planning and control model (SPC); preliminary hazard analysis (PHA); percentage of Safe Work Packages (PSW)
Shen and Walker (2001)	Construction	Australia					X		Quality management (QM); Environmental Management (EM); construction planning; case study
Smallwood (2004)	Construction	South Africa						X	Investigation
Suraji et al. (2001)	Construction	UK				X			Accident causation model; accident analysis
Tim and Salman (2009)	Petrochemical	UK		X					Drilling Management System (DMS); OHS standards.
Toulouse et al. (2005)	Manufacturing	Canada					X		Ergonomic interventions; Lean manufacturing methods; PVA-Kaizen; interviews
Wynn (2008)	Manufacturing	US							Benchmarking study; interviews
Zachariassen and Knudsen (2002)	Construction	Norway	X		X				Elements of Norwegian legislative basis; project auditing, best practices; experience transfer; OHS data sheets; management tools

*) 1. Laws for integration of OHS; 2. Management Systems and OHS risk management; 3. OHS risk management throughout project life cycle; 4.1. Prevention based on historical data; 4.2 Integrating of OHS risk management: industrial experience; 5. Others.

3.1 Laws for integration of OHS

Worldwide, several laws have been created or amended to facilitate the management of OHS in the workplace. EC Directive 92-57-EEC formally requires all parties involved in European Union projects to address safety. Great Britain has enacted the Regulations (CDM, 1994) to require designers to play a role in the identification and mitigation of safety hazards. In Quebec, the purpose of the OHS Act (OHSA, 1979, c. 63, a. 2) is “the elimination at source of dangers related to the health, safety and physical integrity of workers”. In Canada, a new era of governance characterized by attitudes and behaviours has emerged owing to Criminal Code amendments adopted in March 2004 (Federal Act C-21) and possible consequences resulting from criminal proceedings where measures to protect the health and safety of workers do not exist.

It is through the development of these laws and awareness of the criticality of various industries with regard to human life that we note the existence of numerous publications focused on integrating OHS risks into the project management and industrial safety practices. In construction projects, several researchers and experts (Kartam, 1997; Gibb et al., 2006; Fung et al., 2010) have proposed numerous tools to manage the various risks encountered.

Based on project management legislative considerations, Zachariassen and Knudsen (2002) have discussed key elements in Norwegian legislation concerning the integration of OHS into drilling platform construction projects in high seas. Their experiences suggest favouring a systematic approach to integrating OHS. The study is based on the wording of the legislation enforced by the Norwegian Petroleum Directorate (applied in 1995 and amended in 2001), on the current status of risk integration in petroleum companies and on the issues motivating such integration. Recent legislations essentially obliges companies to integrate OHS measures into the design of installations as well as when altering methods (Rivas and Ruskin, 2004). Integration of OHS risk management, promotes systematic transfer of knowledge, a strategy including a description of responsibilities and active involvement of staff with field experience (Zachariassen and Knudsen, 2002).

3.2 Management Systems and OHS risk management

The OHSAS 18001 (2007) standard is the most widely recognized OHS Management System Standard (Ponting, 2009; Tim and Salman, 2009; Khodabocus and Constant, 2010). This structured management system permits organizations to identify, assess and prioritize risks, and implement appropriate control measures to reduce the potential of occupational injuries, illnesses and accidents. The OHSAS 18001 standard is compatible with ISO 9001 and ISO 14001 and is identical in structure with them and thus they should be complementary (Gegic, 2008).

Other OHS Management System Standards ANSI/AIHA Z10-2005 and CAN/CSA Z1000-06 are consensus standards developed in the US and Canada respectively. These standards include the same principles as OHSAS 18001 (2007).

Dionne-Peroulx et al. (2003) undertook the evaluation of the effects of introducing ISO 9000[4] standards and the management of OHS in private companies. Over 300 manufacturers throughout Quebec, both ISO 9000 certified or not were surveyed. The three main dimensions of the study focused on the ISO process (goal, justification and implementation strategy), internal practices used to manage OHS and the level of performance in OHS. The authors determined that as far as OHS was concerned, ISO 9000 certified companies do not enjoy a higher level of performance than non-certified companies. This is consistent with the conclusion of Gey and Courdeau (2005) that issues pertaining to the management of OHS have been overlooked in these standards.

ISO recently sought to close the long recognized gap with arrival of the new ISO 31000 (2009) standard, which acknowledges the management of risks within organizations. ISO 31000 (2009) offers principles and general guidelines for the management of risk (without specifying categories of risks) and remains applicable in industry. This new standard will serve to unite risk management processes with existing standards (including ISO 9001 and ISO 14001). It offers a common approach to the establishment of standards addressing risks without replacing them and will not lead to certification.

[4] Referring to a set of standards relative to quality management published by the International Organization for Standardization (ISO).

3.3 OHS risk management throughout project life cycle

To identify and manage OHS risk associated with a project, an organization requires involvement and participation of the project manager, the project team members, the risk management team, customers, experts, end users, stakeholders and the specialists in risk analysis (e.g. Gambatese, 2000a; Gambatese, 2000b; Zachariassen and Knudsen, 2002; Hare et al., 2006)

Qualitative assessment remains essential in prioritizing OHS risk (e.g. collecting data, modelling techniques and expert opinion). The purpose of this evaluation is to prioritize risks in terms of the likelihood of their occurrence and their impact on the project goals. Qualitative assessment is often supplemented by a quantitative review to the extent possible. Following risk assessment, the process is completed by adopting a risk control action plan integrated into the project management process as an indicator measuring the effectiveness of the approach (PMBOK® Guide, 2008a).

We must mention the investigation of Hare et al. (2006), which sought to integrate OHS during the planning phase of a project. The researchers (Hare et al., 2006) used an approach based on discussions with four steering groups formed by experts in industry and three expert panels in analysis of supplier performance in order to determine factors critical for success and to develop a management model that integrates OHS. Before that the research team intervened, only an entrepreneur managed OHS-related tasks. Once risk management was integrated into the evaluation of projects, some elements of OHS were introduced, on a limited basis, in order to address other types of risks. Such risks now receive greater consideration in construction projects without diminishing the involvement of entrepreneurs, thanks to the evolution that has occurred in managing these risks. The researchers (Hare et al., 2006) identified events and tasks for which integrated consideration of OHS becomes nothing short of imperative, as in the case of communication. They also proposed methods and tools: responsibility charters, assessment charters, risk management workshops, posters and graphics dealing with safety, control lists, milestone dates and verifications through audits.

We shall discuss the safety planning and control model in projects developed by Saurin et al. (2004). Integrated during the planning and control phase of projects, this model comprises three hierarchical levels updated during production planning. The management of safety is integrated into all planning carried out by the company. Operators receive training based on a safety plan before carrying out their planned tasks.

Our review has identified the possibility and opportunity to integrate OHS into project activities upstream the planning phase. Gambatese (2000b) confirmed that owners who take a pro-active role in safety thus influence the safety experience on a construction project. Their research demonstrates that owners can strengthen project safety by taking actions such as addressing safety in the contract, promoting safety awareness and pre-qualifying constructors based on safety.

Similar work by Lingard et al. (2009) has helped Australian Government Agencies integrate OHS into project management practices. A “Model Client Framework” based on input from construction industry clients was thus developed to embed OHS into project management discipline. This life-cycle approach ensures transfer of OHS information throughout the construction supply chain (customer, designer, constructor and end-users). The model is made up of the following elements: The Federal Safety Commissioner’s OHS Principles, the project process map, supporting tools and resources. Among the OHS principles of the Federal Safety Commissioner, we note developing a safety culture, leadership and commitment, developing cooperative relationships, promoting OHS in planning and design, consulting and communicating OHS information to project stakeholders, managing OHS risks and hazards, maintaining effective OHS measures across the project lifecycle and monitoring and evaluating OHS performance. The research shows how this framework improves the integration of OHS and OHS performance into construction projects.

Another important work initiated by Gambatese (2000a) describes recent research in the area of safety constructability and develops a “safety constructability review process” that provides means by which designers can improve safety during the design phase. This process provides access to a range of means and best practices to facilitate, manage and improve safety during the design phase. Among the best design practice, we can cite: (1) minimize the amount of night work and do not allow schedules that contain sustained overtime; (2) provide a clear, unobstructed and spacious work area around all permanent mechanical equipment; (3) position equipment controls and control panels away from passageways and work areas.

We might also mention, as an example, the tool developed by Kartam (1997), who has integrated OHS knowledge into the Critical Path Method (CPM)[5]. This approach is based on four principles of management: (1) planning, (2) organizing, (3) controlling and (4) leading. The tool has three components: control through engineering (specifically regarding the use of protective equipment and safety instructions), training and finally respect for regulatory and standards requirements. This tool makes it possible to manage OHS problems throughout all phases of a construction project. Among the benefits reported, project managers are able to plan, manage and control safety within cost, production, quality and scheduling constraints.

Finally, project management depends on communication, worker attitudes, motivation, skill, health and physical condition (Gibb et al., 2006). The workplace is influenced by congestion on the site, planning of the work and maintenance (Gambatese, 2000a). Other risk factors are linked to the management of projects, the culture prevailing with respect to safety and risk management and the economic climate in which a firm operates. Gibb et al. (2006) therefore proposed the integration of several measures into the management of construction projects, for example, the level of care required at the design stage and the degree of commitment on the part of the companies involved.

3.4 Integrating OHS risk management into industrial safety practices

The analysis and assessment of risks is viewed as a crucial step. Risk assessment plays a major role in identifying and rectifying inequitable situations (Viau, 2009). Tools used to evaluate risks of accidents vary according to their analytical development.

Researchers (e.g. Ciribini and Rigamonti, 1999; Kartam, 1997; Fung et al., 2010) gathered information from several sources to create databases for the tool, including OHS risks by trade, investigations in the field, incident and accident histories and OHSAS standards.

Experts (e.g. Suraji et al., 2001; Gibb et al., 2006; Wynn, 2008; Kutsch and Hall, 2010) often propose numerous tools adapted to managing OHS risks, such as PHA[6]

[5] This tool makes it possible to identify activities having a critical impact on the scheduling of a project. The relationship between activities and deadlines is analyzed to determine which activities are vital to completion of a project within a set timeframe. The consequences of delays are thus brought to light and management of resources can be oriented to reduce bottlenecks.

[6] Preliminary Hazard Analysis: a design tool used in identification and analysis of hazards in a system.

control lists, brainstorming, constraint analysis, benchmarking studies, statistical data accumulated on accidents and incidents and historical data.

3.4.1 Prevention based on historical data

The usefulness of the above-mentioned studies in a given situation depends on planning and managing resources devoted to improving safety and on analysis of a sufficient number of risks associated with accidents that occurred in the past. Accidents are generally caused by interactions between human resources and several risk factors such as work in close proximity to hazardous agents. Human resources can cause hazards by ignorance, negligence or risk-associated behavior (Kutsch and Hall, 2010).

Several recent publications focus on developing methods and tools for risk analysis based on historical data (e.g. Suraji et al., 2001; Gibb et al., 2006; Dassens et al., 2007). Work led by Dassens et al. (2007) stands out in the development of a new method allowing a company to assess dangers emanating from all external and internal sources. The systemic approach adopted using this method makes it possible to study interactions between the company and its environment as well as links in the chain of events leading to danger by using historical data.

The analysis proposed above is carried out following the broad steps of analysis of the system, identification of undesirable events and estimation of the impact of these events (Dassens et al., 2007). Analysis of the system is carried out to acquire in-depth knowledge of the activities, goals, structure, environment and evolution of the system. Identification consists of the recognition, evaluation and characterization of the risks involved in undesirable events. Estimation and evaluation establishes a ranking of the events in terms of their impact. MADS[7] and MOSAR[8] methods are used by Dassens et al. (2007) to address links identified in the chain of events culminating in danger. This research has made valuable contributions to the structuring of elements of risk and the risk management process without providing detail concerning the mechanism required for this management at the operational level.

[7] Methodology for analysis of system dysfunction, also called the danger universe, was initially used as a teaching tool for construction and understanding of the problem of risk analysis. It is constructed on the basic principles of systematic modelling developed by Jean-Louis le Moigne in "general systems theory".

[8] Systemic structured methodology of risk analysis is a tool used to structure a danger and thereby to identify it in a rational manner. This tool is made up of two modules designed to address two considerations: Module A provides macroscopic analysis of proximal risks. Module B provides a microscopic analysis and focuses on detailed and complementary analysis of technical and operational dysfunctions detected in module A (Périlhon, 2003).

We have also identified two important models developed by Gibb et al. (2006) and Suraji et al. (2001) for accidents in the construction industry. The first of these was based on an ergonomic approach. Using a procedure based on the study of a hundred accident cases, Gibb et al. (2006) identified the safety breaches that led to the accidents and suggested actions to reduce them. Risk factors for construction industry accidents can be prioritized using this proposed model. Interactions between the work team, workplace and equipment can thus be examined to determine how an accident occurred. The first model confirms that circumstances surrounding an accident are influenced by several factors, such as nature of the operation, the behavior of the worker and communication within the work team.

The second model (Suraji et al., 2001) addressed possible improvements to an existing site. The goal is to propose practical means for investigating accidents, performing safety audits and implementing risk management systems. Suraji et al. (2001) have offered to test this model in case studies involving five hundred reports drafted by HSE[9] inspectors. The authors of this model classify causes of accidents according to two types of risk factors: factors termed "distant" and others said to be "proximal":

- Distant factors include constraints on design, project management, management of a business and its sub-contractors. These factors also include the influence of decisions, organizational constraints and problems related to the environment within a firm.
- Proximal factors are problems relating to planning, control of projects, construction operations, working conditions and response when faced with danger.

The study revealed that proximal factors cause 80% of all accidents in the construction industry. In great part, these factors are influenced by the organizations safety culture. Management and safety culture affect directly safety performance (Molenaar et al., 2009).

Among the findings of publications in this area, we wish to highlight certain tools, including the principle proposed by Fung et al. (2010), based on a model called RAM[10]

[9] Health and Safety Executive: a British government body engaged in prevention of OHS risks.
[10] Risk Assessment Model: a model used to predict dangers in construction.

created to assess safety risks in construction (Fig. 2) and having as its main goal the classification of risk level for each type of trade or job. Fung et al. (2010) stress the need to assess risks in a faster and systematic manner in response to occupational accidents. This assessment becomes a critical step in achieving safer management of worksites. They followed four steps in developing this principle: (1) examine current safety issues in construction; (2) investigate and identify the various types of risks associated with different trades or occupations; (3) develop a tool based on the RAM model; and, (4) conduct a case study to verify the reliability of the model proposed. This study was based on historical data gathered in the context of a local project over a period of forty months.

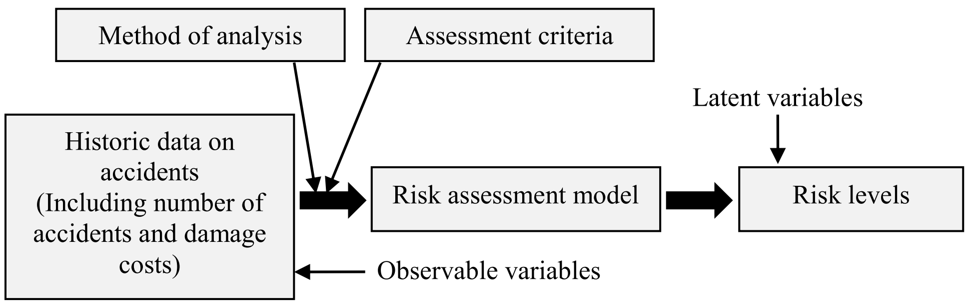

Fig.2. *RAM principle, taken from Fung et al. (2010)*

Fung et al. (2010) relied on a statistical study for the purposes of the model and identified fourteen types of jobs and eighteen types of accidents in the construction industry. Then, they proposed the use of a formula combining frequency of occurrence and severity to interpret the data and estimate the level of risk (R = F x G), excluding other criteria such as the detection and control of risk recently added by some experts and researchers (e.g. Dassens et al., 2007).

Models presented above have contributed to the prevention of OHS risks by exploiting history (background) and know-how in the field. Researchers have validated these models and declared that project performance has improved. The sequence of events leading up to a hazardous situation cannot be identified in some of the models developed because several of these studies separate undesirable events from risk factors.

3.4.2 Integration of OHS risk management: industrial experience

We have identified a limited number of publications on this topic. These publications (e.g. Toulouse et al., 2005; Lamonde et al., 2002) indicate a correlation between integration of OHS and experience of companies to involve their workers.

We uncovered one industrial intervention attempting to integrate prevention of musculo-skeletal disorders (MSD) and OHS problems into the PVA-Kaizen[11] approach. This work was performed by Toulouse et al. (2005) and relied on knowledge acquired during ergonomic interventions. Lean manufacturing methods are used through the intermediary approach based on Kaizen-blitz[12]. Results obtained from the study show that senior managers in small and medium-size businesses and some consultants are in agreement with the use of the PVA-Kaizen approach to integrate OHS. Integrate OHS with continuous improvement projects continues to bring dividends to companies, but success in this regard varies depending on the priorities and motivation of the senior managers (Toulouse et al., 2005).

Shen and Walker (2001) have proposed another intervention to integrate OHS into quality and environment management. Their work opens with a discussion of difficulties confronted in attempting to integrate OHS risks into the system of quality control or management used in projects. Then they comment, with a case study, the advantages such integration conveys in designing and planning projects. This case study of the development of urban infrastructure in Australia (Shen and Walker, 2001) confirms improvements in performance indicators and construction project deadlines that take into account the need of considering OHS risks in concert with the management of the environment. This improvement makes it easier in identifying the risks at the design stage. It also shows how the adoption of a design and construct procurement approach, together with appropriate management techniques, on a successful major freeway project in Melbourne, Australia, was driven by a sound construction planning process, and integrated the construction planning system with OHS, EM and QM systems. The classical system of management fails to address the principles of constructability in design, thereby hampering the completion of projects (Shen and Walker, 2001).

[11] A program aimed at improving productivity proposed to Quebec firms by the Ministry of Economic Development and Regional Research (MDRR).

[12] Also known as "radical change", a Kaizen-inspired approach designed to play on a sense of urgency and focus energies on specific improvements.

Integrating OHS risks with management of the environment permits to develop good practices for project planning. Among the advantages of this integration, we cite improvements in communication and pro-activity.

Finally, we cite the ergonomic intervention to integrate OHS into an industrial project (Factory design in Quebec) as described by Lamonde et al. (2002). This involved analyzing the interactions of two prevention specialists and an ergonomist with the project team. This analysis led to the development of five strategies for achieving more successful integration of OHS: "go step by step, accommodate engineering, legitimize their actions, test whether the design is logical, and record the steps taken." The authors claim that thanks to these strategies, the three stakeholders were able to eliminate a large number of risks at the source and to establish a prevention program prior to start-up of the factory. They also observed other benefits resulting from actions taken by the prevention specialists and the ergonomist, such as equipment operating at higher levels.

We emphasize the guiding principles proposed by Lamonde et al. (2002) and which are applicable to other projects when choosing the approaches to follow, linking actions taken to design and alter projects and optimizing interventions made by experts in ergonomics and OHS with others made initially by persons who are not experts within the firm.

4. Discussion

4.1 State of the OHS integration

Firstly, the integration of OHS risk management in the industry is recognized progressively through the movement toward Total Quality Management (TQM) and Environment Management (EM) (e.g. Matiast and Coelho, 2002; Shen and Walker, 2001). Currently, the researches oriented towards the study of the economic impact of health and safety problems are beginning to unveil the shortfalls in introducing OHS (e.g. Fung et al., 2010). In practice, industry began to introduce OHS considerations to avoid economic losses that are easy to estimate (e.g. Hämäläinen et al., 2009). We can evaluate these losses by the costs of compensation and insurance, the company's reputation and ability to retain its skilled workforce. Currently, several scientifics in this field are working to confirm the gains of OHS's integration with productivity tools (e.g. Shikdar and Sawaqed, 2003). Other researchers involved experts in project teams to improve working conditions and protect workers against diseases (e.g. muscular-skeletal disorders) and dangers (e.g. injuries) (e.g. Lamonde et al., 2002; Toulouse et al., 2005). In many industries, we can see the gap between the willingness of researchers to integrate OHS and priorities of managers (Toulouse et al., 2005).

History has shown that without serious laws and regulations, the companies have a difficulty of changing their practices and perceptions in the absence of tangible economic data. Laws and regulations need time and some effort to build them based on consultations within the OHS network and the working community. On the other hand, we can note that despite the willingness of companies, the support of validated and published solutions, the application of laws and regulations, the dangers are still occurring and sometimes they cause fatal accidents (e.g. Shikdar and Sawaqed, 2003; Smallwood, 2004; Li et al., 2009).

Integrating risk management is not mentioned in several known management standards applied by most industrial sectors. The ISO certification system does not allow company to promote a culture of health and safety (e.g. Dionne-Peroulx et al., 2003; Gey and Courdeau, 2005), without integrating the risk management throughout the processes and organizational framework. Otherwise the specific standards such as environmental management (ISO 14000) do not cover all the OHS risks. The weakness of the OHS integration in management standards mentioned previously is satisfied by the OHSAS 18001 standard. The OHSAS 18001 allows us to have a better control of OHS problems and ensure of maintaining an "acceptable" level of risk. It is important to note that the acceptable level is specified in OHSAS standard by the “level that can be tolerated by the organization having regard to its legal obligations and its own OHS policy” (section 3.1, OHSAS 18001: 2007). This definition could cause problems in OHS risks assessment and management, especially in the absence of laws and regulations. Actually, this problem is present mainly in the manufacturing sector exposed to the mass transfer of activities in developing countries. These countries generally suffer from several problems including lack of laws and regulations that protect workers (e.g. Baram, 2009; Enno et al., 1995).

In the field of project management, if we refer to the PMI® standard (about 323 000 practicing members worldwide), it is clear that risk management does not indicate the systematic integration of OHS risks. The only exception in this area occurs in the Construction Extension (PMBOK® Guide, 2008b) that is implemented through the development of laws and regulations, especially in North America and Europe. Applying the Construction Extension certainly favours a consideration of OHS by defining safety policies, objectives, and responsibilities so the project is planned and executed in a manner that prevents injuries. Most of the previous publications have shown the need of integrating OHS risks throughout the project management (e.g. Gambatese, 2000a). The proposed approaches demonstrate clearly that an involved team project in safety planning and communication and teamwork skills development are necessary (e.g. Gibb et al., 2006; Hare et al., 2006; Saurin et al., 2008). It is important to note that researchers of the same fields do not always agree on the vocabulary used to name the different project management phases and how to do the integration of OHS. These problems complicate the generalization of practices and use of data in research.

Researchers and experts have developed several methods and adapted in most of the cases some tools and approaches known in industry to integrate OHS (Table 1). Despite the use of these known tools and approaches, we mention that the objectives, methodologies and results are largely heterogeneous. Furthermore, there are no consensus among the various sectors regarding the methods and criteria of measurement of OHS integration. In our review, we also reported that only Fung et al. (2010) and Zachariassen et al. (2002) have clearly identified and tried to solve the problem of lack of a systematic approach to integrate OHS risk management.

Briefly, workplace injuries continue to occur for several reasons, relating in particular to the degree of the systematic integration of OHS into project management, the effectiveness of measures taken to promote OHS, exogenous factors (competition, inter-business communication, etc.), endogenous factors (internal communication, culture, organizational approach, etc.) and difficulty associated with managing different types of risks at the same time (Badri et al., 2011).

4.2 Limitations of this review and recommendations

The identification of publications was limited to the databases queried. Almost all of the publications found are peer-reviewed. Other types of literature (e.g. government reports, unpublished reports) were not considered. This literature would provide access to a wider variety of potential sources of knowledge. There are many tools and processes for integrating OHS into construction project decision-making that are not identified in the databases used.

To address these limitations, we suggest future reviews and research that specifically investigate the following innovative areas not mentioned in the present article and which are applicable to OHS: mental models; thinking process tools; cognitive modeling; problem-solving theory; creativity approach; intuitive learning and artificial intuition.

5. Conclusion

This review has examined the recent literature and has summarized briefly the extent to which OHS risks are taken into account in the project management and industrial safety practices, with special focus on the construction industry.

We have thus provided a review of research and practices addressing the integration of OHS risks into the execution of projects and an overview of some of the tools, methods and approaches being developed or adapted to integrate OHS, in addition of a general description of the current status of this integration in various fields.

Our review demonstrates the need to spell out the OHS project risks and plan adequate funding to the project risk management team, if organizations want to avoid dangers and losses that threaten them. Attempts are underway to integrate OHS through timely intervention within a framework of continuous improvement. We now know that researchers are assigning increased priority to integrating ergonomics and OHS risks with production activities.

We conclude that publications identified are mainly derived from the construction industry and we stress that the objectives, methodologies and results are largely heterogeneous. The integration of OHS risk is not systematic in all industrial fields despite the changing and improving laws and management systems.

In order to complete the overview of OHS integration, we will suggest future reviews and research that specifically investigates other innovative OHS applications and many analyses of recent industrial accidents. Complete synopsis will give opportunities for researchers to use or improve methods and approaches to promote OHS risk management in the manufacturing sector that suffer from lack of knowledge in this area.

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