Accident Analysis and Prevention 48 (2012) 223–234

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Proposal of a risk-factor-based analytical approach for integrating occupational health and safety into project risk evaluation

Adel Badri[a,*], Sylvie Nadeau[a], André Gbodossou[b]

[a] Mechanical Engineering Department, University of Quebec, École de technologie supérieure, 1100 Notre Dame West, Montreal (Quebec) H3C 1K3, Canada
[b] Unit of Education and Research in Management Sciences, University of Quebec Abitibi-Témiscamingue, Rouyn-Noranda (Quebec) J9X 5E4, Canada

ARTICLE INFO

Article history:
Received 18 October 2010
Received in revised form 9 April 2011
Accepted 8 May 2011

Keywords:
Occupational health and safety (OHS)
Project management
Analytical hierarchy process (AHP)
Risk factor concentration
Risk assessment
Industrial project

ABSTRACT

Excluding occupational health and safety (OHS) from project management is no longer acceptable. Numerous industrial accidents have exposed the ineffectiveness of conventional risk evaluation methods as well as negligence of risk factors having major impact on the health and safety of workers and nearby residents. Lack of reliable and complete evaluations from the beginning of a project generates bad decisions that could end up threatening the very existence of an organization.

This article supports a systematic approach to the evaluation of OHS risks and proposes a new procedure based on the number of risk factors identified and their relative significance. A new concept called risk factor concentration along with weighting of risk factor categories as contributors to undesirable events are used in the analytical hierarchy process multi-criteria comparison model with Expert Choice© software.

A case study is used to illustrate the various steps of the risk evaluation approach and the quick and simple integration of OHS at an early stage of a project. The approach allows continual reassessment of criteria over the course of the project or when new data are acquired. It was thus possible to differentiate the OHS risks from the risk of drop in quality in the case of the factory expansion project.

1. Introduction

Industrial accidents continue to cause human suffering, capital losses, environmental destruction and social problems (Duijm et al., 2008; Kartam, 1997; Li et al., 2009; Shikdar and Sawaqed, 2003). In recent years, accidents in construction and industry have occurred in spite of rigorous management of projects and robust occupational health and safety (OHS) management systems (Makin and Winder, 2008) in all phases of project lifecycle (Li et al., 2009).

The explosion of a power plant in the start-up phase while testing a gas line in a populated region (43,000 inhabitants) of Connecticut (USA) on February 7, 2010 is reminiscent of a series of similar industrial accidents over the decades in terms of gravity and consequences. In most cases, inquiry into the causes of the accident revealed failure in the identification and evaluation of the impending risks, placing at peril the health and safety of human beings on site and in the surrounding areas. This was the case notably at Bhopal (1984) and at Chernobyl (1986).

In general, risk is evaluated in terms of its consequences with respect to project performance and rarely in terms of human suffering. Smallwood (2004) confirmed that quality, planning and costs are the parameters given the greatest consideration. This is reflected in the decision to install many high-risk production plants near or in densely populated areas (e.g. the AZF chemical plant in Toulouse, France; the now closed Sigma-Lamaque mine in Val d'Or, Quebec). In Quebec, high-risk installations still get the go-ahead in spite of the efforts by the Environmental Public Hearings Office to provide transparent information and to consult citizens.

The aim of this paper is to present a new systematic approach to the evaluation of OHS risks and proposes a new procedure based on the number of risk factors identified and their relative significance. This approach is able to overcome the difficulties of current tools in the manufacturing industry. The proposed approach is based on known techniques and tools, such as multi-criteria analysis techniques (e.g. analytic hierarchy process), expert judgment and the analysis of accidents and incidents. The analytic hierarchy process is selected to minimize the inconsistencies in expert judgments (Fera and Macchiaroli, 2009) and to support approaches that use mixed qualitative–quantitative assessment data (Chao et al., 2005).

This document is structured as follows. In Section 2, we begin by discussing the relevant tools and approaches used to manage project risk in different industrial sectors. We also give an overview of the use of qualitative and quantitative tools in various industries. Section 3 presents the methodology, including the conceptual model of the systematic approach to the evaluation of OHS risks. Given its importance in the approach proposed, the AHP method

* Corresponding author. Tel.: +1 514 3968800x7322.
E-mail addresses: adel.badri.1@ens.etsmtl.ca, badri.adel@gmail.com (A. Badri).

0001-4575/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.aap.2011.05.009

is outlined in Section 4. The proposed approach is then described in detail in Section 5 and a case study of a factory extension is presented to test the proposed approach. Section 6 follows with discussion and suggests possible directions for future research and a conclusion is provided in Section 7.

2. Literature review

Industrial work is risky in many economic sectors, in particular the construction industry (Fung et al., 2010), chemical plants (Vernero and Montanari, 2010), nuclear power plants (Young, 2005) and the mining industry (Hermanus, 2007). Safety problems can result from any of several combinations of causes, which vary from one industry to another. The high level of risk in the construction industry is explained by the nature and characteristics of construction work, low educational level of workers, lack of safety culture and communication problems (e.g. Fung et al., 2010; Gambatese, 2000b). In the mining sector, increasing numbers of subcontractors working in mines, the emergence of new mining ventures and recognition of small-scale mining pose new challenges to the practice of risk control (Hermanus, 2007).

The most effective way to improve OHS performance is to identify and eliminate hazards at the source (Glickman and White, 2007). Risk identification and assessment thus become primary tasks that are part of hazard prevention (Manuelle, 2005). Risk analysis is the foundation of the risk management process (Fung et al., 2010; Liu and Guo, 2009) and presents several challenges (Hagigi and Sivakumar, 2009).

OHS has not always been a preoccupation of process engineers (Hassim and Hurme, 2010). The motivations for integrating OHS risk management into engineering have been discussed recently. These include legislation (Gambatese, 2000b; Zachariassen and Knudsen, 2002), awareness of the importance of protecting workers (Gambatese, 2000a) and in some cases perceived potential to increase profitability and remain competitive (Sonnemans et al., 2002).

Industry has attempted to adapt engineering tools and methods to the assessment of OHS risks. These include quality management tools (e.g. failure methods and critical analysis (FMECA), "What If" analysis and check lists) and other industrial safety approaches (e.g. fault tree analysis (FTA), event tree (ET) and human reliability analysis (HRA)). Several authors have developed OHS risk reduction tools and models used in conjunction with historical data and shop floor know-how (e.g. Cameron and Hare, 2008; Ciribini and Rigamonti, 1999; Fung et al., 2010; Gibb et al., 2006; Hare et al., 2006; Kartam, 1997; Saurin et al., 2004; Suraji et al., 2001). It is important to note that the abovementioned tools are used alone rather than integrated into other types of risk management by an organization.

Quantitative methods of risk management are widely used in many industrial fields (Fera and Macchiaroli, 2009), for example the aerospace and nuclear industries (e.g. Skelton, 2002). These methods generally use equipment and software to analyze data. Quantitative methods are generally expensive and require specialized analysts (Restrepo, 1995). One of the best-known methods is that of the safety review and hazard and operability study (HAZOP) (Calixto, 2007). This method allows assessment of complex situations based on knowledge of several key parameters of a system.

In many industrial fields, the data and information used to assess risk are imprecise and incomplete (Ferdous et al., 2009). Quantitative approaches do not give reliable results when data are lacking (Pinto et al., 2010). Acquiring useful information using quantitative risk assessment based on probabilistic models is not yet possible (Jabbari Gharabagh et al., 2009). In the petrochemical industry, Jabbari Gharabagh et al. (2009) attributed the current difficulties in risk assessment to the complexity of the current quantitative methods. These problems are more significant in the design stage of industrial projects (e.g. Pinto et al., 2010).

Pinto et al. (2010) proposed a qualitative model for health and safety risk assessment based on available data and using a fuzzy logic approach. They concluded that qualitative approaches for human-centered problems are flexible enough to assess risk. Another method worth mentioning was developed by Hassim and Hurme (2010) for assessing the health risks of a chemical process during the design phase. The method takes into account both the hazard associated with the presence of the chemicals and the potential for the exposure of workers to them. An "Inherent Occupational Health Index" has also been proposed to conduct the risk evaluation early in the design phase. Jabbari Gharabagh et al. (2009) concluded that the use of historical data is not only important in risk management, but is also helpful in risk evaluation as an indicator of acceptable risk criteria.

Neglecting the consideration of human factors in risk analysis is due in part to the difficulty of quantifying many of them (e.g. Human risk-taking behavior in Kotani et al., 2007). In addition, human behavior cannot be predicted from analysis of accident and incident histories alone. Evaluation based solely on historical information always runs into difficulties in meeting the challenge of the proactive treatment of risks.

It is always more effective and profitable to integrate risk evaluation beginning at the project design phase (Charvolin and Duchet, 2006). Complete and accurate evaluation will contribute to reducing risks as well as justify monitoring of workers and residents of the surrounding community in the event of damage to the installation, whether caused by an industrial accident or a natural event (Pérusse and Bernier, 2009). Determining the risks and measures for dealing with them before setting the project in motion is without question the wisest course to follow (Gray and Larson, 2006).

Starting from the need to create an appropriate and effective approach that integrates the management of all project risks in the manufacturing sector, our paper explores the possibility of creating such a model for industrial projects using an approach based on mixed techniques.

The proposed approach allows quick prioritizing of identified risks and allows evaluators to identify additional potential causes of undesirable events without nullifying the previous risk element compilation effort. The simplicity of the procedure should facilitate its use in small and medium-sized businesses without requiring a major investment.

3. Methodology

Based on the literature (Aubert and Bernard, 2004; Curaba et al., 2009; Freivalds, 1987; Henderson and Dutta, 1992) and on continuous risk management standards (Dorofee, 1996), this paper proposes a conceptual model for integrating occupational health and safety into project risk evaluation based on multi-criteria comparison (AHP). We have considered a model of risk composed of three elements detailed below and the conventional steps of risk management.

In order to propose a conceptual framework for identifying and assessing risks, we began by tracing the elements of risks that are used for the identification steps. Once the elements of risk are identified, the causality links form the basis of the evaluation and the control steps.

Our analysis is based on a model of risk composed of three principal elements (Fig. 1), namely the risk factors, the undesirable event, and the impact of the undesirable event. In order to control risk, all of the elements must be identified and the various causal