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Risk-informed decision making of safety investments by using the disproportion factor

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ARTICLE INFO

Article history:

Received 13 September 2015

Received in revised form 16 December 2015

Accepted 5 January 2016

Available online 12 January 2016

Keywords:

Disproportion factor

Safety investment

Risk analysis

Decision model

Risk management

Cost-benefit analysis

ABSTRACT

To improve risk informed decision making, a systematic approach is developed. The goal is to analyze and to evaluate safety investments aimed at mitigating and preventing major accidents involving e.g. hazardous materials that might trigger significant financial losses and fatalities. A formulation, explicitly using a disproportion factor, is proposed as a simulation exercise approach to this end. The disproportion factor can be used by any private and public investor to bias decision-makers toward safety. This is especially interesting for deciding about the prevention of high impact low probability (HILP) accidents.

Furthermore experimental simulations have been performed on realistic data to test the proposed decision model and to provide general recommendations. Several types of accidents were considered and the impacts of technical and financial parameters on the disproportion factor, possibly making a safety investment profitable from an economic perspective, are also investigated and discussed in this paper.

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1. Introduction

The concept of operational safety represents a top priority for many industries, and especially for those in the chemical sector, where due to the storage and processing of dangerous materials, major accidents may trigger significant losses, including damages to goods, harm to employees and even detriment to the surrounding communities (Hale et al., 1997).

For this reason, substantial resources are invested every year by public and private organizations to better understand the dangers associated with products/processes and to establish effective safety measures to protect people and the environment of chemical industrial areas. Depending on local circumstances, these measures are taken within a comprehensive regulatory framework, designed at a national and/or international level. The approaches used to decide on which

measures to take, are continuously reviewed to increase their effectiveness and at the same time to decrease cost, if possible.

From a single company point of view, safety investments, just like any other type of investment, might be economically profitable or not, depending on some key factors, as well as on how their financial effects are measured.

Several studies in the literature show that safety investments are not always financially beneficial if compared to the expected consequences of an accident (Reniers and Brijs, 2014). In general, “soft” interventions having lower costs (e.g. training, simple equipment, small changes to work organization) tend to be more profitable than other expensive and more complex measures such as those involving equipment, infrastructure and so on (Targoutzidis et al., 2014).

Since public or private organizations need to justify the budget devoted to investments in safety, executive

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<http://dx.doi.org/10.1016/j.psep.2016.01.003>

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decision-makers usually assess, in a preliminary stage, the impact of safety measures addressing the following strategic and tactical questions: (a) how much should be spent on safety; (b) how much is the lack of safety costing to the business; and (c) what are the most cost-effective solutions (ENISA, 2012).

In the UK, safety is prescribed for any public or private organization, so far as is “reasonably practicable”. Assuming that safety measures are implementable from a technical point of view, the risk that is potentially faced without safety investment (the “do-nothing scenario”) needs to be placed in one scale and the sacrifice, whether in money, time or trouble, involved in the measures necessary to avert the risk needs to be placed in the other. Whether there exists a significant disproportion between risk and sacrifice, a preliminary computation needs to be carried out in order to determine the boundaries, until the point at which the sacrifice can be considered to be reasonably practicable (Robens, 1972; Asquith, 1949).

In other words, a quantitative risk assessment is required to determine how much potential loss could be saved by investments in safety measures. Small and medium enterprises might face particular difficulties since they have limited access to capital. As a result, this inevitably often restricts safety-related investments to only those essential for company survival, meaning that long-term investments are a low priority, even if profitable (Dorman, 2000). Moreover, due to a potential lack of risk expertise, small sized companies can make erroneous safety decisions relying on the belief that their risks as well as the potential costs of accidents are also small, although incident rates for such firms in general are higher (European Foundation et al., 1997).

No matter the size of the business, safety related decisions always present economic implications. However, the way in which safety interventions are economically evaluated represents a critical issue, as many factors are difficult to measure. Moreover, organizations often have difficulties to accurately measure the effectiveness and the cost of related safety activities, since safety is usually an investment that provides hypothetical profit, namely the benefit due to the avoidance of accidents in some distant future. In general, assessments concerning safety investments are done *ex ante* mainly using a quantitative approach and including an evaluation of several aspects such as the legal framework, policies, impact and likelihood of potential accidents, safety budget, etc. Schneider (2006) highlighted that safety-related investments are rarely evaluated in economic terms. For instance, Smallman and John (2001) published a survey in which it emerges that only a minority of British companies adopt a quantitative and well-structured approach to assess safety investments.

In the last years some studies addressed the problem of finding how much an organization should invest in safety. According to Gordon and Loeb (2002) an asset of greater value should not necessarily benefit from a greater investment to protect it. Moreover, there is a point at which the marginal benefits from safety investments are negative. Other studies (Willemson, 2006) demonstrated that there does not exist a fixed percentage for optimal safety investments, since this value might depend on a series of factors such as the assumptions which are used, the business sector, the methodology used to estimate it, etc. In many cases of major accidents solely costs seem to outweigh the hypothetical benefits and therefore to take reputation benefits, legislation repercussion benefits and other factors which are very difficult to measure,

a disproportion factor (DF) needs to be used as a bias in favor of safety.

Although the importance of the DF to evaluate safety investments has been already recognized in several reports, official documents and publications (Baybutt, 2014; Trbojevic, 2005; G.B. Health and S. Executive, 1989; French et al., 2005), a structured methodology to determine a value for the DF to be applied to specific situations is still missing and only few publications have covered this issue. In addition, no universal accounting model has prevailed as a standard method to be adopted and applied to analyze safety investment options.

The study proposed in this paper attempts to fill the existing gap in the scientific literature by proposing a high level decision model that takes into account both the main financial and economics elements related to the investment decision and some technical parameters arising from a risk assessment analysis.

Focusing on high consequence accidents characterized by a low probability of occurrence, a cost/benefit methodology based on the well-known net present value (NPV) calculation is developed by explicitly considering the DF. The latter is used to emphasize the importance of safety over costs to prevent or mitigate accidents. The value of the DF, for which the net present value associated to the safety investment is equal to zero, is used within a more robust economic safety assessment approach to support decision-makers ranking and classifying safety investments. As a result, the methodology could provide recommendations to decision-makers improving their capability to compare alternative safety investments for major accidents. The goal of the model is thus to provide a high level framework supporting the comparison of alternative investment options rather than defining ideal level of DF which may vary depending on different factors (e.g. industry, materials, dimension of the firm).

Based on this formulation, a simulation is carried out to obtain comparable and reliable evaluations while assessing safety investments, as well as exploring the relationships between the main financial, technical and economic variables. Using the results of this sensitivity analysis, private investors and/or policy makers can be informed by a numerical tool in their efforts toward making employees, citizens, infrastructure and systems more safe from major accidents.

To simplify the reading, some abbreviations and acronyms are used in the remainder of the paper, as summarized in Table 1.

The paper is organized as follows. Section 2 presents a brief overview of the literature on how cost/benefit methodologies can be applied to evaluate safety investments. Section 3 describes an innovative approach which combines the NPV calculation with the DF to assess safety investments. Section 4 illustrates a high level decision-making process that can be used by decision-makers to compare and assess safety investments. In Section 5 the results of a simulation are explored in which several accident scenarios are tested and the relationships between the DF and the main technical and financial parameters associated to a set of safety measures leading to a NPV of zero, are investigated. Finally, Section 6 concludes the paper providing some recommendations and suggestions for future work.

2. Literature review

As mentioned before, safety investments are rarely perceived to be profitable from the point of view of a single firm (Rogers,

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