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Major accident management in the process industry: An expert tool called CESMA for intelligent allocation of prevention investments

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ABSTRACT

A tool (called CESMA) was developed to carry out cost–benefit analyses and cost-effectiveness analyses of prevention investments for avoiding major accidents. A wide variety of parameters necessary to calculate both the costs of the considered preventive measures and the benefits related with the avoidance of accidents were identified in the research. The benefits are determined by estimating the difference in (hypothetical) major accident costs without and with the implementation of a preventive measure. As many relevant costs and benefits as possible were included into the tool, based on literature and expert opinion, in order to be able to deliver an all-embracing cost–benefit analysis and cost-effectiveness analysis to assist in the investment decision process. Because major accidents are related to extremely low frequencies, the tool takes the uncertainty of the unwanted occurrence of a major accident into account through the usage of a so-called 'disproportion factor'. Compared with existing software, the CESMA tool is innovative by striving for an as-accurate-as-possible picture of costs and benefits of major accident prevention, and taking the uncertainties accompanying disastrous events into consideration. Furthermore, an illustrative example of CESMA is presented in the paper.

Keywords: Cost–benefit analysis; Cost-effectiveness analysis; Major accidents; Disproportion factor; Expert tool; Process industries

1. Introduction

Companies operating in the process industry face many risks. There are some important reasons as to why prevention investment decision-makers really require more objective and more adequate aids and tools for deciding about accident prevention. The first reason is optimization, as company management often has difficulties with this decision-making process: Paltrinieri et al. (2012) and Gavious et al. (2009) indicate that there is a general lack of knowledge concerning the full range of costs related to accidents, as well as difficulties to determine these costs and benefits. Moreover, there is a widespread believe that accident costs are often inevitable. Secondly, analyses of accidents show that some could have been prevented if similar historical accidents were analyzed carefully and costs' and benefits' information was used to make prevention decisions for similar situations in similar plants. Let us take any major accident as an example. Toulouse (2001), Buncefield (2005), Deepwater Horizon (2010), Fukushima (2011), an what have you: all these accidents were disasters with huge financial repercussions for the company concerned, and if this company would have seriously considered the scenario of this major accident, and made a thorough cost-benefit analysis, it is rather evident in such cases that the averted disaster benefits would outweigh the prevention costs by many orders of magnitude. The decision to invest in certain preventive measures or not, might then have been different.

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Meyer and Reniers (2013) and Reniers and Sörensen (2013) indicate that accidents can actually be divided into three different types based upon the amount of information available and the level of uncertainty associated with the accident. Type I accidents are characterized by the availability of a lot of historical data and low levels of uncertainty, and can thus be predicted fairly accurate using well-known statistical methods. These accidents are on average labeled as work-related accidents or occupational accidents, such as small injuries due to falling or minor material damage. Type II accidents indicate incidents where historical data is not widely available, and characterized with high levels of uncertainty, making it hard to predict them. In contrast to type I accidents, regular statistical tools cannot be used and the estimated generic frequency of the occurrence of these accidents should be handled with great caution. These accidents are usually catastrophes with a lot of property and business interruption damage, and often also multiple fatalities. Type III accidents are truly unknown: unlike the previous two types, there is no historical data available about such accidents. This type of accidents is regarded as impossible to predict, since such an accident has never happened before. A type III disaster can also be called "a black swan accident". Because a type III accident is impossible to predict, such type of accidents do not really fall in the scope of this study. However, the difference between the three types of incidents may be hard to understand at first sight, and to develop a disaster prevention investment tool, it is thus important to determine the definition of 'major accident'.

Based on company experts' opinion, 'a major accident' is defined as 'an accident deviating from normal expectations with an extremely low probability of occurrence, and which causes at least several fatalities on site and/or one fatality and many injured off site and/or important environmental damage and/or material damage worth of at least tens of millions of euros and/or huge international press attention.' This definition makes very clear that major accidents are quite different from (much more frequent) occupational accidents. The definition is also independent from any industrial sector and can thus be used in any organization.

Existing cost–benefit software tools described in literature are focused on occupational (type I) accidents instead of major (type II) accidents and their scope is rather limited. Some examples of such software tools include: CEOccAcc tool (Vandekerckhoven, 2008), Safety pays (OHSA, 2013), Prevention Matrix (Prevent, 2011), Tyta (Agency for Safety and Health at Work, 1999), SZW (Ale, 2013), AKK (Rzepecki, 2002), Economic Assessment (Niven, 2000), Annual accident cost calculator and Incidents costs calculator (HSE, 2005), Productivity assessment (Oxenburgh and Marlow, 2005), ORC return on health, safety and environmental investments (Linhard, 2005), Potential-method (Bergström, 2005), Tool Kit (Amador-Rodezno, 2005). These tools all assist in estimating the direct and indirect costs of accidents. These tools as well as the CESMA tool that was elaborated ('CESMA' is an acronym for 'Cost-Efficient Safety for Major Accidents'), described further in this article, have in common that they all direct a great importance to indirect costs, as they often largely exceed the direct costs (Vandekerckhoven, 2008). Especially in case of major accidents, this observation should be kept in mind when deciding on prevention measures. With respect to major accident prevention, a tool, not available at present, is needed to help the decision-maker, since the major accident scenarios and their potential consequences are much harder to identify and to quantify, and analyses for major accidents involve much greater levels of uncertainty than analyses for occupational accidents. Therefore, the tool described in this paper was developed.

Three main reasons are conceived why companies should consider using a tool in the decision-making process of investing in safety measures related to major accidents. The first reason is optimization, as company management often has difficulties with this decision-making process. This can be the case because there is a general lack of knowledge of the full range of costs related to major accidents, and the measurement difficulty of costs and benefits related to such accidents. Secondly, it can assist to convince managers of the importance of safety investments from an economic point of view, and it can aid managers in the efficient safety budget allocation, as some safety investments may turn out to be more efficient compared to others. Thirdly, analyses of major accidents show that some major accidents could have been prevented if similar historical accidents were analyzed carefully and costs and benefits information was used to make prevention decisions for similar products in similar plants.

The CESMA tool that was developed actually allows the user to execute both cost–benefit analyses and cost-effectiveness analyses specifically for major accidents, in order to evaluate investments in safety measures to prevent, protect or mitigate against such types of High Impact, Low Probability accidents. The tool also takes uncertainty with respect to the occurrence of costs and benefits, into consideration.

2. Literature study

2.1. *Cost/benefit analyses*

Cost–benefit analyses are used to determine whether an investment represents an efficient use of resources. In the case of this research, the resources are assumed to be money and time. An investment project, for example a safety measure, is an allocation of money and time in the present that will result in a particular stream of hypothetical benefits in the future. The role of a cost–benefit analysis is to provide information to the decision-maker, in this case an employee or a manager who will appraise or evaluate the investment project (Campbell and Brown, 2003). The main purpose of the analysis is to obtain relevant information about the level and distribution of benefits and costs of the safety investment project. Through this information an investment decision within the company can be made in a more objective way. The analysis' role is to provide an objective evaluation and not to adopt an advocacy position either in favor or against the safety investment, as there are also many other aspects that should be taken into account when deciding about safety investments, such as social acceptability and regulatory affairs. Claims resulting from damage to society and others will also be included, but damage to society and others for which there will be no claims toward the company, are excluded. There is no doubt that major accidents have wider implications than the costs and benefits strictly related to the organization, but if these do not affect the firm's financial position, then they are omitted from the decision-making process as these do not fall in the research scope of this article.

In case of a cost–benefit analysis related to safety investments, the costs going hand in hand with both the situation without and with the prevention measure should be

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