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A sequential method to identify underlying causes from industrial accidents reported to the MARS database

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A B S T R A C T

This paper presents a method designed to identify underlying causes leading to industrial accidents. The method developed intends to facilitate the learning process from accidents by identifying possible causes related to the accidents that were not directly stated in an accident report, but that can be deduced following the description of the event, in particular with regard to the quality of the safety management systems in place at the industrial establishment at the time of the accident. The method has been prepared following a sequential approach, although a combination of the philosophy behind other existing accident models has been taken into consideration. The starting point to develop the model is the causes for accidents included in the MARS database of the European Commission. These causes have been extended by considering typical operational or organisational failures that are normally related to the original reported cause. The extension of causes has been performed by adding three follow-on levels of possible underlying causes. The first level could be considered as a direct cause of the accident and, the last level being more applicable to the foundation of establishing safety: "Safety Management System or the Safety Culture".

In order to check the applicability of the method developed, it has been validated by a group of experts of the European Federation of Chemical Engineering, in order to reinforce the strategy adopted by the authors. Moreover, the method has been used to analyse the total set of accidents reported to the MARS database. The objective is to determine the efficiency of the method in identifying underlying causes, and to establish a link between the results obtained and the actual causes stated in the reports. In this way, it is possible to establish a system to go deeper into the analysis of past accidents, in order to obtain lessons learned, and to avoid recurrence of similar accidental scenarios in the future, as well as to give directions for a better reporting system of industrial accidents.

1. Introduction

1.1. General

This paper is a result of a joint project between the Major Accident Hazards Bureau of Joint Research Centre (JRC) of the European Commission and the National Centre for Learning from Accidents, a part of the Swedish Rescue Services Agency, on the MARS database.

MARS (Major Accident Reporting System) was established in 1984, and it is the system used by the European Commission to keep track and to handle the information of industrial accidents occurred in EU Member States, as stated in the requirements of the Seveso II Directive (EC, 1997). The reporting to the MARS database is done by what is known as Competent Authorities in the member states. Soon after an accident, a short report is issued which is then followed by a full report when the full details are available. Detailed information on MARS can be found in the JRC reference (Joint Research Centre, 2008).

One important use of the MARS database is to give a basis for legislative actions in the EU countries. For a correct prioritization of the actions, one would need a full picture of the underlying causes for the accidents.

The analysis of past accidents in process industries is a useful method for identifying common aspects regarding the causes that triggered or contributed to such events. The MARS system provides different possibilities for introducing the identified causes that led to an accident, e.g., insertion of free text or selection from pre-defined lists (Mushtaq & Christou, 2004).

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In the last years, different analyses have been performed on the information included in the MARS database. Previous studies on the MARS accidents have covered various aspects related to the causes of the accidents. Some of these analyses have been performed at a general level (Sales, Mushtaq, & Christou, 2007a), while others were aimed at obtaining lessons to be learned, focusing on specific issues such as handling of dangerous substances (Drogaris, 1993), efficiency of emergency systems (Kirchsteiger, 1999), management issues (Mushtaq, Christou, & Duffield, 2003) or chemical reactions (Sales, Mushtaq, Christou, & Nomen, 2007b). The analyses so far have been based mainly on the causes directly reported from the Competent Authorities, with little attempt to a deeper analysis of underlying causes.

There are several objectives of the joint project. General objectives are:

- to learn more about underlying causes, especially regarding organisational aspects, from the accidents reported in MARS;
- to link underlying causes to issues of safety management systems and safety culture;
- to identify weaknesses in the quality of reporting and analysing.

The primary objective of this paper is to determine whether it would be possible to go deeper into underlying causes of the reported accidents. Secondary objectives are – provided that the primary objective can be achieved:

- to compare the extent of underlying causes generated from a deeper analysis with those actually reported in the MARS accident reports,
- to compare the distribution of underlying causes with and without the deeper analysis, and
- to give a basis for evaluating whether the correct conclusions are drawn from the MARS reports or if, in the case of too shallow analyses of the causes, the wrong conclusions and non-optimum decisions in the legislative work of the European Commission can be the case.

In order to carry out the deeper analysis, a reasoned and systematic method had to be developed and its feasibility had to be validated.

1.2. Theoretical background

1.2.1. Accident models

There are several types of accident analysis models. Hollnagel (2004) distinguishes three types:

- sequential,
- epidemiological, and
- systemic models.

Sequential models are the oldest ones, originally developed by researchers such as Heinrich, Petersen, and Roos (1980) and further refined by others, e.g., Bird and Germain (1985) in the ILCI model. These were followed by epidemiological models developed in particular by Reason (1997). The most modern models are of the systemic type, developed among others by Dekker (2006) and Hollnagel (2004). Often new models criticise or even disqualify older ones. However, in reality these models can be complementary to each other, each one having its strengths and its weaknesses. Fig. 1 shows a schematic representation of a sequential model (Kjellén, 2000), which includes the idea of "root causes".

The root cause can be defined either as "the combinations of conditions and factors that underlie accidents or incidents, or even as the absolute beginning of the causal chain" (Hollnagel, 2004). This is illustrated in Fig. 2.

In every accident and near-miss, there are normally, apart from the direct cause(s), some additional aspects that have had influence on the probability for the event to happen and on the course it took. There are often latent conditions and situational factors in play. With *causes*, we understand both the direct causes which trigger the event, and underlying causes. Typical examples of causes can be a classical mistake or error by an operator or a direct failure of some equipment, but also inadequate training, which led to the mistake or inadequate maintenance, which led to the equipment failure.

Other contributing facts and circumstances can also be regarded as causes. These may be called explanations (Dekker, 2006) or *latent conditions* (Reason, 1997). These concepts usually refer to less obvious conditions, which can often be dormant for a long time, but which can contribute to the course of events, once a triggering direct cause occurred. Typical examples of latent conditions could be decisions at a higher organisational level leading to deficiencies of the design/engineering, inadequate training, deficiencies of procedures and instructions, deficiencies in preventive maintenance, and so on. Latent conditions could also be lack of or deficiencies in safety barriers of various kinds (Hollnagel, 2004).

With *situational factors*, we understand factors that are not constantly present but turn up occasionally and can make it more difficult to perform a certain task in a correct and safe manner, and thereby contribute to trigger an incident. Typical examples of situational factors can be the fact that a work place is occasionally very noisy, an unfavourable weather influence, or a particularly high stress level.

In most accidents, not only one person or one organisational level is involved, but the reasons and causes behind accidents are distributed among different persons and organisational levels. This is, for example, expressed by Rasmussen and Svedung (2000) in their model of a socio-technical system. This view has also been used in the present work.

In our opinion, there are almost always some sequential elements of causes (e.g., lack of resources resulted in poor

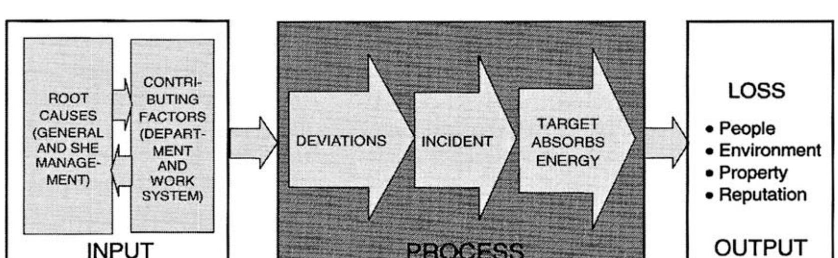

Fig. 1. Sequential model of accident after Kjellén (2000).