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In-depth analysis of the causal factors of incidents reported in the Greek petrochemical industry

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ABSTRACT

This paper presents a statistical analysis of all reported incidents in the Greek petrochemical industry from 1997 to 2003. A comprehensive database has been developed to include industrial accidents (fires, explosions and substance releases), occupational accidents, incidents without significant consequences and near misses. The study concentrates on identifying and analyzing the causal factors related to different consequences of incidents, in particular, injury, absence from work and material damage. Methods of analysis include logistic regression with one of these consequences as dependent variable. The causal factors that are considered cover four major categories related to organizational issues, equipment malfunctions, human errors (of commission or omission) and external causes. Further analyses aim to confirm the value of recording near misses by comparing their causal factors with those of more serious incidents. The statistical analysis highlights the connection between the human factor and the underlying causes of accidents or incidents.

1. Introduction

Many researchers agree that the famous Bird triangle [1] (Fig. 1), which relates the numbers of near misses and minor incidents to the number of important accidents in a plant is valid generally with small deviations. Years earlier in a similar triangle model Heinrich [2] tried to point out that prevention needs to be aimed not only at events with serious consequences but also at those in the lower levels of the pyramid. Heinrich's triangle has been often misinterpreted by practitioners and researchers as regards the causes of minor and major injuries. The original text makes no claim that the underlying causes of accidents of different degrees of seriousness are the same. According to Hale [3] we should ask: "given a minor injury, whether it could have been more serious. In other words, was the sequence leading to it also one that could have led to a much more serious injury or damage? If so, we can add it to the material for learning about major accident prevention". Hale's statement (deriving from Heinrich's work) points out the importance of including the near misses in any analysis. Indeed, near misses are events that could have led to serious accidents. If we can follow the sequence that led to a near miss, we can examine the casual factors that could also have resulted in a more serious accident (either major injury or an industrial accident).

In order to use effectively the accident pyramids it makes sense to "construct" pyramids by cause (or deviation) for a single industrial (or activity) sector at national level and for the same type of accidents (meaning occupational or industrial ones), as suggested by Jacinto and Soares [4].

Common cause hypotheses have been adopted by many analysts and most of them agree that minor accidents and near misses are also very important for extracting valuable information. Major accidents are not the only incidents that characterize the safety status of an establishment, nor are they the only events from which important lessons can be learned. Important conclusions can be drawn from the analysis of near misses or industrial incidents without major consequences as well as from occupational accidents. Therefore all types of incidents should be recorded and analyzed, and the findings should be communicated to the interested parties. Multifactorial statistical analysis of these incidents may provide significant insight into the understanding and prevention of similar incidents or accidents in the future. Many sectors, such as the railway sector in the UK [5], the industrial sector in Germany [6], and the mining sector in Australia [7], carry out analyses of near misses and accidents without significant consequences in order to reveal operator errors and system deficiencies. The analysis of major accidents is indispensable for the further development of the state of the art in current safety technology and perception [6]. Collecting

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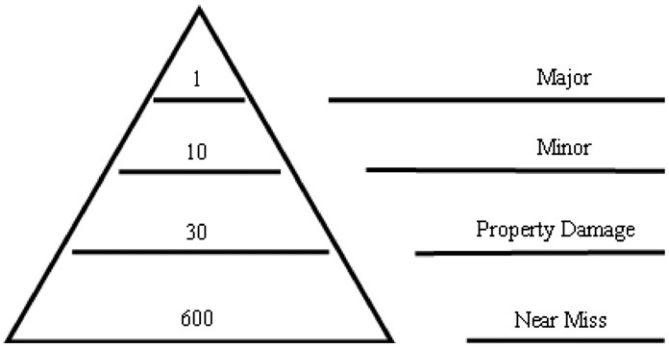

Fig. 1. Bird's triangle (Bird and Germain [1]).

information on major accidents directly supports this objective. However, in addition, non-notifiable accidents can offer important information. Kirchesteiger [8] claims that, "the same deficiencies can be revealed by events without accident consequences … they can provide a useful complement in identifying deficiencies and promoting changes to the actual safety system, the ultimate aim being to avoid the accidents before they occur". Apart from near misses, important conclusions for the safety culture of an establishment can also be drawn from ordinary and occupational accidents. Findings concerning operators' behavior and habits, together with trends concerning mechanical equipment and the management's safety policy, can be revealed by examining the frequency of certain events and the overall safety status of the establishment. CIRAS, the confidential incident reporting and analysis system in the UK railway national system pays particular attention to the investigation of near misses and non-severe occupational accidents [5].

However, the notification of minor injuries, near misses and hazardous situations and other types of losses, in order to extract experience and important lessons, can prove more challenging [9]. Since this type of data is not usually gathered, special care has to be taken to include these data in a particular analysis or ask directly for data related to near miss events.

For the purposes of the present analysis, the authors developed a database to include original data for all types of incidents (comprising industrial accidents, occupational accidents and near misses) from the Greek petrochemical industry. A statistical analysis of the incidents included in that database has been previously performed [10]. In that analysis human factors, either alone or in combination with other organizational and managerial factors, predominated as causal factors of the incident. Causal factors related to the category of human factors participated in a large percentage of all reported incidents. It is to be noted that counting the organizational/management related factors, which in some cases can also be grouped within the category of human causative factors, the overall percentage reaches 73% of total reported incidents.

In recent decades it has been clarified that human actions constitute a major source of vulnerability to the integrity of interactive systems both complex and simple. "Human errors" comprise inappropriate, incorrect or erroneous human actions and thus are causes of great concern [11]. However the deeper analysis of major industrial accidents in diverse sectors revealed that the events leading to an accidental outcome had their origins in the organization and management of the system. For this reason all sectors related to systems safety from probabilistic risk assessment (PRA) to accident investigation and causation are changing focus from technical and human failures to organizational factors and related causal factors [12–15].

Indeed Mohaghegh et al. [12] include in their Bayesian network for PRA of complex socio-technical systems factors that relate both to the organizational structure and climate as well as to individual and group Performance Shaping Factors (PSFs) while Dien et al. [13] present as predominant organizational failures the weaknesses of the organizational safety culture; the complexity of the organization; the limitation of the operational feedback; the production pressures as well as the failure of control organizations. Jacinto et al. [14] present an extensive analysis of the influence of workplace and organization factors on occupation accidents in the Portuguese food industry, while Saleh et al. [15] support that many accidents share a conceptual sameness in the way they occur through a combination of system design and technical flaws, operational or workforce failings and compromised organizational behaviors and management shortcomings, pointing out in this way the need to search for the genotypes and not only the phenotypes of accident events as the current practice mainly does.

Root cause analysis in order to identify important risk influencing factors has been performed in the Norwegian petroleum industry, identifying organizational and managerial factors (such as values in the organization, personal attitudes, planning, use of procedures, competences, etc.) as important contributors to accidents of different levels through the use of logistic regression analysis [16,17]. A similar approach has been followed by the present authors in order to identify the causal factors that contribute most to incident events of various types in the Greek petrochemical industry.

During the development of the database the authors took particular care to include both human and organizational causal factors by creating adequate fields to incorporate this information. Consequently during the multifactorial and the logistic regression analysis of the incidents specific care has been given to focus the analysis also towards human and organizational causal factors.

Section 2 of the paper provides a detailed description of the database, along with a brief overview and explanation of the fields relevant to the analysis. Section 3 gives an overview of the methodology used, while Section 4 presents the results of the multifactorial analysis and Section 5 makes the discussion of these results. Finally Section 6 draws conclusions from the development of the database and the analysis of the data.

2. Description of the database

The database covers all accidents and incidents in the Greek Petrochemical Industry for the period from 1997 to 2003 [18]. The establishments represent the entire industry in Greece together with the Cyprus Refinery, and range from extraction sites and offshore facilities to refineries, production and storage sites in central and northern Greece and in the Republic of Cyprus. A total of 5000 people work in this sector, more than 3000 of whom are employed at production and storage sites. The research team acquired the data directly from the different establishments by obtaining access to their archives and to the initial reports of the incidents. The data was collected in collaboration with the safety engineers of the sites under a specific cooperation memorandum, which included a confidentiality clause. Data collection took place over a period of one year with on-site visiting, surveying of the recording systems, checking of the initial reports and meeting with the safety personnel in their places of work. Additional discussions and meetings with certain key personnel and operators were held, if necessary, to collect more details concerning certain incidents in order to define the exact evolution of an incident. These discussions focused on extracting the underlying