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Human factor risk management in the process industry: A case study

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A B S T R A C T

In this work, a new procedure called Human Factor Risk Management (HFRM) was developed in order to integrate Human Factor in a Refinery Risk Management System. Taking into consideration historical data regarding Environmental Accidents, Near miss, Injuries and Operating accidents occurred in a refinery over the last years a panel of experts defined the performance shaping factors (PSFs) and risk associated with adverse events. A conceptual model, based on Association Rules (AR), has been proposed for investigating the network of influences among adverse event typology, human error causes, refinery plant area involved in the adverse event, performance shaping factors (PSFs), risk index and corrective actions.

The results obtained using the association rules method proved to be useful for assessing human practices and human factors which influence high-risk situations. The human factor analysis carried out in this paper was planned as a dynamic process and can be repeated systematically. The association rules technique, taking into consideration a wide set of objective and predictive variables, shows new cause–effect correlations in refinery processes never described previously, highlighting possible adverse events and supporting decision-making in these areas.

1. Introduction

The analysis of human factors and their connection with safety management has been pointed out after the Three Mile Island Accident. The analysis of this case brought great changes in dealing with human performance problems especially in the companies involved in hazardous activities [1]. A better understanding of human error and its consequences can be achieved through the application of human factor identification models. To accomplish this, the human error must first be removed from the emotive area of blame and punishment and engaged in a systems perspective. From this point of view, the human factor is treated as a natural consequence arising from a discontinuity between human capabilities and system demands. The factors that influence human error can then be documented and managed. Such efforts are an essential component in an overall scheme of process safety management [2]. According to Cacciabue [3], the need to include Human Factors considerations in the design and safety assessment processes of production systems is generally accepted by almost all stakeholders. The process of safety management consists of well-defined steps aimed at avoiding losses and identifying opportunities to improve security, quality and, as a consequence, performance in an organization [4]. The attitude that is generally adopted towards industrial activities is a cost-benefit approach: The activity is undertaken if it provides economic benefits that justify and reward the effort of undertaking it. Risk management is part of these efforts and has to be carried out in order to avoid losses that will overwhelm every reached, promised or foreseeable benefit.

Current accident experience suggests that so-called high-risk industries are still not particularly well protected from human error. This, in turn, suggests the need both for the means of properly assessing risk attributable to human error and for ways of reducing system vulnerability to human error impact [5].

In this paper we propose a Human Factor Risk Management (HFRM) methodology that, using the synergies provided by the simultaneous adoption of risk and human factor analysis, enables continuous improvement process in terms of plant reliability at the lowest possible cost. Human Factor Risk Management procedure was developed in order to integrate Human Factor in a Refinery Risk Management System.

The drivers for developing a new Human Factor Risk Management (HFRM) model are:

1. Integration of human factor risk management into the organization as a part of achieving their overall goal of a managed corporate culture.
2. Increase the human factor contribution to company functions and activities.
3. Provide, for every refinery plant, risk reduction recommendations to mitigate the potential for human error.
4. Reduce costs arising from human performance limitations and add value through improved human performance.
5. Meet demand for business owners and high-level managers.

In a processing industry like a refinery, the number of annual failures is likely to be very high, partly as a result of the normal wear of the components which are often subject to intensive working conditions [6]. Within this context, this study attempts to identify the human practices and factors which influence high accident risk situations. The Safety, Quality and Environment (SQE) committee of the refinery has shown that human error is a main contributory cause to more than 30%

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Table 1
Human causes list.

Human error causes (practices or actions below standards)
Operation carried out without authorization
Necessary operation/procedure was forgotten
Incorrect choice of raw material
Lack of precision/inappropriate speed of performance/haste
Warning given incorrectly/insufficiently/to the wrong person
PPE (Personal Protective Equipment) used badly/faulty
Inadequate knowledge of regulations and procedures
Made inoperative a control system
Incorrect loading/lifting/substitution of equipment
Incorrect/inappropriate use of equipment/appliances
Incorrect position or posture during the developed activity
Maintenance/action/operation carried out on equipment in run
Bad habits
Lapse of concentration/detrimental behavior

of adverse events, 70% of which could have been prevented by management actions. The SQE committee identifies as human errors what Reason [7] called “Person Approach”, the longstanding and widespread tradition of the person approach focuses on the unsafe acts—errors and procedural violations. The percentage of adverse events connected to human errors is evaluated using historical data collected by the refinery and based on a human causes list (see Table 1). Human errors committed during the design and construction phases of the refinery plants are not included. If more than 30% of the causes of adverse events are related to “human error”, that means that different aspects and different items are grouped under this voice. The use of a sound classification can be useful to better specify and direct the study towards methods of prevention [8]. Unfortunately, in the field we are approaching there is no universally agreed classification system, hence the taxonomy we would like to adopt must be made for our specific purpose.

The principal result of any classification process is that interpretation can improve problem-solving performance in the area of interest [9]. Therefore, classifying and finding relationships among a set of variables is a complex and common problem even in Risk Management.

In the present work, with specific reference to a medium-sized refinery, all the information useful for identifying the factors which lead to critical events in the workplace was collected. A thorough understanding of the variables which influence a particular problem is essential for finding increasingly efficient solutions. Nevertheless, a great deal of data is often collected which is difficult to understand, considering the number of variables involved. As a Data Mining technique, Association Rules methodology is promising because of its advantages over standard statistical techniques. The use of statistical techniques, such as linear regression, is based on general assumptions regarding the data set, which are normally difficult to satisfy. In the case examined here, the intrinsic structure and complexity of the data collected might jeopardize the use of traditional tools for analysis since the variables presented some critical aspects. First of all the high number of predictive variables is a problem of considerable importance for standard statistical analysis in general. Moreover, a parametric analysis typically adopts the independence hypothesis while the relationships between the independent variables can be a problem in this study. Finally, we have to face the non-homogeneity and non-linearity distribution of data collected.

From this point of view, Association Rules are a valid alternative and complementary tool to parametric methods, guiding the researcher towards a more thorough understanding of the data.

When employing Logistic Regression (LR), it may be difficult to understand the impact of an individual risk factor or interplay between multiple risk factors. Researchers typically need to formulate a hypothesis for each risk factor combination before doing a formal evaluation, which may become practically infeasible even for a moderately sized set of variables. On the other hand, in Data Mining, many patterns may be extracted in a single run, but many resulting formats are of low readability. Association Rules may be used to avoid these problems because it provides: 1) numerous readable patterns (rules) that describe the interaction between variables; 2) more straightforward interpretation than for the LR coefficients; and 3) numerous interpretable measures of rule interest, which facilitate identification of relevant rules and rule comprehension.

The rest of the paper is organized as follows. Section 2 presents the literature review about methods and procedures for analyzing the human factor and human error in the industry. Section 3 describes the research approach proposed in this work analyzing in the sub-sections all phases of the Human Factor Risk Management (HFRM) procedure. In Section 4 a Human Factor Risk Analysis methodology application is used to illustrate the application of the proposed method. In Section 4.1 the results obtained are discussed. Finally, the conclusions are presented in Section 5.

2. Literature review

The first classification and description of human reliability assessment methods has been developed by Bell and Holroyd [10]. They identified 72 potential human reliability related tools and 17 of these tools were considered to be of use to Health and Safety Executive (HSE) major hazard directorates. They highlighted that different tools may be appropriate depending on the ‘maturity’ of the site with regard to quantified human risk assessment. Another interesting classification of Human Factor and Human Assessment Reliability methods has been proposed by Calixto et al. [11]. They suggested a classification according to three stages in time. The first twenty years (1970–1990) is known as First Human Reliability Methods Generation, which focuses on human error probabilities and operational human error. The Second phase, the next fifteen years (1990–2005) is known as second Human Reliability Methods Generation and focuses on Human performance Factor and cognitive processes. Finally, the third phase started in 2005, continues today and is represented for methods that focus on human performance factors relations and dependencies.

The majority of work in human factor and human error prediction in industry has come from the nuclear power industry through the development of expert judgment techniques such as Success Likelihood Index Methodology (SLIM), Human Error Assessment and Reduction Technique (HEART) and Technique for Human Error Rate Prediction (THERP) [12]. The lack of human error data and the potentially severe consequences of nuclear industry accidents led to an extensive use of methods based on expert judgment.

The success likelihood index methodology (SLIM) was developed under the sponsorship of Brookhaven National Laboratory and the U.S. Nuclear Regulatory Commission to quantify operator actions in the plant response model of a probabilistic risk assessment. This technique is based on the assumption that the human error rate in a specific situation depends on the mutual effects of a relatively small set of performance-shaping factors (PSFs) that impact on the operators’ ability to perform the action successfully. Since the comparative work by Kirwan et al. [13], SLIM has evolved into a widely known expert judgment technique that employs judges to provide numerical feedback that is used as input to formulate the probabilities connected to the human error. The SLIM technique has taken on several forms since its initial development and follow-on modification. An example is the Failure Likelihood Index Method (FLIM), which utilizes a Failure Likelihood Index (FLI) as opposed to a Success Likelihood Index (SLI) (Chien et al., [14]).

Dougherty and Fragola [15] analysed time reliability correlations (TRCs) to predict the probability of failure of an action. A TRC is a probability distribution based on the time to complete an action and the actions likelihood of success (Di Mattia et al., [16]). The Dougherty and Fragola approach was based on the idea that if an accurate diagnosis is not developed within a critical period of time, then a failure occurs. Kirwan [13] carried out an in-depth review and evaluation of a wide range of Human Error Identification (HEI) techniques. SLIM was