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Analysis and Classification of Occupational Data: a Practical Comparison

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Human performance is the centre of any safety management system. Errors are shaped and provoked by the upstream work place and organizational factors, which are the major root causes. A careful investigation and classification of data related to the occupational accidents provides opportunities to review and improve safety management systems which help to reduce and eliminate the risk from the resources.
The aim of this paper is to perform a comparison between two risk assessment tools in terms of safety data considering human related elements which are: Human Factor and Classification System HFACS that is perhaps the most widely used human factors accident analysis framework and the risk assessment part (Root cause analysis) of World Class Manufacturing WCM that is used highly in manufacturing as the relevant management system and the practices help to increase their efficiency. The objective of this study is to improve the investigation and classification of data related to the work accidents which, allows to analyze industrial data collected for preventive purposes in occupational safety.

1. Introduction

Human errors have become widely recognized as a major contributor cause of serious accidents. As human factor plays a key role in safety at work and prevention it should be treated with dedicated techniques. Thus a variety of Human Error Identification (HEI) tools and techniques have been developed for error identification and classification which include error taxonomy and moreover human error quantification component. Identifying what errors (both active and latent) contribute to accident occurrence can be difficult because there is no well defined start of the causal chain of an accident and exactly the same events can lead to widely different consequences (Rasmussen, 1980). Reason (1990) proposed “Swiss Cheese Model” included three system levels: unsafe acts, local workplace factors and organisational factors. An accident trajectory passes through the holes, which represent gaps in defences, barriers, safeguards and controls, resulting in an accident. Furthermore many more well-known techniques were developed like, Human Hazard and Operability Study (HAZOP), Cognitive Reliability and Error Analysis Method (CREAM), and the Human Factors Analysis and Classification System (HFACS). HFACS is a widely utilized tool for investigating and classifying human contributions to accidents under a widespread evaluation scheme. Using this method is possible to characterize quantitatively the role of human factor that allow development of practical approaches to achieve appropriate preventive measures and mitigation strategies.
The goal of this study is improving actual used human error analysis tools and replace or upgrade them with more efficient one. So in this study HFACS method, considering its benefits, was chosen and compared with Root Cause Analysis method used commonly as an investigation and analysis tool by WCM in many important machine industry like Fiat. WCM is a production system that regards the organization of the factory that includes quality system, maintenance, cost management, logistics, environment and safety management, through using rigorous methods and standards and in an optical continuous improvement.

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1.1 Historical review

HFACS is a generic classification system, has been originated and adopted in US aviation and marine corps. Now it is widely applied and promoted in several industries; as an example: Aviation and aircraft (Wiegmann and Shappell, 2001), maritime activity and navigation (Chauvina et al., 2013; Chen et al., 2013), railway and train (Baysari et al., 2008), mining (Lenné et al., 2012), and nuclear industry (Kil et al., 2014).
The application of taxonomy HFACS allows to understand the general trends of human errors in a structured way to identifying the causes of an accident, but only represents the first step in the analysis of the problem. The instrument, in addition to identifying the major sources of accidents in terms of frequency, is not sufficient to describe the relationships between the different categories of the levels. In order to quantify the relationships between the different factors several techniques have been proposed, such as: "Multiple Correspondence Analysis" identifies patterns of contributing factors of accidents (Chauvin et al., 2013); "Why Because Graph" technique was present in a study of causality in maritime accidents (Chen et al., 2013); Salamon et al. (2012) have compared some methods: Accimap, HFACS, and STAMP. Moreover, Juned Akhtar and Bouwer (2014) have developed a Bayesian Network for modeling the risk of maritime ship accidents.
Root cause analysis is another risk assessment commonly used tool that is presented in World Class Manufacturing system. WCM has its origins in the 80s. The WCM was first presented as an organic approach by Schonberger (1986). The term WCM is a collaboration between Fiat and the best European and Japanese experts with goal of raising production standards in a world standard. The WCM is a set of concepts, principles and techniques for managing the operational processes of a company. The model was redesigned and implemented by Prof. Yamashina from Kyoto University (Yamashina, 1998). Now this method is used by machine company like Fiat (Massone, 2007).

2. Methodological frame work

Human behaviour is often a root or significant contributing cause of system failure. Risk assessment is an essential and systematic process for assessing the impact, occurrence and the consequences of human activities and constitutes useful tools for the safety management system. The diversity in risk analysis procedures is such that there are many appropriate techniques for any circumstance and choice of them also depends on the availability of data and expected results (Marhavilas et al., 2011). Through a qualitative analysis of human and organizational factors (HOF) responsible for occupational accidents it's possible to identify the errors that frequently result in the occurrence of incidents/undesired events and provide inputs for the analysis in the next phase. After should be a quantitative analysis of accidents that provides corresponding safety prevention measures. The systematic consideration of human error in the design, operation, and maintenance of highly complex systems can lead to improve safety and achieve more efficient operation. Work place design, safety culture, in addition to training, competence, task complexity, stress, etc. constitute a group of factors that influence operators' behaviour.

2.1 HFACS

Human Factors Analysis and Classification System (HFACS) is a semi qualitative risk analysis method that identifies failures and reflects error levels imposed by taxonomy analysis (Reinach and Viale, 2006). It is a commonly utilized tool for investigating human contributions to accidents under a widespread evaluation scheme. HFACS has a basic structure (Figure 1) that provides taxonomies of failure modes across the following four levels:

1. Unsafe act is defined as error or violation that is committed in the presence of a hazard or potential unsafe condition. Represent active errors that are directly related to worker behaviours.
2. Pre-conditions for unsafe act are conditions such as individual and environmental factors that influence human behavior.
3. Unsafe supervision represents failure because of inadequate supervision or leadership.
4. Organizational influences represent rules and decision of supervisors and managers may have adversely impact on trends of the events.

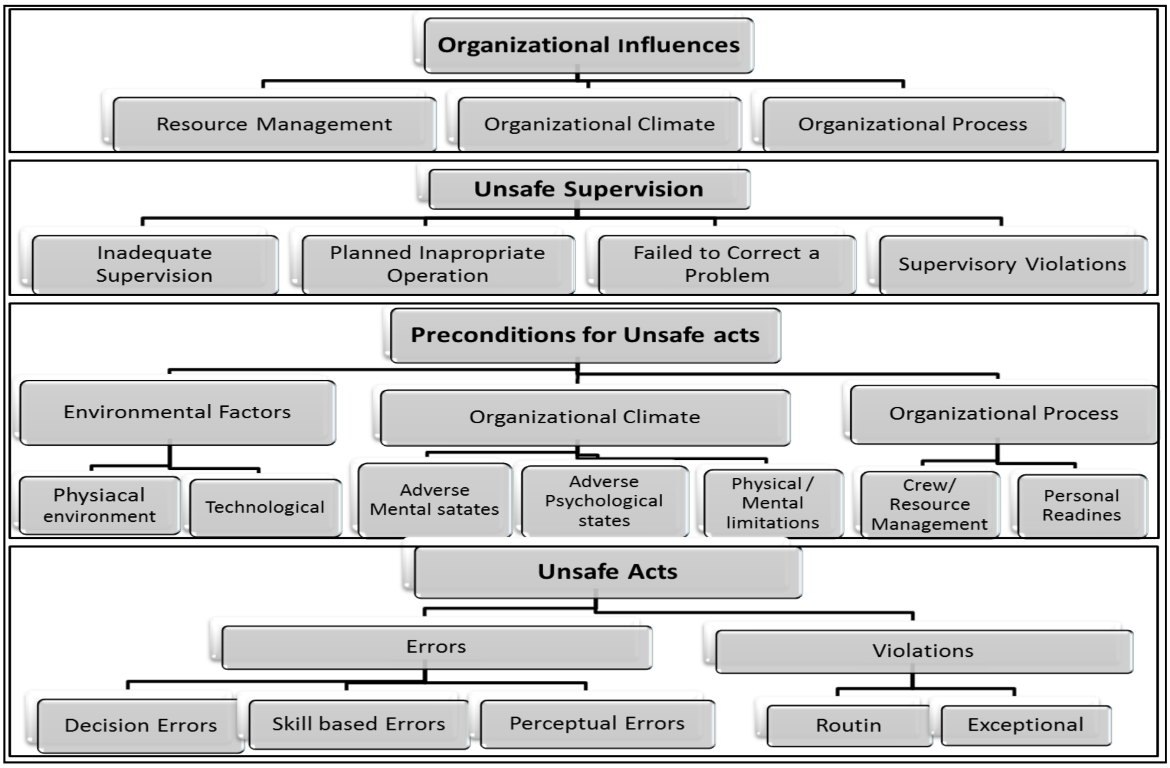

Figure 1. HFACS basic structure.

The goal of this technique is to determine the reasons for human error occurrence, the factors that influence human performance, and how likely the errors occurred. It considers all possible contributing factors in the chain of events leading to an injury that helps to identify (indirect and direct) root causes, and eliminate/prevent hazards to an acceptable level or correct them as much as possible leading to safety occurrence.

2.2 Root cause analysis (by WCM)

The goal of WCM is to continuously improve production performance, considering Safety, quality, and environment. The basic structure is made in two lines of actions: ten pillars of technical activities and ten managerial pillars. Safety management is one of the important pillar of the system that presents root cause analysis method for investigation and analysis of human errors, as the injury prevention in WCM remains an important value. Figure 2 presents the basic structure of this method and related countermeasures. Failures are divided in two principal groups:
1. Unsafe act (UA) that divides in five subcategories: competence (knowledge), Attitude (behaviour), management, precautions (Attention) and personal conditions.
2. Unsafe condition (UC) that divides in two subcategories: tools (equipments) and procedures (systems).
Each category presents subcategories with related countermeasures or preventive actions.
Human action (UA), in the pyramid of accidents in WCM, is understood as the less dangerous and isolated factor while in HFACS, it presents an active error and in direct relation with the system. Errors are shaped and provoked by the upstream workplace and Organizational factors. Therefore Human error is a consequence, not a cause and these latent failures of the organization are the product of some individuals somewhere else in the system (e.g. supervisors, maintenance personnel, designer). WCM presents some target to be achieved by the company like: zero occupational accidents, and higher reported UA and UC. The higher presence of these repeated errors is one of the limitation of WCM. So it needs to be completed or integrated with a more efficient method like HFACS to reduce such errors.

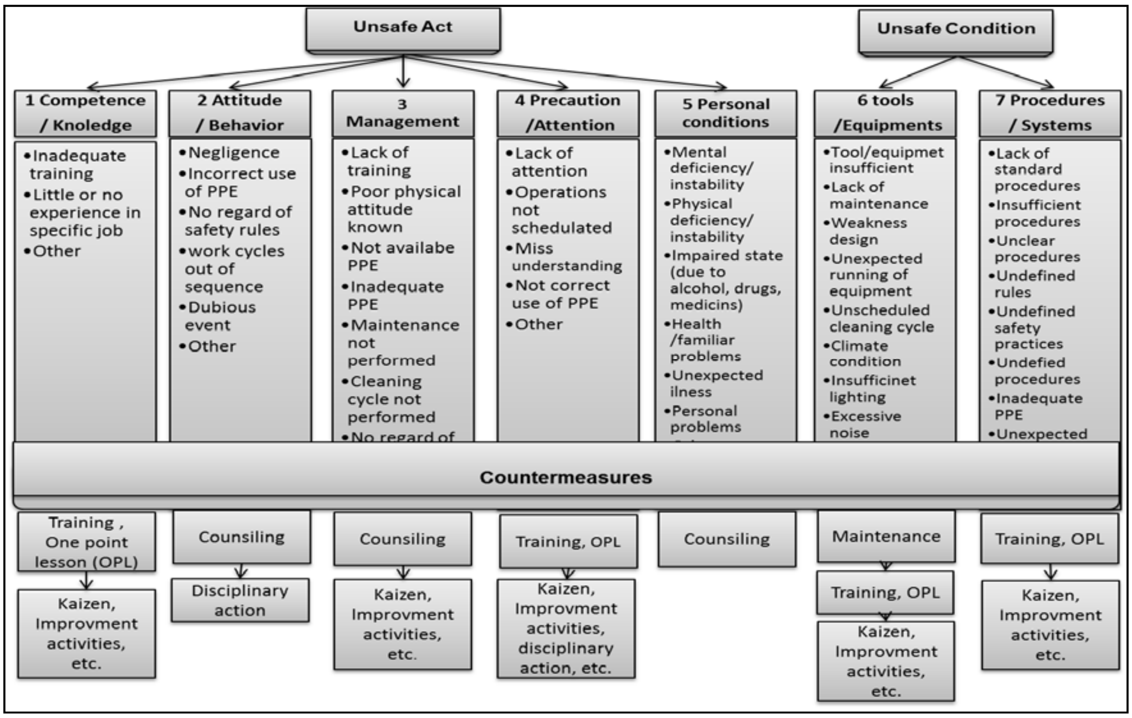

Figure 2. Root Cause Analysis in WCM.

3. Comparison of two methods

Effectiveness of preventive actions is closely related to an objective assessment or quantitative of the behavior, as an event intended observable, measurable, countable, and reproducible. Taking into account neither risk assessment techniques could be considered better and modes of action can be defined on the basis of the types of possible errors. Each method presents advantages and disadvantages and can almost be appropriate depending on the context to be examined and available resources and expertise.

In this study HFACS taxonomy was developed and adapted to an industrial case study in Fiat and confronted by WCM method. Below is presented a summary by comparing two methods:

Root cause analysis (in WCM) has a different format with HFACS analysis. In fact they correspond two different ways of interpreting a reality. The simplest case for this difference is seen in the pyramid of accidents in WCM, where human action (UA) is understood as the less dangerous and isolated factor while in HFACS, it presents an active error and in direct relation with the system.

One of the main advantages of HFACS tool is the systematic approach and the comprehensive examination of all possible factors (the incidental causes) that contribute to the chain of events leading to an adverse event.

HFACS has a more detailed classification system so it is a commonly utilized tool for investigating human contributions to accidents under a widespread evaluation scheme that helps to find and link the corrective or preventive measures.

Furthermore, analyzing at the same time of data collection and making interviews with workers and supervisors is another advantages of the HFACS methodology which avoid losing important information that are necessary for identifying root causes and effective measures.

HFACS respect with another method can distinguish errors from violations. Errors represent ‘‘the mental or physical activities of individuals that fail to achieve their intended outcome’’ whilst violations refer to ‘‘the willful disregard for the rules and regulations that govern the safety’’ (Shappell and Wiegmann, 2013).

On the other hand synthetic database and lack of information for classification in WCM presents obstacle for correct analysis of errors. As an example for violation/omission it is not possible to distinguish between single or generalized and routine or exceptional action. So more often the countermeasures result inefficient.

Noted HFACS also presents some disadvantages as below: It is very complicated and difficult to trace causes and analysis; Classification depends on experiences and instructions of the analyst, moreover if they have the same level of education, same data could be evaluated in a different way. Usually it is recommended at least two trained analyst be involved in the industry to have a higher reliability of final result (Li et al., 2008); Moreover practical approaches of quantifying human error within the accident process and mathematical tools like Fuzzy or Neural Networks for incorporating human factors in system reliability should be integrated and developed.

4. Associated measures

To get an accurate analysis of the occupational data base and diagnosis of problems, is required a procedure to categorize, find and analyze key issues obtained from the investigation. For these reasons and based on general objectives HFACS methodology was chosen and adopted for analysing data bank Fiat. A sample of database have been reclassified decision tree in order to facilitate data analysis according to the HFACS method. As a result, in order to reduce occurrence of the undesired events could be suggested improvements in resource management, organizational climate, and organizational process. Table 1 shows explicit links between some most frequent errors and the proposed preventive measures to be taken. Previously a summary of these measures was discussed by Lenné (Lenné et al, 2012).

Table 1: Explicit links between the errors and the measures to be taken.

Failures	HFACS Failure	Preventive measures
Skill based errors (memory/ attention failed)	Adverse physiological states	1. Development of procedures for detecting and managing fatigue 2. Supervisor training in procedures for detecting and managing fatigue 3. Fatigue management workshops 4. In-depth analysis of skill-based error data
Training and experience	Unsafe act (Human)	1. Adequacy of training (Frequency, recent training, fidelity of simulation program) 2. Experiences/Practices of real operating events 3. Learning of the past events/experiences 4. Career of the operators
Violations (accepted practices/ norms)	Adverse mental states Team resource management Physical environment	1. In-depth analysis of violations data 2. Evaluation/redesign of procedures prone to violation 3. Evaluation/redesign of equipment prone to violation 4. Enhance awareness of violation activities
Inadequate Supervision	Adverse mental states Team resource management	1. Assessment of current supervisory system 2. Redesign of supervisory of system 3. Clear definition and communication of supervisor roles and responsibilities 4. Encouragement of communication and high levels of interaction between supervisors and sub-ordinates
Organizational Influence (climate and resource management)	Inadequate supervision	1. Assessment of procedures and procedure development and implementation system 2. Revise of procedure development and implementation system 3. Redevelopment of selected problem procedure

5. Conclusions

Human error is a consequence, not a cause and errors are shaped and provoked by the upstream workplace and Organizational factors. Human Error Identification tools identify all possible root causes and help to eliminate or correct errors. Study of industrial databases reveals that human errors refers not only to operator errors but also to those failures associated with design, procedures, management, maintenance, training, work environment and so on. These latent failures of the organization are the product of some individuals somewhere else in the system (e.g. supervisors, maintenance personnel, designer). Because of higher presence of repeated errors (UA and UC) in such system like WCM, need to be completed or integrated with a systematic methods like HFAC. Here was chosen and discussed HFACS between different methods because of its benefits and effectiveness. A major advantage of such tool is systematic approach and comprehensive consideration of all possible contributing factors in the chain of events leading to an injury/accident, including decision and judgment errors that occur at all organizational levels. That is proved more efficient in categorizing errors from existing investigation methods and in capturing of full range of relevant human factors respect other frequently used method like root cause analysis in WCM which is applied frequently in machines company. Moreover here was presented a summary of proposed measures to address associations with HFACS method.

Abbreviations

CREAM Cognitive Reliability and Error Analysis Method
HAZOP Human Hazard and Operability Study
HEI Human error identification
HFACS Human Factor Analysis and Classification System
UA Unsafe Act
UC Unsafe Condition
US United States
WCM World Class Manufacturing

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