HFACS-MI Analysis of Queensland Mining Incidents

Trudy Tilbury

A/Senior Principal Ergonomist/Principal Human Factors Advisor
Queensland Mines and Energy, Safety and Health

Jessica Patterson

Graduate Research Assistant
Clemson University, USA

Abstract

Safety and health in Queensland mining continues to improve, but we still have preventable incidents. Queensland Mines and Energy (QME) commissioned Clemson University to develop a system to analyse the role of human factors in Mining incidents, based on the Human Factors Analysis and Classification System (HFACS). Clemson researchers examined 508 mining incidents/accidents from Queensland mining using the HFACS-MI (Mining Industry) framework. The framework considers causal factors of an incident at five levels starting with unsafe acts and moving upward to consider preconditions for unsafe acts, unsafe leadership, and organisational influences.

Most of the incidents analysed were high potential incidents. Human factors contributed to unsafe acts in 95% of the 508 incidents/accidents. Skill-based errors (also referred to by QME as routine disruption errors) were the most prevalent error type (50%), but decision errors were also common (41%). With further analysis, results suggest that "attention failures" and "technique errors" are the common skill based errors. Decision errors were most often "procedural" and "situational assessment" problems. Perceptual errors and violations were significantly less common (4% and 5% respectively).

The results of the HFACS-MI analysis undertaken by Clemson University showed that improving knowledge and awareness of the role of human factors in incidents is critical for a goal of zero harm. QME is using HFACS-MI in a team based approach to review human factors in more recent incidents, and develop consistent information and training for inspectors and industry. One goal of the review and training is to adapt components of HFACS-MI for use in early stages of investigations. Further plans include working with an industry partner to ensure the HFACS-MI will assist industry both in investigations and in prevention of incidents due to human factors issues.

Introduction

The aim of this paper is to summarise the final analysis of 508 Queensland mining incidents using HFACS-MI, as well as provide QME updates on future

directions. The background to HFACS-MI development and terminology is discussed in the 2008 paper by Patterson, downloaded from http://www.qrc.org.au/conference/_dbase_upl/Papers2008_Patterson.pdf. A brief background to HFACS-MI is provided here. For the purposes of this paper, incidents and accidents are referred to as incidents. Nanocodes are the codes, and their descriptions, assigned to the causal factors at a subcategory level)

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HFACS-MI Background

HFACS-MI is an adaptation of the Human Factors Analysis and Classification System (HFACS) described by Wiegmann and Shappell (2003). HFACS was developed for classifying human factors causal factors within the Aviation industry, and incorporates most of the key components of Reason's Swiss cheese model (1990). The Reason model is well known in Mining Safety, and the role of 'latent errors' influencing operator error is explained below:

"Rather than being the main instigators of an accident, operators tend to be the inheritors of system defects created by poor design, incorrect installation, faulty maintenance and bad management decisions. Their part is usually that of adding the final garnish to a lethal brew whose ingredients have already been long in the cooking". (Reason, Human Error, 1990)

Similar concepts (e.g. that causal factors are found at a number of different levels within an operation) are the basis of ICAM (Incident Cause Analysis Method) developed by BHP Billiton.

The HFACS-MI framework lists 21 causal categories (and subcategory descriptors or nanocodes) within Reason's four levels of human error, as well as an added level to incorporate the potential impact of outside influences on mining incidents. Figure 1 shows the framework for HFACS-MI.

The HFACS-MI framework will expand the availability and understanding of possible human factors causal factors currently used in incident investigations as there has been less focus on organisational and leadership contributions. As human factors issues are often less visible and understood in incident causation, HFACS-MI provides codes and descriptors to supplement or complement current investigation methods or techniques.

HFACS-MI Causal Factors and Descriptions

Information on the most commonly found HFACS-MI causal factors is provided, with the complete descriptions based on the original HFACS causal factors descriptions. The main variations to terminology were at the lower levels of "Unsafe Acts", "Preconditions for Unsafe Acts" and "Unsafe Leadership". Information on "Unsafe Leadership" or the factors in unsafe supervision can be found in the paper by Patterson (2008), and in QGN 14 (2008), pgs 16-17.

This first or lowest level of HFACS-MI describes the unsafe acts of the operator directly leading to an incident. These unsafe acts are commonly called "operator error". As most incident investigations focus at this level, this is where most information is available. In HFACS MI, unsafe acts are classified into two categories, errors and violations. Errors refer to activities that fail to achieve the needed outcomes whereas violations are the conscious disregard of established rules and regulations. There are three basic types of errors: decision, skill-based (routine disruption), and perceptual. Violations are either routine or exceptional.
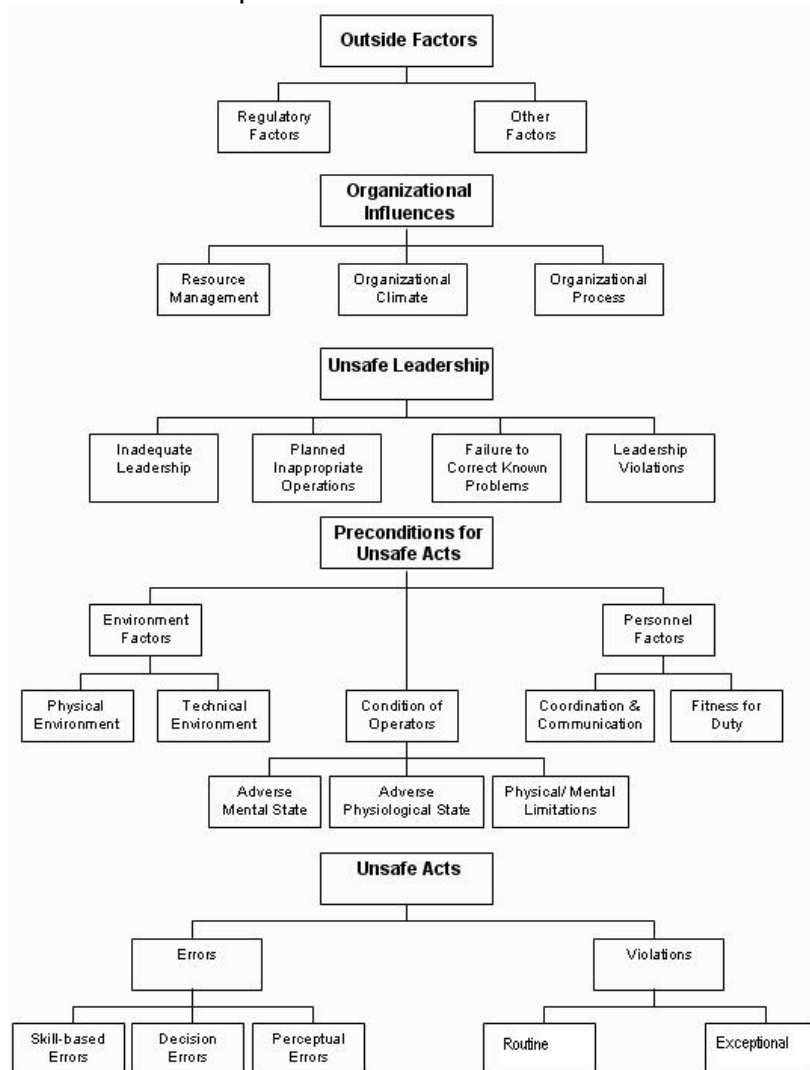

Figure 1: HFACS-MI Taxonomy

Decision Errors. Decision errors represent intentional actions that proceed as intended, but the plan proves inadequate or inappropriate for the situation. These errors mainly arise because of inadequate knowledge or poor choices. Decision errors are more common with lack of suitable training and experience, but sometimes skilled operators facing something unexpected, or changed conditions, will also make decision errors based on what they did previously.

Skill Based (or Routine Disruption Errors).Unlike decision errors, routine disruption (or skill based) errors occur with little conscious effort during automated or routine tasks. Routine disruption errors are susceptible to failures of memory or attention. Attention failures have been linked to breakdowns in visual scanning, task fixation, and unintended activation of controls. Memory failures can appear as missed steps in check list, or forgetting intended actions or plans. These errors increase when stress levels increase, or example during emergencies, or when there are time pressures. The technique in carrying out a task, or the way an individual uses equipment can cause an increased likelihood of committing an error, particularly when operating controls.

Perceptual Errors. Perceptual errors occur when sensory input is degraded, for example in underground environments where vision is often limited. The error is due to the operator misinterpreting the input, with the environment itself considered a 'precondition'. Operators, especially those working underground, are often in areas with limited lighting and constantly changing conditions.

Violations. Violations are identified in two distinct forms, routine or exceptional violations. Routine violations are usually more common, as they occur when rules and regulations are not followed, and this rule breaking is tolerated at higher levels. Exceptional violations, on the other hand, are rare or isolated departures from rules and regulations. Exceptional violations are difficult to correct because they are unpredictable. As management doesn't condone exceptional violations, these are more likely to result in disciplinary procedures.

Preconditions for Unsafe Acts

While the unsafe acts of the operator have continually been linked to accidents, the preconditions to the unsafe acts are often directly linked as a causal factor to the unsafe act. Preconditions are generally latent system failures that are not identified at the time, but are later found to contribute to an incident. For example, in mining less than adequate design of equipment was a causal factor in incidents. Preconditions for unsafe acts include environmental factors, conditions of the operator, and personnel factors.

Environmental Factors

Physical Environment. The physical environment refers to both the operational (for example, tools, machinery) and ambient (temperature, visibility, noise etc.) environments. Mining operations, especially those underground, take place in adverse environmental conditions. Miners are often exposed to hot, humid conditions which can lead to a decrease in attention, physical fatigue or dehydration. In addition, dusty conditions that reduce visibility are part of the physical environment.

Technological Environment. The technological environment deals with the design of equipment and the interaction between operators and equipment. The displays and control designs within equipment play a critical part in human error. This has been raised in previous reviews of mining incidents, with many examples in Queensland Mining.

Conditions of Operators

Adverse Mental State. The adverse mental state of the operator covers a broad range of conditions that can affect their performance. These include mental fatigue, task monotony, distraction, inattention, inherent personality traits, and attitudinal issues such as overconfidence, frustration, and misplaced motivation.

Adverse Physiological State. Adverse physiological state refers to medical and physiological conditions that affect performance. In mining, a common issue would be excessive heat causing dehydration or impairs performance. This category also includes the effect that over-the-counter medications have on temporary medical conditions, such as colds and headaches.

Physical/Mental Limitations. This category refers to situations when abilities are exceeded by the demands of the job, task or environment, including when all workers would have reduced capacity. For example, the visual system acts differently in dark environments, meaning workers will have less visual acuity at night or underground. Other examples, for individual workers, could be with mental aptitude to memorise lengthy procedures or perform complex steps in equipment operation. Physical capacity is required to interact with equipment, or provide assistance in an emergency.

Personnel Factors

Communication and Coordination. Effective communication and coordination is required for safe operations. Poor coordination of activities, for example between the site and contractors, leads to confusion in responsibilities and information provided to all parties. Communication breakdowns are possible at any level within mining operations, and communication causal factors are also present at an organisational level.

Fitness for Duty. It is the responsibility of an employee to arrive for work in a condition which allows them to work safely. Mine sites have addressed drugs and alcohol in FFW policies, procedures and testing.

HFACS-MI Analysis and Discussion

Causal factors were identified at all levels except for 'Outside Factors'. For both 'Organisational Influences' and 'Unsafe Leadership', causal factors tended to be in a single category. Causal factors at the lowest two levels of the taxonomy were found for multiple categories, and are discussed next.

Unsafe Acts of the Operator

Most of the data was gathered at the unsafe acts level. Nearly all cases analysed identified at least one causal factor at the unsafe acts level (95%). All the 508 incidents and accidents analysed provided a fairly descriptive account of events. Age and experience data could not be analysed as this information was only available for a small percentage of accident cases.

As can be seen in Figure 2, the most often identified unsafe act was skill based or routine disruption errors, followed by decision errors, and violations.
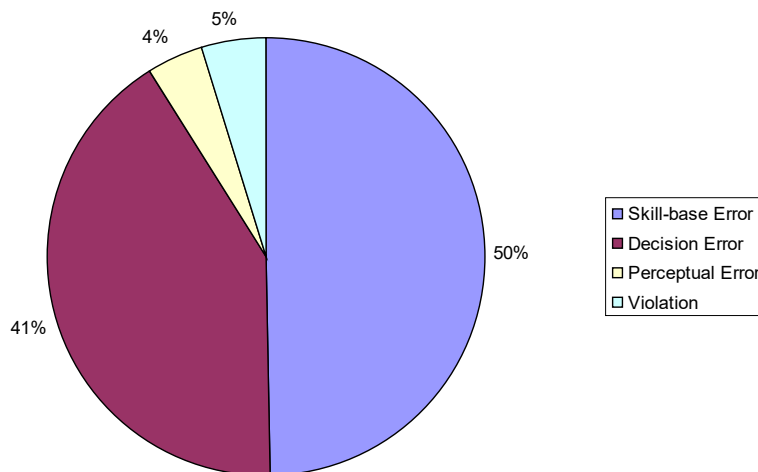

Figure 2: Unsafe Act by Category

It can be seen that 50% of unsafe act codes identified are associated with routine disruption errors. Decision errors also account for a large percentage of codes identified. Perceptual errors were a small proportion (4%), with violations accounting for only 5% of all unsafe acts.

Figure 3 below shows the five main error categories, and they are described in more detail on the next page.
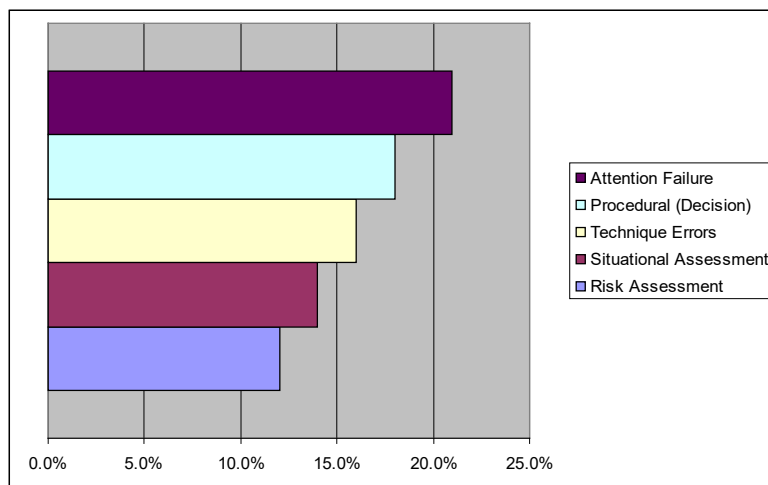

Figure 3: Most common error categories

Attention Failure (Routine Disruption/Skill based) errors – which are self-explanatory.

Procedural (Decision) errors refer to when an operator applies an incorrect procedure or misapplies a procedure for a task. The correct knowledge of a procedure is also part of the unsafe act. An operator may not follow the correct steps in the procedure because of lack of training or lack of retention of information.

Technique Errors (Routine Disruption/Skill based) refer to the way in which an operator completes a task and how well it is performed.

Situational Assessment (Decision) deals with identifying hazards and the response taken when a hazard is identified. When an operator is unable to identify all hazards or take correct action when a hazard is present, the likelihood of an adverse event increases

Risk Assessment (Decision) refers to the operator's ability to identify the appropriate level of risk assessment, as well as carry out a complete and thorough risk assessment, JSA, Take 5, etc before commencing tasks. Operators must also decide when the right level of risk assessment is required. This is often an area of confusion or difficulty with changing site tools, forms and standards.

Preconditions for Unsafe Acts

The physical environment was most cited precondition (39%), followed by the technological environment and communication or coordination respectively. Fitness for duty and adverse physiological states were the least identified factors and are not significant causal factors in this analysis.
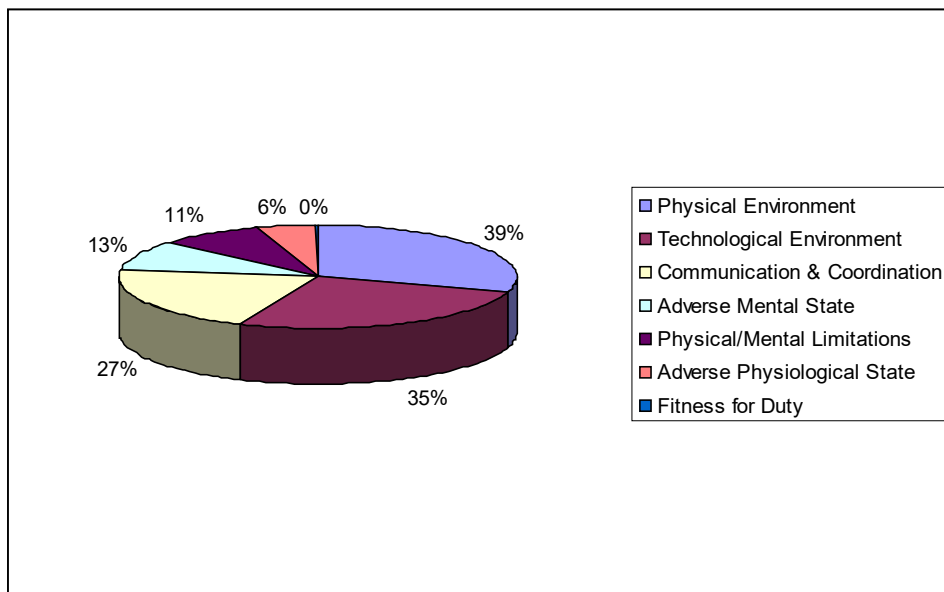

Figure 4: Preconditions for unsafe acts

The technological environment, including availability of warnings, PPE, equipment condition, is already major area of focus in mining safety. It is not surprising that on further analysis, "equipment design and construction" represented 42% of technological environment nanocodes. Design of equipment from the OEM and modifications to equipment done on site were captured in this nanocode, as was construction on the mine site.

Communication and coordination problems were also often identified preconditions, with communication much more significant than coordination. Communication examples included failing to make positive communication, inadequate communication of work instructions, inadequate communication between workers. Adverse physiological state was only identified as a causal factor in 6% of cases analysed, with Fitness for work less than 1%.

At the higher levels, there was enough detail to identify causal factors at both unsafe leadership and organisational influences levels.

Unsafe Leadership

Unsafe leadership was identified in 36.6% of cases analysed. Most causal factors (62.3%) at the unsafe leadership level fell into the 'inadequate leadership' category. Further analysis of unsafe leadership showed that training (43.9%) was the most identified causal factor. "Safety oversight" was another highly cited causal factor (28%). On most sites, workers are either working alone or with limited direct supervision which may limit consistent monitoring of tasks, or planned work.

Organizational Influences

Causal factors at the organisational level were fewer than other levels of HFACS-MI. Less than 10% of cases identified an organisational influence as a contributing factor. This is much lower than similar HFACS analysis in aviation, and could represent a lack of thorough or comprehensive investigation of causal factors. The most common organization factor was organizational process (79% of organizational codes). Further analysis of the organizational process category showed that problems with "procedures" were most common, usually a lack of a SOP or SWI for a given task. Other human factors issues with procedures will be discussed in the "Implementation" section

Role of Mine Type

To discover if differences existed between types of mining operations, analysis classified mines according to type. This was done only at the lowest level of unsafe acts. Mine type was classified as Quarry, Open Cut Coal, Open Cut Metalliferous, Underground Coal and Underground Metalliferous. Results are presented in Figure 5.

Skill based (or routine disruption) errors were the most represented error type, except for underground metalliferous which had this causal factor in only

39.8%. This could suggest that operators at underground metalliferous sector are more often engaged in not routine tasks that are not covered by procedures.
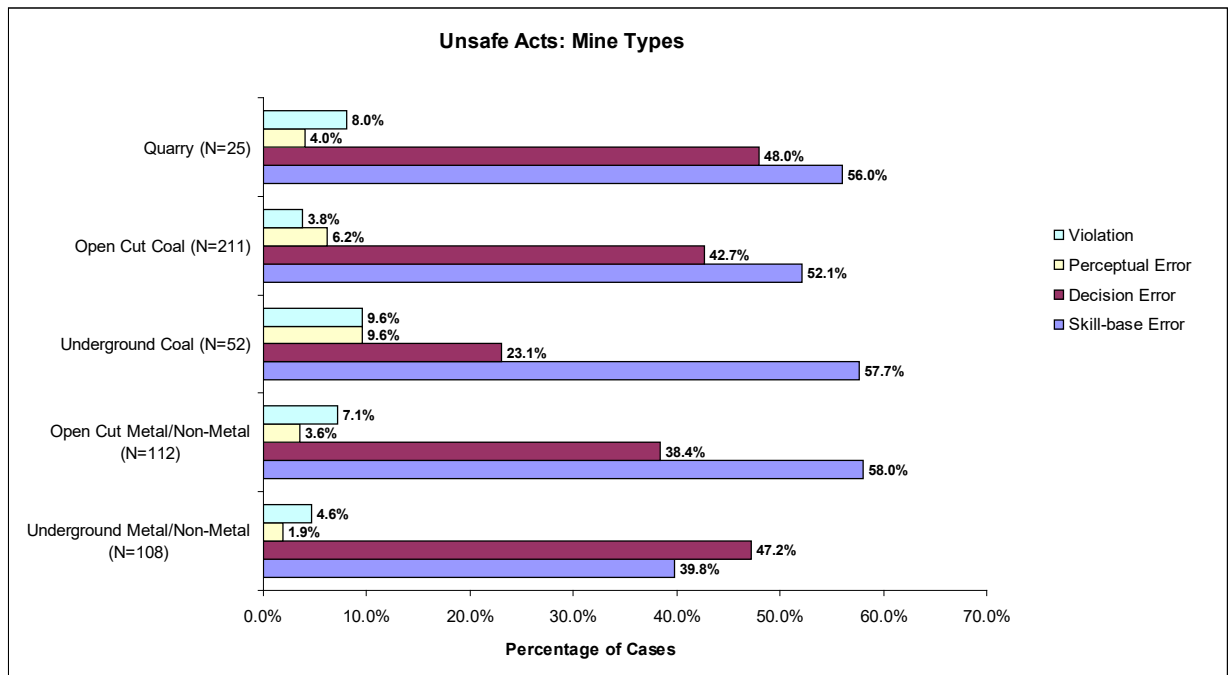

Figure 5: Unsafe Act causal codes for

Underground coal mines had the lowest percentage (23.1%) of cases with decision errors as a causal factor, while quarries had the highest percentage (48.0%). There were a fairly small number of underground coal mines in the analysis, and that may affect extrapolation of results for underground coal. Further analysis is also required to determine why decision errors are playing such a major role in quarrying incidents.

When looking at violations, open cut coal and underground metalliferous mines have significant less incident cases (4% and 5% respectively) than underground coal (10%). Quarries and underground metal/non-metal mines also have more cases attributed to violations (8% and 7% respectively), than the averaged figure across industry of 5%.

Perceptual errors were most often identified with underground coal mines (10%), but as mentioned, a larger number of underground coal mines would be required to draw further conclusions.

QME HFACS-MI Implementation Project

In order to review the comprehensive analysis of incidents using HFACS-MI, including appropriate nanocodes and recommendations by Clemson researchers, QME launched a statewide project. The focus of the project for 2009 and 2010 is on raising awareness of the role of human factors in mining incidents with QME Inspectors, and then industry.

Several QME Mines inspectors contribute to the project team, with a goal of developing plain English information on common human factors issues identified during investigations. One example is the role of procedures in decision errors.

From the HFACS-MI analysis, decision errors attributed to a procedural error nanocode was one of the highest contributions to unsafe acts. It is still common to rely on procedures as a control measure (or defence) for many hazards in mining. Investigation methods such as TapRoot™ and ICAM include specific categories for procedures, and the role of human error in developing procedures has been identified in other industries. Some examples of human factors issues in the procedure category could include:

a. Conflicting Policies or Procedures
b. Confusing Policy or Procedure
c. Inaccurate Policy or Procedure
d. Non-site specific Policies or Procedures
e. Lack of Policy or Procedure
f. Old vs. New Policy or Procedure
g. Excessively complex or difficult policy or procedure
h. Policy or procedure not available for reference or review in work area
i. Policy or procedure change not communicated to workers
j. Less than adequate or no training in procedure

Conclusion

The HFACS-MI analysis has provided some direction as it has identified the high contribution of reducible human error in mining incidents. Further work is needed to address some issues with terminology, understanding and consistency of application of human factors. To this end QME is continuing to gather more incident reports and investigation reports to add to the growing database as well as explore opportunities to partner with industry.

References

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