# Human Factors in Queensland Mining:
QME Project to improve identification and awareness of the role of Human Factors in mining incidents and accidents

## Overview

Queensland Mines and Energy (QME) initiated in March 2008, a review of the role of human factors in mining incidents and accidents in Queensland. The initial component of the project was the commissioning of a research project to:

1. translate the HFACS (Human Factors Analysis and Classification System) into a mining context, and

2. analyse human factors involvement in Queensland mining using QME incident and accident reports provided to the Department

The project was conducted through Simtars by PhD student, Ms Jessica Patterson, Clemson University, South Carolina, USA, between March 2008 and February 2009. Ms Patterson was based at Simtars for the duration of her project, and the support of Simtars is acknowledged.

The attached technical report contains the analysis of 508 mining incidents/accidents using the HFACS-MI framework, with coding undertaken by Clemson University. The report was prepared to highlight key findings from the analysis of Mining incidents and accidents in Queensland during the period of 2004-2008. It reflects the findings in Ms Patterson's research and analysis, and may require some level of understanding of human factors and research methodology and terminology.

The research was undertaken independently by Ms Patterson, with visits to some mine and quarry sites and a number of regional offices in Queensland. Although Ms Patterson was assisted by QME personnel, the data collection, analysis and interpretation are solely that of Clemson University.

Queensland Mines and Energy

Simtars

## Terminology and acronyms

FIFO: Fly in Fly out

Human Factors: Human factors is a scientific discipline that applies systematic, evidence-based methods and knowledge about people to design, evaluate and improve the interaction between individuals, technology (including equipment) and organisations. Human factors principles, analysis and knowledge can also be used to identify known human factors contributors to human error in incidents and accidents. There is evidence and a body of knowledge on the role of human factors in incidents and accidents in the areas of aviation, rail, nuclear power, and other safety critical industries.

JSA: Job safety analysis

LTA: Less than adequate

Nanocode: Detailed description of each of the HFACS-MI causal factors for specific coding

OEM: Original equipment manufacturer

SOP: Safe operating procedure

SWI: Safe work instruction

Note: After the report was completed, feedback from the QME Inspectorate was that the term “Skill based errors” was confusing. Many associated skill based error with ‘lack of skill’ or competency, which is not the case. QME is using the term routine disruption errors as an alternative, and this is reflected in the report whenever possible.

# Analysis of mining incidents and accidents in Queensland, Australia

## from 2004–2008 using the HFACS-MI framework


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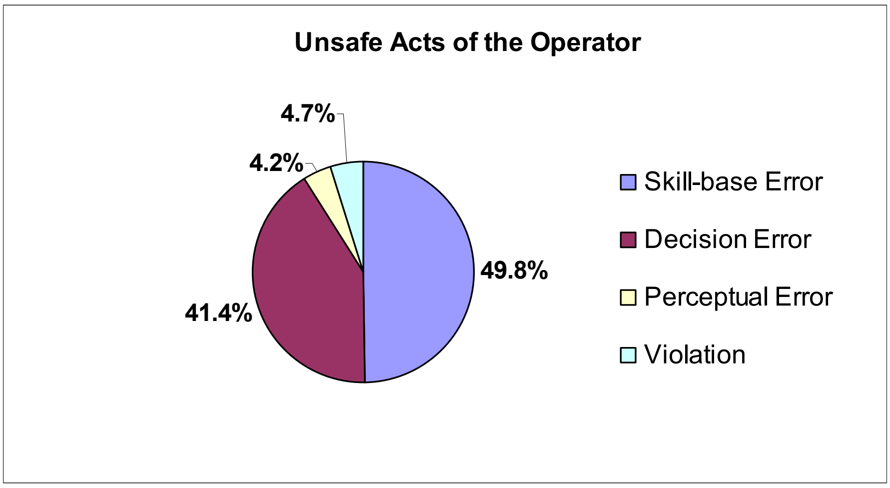
## EXECUTIVE SUMMARY

Human factors in mining incidents and accidents are an important issue for the mining industry in Queensland, Australia. To address this issue, the Department of Mines and Energy (DME) launched a project aimed at identifying human factors issues of particular relevance to the mining industry. To identify the source of human error related events, DME requested the assistance of Clemson University.

Clemson University researchers examined a total of 508 mining incidents/accidents from across all three geographical regions of Queensland using a human error analysis framework modified specifically for the mining industry, the Human Factors Analysis and Classification System-Mining Industry (HFACS-MI). This framework is a complex linear incident/accident investigation model that enables users to systematically examine human causal factors of an event. HFACS-MI considers the causal factors of an incident/accident at five levels starting with the unsafe act itself and moving upward to consider preconditions for unsafe acts, unsafe leadership, organizational influences and finally outside factors. Most of the incidents/accidents looked at were considered high potential and did not result in significant injury to the people involved.

Routine disruption errors (also referred to as skill-based errors by Reason and Shappell) were the most prevalent error form identified throughout the data but other error forms were also identified. A fine-grained analysis was conducted in order to better understand how these errors manifested themselves in the field. Results suggest that “attention failures” and “technique errors” are the primary type of errors. Decision errors were most often “procedural” and “situational assessment” problems. Perceptual errors and violations were less often identified as contributing factors.




This report provides a detailed breakdown of each of the HFACS-MI levels. There are a number of key findings which will be summarized in this report. While violations are relatively minor, it is important that they be addressed immediately. An operator, who wilfully disregards the rules and procedures on minor tasks, is likely to disregard the rules and procedures on more complex tasks particularly if the operator is not reprimanded. Additionally, steps need to be taken to reduce the following types of unsafe acts: attention failures, unintentional procedural breaches, technique failures, and overall situational assessment. Overall, HFACS-MI proved to be a useful tool in the analysis of mining incidents and accidents. The continued use of HFACS-MI in the future should lead to a better identification and understanding of human factors related issues and causal trends.

# INTRODUCTION

The mining industry has historically been viewed as a high risk environment. While the industry has seen recent success in safety, it still remains one of the most high risk professions worldwide (Mitchell, Driscoll et al. 1998) leaving investigators with the often difficult task of identifying incident/accident causes in the hope of preventing or mitigating future incidents/accidents. In Australia, as in most of the world, the mining industry continues to have accident rates higher than that of any other industry (Bennet and Passmore 1984; Hull, Leigh et al. 1996). From July 2006 – June 2007, there were 367 reported mining accidents in Queensland, Australia with a frequency rate of 5 accidents for every million hours worked (DME 2008). This means that on average, once a day a miner in Queensland is injured on the job.

What defines an incident or accident in the mining industry? The Queensland Government supplied definitions of both incident and accident in *Coal Mining Safety and Health Act 1999* and *Mining and Quarrying Safety and Health Act 1999*. An accident is an "event, or series or events, at a mine causing injury to a person." A serious accident is an "accident at a mine that causes the death of a person, or a person to be admitted to a hospital as an in-patient for treatment of injury". A high potential incident is an "event, or series of events, that causes or has the potential to cause a significant adverse effect on the safety and health of a person." While the definition of an accident is fairly concrete, the definition of a high potential incident leaves room for some interpretation on the part of the investigator. There were 5,822 accidents/incidents reported to DME over the time period of this analysis (January 2004-June 2008). Almost 90% of these cases are classified as high potential incidents, less than 1% are fatalities, 2% are lost time accidents and 7.7% are non reportable incidents. While these types of incidents general do not include injury, they can still be costly. Even minor incidents cause machine downtime for investigation and repairs and the allocation of human resources to correct the problems. This takes workers away from other areas and can hinder productivity. Regardless of severity, accidents and incidents are a serious issue facing the mining industry.

Adverse working conditions lead miners to be exposed to hazards including flooding, explosive agents, and the risk of asphyxia (Mitchell, Driscoll et al. 1998). Although these hazards are present, the majority of accidents cannot solely be attributed to adverse working conditions. A study by the US Bureau of Mines found that almost 85% of all accidents can be attributed to at least one human error (Rushworth, Talbot et al. 1999). In Australia, two out of every three occupational accidents can be attributed to human error (Williamson and Feyer 1990). With the high percentage of incidents and accidents attributed to human error, it is vital that accident investigations include contributing factors attributed to human error.

## Human Factors Analysis in the Queensland Mining Industry

At the Queensland Mining Industry Safety and Health Conference in 2007, a request was made by industry to introduce human factors analysis to incident/accident investigations. To meet this request, the Department of Mines and Energy established a grant with Clemson University for a human factors specialist to investigate the mining incidents/accidents from a human factors perspective. The goal of this grant was to identify trends in human error that can be systematically looked at to reduce future incidents/accidents. To accomplish this goal, 508 incident/accident cases from across Queensland occurring from 2004-2008 were collected. The cases were coded using a modified version of the human factors analysis and classification system (HFACS) initially developed by Wiegmann and Shappell (2003) for use in the U.S. Navy and Marine Corps. The modified version, the human factors analysis and classification system-mining industry (HFACS-MI), was developed to specifically meet the needs of the mining industry.

**Rationale for using an HFACS-MI Analysis**

With the vast number of incidents/accidents in the mining industry attributed to human error, an approach that addresses human error issues is vital. Little research has been done on human error in mining. In fact, the specific types of human error that frequently occur in mining accidents are still unknown. To date, a systematic evaluation of mining incident/accident for human error causal factors has not been done.

The aim of this study was to examine a large body of mining incidents/accidents from Queensland, Australia. After collecting and identifying incidents/accidents with human error causes, a more detailed human error analysis was performed. Given the previous success that HFACS has had in a variety of industries, it seemed reasonable to apply the HFACS framework to the mining incidents/accidents in hopes that similar results could be achieved. A brief description of the HFACS framework and modifications made for the mining industry (HFACS-MI) can be found below. For a more detailed description of HFACS, the reader is encouraged to read previous work of the developers (ex. Wiegmann and Shappell 2001b; Wiegmann and Shappell 2001a; Wiegmann and Shappell 2003).

## HFACS-MI

It is generally accepted that incidents/accidents do not happen in isolation. They are the result of a chain events often starting in the organizational level and culminating with an unsafe act on the part of the operator(s). As a result, incident/accident investigation has shifted away from blaming the operator to a more sequential theory of accident investigation. One highly used and regarded systems approach model is the “Swiss cheese” model of human error developed by Reason (1990). This model attempts to describe the active and latent failures within the system that combine to cause an incident/accident.

Reason’s model describes human error in four levels (organizational influences, unsafe supervisions, preconditions for unsafe acts, and unsafe acts of the operator). In this model each level affects the next. Incidents/accidents take root with the decisions made by those at the top of the company which in turn affect managers and supervisor who oversee the day-to-day operations of the organization. It is often at the day-to-day operations level that the results of higher levels culminate into an accident. The employees at this level are often most visibly associated with a system failure as their actions can be seen as the direct cause of an accident. It is when accident investigation focuses on operator error that organizational deficiencies are ignored and left to resurface in other incidents and accidents.

Reason describes system deficiencies as “holes” within each organizational level. These deficiencies can be classified as active or latent failures. Active failures are the unsafe acts of those directly in contact with the system and are most often associated with incidents/accidents. These failures can be classified as errors or violations and intended or unintended actions. Unintended errors are classified as slips and lapses. These types of errors are generally associated with automatic actions and result from memory lapses or attention failures. Intended errors are classified as mistakes. Mistakes occur when an the individual fails to carry out the action as intended or carries the action out as intended but the action was the incorrect response for the situation. Violations are intended actions that are carried out with wilful disregard to the established rules and regulations. Latent conditions of a system often go unnoticed until an adverse event occurs. These latent conditions lead to two results, those that create error provoking conditions and those that create weaknesses in system defences (Reason 2000). The combination of these active and latent failures results in an accident.

While the work of Reason (1990) revolutionized the contribution of human error in accident investigation, the model lacked a systematic way of identifying and classifying active and latent failures. The human factors analysis and classification system (HFACS) was developed to fulfil this need (Shappell and Wiegmann 2000; Wiegmann and Shappell 2003). The HFACS framework was developed for use with aviation accidents in the U.S. Navy and Marine Corps. Since its development, HFACS has been used in civil aviation (Wiegmann and Shappell 2001b; Wiegmann and Shappell 2001a; Wiegmann, Faaborg et al. 2005; Shappell, Detwiler et al. 2007), aviation maintenance (HFACS-ME: Krulak 2004), air traffic control (HFACS-ATC: Broach and Dollar 2002), railroads (HFACS-RR: Reinach and Viale 2006), medicine (ElBardissi, Wiegmann et al. 2007), and remotely piloted aircrafts (Tvaryanas, Thompson et al. 2006). The HFACS-MI framework describes 21 causal categories within Reason's four levels of human error and an additional level to evaluate the role of outside influences on mining incidents/accidents. Figure 1 shows the framework for HFACS-MI.

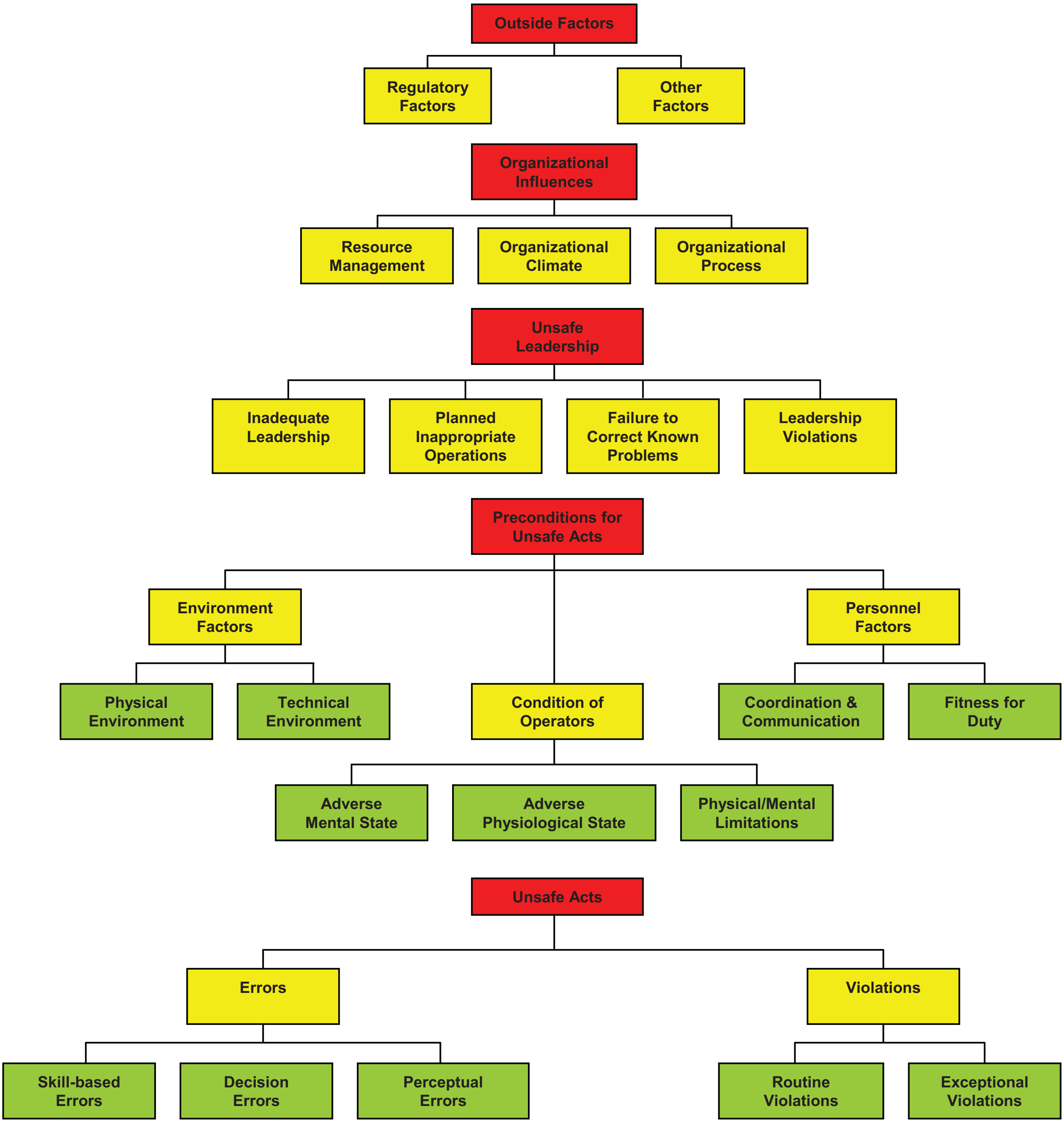



**Figure 1: The Human Factors Analysis and Classification System-Mining Industry**

**Unsafe Acts of Operators**

This first level of HFACS-MI describes the unsafe acts of the operator that directly lead to an incident/accident. This level is typically referred to as operator error and is where most accident investigations are focused. Unsafe acts typically dominate accident databases as they are easy to identify and place the blame on a select few people. Unsafe acts of the operator are classified into two categories, errors and violations. Errors refer to activities that fail to achieve the desired outcomes whereas violations are the conscious disregard of established rules and regulations. In the HFACS framework, errors are divided into three basic types (decision, routine disruption, and perceptual) and violations are divided into two forms (routine and exceptional). A partial list of 'Unsafe Acts of Operators' nanocodes can be found in Table 1.

***Errors***

**Decision Errors.** Decision errors represent intentional actions that proceed as intended, but the plan proves inadequate or inappropriate for the situation. Decision errors occur during highly structured tasks and are divided into three types, rule-based errors, knowledge-based errors, and problem-solving errors. Rule-based errors occur when a situation is either not recognized or is misdiagnosed and the wrong procedure is applied. Knowledge-based errors occur when an operator chooses between various action plans but selects the incorrect procedure for the situation. This error form can be exacerbated by time pressure, inexperience, stress, etc. Problem-solving errors occur when an individual is put in a situation where the problem is not well understood and no formal procedure exists. A novel solution is required for these situations. During these situations individuals must resort to reasoning and thought-processing which is often time consuming and mentally taxing.

**Routine Disruption Errors (Also referred to as Skill-based Errors).** Unlike decision errors, routine disruption errors occur with little conscious effort during highly automated tasks. As tasks become more familiar to an individual, they also become more automated. After some time, it does not take much conscious thought for an individual to navigate a car home following the same route everyday. The routine disruption error would arise when the person simply drives past his desired turn without noticing. Routine disruption errors are susceptible to failures of memory or attention. In the example given above, a loss of attention to where one is going could lead to the error. Failures of attention have been linked to breakdowns in visual scanning, task fixation, and inadvertent activation of controls. Consider an operator who is busy checking the status of the ground support and activates the incorrect control on the jumbo.

Memory failures often appear as missed steps in checklists, forgetting intentions, or place losing. Most people can relate to others that get somewhere only to realize they have no idea what they came to get. In everyday situations, these failures have minimal consequences. Consider the pedestrian on a mine site who forgets to wait for radio confirmation before proceeding into an area with heavy vehicles. The consequence of this action could quite literally lead to death. These errors increase during emergency situations when stress levels increase.

Routine disruption errors are also caused by the technique employed to carry out a task. Even with similar backgrounds in training and experience the way an individual operates equipment can cause an increased likelihood of committing an error. An operator may move controls using tactile clues only when deciding which lever to move. When compared with other techniques for operation, such as the added use of visual clues, this way could lead to more unintentional errors being committed.

**Perception Errors.** Perceptual errors occur when sensory input is degraded, usually in an impoverished environment. The error is not the degraded input being used, but the misinterpretation of the input itself. In the mining industry, the effect of a degraded physical environment has seen very little research. Operators, especially those working underground are often in areas with limited lighting and constantly changing ground and rib conditions.

***Violations***

Violations represent the wilful disregard of established rules or regulations. They can manifest in two distinct forms, routine or exceptional violations. The difference between the types of violations does not reflect the seriousness of the act, but rather the frequency and the reaction of management.

**Routine Violations.** Routine violations refer to the wilful disregard of rules and regulations that are condoned by persons in positions of authority. These violations tend to be habitual and accepted as part of what goes on in the organization. Consider for example, the operator who continually drives above the posted speed limit on the haulage roads. As this is normal on city roads, many people do not think anything of driving 5-10 kph over the posted speed. Since this act occurs frequently and there are few adverse events as a result, the enforcement of the rule is not a priority. In order to prevent routine violations from occurring, one must look to the members of authority to begin enforcing all of the rules.

**Exceptional Violations.** Exceptional violations are isolated departures from rules and regulations. These departures are not condoned by management nor are they indicative of an individual's behaviour. For example, imagine an operator who violated regulations by operating a piece of equipment that he or she is not authorized to use. Exceptional violations are difficult to correct because they are unpredictable due to their departure from normal behaviour.

**Table 1: A partial listing of the unsafe acts of operators**

| Errors | Violations |
|---|---|
| **Decision Errors** (rule-based errors, knowledge-based errors, and problem-solving errors) | **Routine** (Bending of the rules and regulations tolerated by members of authority) |
| □ Use of defective/incorrect equipment | □ Operating vehicle/equipment at speeds greater than the posted limit |
| □ Failure to report equipment faults/failures | |
| □ Caution/warning ignored | □ Failure to follow posted signs |
| □ Risk assessment not completed | □ Improper use of PPE |
| □ Improper attempt to save time | □ Taking shortcuts |
| **Routine Disruption Errors or Skill based Errors** (Occur without significant conscious thought. Vulnerable to failures of attention, memory, or technique | **Exceptional** (Isolated departures from the rules, not tolerated by members of authority. Difficult to predict |
| □ Reversed/omitted steps in a procedure | □ Operating/working on equipment without |
| □ Failure to lower equipment attachments | □ authority |
| □ Inadvertent operation | □ Entry into unauthorized areas |
| □ Isolation of incorrect equipment/machinery | □ Intoxicated at work |
| □ Improper lifting | □ Operating equipment without competency |
| **Perceptual Errors** (Occur when sensory input is degraded) | |
| □ Misjudged distance | |
| □ Misjudged surface conditions | |
| □ Misinterpreted warnings | |

**Preconditions for Unsafe Acts**

While the unsafe acts of the operator have continually been linked to accidents, the preconditions to the unsafe acts must also be understood in order to reduce incidents/accidents. Preconditions are generally latent system failures that lay dormant for long periods of time before ever contributing to an accident. Understanding the preconditions that an individual is placed under will help identify other areas for organizational improvements. Preconditions for unsafe acts include environmental factors, conditions of the operator, and personnel factors. Table 2 gives a partial list of 'Preconditions for Unsafe Acts' nanocodes.

***Environmental Factors***

**Physical Environment.** The physical environment is often looked at and cited in accident databases. The physical environment refers to both the operational (tools, machinery, etc.) and ambient (temperature, weather, etc.) environments. Mining operations, especially those underground, take place in adverse environmental conditions. Miners are often exposed to high temperatures which can lead to a decrease in attention, dusty conditions that reduce visibility, and dehydration, all of which can contribute to unsafe acts.

**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. Within Australia, differences in control locations may become a major issue. Most equipment is designed and manufactured overseas where standards are different. Even the side on which an operator sits in the truck will change depending on whether the truck was designed on the American standard of drivers sitting on the left, or if the design was modified to be driven from the right as is standard in Australia. This change in seat position can have an effect on operators who are inexperienced and unfamiliar with the new layout or who are constantly switching between left and right hand drive vehicles.

***Conditions of Operators***

**Adverse Mental State.** The adverse mental state of the operator covers a broad range of mental conditions that can affect the performance of an operator. These conditions include mental fatigue, 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. Physiology refers to the normal functioning of an organism and in this case of an individual person. It may be part of an individual's normal body function to have an overactive sweat gland. While this in itself will not preclude safe operation, combined with a hot humid environment and restricted water access, dehydration could be a major problem. It is important to identify these conditions in order to ensure that actions are taken to ensure individuals are not at an increased risk of harm due to medical or physiological conditions. This category also covers temporary medical conditions such as colds, headaches, etc. and the affects of the over-the-counter medications that people take to relieve these conditions.

**Physical/Mental Limitations.** While many people are sometimes unwilling to admit it, there are occupations that are simply beyond the capabilities of some individuals. All of us cannot aspire to be test cricket players in a week, and similarly may not have the physical or mental capabilities to operate complex, heavy-duty machines in often adverse environments with limited experience. This category refers to situations when individuals' capabilities are exceeded by the demands of the job.

This category takes into account many different forms of incompatibility. Some of these incompatibilities are possessed by all humans. The human visual system is known to be limited in dark environments so precautions must be taken to account for this decrease in visual acuity. Other areas of incompatibility are often overlooked simply because people do not want to offend others. These incompatibilities are those referring to physical and mental aptitude. Some people do not possess the mental aptitude to correctly react to novel situations or to memorize different procedures. Some individuals lack the physical ability to safely perform a job. This includes not having the physical strength to operate the controls, having incompatible anthropometric measurements for machines and poor physical health to complete strenuous aerobic tasks.

***Personnel Factors***

**Communication and Coordination.** Communication and coordination within an organization is vital for safe operations. Poor coordination between personnel, management, and contractors leads to confusion in responsibilities and overall breakdowns in organizational pathways. Communication breakdowns can occur between varieties of people within the work site - within workgroups, between workgroups, between management and personnel and between management and contractor.

**Fitness for Duty.** It is the responsibility of an employee to arrive for work in a condition which allows them to work safely. To a large extent, mine sites have taken measures to ensure that workers show up to work not under the influence of drugs and/or alcohol. Unfortunately, other factors play a significant part of being fit for duty. These factors include showing up to work with adequate sleep, avoiding physical overexertion during free hours, and maintaining a healthy diet. Within the mining industry, shift work is very common. Engaging in shift work can lead to poorer sleep patterns and nutrition which can negatively affect circadian rhythms and result in lack of fitness for duty.

**Table 2: A partial listing of preconditions for unsafe acts**

| | |
|---|---|
| **Environmental Factors** | |
| **Physical Environment** (Operational and ambient environment) | **Technological Environment** (Issues related to design of equipment and controls, display/ interface characteristics and automation) |
| ☐ Inadequate ventilation | ☐ LTA or defective PPE |
| ☐ Energized electrical equipment | ☐ Defective equipment or tools |
| ☐ Loose/falling rocks | ☐ Poor man/system interface |
| ☐ Slippery roadways | ☐ SOPs not accessible/poor format |
| ☐ Confined space | ☐ Safety device missing/not installed |
| **Conditions of Operators** | |
| **Adverse Mental Sate** (Mental conditions that affect performance) | **Adverse Physiological State** (Medical/ physiological conditions that preclude safe operation |
| ☐ Overconfidence | ☐ Spatial disorientation |
| ☐ Frustration | ☐ Medical illness |
| ☐ Task fixation | ☐ Previous injury or illness |
| ☐ Peer pressure | ☐ Sleep deprivation |
| ☐ Drowsiness | ☐ Dehydration |
| **Physical/Mental Limitations** (Situations exceed the capabilities of the operator) | |
| ☐ Visual limitation | |
| ☐ Hear deficiencies | |
| ☐ Respiratory incapability | |
| ☐ Inappropriate height, weight, size, etc. | |
| ☐ Learning ability limitations | |
| **Personnel Factors** | |
| **Communication and Coordination** (Poor communication and coordination among personnel) | **Fitness for Duty** (Failure to prepare mentally or physically for duty) |
| ☐ Lack of teamwork | ☐ Self medicating |
| ☐ LTA briefing | ☐ Hung-over |
| ☐ Ineffective communication methods | ☐ LTA nutrition |
| ☐ Standard terminology not used | ☐ Overexertion off duty |

## Unsafe Leadership

According to Reason (1990), the actions of people in leadership positions can influence the performance and actions of operators. As such, the causal chain in accident investigation should include factors at this level. Unsafe leadership is divided into four categories, inadequate leadership, planned inappropriate operations, failure to correct known problems, and leadership violations. A partial listing of 'Unsafe Leadership' nanocodes can be found in Table 3.

### *Inadequate Leadership*

Leadership is responsible for providing personnel with the opportunity for safe operation. This is done through adequate training, oversight, incentives, guidance, etc. While leadership has the responsibility to provide these things, it is not always done. With training issues, it comes down to leadership to arrange and authorize training programs. When employees are not given the opportunity to attend training sessions, decision making abilities are not developed which could lead to an increase in decision errors. Oversight is also an important part of leadership responsibilities. While it is important to trust the competency of operators, leadership must still be present to prevent the breeding of violations within the system.

### *Planned Inappropriate Operations*

The category of planned inappropriate operations refers to situations where actions are initiated that put personnel at an unacceptable level of risk. While these actions may be acceptable during emergency situations, they are unacceptable during normal operation. Consider for example, leadership that allows a worker to pick up extra shifts in order to cover poor shift scheduling or allowing an operator to continue to work after completing a 12-hour shift will possibly lead to drowsiness and increase the potential for human error.

### *Failure to Correct Known Problem*

The third category, failure to correct known problems, refers to instances where unacceptable conditions or behaviours are identified but actions are not taken to correct them. While most correction measures are usually left to those in authority, instances of unacceptable behaviours are more likely to surface when authority figures are not present. It is therefore vital that everyone in the organization take an active role in correcting known problems. Inconsistent actions or discipline promotes violation of rules and regulations.

### *Leadership Violations*

The final category, leadership violations, is reserved for situations in which established rules and regulations are wilfully disregarded by those in positions of leadership. Leadership violations are rare in nature, but their effects can permeate throughout the organization. When employees witness the mine leadership disregarding rules and regulations, a culture is created where following the rules is not a priority.

**Table 3: A partial listing of unsafe leadership**

| | |
|---|---|
| **Inadequate Leadership** ( Failure to provide guidance, training, oversight, etc. to ensure a job is done safely and efficiently)<br>□ No formal training provided<br>□ Training not reinforced on the job<br>□ Failure to ensure competency<br>□ Lack of appropriate incentives<br>□ Failure to provide PPE | **Failure to Correct Known Problem** (Deficiencies among individuals, equipment, etc. that are known and are allowed to continue)<br>□ LTA identification of hazards<br>□ Failure to stop unsafe tendencies<br>□ Failure to update SOPs |
| **Planned Inappropriate Operations** (Operations that can be debatable and different during emergencies, but are unacceptable during normal operations)<br>□ Excessive workload<br>□ Poor shift turnover<br>□ Unrealistic expectations<br>□ Meaningless or degrading activity<br>□ Failure to provide adequate breaks | **Leadership Violations** (Wilful disregard of rules and regulations by supervisors)<br>□ Violation of SOPs<br>□ Encourage bending of rules<br>□ Fraudulent documentation<br>□ Authorized unqualified worker to perform task |

## Organizational Influences

Organizational failures can be further traced to deficiencies within the highest levels. Latent conditions within the organizational level often go unnoticed during accident investigations. These factors are difficult to find unless a clear understanding of the organization's framework is understood and a consistent accident investigation framework used. Identification of causal factors at this level can also be hindered by the unwillingness to apportion blame to the company for fear of liability. Organizational influences are divided into three categories, resource management, organizational climate and organizational process. A partial listing of 'Organization Influences' nanocodes can be found in Table 4.

### *Resource Management*

The most obvious corporate decisions are those that relate to the allocation of resources. Organizational resources include equipment, facilities, money, and humans. The allocations of these assets often are based on two conflicting objectives, safety and profit. Part of resource management deals with the allocation and availability of personnel. Failures of resource management can occur when an unfavourable ratio of leadership to workers exist.

### *Organizational Climate*

An organization's climate refers to a range of variables that affect performance, including the organizational structure, culture, and policies. Organizational structure is most often viewed as the chain of command that is employed within the company. The way that different levels of management and employees interact and relate with one another is all part of the organization's climate. Culture refers to the attitude, values, beliefs, and customs that are used as guidance. In many organizations, the culture reflects the manner in which tasks are carried out regardless of the rules and policies that should be followed. A company's policies refer to both the written procedures that are used and the unwritten policies that are embedded in the organization.

### *Organizational Process*

The final category of organizational influences, organizational process, refers to the decision making that governs the day-to-day operations of an organization. Organizational process includes the creation and dissemination of standard operating procedures, roster selections, and the establishment of safety programs.

**Table 4: A partial listing of organizational influences**

| | |
|---|---|
| **Resource Management** (Corporate level decision making regarding the allocation and maintenance of organizational assets such as human resources, monetary asset, and equipment/facilities) | **Organizational Climate** (The working atmosphere within the organization. This is reflected in its' structure, polices, and culture.) |
| ◻ Short staffed | ◻ LTA organizational communication |
| ◻ LTA employment selection | ◻ Unclear reporting relationships |
| ◻ Use of non-approved contractor | ◻ LTA hiring, firing, retention |
| ◻ Excessive cost cutting | ◻ LTA shift Roster |
| ◻ Purchasing unsuitable equipment | ◻ Conflict Avoidance |
| **Organizational Process** (The formal process by which things get done within the organization. Divided into operations, procedures, and oversights) | |
| ◻ Lack of SOPs, SWIs, JSAs | |
| ◻ Unclear definition of objectives | |
| ◻ LTA risk management | |
| ◻ Time pressures | |
| ◻ LTA performance measures | |

## Outside Factors

Rarely, if ever, do organizations operate in isolation. Depending on the type of work being conducted, an organization will be regulated by a government body. Even those that do not have a specific government entity oversight are still required to comply with safety and health regulations. Additionally, an organization must answer to the community. This fifth and final level of the HFACS-MI framework is not part of the original framework developed by Wiegmann and Shappell (2003). It was modelled after the work of Reinach and Viale (2006) on problems within the rail industry. A partial listing of ‘Outside Factors’ nanocodes can be seen in Table 5.

### *Regulatory Factors*

As a government entity, DME has a responsibility to the industry it oversees, as well as workers in the industry. DME is split into many groups, but the two main groups dealing with mining are Safety and Health and the inspectorate. The inspectorate regulates industry, provides advice and guidance but is not responsible for safety. Safety and Health is there primarily for the worker. DME must ensure inspectors and others who interact with industry and unions are seen as unbiased, knowledgeable, adequately trained, and competent in their positions. Deficiencies in any of these areas could lead to suboptimal enforcement of legislation and inadequate guidance on safety issues and concerns. It is this level of the HFACS-MI framework that will allow DME to ensure that its actions do not adversely affect safety and health.

### *Other Factors*

Besides government influences, organizations face a myriad of other outside influences. Organizations are pressured by different sources to ensure safety and health. The community in which an organization is located might pressure the organization to hire locally which could lead to an increase need for training. Legal pressure is always a concern as many organizations become fearful of prosecution for their actions. Economic pressures could force an organization to increase production which in turn could overwork employees. Pressure from environmental groups could lead to changes in procedures and policies which would have to be effectively communicated throughout the organization. Changes in the overall surrounding population may have an effect on safety and health. Australia, as in other parts of the world, is seeing an overall aging of the work force and a decrease of younger workers entering into higher risk industries. All of these outside influences have the ability to adversely affect the safety and health performance of an organization unless the organization recognizes them and takes steps to mitigate their impact.

**Table 5: A partial listing of outside factors**

| **Regulatory Factors** ( The affect government regulations and policies have on health and safety) | **Other Factors** (The affect outside pressures including economic and social have on health and safety) |
|---|---|
| □ Failure to take action regarding safety risks | □ Economic pressure |
| Inspector inexperience | □ Legal pressure/fear |
| □ Inadequate regulations | □ Aging workforce |
| □ Infrequent inspections | □ Social obligations |
| □ Unclear regulations | □ Environmental influences |

## METHOD

### Customize HFACS-MI

The first step in the analysis was to modify the HFACS framework for the Queensland mining industry. The modified framework was called human factors analysis and classification system-mining industry (HFACS-MI). There were no changes to the framework at the unsafe acts level. For the preconditions for unsafe acts level, ‘personal readiness’ was changed to ‘fitness for duty’ and ‘crew resource management’ was changed to ‘communication and coordination’ to keep with terminology familiar throughout the mining industry.

For the unsafe supervision level, all references to supervision were changed to leadership. This was changed because of the extensive hierarchy of management at each mine site. It was believed that using the word supervision would lead users to only think about those latent conditions which could be attributed to the operator's immediate supervisor. On large mine sites, there are a number of people who make decisions at the supervisor level who are not direct supervisors for operators, such as the Site Senior Executive. These higher up decisions are not always at the organizational level as a single company can control multiple mines across the state and world. The organizational level was left unchanged, but the coders were instructed that the organizational structure could be global and to remember that decisions at this level are not always made at the mine site. A fifth level was added to incorporate influences outside of the organization. This level includes regulatory, social, political, environmental, and economic influences.

Examples of each causal factor were generated to use as a guide during accident investigation. The first step involved in developing these examples or 'nanocodes' as named by Wiegmann and Shappell was a brainstorming session with a focus group. The focus group compromised of seven people, included inspection officers, mines inspectors, and regional inspectors of mines. All members of the focus group worked for the Department of Mines and Energy and had at least 5 years of experience within the mining industry. Individual and small group non-structured interviews were then held between mine operators and a human factors specialist to gain more first hand knowledge of active and latent failures. Mine workers interviewed had between less than 1 year and 20 years experience in the industry. After this list of examples was compiled, it was reviewed and categorized by a group of seven people with mining experience and a group of four people with HFACS experience. Where disagreements existed, discussions were held until a consensus agreement was reached.

**Data Acquisition**

Data was collected from mining incident/accident reports obtained from the Department of Mines and Energy (DME) in Queensland, Australia. The author collected the data personally at regional offices throughout Queensland, Australia. Mines and quarries in Queensland are divided into three separate regions; northern, central, and southern. Demographic information about the mine, including type, size, location, etc was also gathered.

All mines and quarries in Queensland are required to report lost time, high potential lost time, high potential no lost time and fatal incidents/accidents to DME within 24 hours of the event. Investigation reports for the purpose of this study were selected based on the following criteria: an initial report was made to DME, a follow up report was submitted by the mine, and an accident investigation was conducted by either the mine or DME. Incidents/accidents that did not involve human error, including instances of spontaneous combustion of coal, fires, and mechanical failures were removed from the study. In total, 508 incident/accident cases that occurred in the four and one-half year span between 2004 and 2008 were used in the analysis. Mines involved in the analysis included open cut and underground coal mines; open cut and underground metalliferous mines; and quarries.

**Data Classification**

Once the nanocodes were created, groups of two to five human factor specialists with HFACS training coded the set of 508 incident/accident cases. Each human factors specialist had at least a Master's degree in a human factors field and experience working with HFACS.

As prior HFACS studies have demonstrated a high inter-rater reliability, analysis using consensus coding was deemed appropriate for the analysis. Consensus coding allows coders to discuss events and prevents isolated decision making. Consensus coding is also more likely to reflect the coding process for DME after the completion of this project. If coding is not done in a group, then two individuals would need to independently code each case and then an arbitrator would need to make final decisions where differences between the coders exist.

Data was coded using the narrative, sequence of events, findings and/or recommendations sections of each report. These sections were comprehensive and covered all relative points of the investigation. All identifiable information was removed from the reports prior to the coding process. During the coding process, each rater was supplied with copies of the HFACS-MI framework and corresponding nanocodes. All coding were reviewed by the author to ensure accuracy of the data.

### Data Analysis

After all of the data was coded, the analysis phase of the project began. This phase allowed the authors to fully examine the relationships between human error causal factors and various characteristics such as mine type, mining material, time of day and year.

## RESULTS AND DISCUSSION

### HFACS-MI Nanocodes

The HFACS-MI nanocodes were developed in detail prior to the coding process.

### Overall Results

The results for this analysis were fairly robust in nature. Causal factors were identified at all levels except for ‘Outside Factors’. For both ‘Organizational Influences’ and ‘Unsafe Leadership’ causal factors tended to be concentrated on a single category. Causal factors at the lowest two levels were dispersed over multiple categories. Table 6 shows the frequency and percentage of incident/accident cases associated with each HFACS-MI category. The percentages at each level can add up to more than 100% as more than one category could be associated with an individual case. A more detailed analysis of each level is provided in the next sections.

**Table 6: Frequency and Percentage of Cases Associated**

| HFACS Category | N (%) Mining Accidents (N = 508) | |
|---|---|---|
| Outside Factors | | |
| Regulatory Influences | 0 | (0.0) |
| Other Influences | 0 | (0.0) |
| Organizational Influences | | |
| Organizational Climate | 7 | (1.4) |
| Organizational Process | 42 | (8.3) |
| Resource Management | 5 | (1.0) |
| Unsafe Leadership | | |
| Inadequate Supervision | 144 | (28.3) |
| Planned Inappropriate Operations | 60 | (11.8) |
| Failed to Correct Known Problems | 20 | (3.9) |
| Supervisory Violations | 7 | (1.4) |
| Preconditions for Unsafe Acts | | |
| Environmental Conditions | | |
| Technical Environment | 179 | (35.2) |
| Physical Environment | 198 | (39.0) |
| Conditions of the Operator | | |
| Adverse Mental State | 64 | (12.6) |
| Adverse Physiological State | 32 | (6.3) |
| Physical/Mental Limitations | 55 | (10.8) |
| Personnel Factors | | |
| Coordination and Communication | 138 | (27.2) |
| Fitness for Duty | 2 | (0.4) |
| Unsafe Acts of the Operator | | |
| Routine Disruption Errors | 299 | (58.9) |
| Decision Errors | 249 | (49.0) |
| Perceptual Errors | 25 | (4.9) |
| Violations | 28 | (5.5) |

## Unsafe Acts of the Operator

A large amount of data was gathered at the unsafe acts level. Nearly all cases analysed identified at least one causal factor at the unsafe acts level (94.7%). The large number of unsafe acts found in the incident/accident reports was not surprising as most of the reports gave a fairly descriptive account of events.

The following section presents a general analysis of the unsafe acts identified. It also provides a snapshot analysis differentiating unsafe acts based on mine type, mine material, time of day and year. A breakdown of each of these factors can be found in Appendix A. Age and experience data could not be analysed as this information was only available for a small percentage of cases.

### *General*

Similar nanocodes were combined to obtain a more accurate representation of the data. Since the nanocode “working at heights without protection” is just a more specific example for “improper PPE” the nanocodes were combined, along with other nanocodes, and are represented by “PPE/Equipment/Tools (Decision)”. The percentages of incident/accident cases associated with each unsafe act nanocode are displayed in Figure 3. The results do not add to 100% as some cases are not associated with an unsafe act and others are associated with more than one unsafe act. As can be seen in Figure 3, the nanocodes with the highest percentage of cases with at least one occurrence are:

- Attention Failure (Routine Disruption) – 21.0%
- Procedural (Decision) – 18.0%
- Technique Errors (Routine Disruption) – 16.0%
- Situational Assessment (Decision) – 14.0%
- Risk Assessment (Decision) – 12.0%

Also evident in Figure 2, is that nanocodes associated with violations and perceptual errors combined only represent 10.2% of all nanocodes.

"Procedural" errors generally 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 carry out a procedure incorrectly simple because he does not know the correct steps in the procedure either due to lack of training or lack of retention of information. "Technique errors" refer to the way in which an operator completes a task and how well it is performed. "Situational assessment" deals with the identification of hazards and the response taken when a hazard is identified. When an operator is unable to correctly identify hazards or take appropriate action when a hazard is present, there becomes an increased risk of an adverse event happening. Finally, the "risk assessment" nanocode refers to the operator's ability to carry out a complete and thorough risk assessment, JSA, Take 5, etc before commencing tasks for which one is required. An operator also must identify the correct controls needed to mitigate any hazards which arise from the task.

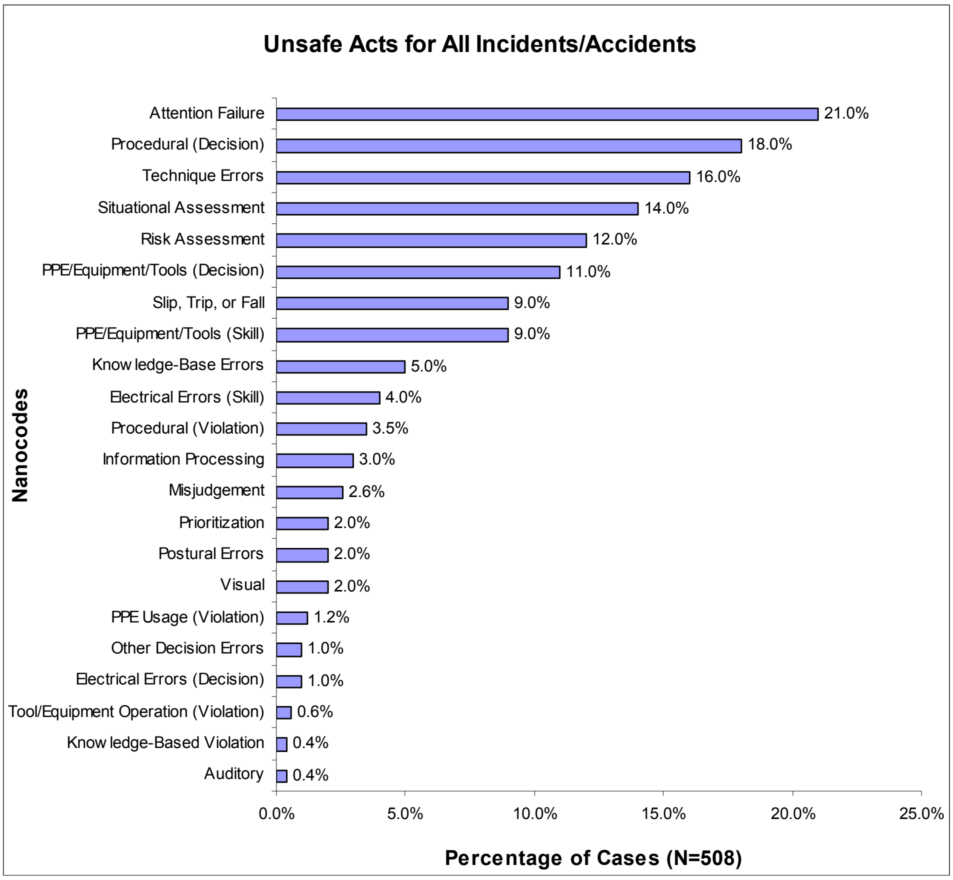



**Figure 2: Unsafe Acts- Nanocode**

The most often identified unsafe act was routine disruption errors, followed by decision errors, and violations. Perceptual errors were identified in less than 5% of cases analysed. At least one routine disruption error was identified in 58.9% of cases analysed. From Figure 3 it can be seen that 49.8% of unsafe act codes identified are associated with routine disruption errors. Decision errors also account for a large percentage of codes identified. Perceptual errors and violations are nearly similar in frequency and combined account for less than 9% of codes.

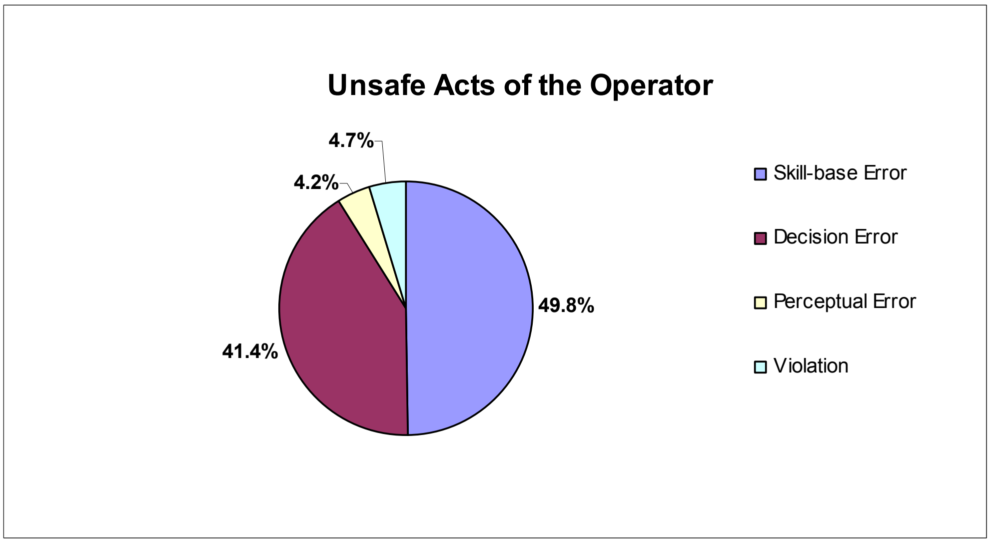



**Figure 3: Unsafe Acts- Percentage of Codes**

When looking at just routine disruption errors, the nanocodes "attention failure" and "technique errors" appear to be the major contributors as they make up 32% and 24% of the codes, respectively (see Figure 4). "Postural errors", which deal more with manual handling tasks, represent a very small percentage of routine disruption error codes.

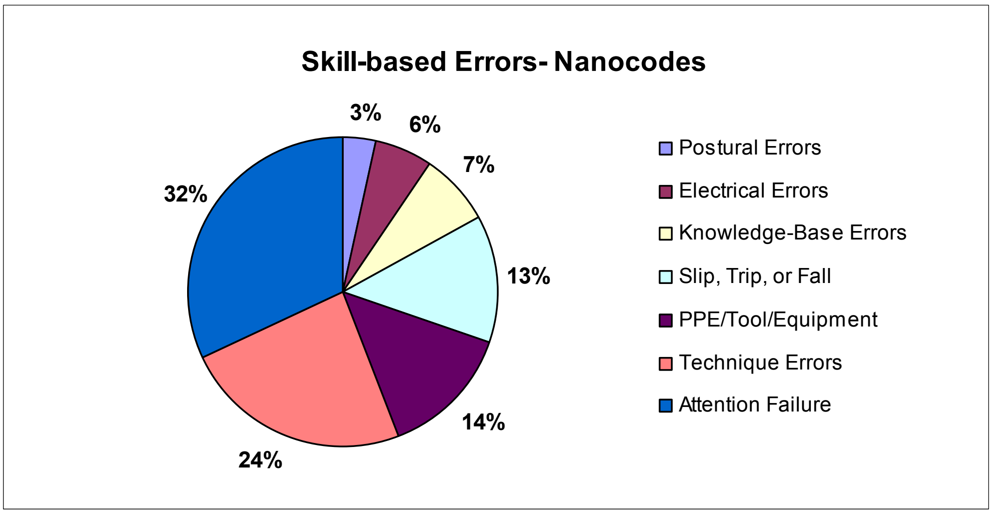



**Figure 4: Routine Disruption- Percentage of Codes**

Decision errors are associated with 49.0% of all incident/accident cases analysed and represent 41% of unsafe act codes identified. As can be seen in Figure 5, "procedural" errors are the major contributor to decision errors at 29%. "Situational assessment" also heavily contributes to decision errors at 22%. "Electrical errors" and "other decision errors" contribute very little to decision error codes at only 2% each.

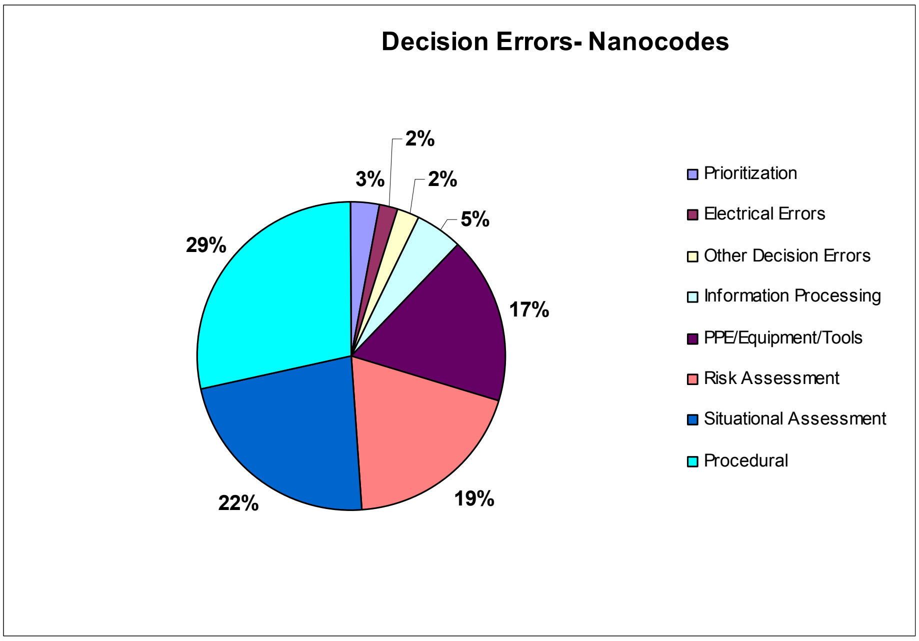



**Figure 5: Decision Errors- Percentage of Codes**

The majority of violations (62%) can be attributed to a "procedural" violations nanocode (see Figure 6)[1]. Twenty-one percent of violations can be attributed to the nanocode "PPE usage". Even though violations contribute to a small percentage of unsafe acts overall (5.5%) they need to be investigated given their serious nature.

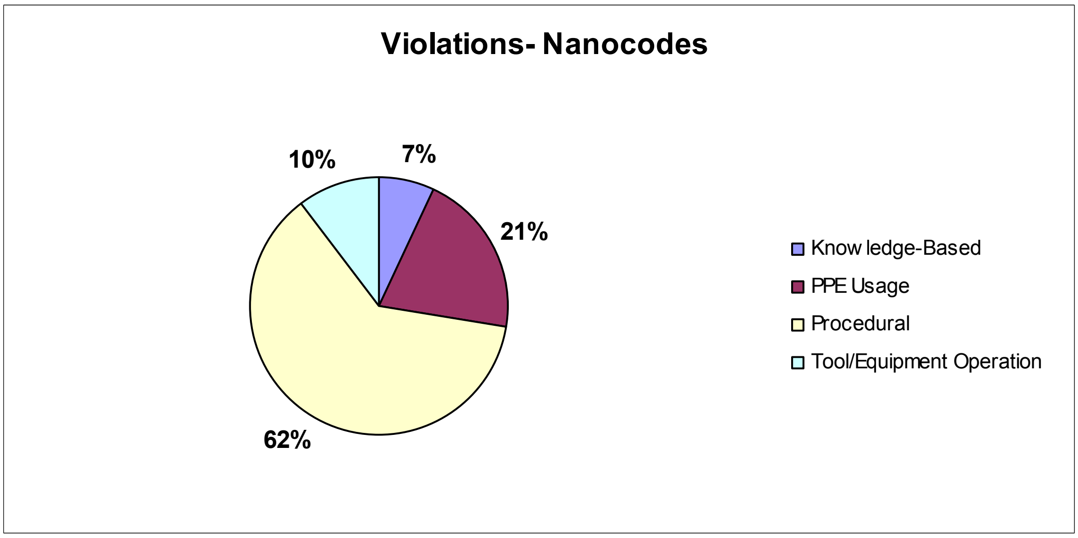



**Figure 6: Violations- Percentage of Codes**

While perceptual errors only contributed to 4.2% of all codes at the unsafe act level, the classification of these errors is still relevant. The majority of perceptual errors (52%) can be attributed to the "misjudgement" of height, distance, speed, or weight (see Figure 7). More importantly, 72% of cases where a perceptual error was identified also identified the physical environment as a contributing factor. Given this, to decrease the frequency of perceptual errors, the physical environment, specifically "visibility" and "road/surface conditions" would need to be improved.

[1] Violations were not coded into exception or routine due to a lack of detailed information in case descriptions.

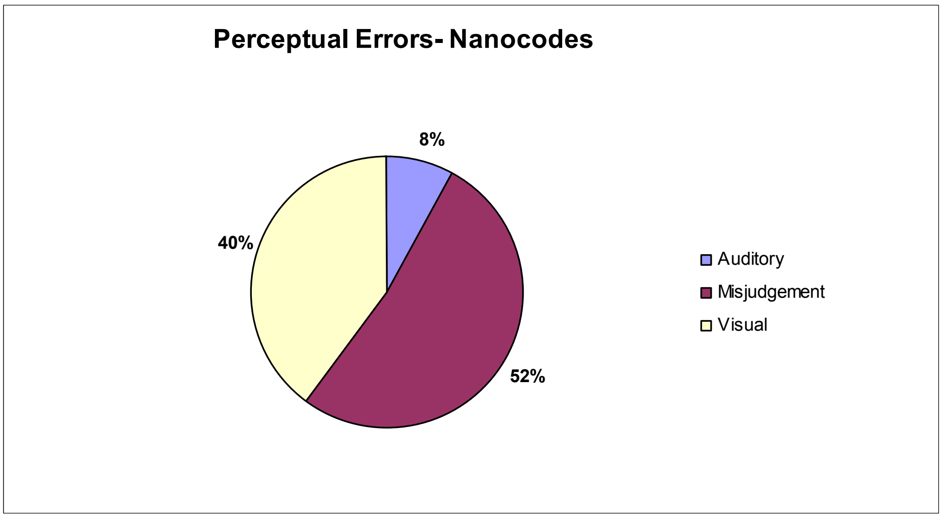



**Figure 7: Perceptual Errors- Percentage of Codes**

### *Mine Type*

There are five basic mine types that were looked at for this analysis; underground metal mines, underground coal mines, open cut metal mines, open cut coal mines, and quarries. Since all incident/accident cases were attributed to a particular mine, the entire data set was used in this analysis. The graph in Figure 8 presents the breakdown of unsafe act causal codes for all mine types.

The percentages of routine disruption errors were generally stable across all mine types except for underground metal/non-metal mines which had only 39.8% of cases with a routine disruption error as a causal factor. This decrease in routine disruption errors along with an increase in decision errors suggests that operators at underground metal/non-metal mine are more often engaged in tasks that are not routine and thus have to decide how to proceed without the use of standard procedures.

Underground coal mines had the lowest percentage (23.1%) of incident/accident cases with decision errors as a causal factor while quarries yielded the highest percentage (48.0%). With such a high percentage for quarries, it will be important to investigate why decision errors are playing such a major role in incidents/accidents. Decision errors are associated with carrying out an inadequate or inappropriate plan. These errors arise as a result of insufficient knowledge or poor choices. Given this, quarries might be lacking a structured and thorough training program for employees or a lower level of skilled operators. Underground coal mines may exhibit such a low percentage of cases attributed to decision errors because of the highly structured nature of the tasks coupled with the reality that most tasks are associated with a written and practiced procedure so employees are never compelled to create their own plan.

For all mine types except for open cut coal, violations were attributed to more cases than perceptual errors. Violations were identified in 5.5% of cases when all the data was aggregated. In this analysis, it can be seen that open cut coal and underground metal/non-metal mines have significantly less incident/accident cases with violations as a causal factor with 3.8% and 4.6% respectively. Overall, underground coal mines have the greatest number of cases with a violation as a contributing factor (9.6%). Quarries and underground metal/non-metal mines also have more cases attributed to violations with 8.0% and 7.1% respectively, than the overall data.

Perceptual errors were most often identified with underground coal mines (9.6%). Given the smaller number of underground coal mines analysed than any other type of mine and the high percentage of perceptual errors it may be that the environment at underground coal mines lends itself to create perceptual errors. Perceptual errors may show a reduction if the sensory environment is improved, for example by improving the lighting to prevent visibility issues.

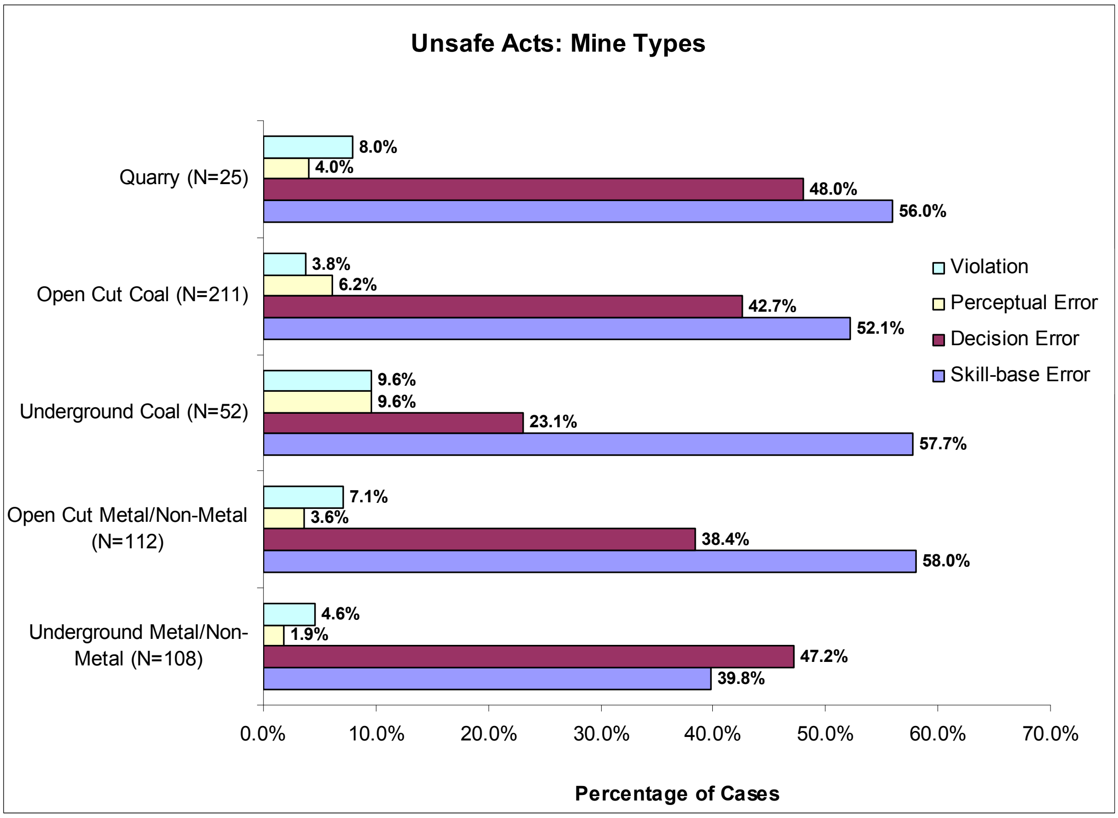



**Figure 8: Unsafe Acts by Mine Type**

### *Coal vs. Metal/Non-metal Mines*

There are two basic categories for mining material used in this analysis, coal and metal/non-metal. Metal/non-metal includes a variety of materials such as zinc, copper, gold, lead, etc. All 508 cases were used in this analysis.

When the data is clustered based on mining material, differences in unsafe acts are less noticeable (see Figure 9). In fact, routine disruption errors are nearly identical with coal mines having 59.7% of cases associated with a routine disruption error and metal/non-metal mines having 58.0% of cases associated with a routine disruption error. A slight difference is seen with decision errors. Coal mines had 46.4% of cases associated with a decision error where as metal/non-metal mines had 51.8%. This would suggest that operators in coal mines are better at handling abnormal or novel situations quickly.

Neither perceptual errors nor violations are greatly associated with incident/accident cases regardless of mining material. Perceptual errors, which occur in degraded sensory environments, are more often attributed with coal mine incidents/accidents than metal/non-metal mine incidents/accidents. From the previous analysis on mine type, the main contributor of coal perceptual errors was underground coal mines. Violations on the other hand, exhibit the opposite trend and are more often attributed to metal/non-metal mining incidents/accidents.

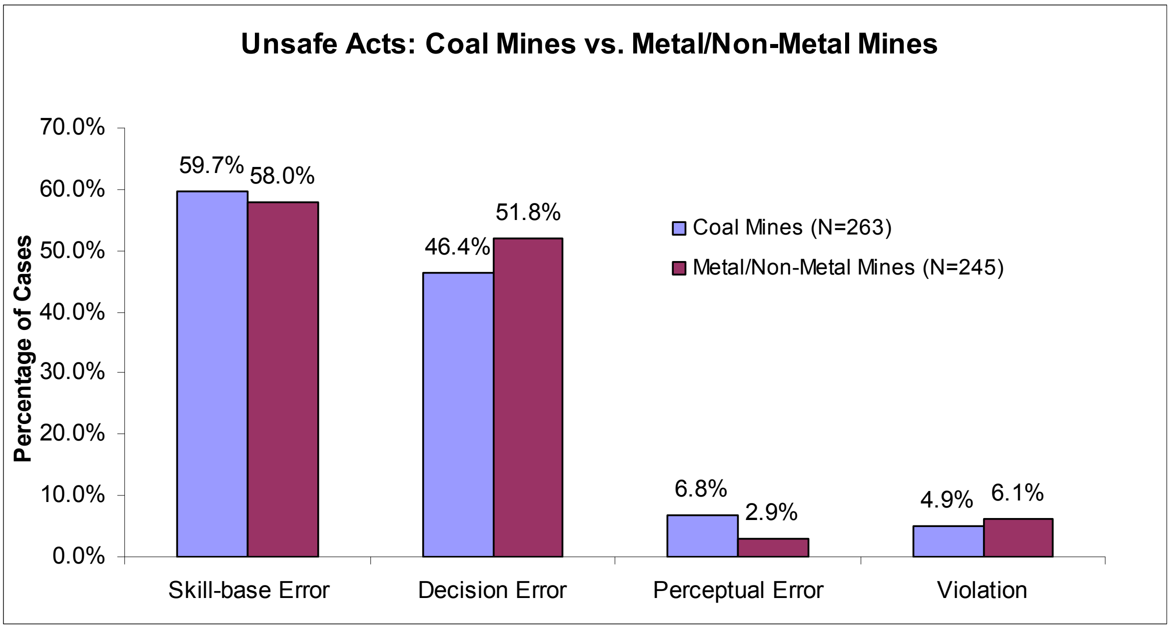



**Figure 9: Unsafe Acts by Mining Material**

### *Time of Day*

Data regarding the time of day when an incident/accident occurred was available for all cases. Incident/accident event times were sorted into six four-hour groups. These groups were organized based on typical shift times. For example, most 12-hour morning shifts start at 0600, so this was used as the start of one time group (see Appendix A). Each group consists of accidents in a four hour time span to ensure that enough events occurred for a comparison to be made.

While in other analyses routine disruption errors remained fairly consistent across categories, they showed an interaction with the time of day. Routine disruption errors are identified in a higher percentage of incident/accident cases between the hours of 1800 and 0159. This time frame generally represents the beginning and middle of a 12-hour night shift. As routine disruption errors generally occur during routine tasks often repetitive in nature, special consideration should be made to ensure that operators on the night shift remain vigilant and engaged in the task at hand. This can be done in numerous ways including task rotation, increased communication, and job monitoring.

Decision errors were found to contribute to the lowest percentage (24.0%) of incidents/accidents between the hours of 1800 and 2159. This time period represents the first 4-hours of a 12-hour night shift. The remaining time periods had between 36.0% and 48.4% of incidents/accidents with at least one decision error as a contributing factor.

Perceptual errors also showed a trend when viewed by incident time. Fifty-two percent of perceptual errors identified occurred from 2200-0559. About 11% of incidents/accidents that occurred between 2200-0159 and 0200-0559 had at least one perceptual error as a contributing factor. During these periods, there is less natural light available which could lead to a degraded sensory environment. From 1000-1359, the lowest percentage (0.8%) of cases had a perceptual error as a contributing factor.

Violations showed a steady trend across time with the highest percentage of cases (7.0%) with at least one violation as a contributing factor occurring from 0600-0959. Violations did not appear to be a major contributing factor for any time period.

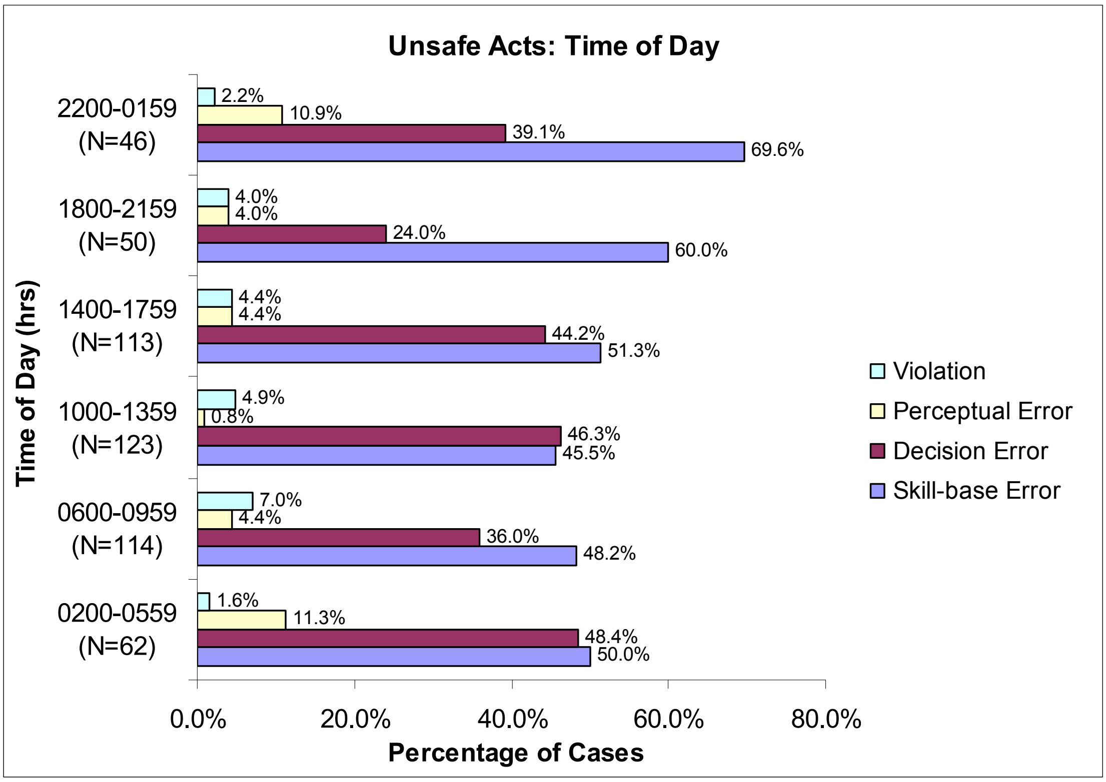



**Figure 10: Unsafe Acts by Time of Day**

### *Year*

Incident/accident date information was available for all cases used in this analysis. Incident/accident cases occurred between January 2004 and June 2008. Only six months of data was collected for 2008 as that was all that was available at the time of data collection. The 'percentage of cases' value was determined based on the number of cases for that particular year. The results for each year may not add up to 100% as each case could have more than one error type as a contributing factor. From Figure 11, it can be seen that routine disruption errors are the main contributor in all years except for 2008 where there is little difference between routine disruption and decision errors. Both perceptual errors and violations remain relatively constant over the five year period. Routine disruption errors show a slight downward trend from 2004-2006 and then jump up in 2007 and continue to decline in 2008. The overall trend is fairly stable. Given the greater number of cases analysed from 2007, the downward trend exhibited by the first three years may simply be caused by fewer incident/accident cases being analysed and the count for 2007 may be more accurate. This said there appears to be is no real reduction in routine disruption errors during this time period.

There is a decrease in decision errors in 2007, but the percentage of cases in 2005, 2006 and 2008 are similar.  Given the relatively stable rate of decision errors before and after 2007, it appears that there is no significant reduction of decision errors exhibited. Perceptual errors and violations remained constant over the five year period analysed.

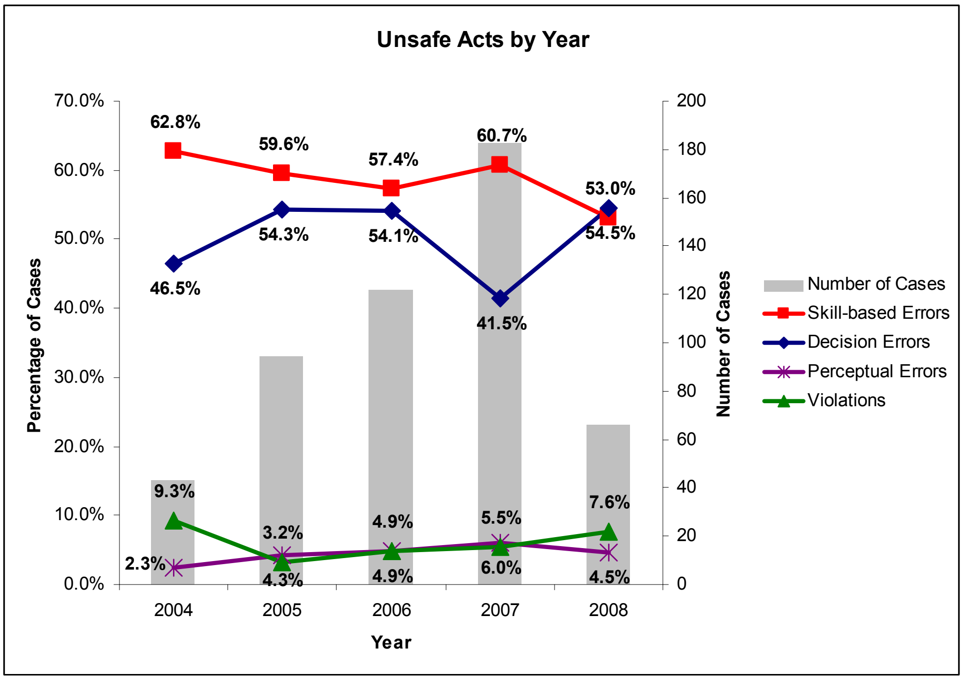



**Figure 11: Unsafe Acts by Year**

Since routine disruption errors account for a majority of the unsafe acts, the routine disruption errors nanocodes were analysed over the 5 year time period (Figure 12). The "attention failure" nanocode was the highest occurring nanocode for every year except 2005. Attention failures have a noticeable decrease from 2004-2006 but then in 2007 and 2008 returns to previous levels. Technique errors show a dramatic increase in 2005 but in all other years remains fairly stable. Of note is that all routine disruption error nanocodes except for electrical errors show a decline from 2007-2008. This mimics the decline in total routine disruption errors over the same period. This suggests that there is not a specific type of routine disruption error being improved but that there may be an overall improvement in errors.

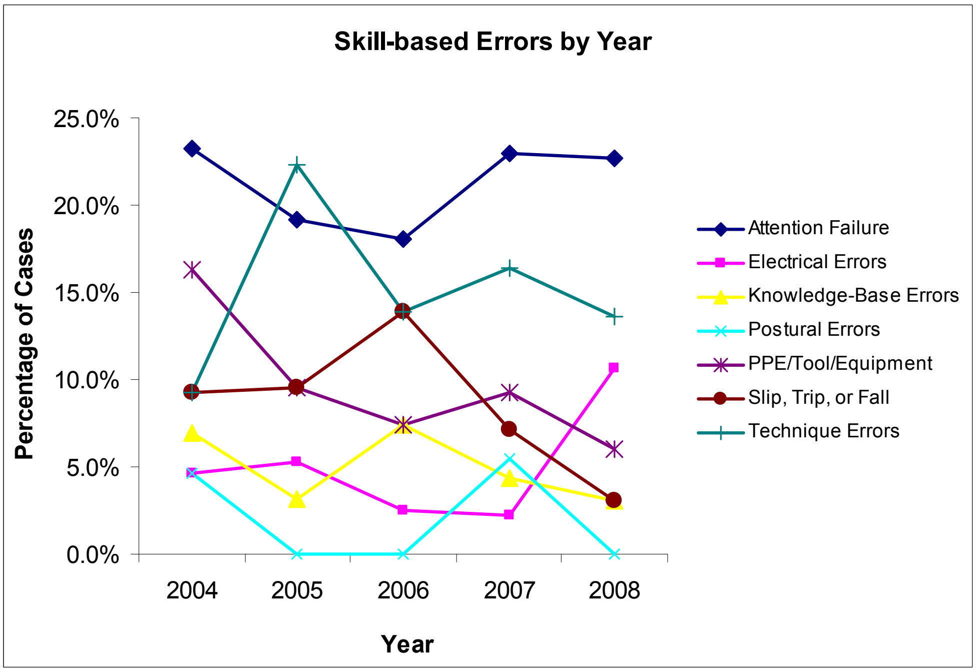



**Figure 12: Routine Disruption Error Nanocodes by year**

***Age and Experience***

During the data collection portion of this project, it became evident that age and experience were not readily available for most incidents/accidents. Information on the person(s) involved is only required to be provided to DME when there is a lost time injury. When date of birth is given, it is for the person who was injured, who may not be the person with the attributed error. Given this, there was insufficient information to analyse unsafe acts based on age and experience. If this is a factor of particular interest to DME, notification and investigation requirements to mines needs to be changed to include the collection of age and experience data for all incidents/accidents.

**Preconditions for Unsafe Acts**

The most often cited precondition was the physical environment, followed by the technical environment and communication/coordination respectively (Figure 13). Fitness for duty and adverse physiological states were the least identified factors and do not appear to be significant causal factors.

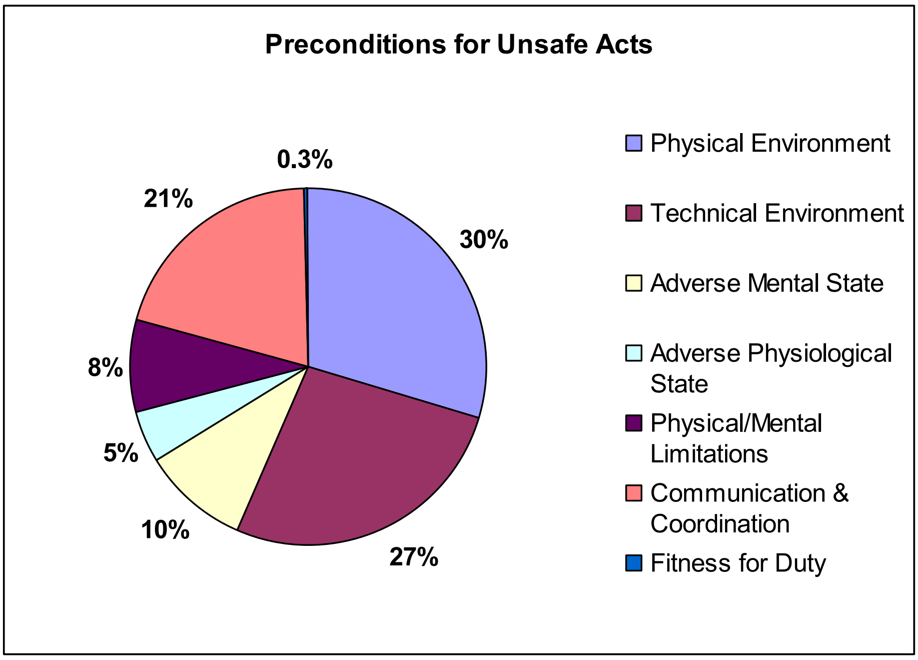



**Figure 13: Preconditions for Unsafe Acts- Percentage of Codes**

Given the harsh and continually changing environment that miners work in, it was expected that a high percentage of incident/accidents cite some form of physical environment as a contributing factor. The physical environment was cited as a causal factor in 39% of cases and 27% of preconditions codes identified dealt with the physical environment. The most often cited physical environment nanocode was “surface/road conditions” which was a causal factor in 19.1% of cases (Figure 14). Surface/road conditions included slippery surfaces/roads, uneven roadways, etc. Many instances for surface/road conditions were associated with a “slip, trip, or fall”. Twenty-five out of 45 (55.5%) instances of “slip, trip, or fall” also had “surface/road conditions as a contributing factor. Visibility was also frequently identified as a causal factor, contributing to 11% of cases. Visibility included instances where there was an absence of adequate lighting and when there was glare caused by the sun.

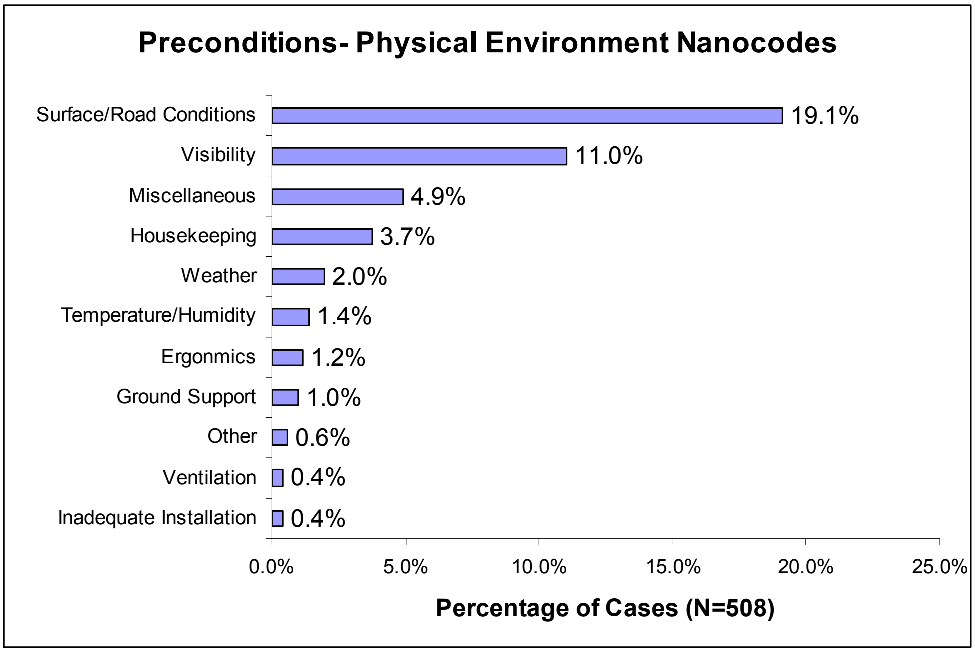



**Figure 14: Physical Environment Nanocodes**

The technical environment was also highly cited as a contributing factor. The technical environment includes the availability of warnings, PPE, condition of the equipment being used, etc. The most prevalent technical environment nanocode was "equipment design/construction". The nanocode was identified with 17.7% of all cases and represented 41.7% of technical environment nanocodes. Causal factors identified dealt with both the design of equipment from the OEM and modifications to equipment done on site. Also included were construction issues on the mine site not including the construction and design of roads. Of interest is that 6.9% of cases involved failures with "PPE/guards/safety devices". Some of these are issues that are government regulated, such as the use of guards, and can be corrected with regular inspections.

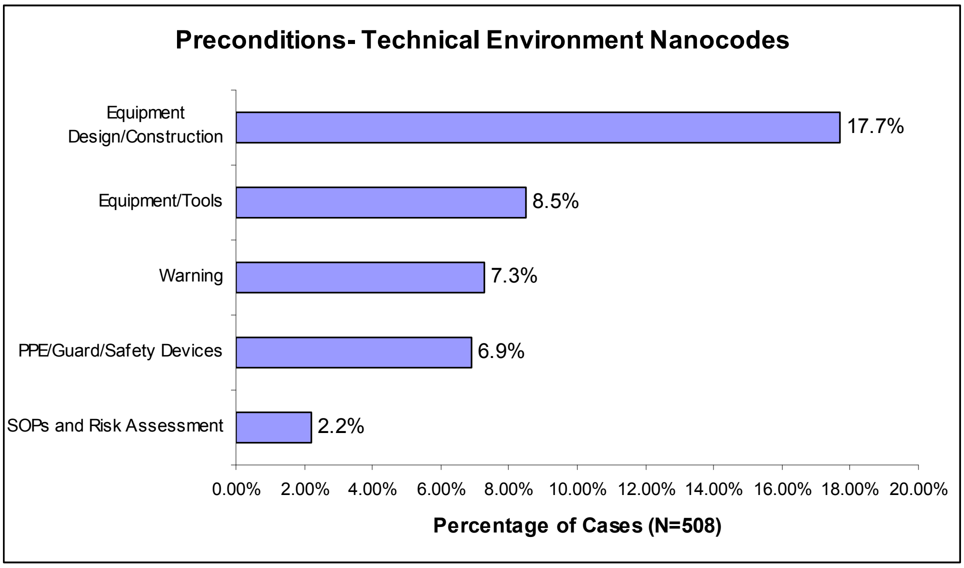



**Figure 15: Technical Environment Nanocodes**

As can be seen from Figure 13, communication and coordination problems were identified in 21% of cases analysed. When broken down, 97% of contributing factors for this category involved problems with communication. Communication problems can be described as failure to make positive communication, inadequate communication of work instructions, inadequate communication between workers, etc.

Adverse physiological state was only identified as a causal factor in 6.3% of cases analysed. This category includes workers who fell asleep on the job. Given this percentage, it appears that fatigue is still an issue on mine sites. Most mine sites have fatigue management plans, however, the effectiveness of these plans needs to be reviewed. Workers need to be encouraged to report symptoms of fatigue.

**Unsafe Leadership**

Unsafe leadership was identified in 36.6% of cases analysed. The majority of causal factors (62%) at the unsafe leadership level fell into the 'inadequate leadership' category (Figure 16).

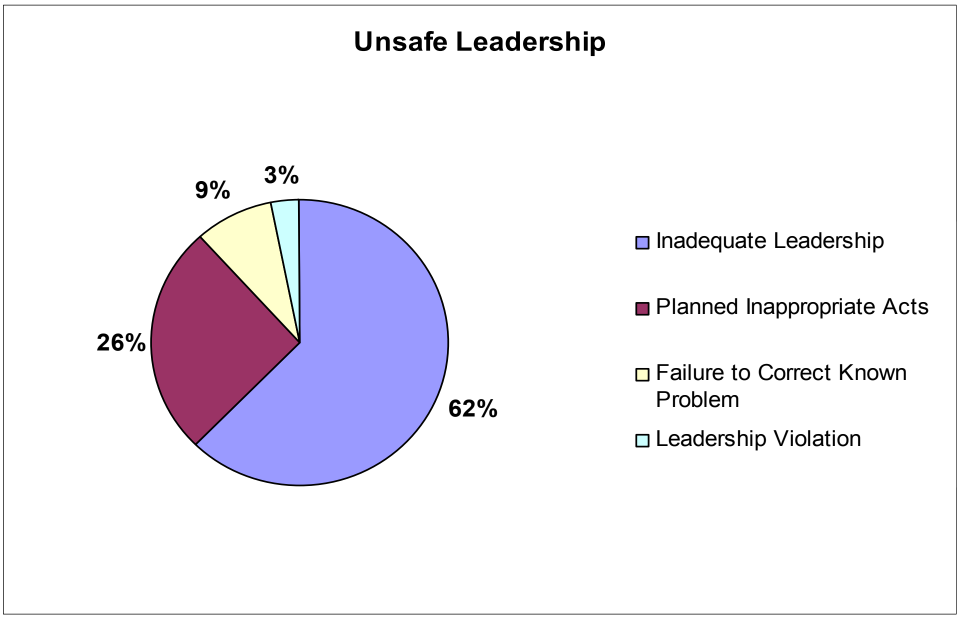



**Figure 16: Unsafe Leadership- Percentage of Codes**

The most often cited nanocode at this level was training which accounted for 43.9% of inadequate leadership codes and was a contributing factor in 15.6% of all cases (Figure 17). Training involves more than just the initial teaching of procedures and policies at a mine site. There is also hands-on training, refresher training, training when SOPs change, etc. It is not enough to teach an operator once how to do something. Retention of material is important and often a lack of retention will lead to mistakes. An operator must have more than just a casual understanding of the material. He or she must be competent and able to take what was learned and apply that knowledge in different situations.

As of June 2002, Beach and Cliff (2003)reported that FIFO sites in Queensland experienced turnover rates that ranged from 10% to 28%, with an average of 21%. They also found that turnover appeared to be higher amongst professional and managerial staff. This means that more of the experienced workers were job jockeying and one would expect this to affect the training workers received. Although this study concluded before the analysis of cases in this study began, no major changes in the mining industry in Queensland have occurred that would indicate that this trend has been counteracted.

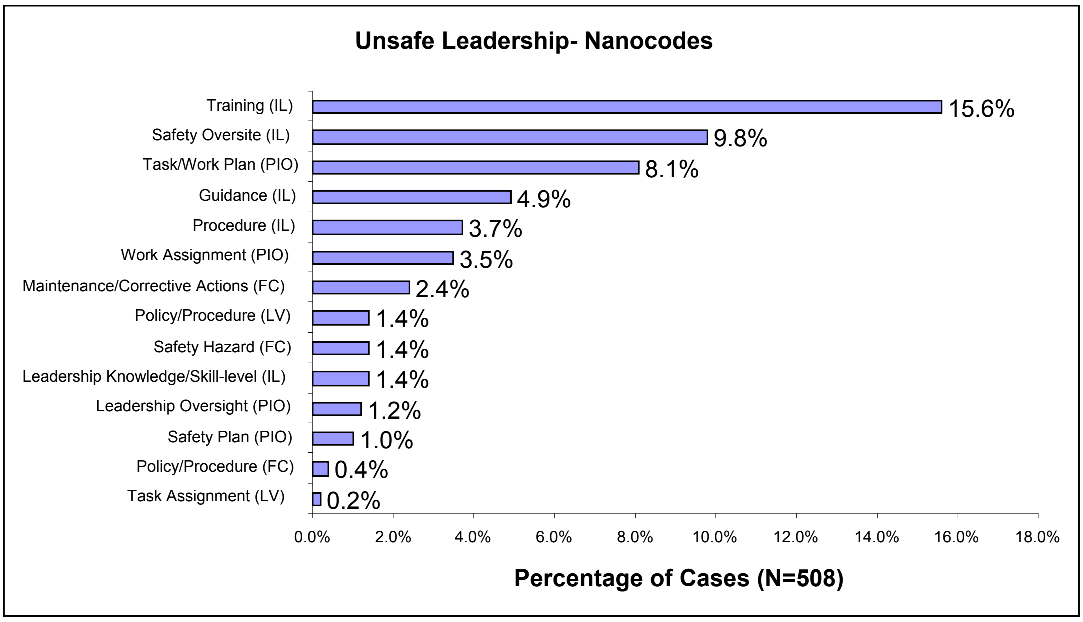



**Figure 17: Unsafe Leadership Nanocodes**

"Safety oversight" was another highly cited causal factor. With the large scale of some of the mines in this analysis, a lot of workers are either working alone or out of sight of management. With leadership not immediately on hand, workers are unable to quickly ask questions about tasks. Some of these questions could be covered by more comprehensive pre-task talks between leadership and operators. This would allow a clearer picture on what exactly is to be done. Without consistent monitoring of work, inappropriate behaviours and incorrect procedures are unable to be identified and rectified immediately.

## Organizational Influences

Causal factors at the organizational level were fewer than other levels of HFACS-MI. Only 9.6% of cases identified an organizational influence as a contributing factor. The most common organization factor was organizational process which accounted for 77.8% of organizational codes (Figure 18).

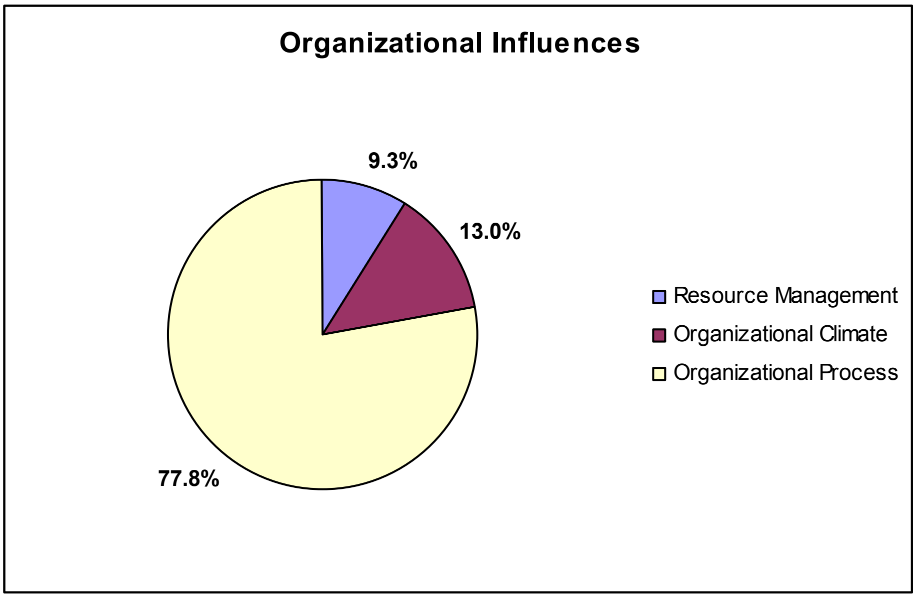



**Figure 18: Organizational Influences- Percentage of Codes**

The organizational process category was attributed to 8.3% of cases. Within organizational process, problems with “procedures” were most common (77.2% of codes). Problems with procedures mainly dealt with the lack of a SOP or SWI) for a given task. Without these standard procedures, operators are often required to select the method for completing the task. However, the method may not always be completed in the safest way.

**Outside Factors**

As expected, no causal factors were found at this level. This result reflects the current state of the system in which causal factors attributed to outside of the system are not identified. Gathering information at this level will allow for DME to identify areas of improvement of itself and employees.

## CONCLUSIONS

Findings from this project indicate that human error plays a significant role in many of the incidents/accidents that occur at Queensland mines. The analysis presented in this report has highlighted areas of human error that have shown significant trends throughout the mining industry. The results presented should provide a starting point for addressing human error related issues in mining and areas that would benefit from improvements.

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## Appendix A: Breakdown of demographic data

Breakdown of mine types

| Mine Type | Number | Percentage of Total (%) |
|---|---|---|
| Underground Metal | 108 | 21.3 |
| Open Cut Metal | 112 | 22.0 |
| Underground Coal | 52 | 10.2 |
| Open Cut Coal | 211 | 41.5 |
| Quarry | 25 | 4.9 |

Breakdown of coal vs. metal/non-metal mines

| Mine Material | Number | Percentage of Total (%) |
|---|---|---|
| Metal/Non-metal | 245 | 48.2 |
| Coal | 263 | 51.8 |

Breakdown of time of day of incident/accident

| Time of Day | Number | Percentage of Total (%) |
|---|---|---|
| 0200 – 0559 | 62 | 12.2 |
| 0600 – 0959 | 114 | 22.4 |
| 1000 – 1359 | 123 | 24.2 |
| 1400 – 1759 | 113 | 22.2 |
| 1800 – 2159 | 50 | 9.8 |
| 2200 – 0159 | 46 | 9.1 |