Mine Health and Safety Council

MHSC

IDENTIFY OPPORTUNITIES TO IMPROVE THE SAFETY OF BARRING-DOWN PRACTICES

Milestone Report 16: Final Report – Identify opportunities to improve the safety of barring-down practices

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Delivery of Final Project Report	Final Report and Development of Barring Training Programme	

5 Executive Summary

Barring is a routine task performed daily in the South African mining environment. This task is considered to be the first line of defense in combating fall of ground accidents in gold and platinum mines, as well as at collieries. Barring is one of the features of the early entry examination procedure that takes place at every working area, both blasting faces and non-production ends, of mines every day across the country. Gas detection is the other vital part of this routine. Barring of the hanging wall/ roof and sidewalls/ rib sides of excavations is also completed pre-task and post-task for activities such as support installation and the drilling of blast holes.

In the recent past the prevalence of barring accidents had been on the increase necessitating the need for this research. In order to prevent and reduce the number of accidents that occur during the act of barring, understanding of the nature of the accident's initiation is required. Equally critical is being able to identify the root causes of the accident. The most dominant immediate cause of barring accidents in the study, across the commodities of platinum, coal and gold, was found to be deviation of individuals from the standard and this was evident for 50% of the accidents studied. Immediate causes vary from root causes as they are readily apparent and immediately precede the contact whilst root causes are the deeper, more fundamental causes that allow the immediate cause to exist.

Inadequate training and inadequate leadership are the highest ranked root causes of the barring accidents investigated for this study. Observations showed that some leaders were not promoting safety adequately, not enforcing standards and often not having a visible felt presence underground. Likewise inadequate training was highlighted as a root cause for eight of the forty-eight accidents considered. This exposed that injured employees displayed inadequate recall of training material, there was inadequate training effort by the mine and inadequate initial training or orientation/ awareness training was completed for new employees.

For 15% of accidents studied, a root cause of poor habits or personal preference existed and this is concerning as it shows that numerous employees have a settled or regular tendency to practice risky behaviour by not barring correctly, not barring at all or even taking up an unsafe position during the act. The social aspects such as human behaviour, leadership and communication were explored in great detail to ascertain the dominant themes surrounding behaviour and attitude of workers at the various champion mines. Detailed recommendations on situational leadership and management and changing employee behaviour aim to provide industry with feasible solutions to reduce the number of incidents and fatalities. Such examples as improved leadership visibility requirements, soft skills training, and behaviour based safety training, culture change initiatives as well as the usage of the technological advancements also are detailed as recommended best practices.

The identification of leading practices that pertain to the barring act are those operational actions that will show how best to provide and maintain a safe working environment for employees. These suggestions must enable long term improvements to the barring process which is a subset of the FOG leading practice outlined in the current MOSH adoption system. Ultimately, the leading practices that have the greatest occupational health and safety improvement potential would be selected by technical experts that typically will form a part of the MOSH adoption team for that practice. Leading practices pertaining to the barring act were identified in the areas of risk assessment, skills, training, leadership, human behaviour and communication. This is based upon underground visits and observations of the daily barring process made by rock engineering teams and social study assessments that were completed.

The development of innovative barring training material is already a leading practice specified prior to the commencement of this study. Investigation of the many leading practices for barring identified the positive leadership behaviours and communication practices prevalent in expert mental models for inclusion in the barring training program. Desktop virtual reality techniques are the most prevalent and popular type of system where users will learn without being fully immersed in a computer generated environment. Considering the diversity of people (race, gender, culture, attitudes, perceptions, habits, behaviour) within the mining industry, an emotive captivating story is used to link modules in the training material.

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7 List of Abbreviations/ Terms

The following list of abbreviations defines terms used in this research report.

ABS-P: Trigger and team classification system used in conjunction with HITS
AEM: Acoustic Energy Meter
ALLeRT: Apply Lonmin Life Rules and Triggers
BBS: Behaviour Based Safety
BC: Behavioural Communication
CCFO: Critical Cross-field outcomes
COPA: Community of Practice for Adoption
CSIR: Council for Scientific and Industrial Research
EE: Entry examination
EEE: Early entry examination
ESD: Electronic Sounding Device
FOG: Fall of ground
HITS: Hazard Identification and Treatment System

HIRA: Hazard Identification and Risk Assessment
ITA: Integrated Thermal Acoustic Device
LB: Leadership Behaviour
LPAG: Leading Practice Adoption Guide
LP: Leading Practice
MOSH: Mining Industry Occupational Health and Safety
Mental Model: A mental model may be described as an internal representation of external reality that a person makes for oneself. It was first suggested by Kenneth Craik in 1943. These models are said to play a major role in cognition, reasoning and decision making.
OHS: Occupational Health and Safety
PPE: Personal Protective Equipment
RMT: Rock Mechanics Technology group (based in the UK)
SAQA: South African Quality Authority
SIMRAC project reports: Safety in Mines Research Advisory Committee establishes the need for OHS projects and previously these were previously grouped as GEN (general), COL (coal research) and GAP (gold and platinum research).
SLAM: Stop, Look, Assess and Manage
TARP: Trigger Action Response Plan
XDM: Experimental Development Model (with reference to mechanical jaws in the relevant research study)

8 Introduction

Barring is the removal of loose slabs of rock from roofs and walls of excavations. It may be performed manually with a steel or aluminium pinch bar (most locally used materials) or by using a mechanical barring machine. When barring manually, the miner checks the soundness of the rock by striking the roof; a drum-like sound usually indicates that the ground is loose and should be barred down. The person performing the act of barring must follow strict rules in order to avoid injury while barring (e.g. barring from good ground to unchecked ground, maintaining good footing and a clear area to retreat and ensuring that barred rock has a proper place on which to fall).

Manual barring requires considerable physical effort, and it can be a high-risk activity. Figure 1 shows the possible impact of rock related practices over a two and a half year period in South African Mines (van Zyl and Adams, 2012). Note the number of fatalities that could have been prevented related to barring.

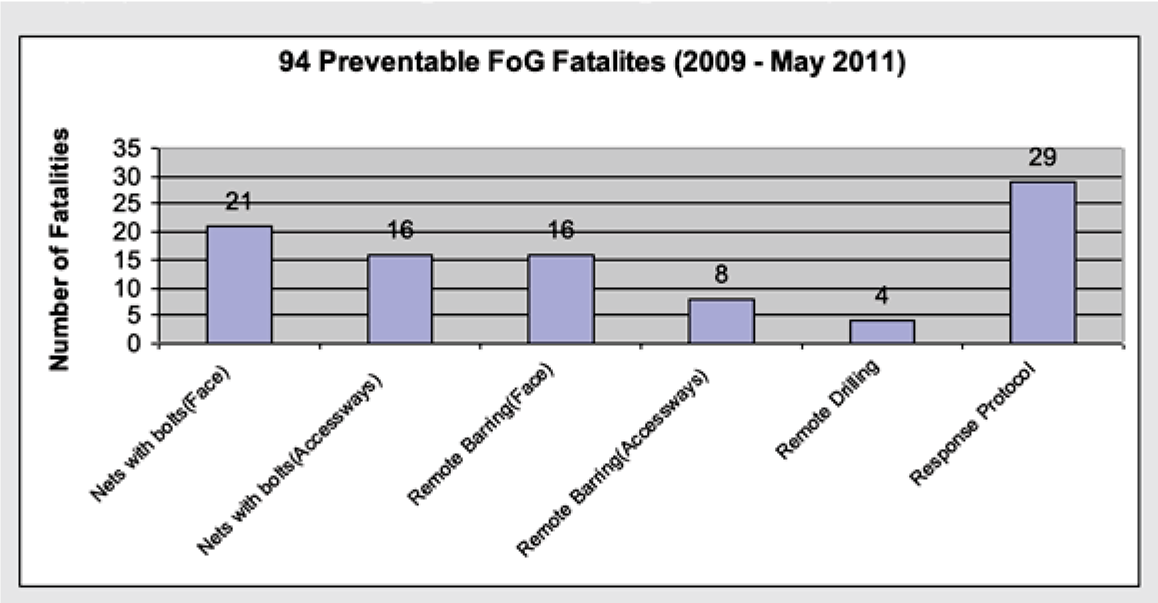

Figure 1: The possible impact of rock related practices over a two and a half year period in South African Mines (after van Zyl and Adams, 2012)

Effective barring is a function of many variables of which excavation height is an important factor e.g. for high excavations, the person may not have the requisite leverage to effectively dislodge a potentially loose rock even if a long pinch bar is used. The use of baskets on extendable booms so that miners can manually bar the roofs of high excavations introduces additional safety hazards, such as possible overturning of the barring platform by falling rocks, no escape route for the person barring, etc. Other factors such as physical stress, suitable equipment selection, positioning and secure footing of barrer, and the aid of a 'spotter/ buddy' may all contribute to whether the barring act is completed successfully (GEN 801, 2002).

With the evidence to support that barring is a difficult task to undertake, the research question can thus be formulated as: How can the safety of barring practices be improved? Much literature is readily available (locally and internationally of best practices relating to barring) and many supporting studies have been conducted to date. However, the research outcomes expected of this project encompass the act of barring, improvement of the technique (if necessary), and training methods used, and is thus highly relevant to the South African Mining Industry with a focus on both hard rock and coal environments.

The research hypothesis may thus be stated as:

The analysis of barring-down related accident and incident data from various sources will lead to the identification of leading practices, feasible implementation solutions and improved training material for use in the South African Mining Industry.

The main objective of the study is to identify how barring practice and worker safety during barring can be improved. To achieve this, the study was divided into a number of separate phases detailing the identification of opportunities to improve the safety of barring-down practices in the underground environments of the coal, gold and platinum commodities of the South African mining industry.

9 Field Data Collection

Data was collected directly from the champion mines identified and this on-site assessment component focused on ten identified areas. These areas are risk assessment, skills, training, equipment selection, geotechnical environment, size of excavation less than 2m high, size of excavation greater than 2m high, leadership, human behaviour and communication.

A social study (Section 17) also forms part of this report, paying particular attention to the areas of leadership, human behaviour and communication. Underground visits, data collection on surface and various social assessment tools were employed in order to obtain qualitative and quantitative data.

Three major mining houses in the platinum industry in South Africa were requested to act as champion mines for the barring study. Eleven mines/ shafts were visited in the platinum commodity. The identities of the champion mining houses are widely known within the study group but they are referred to as Mining House A, B and C (randomly selected) due to the highly sensitive nature of the data that was obtained. More detailed individual feedback has been given on-site to ensure that the best corrective actions will be put in place.

Shown in the table below (Table 1) is the distribution of the platinum mines/ shafts that were visited per mining house. Also shown are the number of shifts spent underground and the number of working ends visited by Golder personnel. Barring observations during entry examination in the course of morning shifts was the focus of these underground visits.

Table 1: Platinum Champion Mines

Mining House	Reported Name	Date of visits	Number of shifts underground (including night shift)	Number of working ends visited
A	Mine/ Shaft 1	02-03-2015 to 05-03-2015	4	8
	Mine/ Shaft 2	02-03-2015	Surface visit only for data collection	

	Mine/ Shaft 3	10-03-2015 to 11-03-2015	2	7
	Mine/ Shaft 4	06-03-2015	1	3
B	Mine/ Shaft 5	09-04-2015 to 13-04-2015	4	8
	Mine/ Shaft 6	24-03-2015 to 27-03-2015	5	11
	Mine/ Shaft 7	16-04-2015	Surface visit only for data collection	
	Mine/ Shaft 8	14-04-2014 to 16-04-2014	3	5
	Mine/ Shaft 9	17-03-2015 to 20-03-2015	5	16
C	Mine/ Shaft 10	21-04-2015	1	4
	Mine/ Shaft 11	22-04-2015 and 23-04-2015	2	6

Two key mining houses in the gold industry in South Africa were requested to act as champion mines for the barring study. Sixteen shafts in the gold commodity were visited in total. These companies are referred to as Mining House D and E in the study.

Table 2 shows the distribution of the mines/ shafts that were visited per gold mining house.

Table 2: Gold Champion Mines

Mining House	Reported Name	Date of visits	Number of shifts underground	Number of working ends visited
D	Mine/ Shaft 1	06-05-2015 to 07-05-2015	2	6
	Mine/ Shaft 2	08-05-2015 to 10-05-2015	2	5
	Mine/ Shaft 3	12-05-2015 to 13-05-2015	2	2
	Mine/ Shaft 4	12-05-2015 to 13-05-2015	2	2
	Mine/ Shaft 5	12-05-2015 to 13-05-2015	2	2
	Mine/ Shaft 6	14-05-2015	1	2
	Mine/ Shaft 7	15-05-2015	1	2
	Mine/ Shaft 8	18-05-2015	1	4
	Mine/ Shaft 9	19-05-2015	1	4
	Mine/ Shaft 10	20-05-2015	1	4
	Mine/ Shaft 11	22-05-2015	1	2
	Mine/ Shaft 12	22-05-2015	1	1
	Mine/ Shaft 13	Surface visit only for data collection		
	Mine/ Shaft 14	Surface visit only for data collection		
E	Mine/ Shaft 15	17-06-2015 to 18-06-2015	2	4
	Mine/ Shaft 16	22-06-2015 to 23-06-2015	2	2

Four mining houses volunteered to act as coal commodity champion mines for the study. The coal study group comprised eleven shafts. In this report they are referred to as Mining House F, G, H and I.

Many underground shifts (early shifts) were undertaken by a Golder engineer (increasing to two people towards the end of the site period) to observe the act of barring during entry examination in order to identify leading practices for the activity, and determine what practical solutions could be suggested in the study.

Shown in the table below (Table 3) is the distribution of the mines/ shafts that were visited per coal mining house.

Table 3: Coal Champion Mines

Mining House	Reported Name	Date of visits	Number of shifts underground	Number of sections visited
Mining House F	Mine/ Shaft 1	20-07-2015 to 22-07-2015	2	2
	Mine/ Shaft 2	23-07-2015 to 24-07-2015	2	3
	Mine/ Shaft 3	28-07-2015 to 30-07-2015	3	3
	Mine/ Shaft 11	Surface data collection only		
Mining House G	Mine/ Shaft 4	12-08-2015 to 13-08-2015	2	2
	Mine/ Shaft 5	18-08-2015 to 19-08-2015	2	2
	Mine/ Shaft 6	20-08-2015	1	1
	Mine/ Shaft 7	21-08-2015	1	1
Mining House H	Mine/ Shaft 8	25-08-2015	1	1
	Mine/ Shaft 9	26-08-2015	1	1
Mining House I	Mine/ Shaft 10	28-08-2015	1	1

10 Rock Engineering Findings

10.1 Methodology

Approximately 1300 man hours were spent underground and on surface by three Golder engineers collecting data at thirty-seven shafts of the champion mines. This data comprises mostly underground observations of the barring process during entry examination as well as the responses from 273 underground workers from an anonymous barring questionnaire. Information obtained from the questionnaire survey include basic employee details such as age, occupation, years of mining experience, place of birth, ethno-linguistic group and number of dependents. The respondents were individually interviewed post observation of barring activities. This survey was conducted mostly in English and Fanakalo to ascertain details on barring training, the respondent’s knowledge of the champion mine specific barring rules, and his/ her overall competency with regards to the understanding of the basic barring process. Tswana/ Sotho were the languages used by one observer in the Rustenburg area and Zulu was used predominantly in the Carletonville area.

The questionnaire respondents gave the barring research team data which allowed the assessment of the effectiveness of the various mine specific training programmes. It could also be ascertained whether understanding was achieved in the knowledge transfer and what are the preferred methods of training for most workers. Summaries of the respondent data is shown in the training assessment section (Section **Error! Reference source not found.**).

10.2 Listing of underground observations on the barring process

Actually observations of the barring act were viewed as the most important method to obtain information on how the act could be improved. The following list indicates the most common underground observations made per commodity. It specifies mostly deviations from the expected standard practices. Leading practices (LP) are briefly mentioned below but they are discussed in more detail in Section 20.

10.2.1 Platinum

1) The most common deviation from the accepted standards included not barring at all, even where the need was clearly apparent. Not adhering to the mine specific entry exam (EE) procedure or the MOSH EE procedure completely was also common. This was mostly due to perceived production driven stresses. This lack of adherence was typically observed at Mining House A and C. Mining House B showed a greater adherence to carrying out barring during the EE process.

2) Where the MOSH process was not done by crews, barring was completed in un-sequenced, rather disorderly manner. This resulted in many uninspected areas still needing to be made safe even though blasting proceeded.

3) Mid-shift barring has become less prevalent with preferences to early entry examination, pre-task and post-task barring only. However, it was observed that pre-and post-task barring was not completed diligently either. Personnel recall the practice of mid-shift barring but indicate that these campaigns last for a short time after implementation. It is clear that the energy and momentum of these campaigns dissipates when they are not driven by the upper ranks of leadership at the mines.

4) Positioning of personnel down dip of the structure or loose rock being barred in the hanging wall was very frequent.

    a. Experienced employees indicated that they believed they understood where the rock would fall and thus took a ‘calculated risk’.

b. Some employees at Mining House A and B showed total lack of adherence to the correct positioning part of the standard and could not validate their reasons.

c. Often, the person barring had no alternative but to bar from a down dip position due to the orientation of geological structures. More positively, workers then attempted to stand to the side of the loose rock rather than immediately down dip of it. This was observed in raises as well.

5) Pressure from supervisors to blast and to enter unsafe areas was a common observation at Mining House A. Overall, further leadership deficiencies (by miners, shift boss's and mine overseers) included production supervisors not entering panels but rather staying at the waiting place, the covering up/ non-reporting of minor incidents and accidents, condoning the skipping of the making safe process, and condoning rushing through the process.

   a. Often mining faces were already being drilled during the shift when Golder personnel were meant to accompany and observe the barring process during EE. Crews were accompanied underground so no reason would be acceptable to find visitors a hindrance to the daily activities or a time constraint. Poorly behaved crews often proceeded with face preparation instead of hangingwall examination whilst the miner or team leader was being interviewed.

   b. Many times visual examination as a tool was not used as effectively to identify hazards (especially loose rocks) in their surroundings.

   c. Negative attitudes of personnel in leadership roles abound at Mining House A where opinions exist such as 'barring cannot be improved upon' and "all people understand the importance of the act completely". It was clearly observed that not all personnel understood the barring act completely, or the implications of not following the standard.

   d. Trainers at underground training facilities (A and C) were not always effective. Mining House B stood out and excelled in this respect. Trainers were even observed undergoing assessment which ensured competency. Practical mining experience by these personnel was also evident. Mining House A had one particularly effective surface trainer whose impact was observed even underground. Personnel recalled and mentioned his teachings and how it had impacted them and their behaviour.

6) Sounding of the hanging wall was effective when utilised correctly. Occasionally barrers would sound without paying attention or listening. Also noted was that even loose hanging wall could

produce a slightly solid sound depending on the size of the block or rock type, making identification of loose blocks in some areas more difficult.

7) Watering down of working areas was consistently completed where it was required i.e. close to the newly blasted face. Mine standards do not always include watering down as part of the steps to safe barring. This is logical as not all areas needed watering down prior to barring. The use of a ‘Lokoba stick’ at one of the shafts is a good practice and ensures a sequenced approach to watering down and barring.

8) Barring of sidewalls in development ends needed more emphasis across all mines and shafts visited.

9) Ill-fitted or loose gaskets hindered the barring process at various shafts of the platinum champion mines. Workers then generally chose to discard gaskets which slid down their pinch bars. On 5 out of the 27 underground visits, drill steel gaskets were used on pinch bars, which had the same effects as ill-fitted gaskets. Conversely, there were instances when in-house gaskets made from old conveyor belts were used and these were secured too tightly onto pinch bars, leaving workers to struggle with moving these gaskets up or down to cover their hands when barring. These inadequacies with gaskets led to barrers often not placing their hands behind gaskets.

10) Buddy barring was a best practice identified at various shafts and the team spirit displayed by these crews was the differentiating factor to their barring routine. One person was not left to bar for long periods of time and visual examination was improved by having many people in the crew perform the task. Mining House B – Mine/ Shaft 6 displayed the best example of this leading practice. The team worked well together and followed the MOSH EE process strictly.

11) Geotechnical environments and the different reefs being mined, whilst producing varying hanging wall conditions do not appear to necessitate different methods of barring. The standards at all mines/ shafts were adequately designed to carry out the process in differing geotechnical environments. Whilst the number of steps may have varied at different mines, the process was the same.

12) Researchers were informed that the use of scalers in certain mechanised sections was discontinued due to extensive hanging wall damage. Operator skill is essential to make this an effective leading practice. The benefits of using scalers in future should not be discounted.

13) Watering down in mechanised sections was concerning as personnel often washed the hanging wall from the second split right to the face and then returned under hanging wall that had not been inspected.

14) The use of an entry examination LED light was identified as a leading practice at Mining House B. The logistics of carrying additional equipment and charging units was clearly difficult but the value added to the inspection process was incomparable.

15) The use of safety nets has led to some individuals and crews having a perceived sense of security when working under the net. They then do not bar as thoroughly as is necessary and rush through the EE process to install nets.

16) Where other issues were central to a worker's quality of life at that time such as remuneration, reward and recognition; and where dissatisfaction was apparent, these personnel showed disregard for the importance of the barring act and their own safety because of these financial and other stresses.

17) The negative perception about women in mining and specifically women barring was dominant at Mining House A and C. These non-barring specific factors were investigated in more detail by the Social team and are discussed in detail below.

10.2.2 Gold

Many observations at the gold mines show similarities with the platinum environment barring:

1) MOSH entry examination was not completed to standard in most working places visited:

    a. Crews often did not enter panels from behind the second line of support and thus had entered 'no-go zones'.

    b. The installation of temporary support was completed on numerous occasions without thoroughly making safe.

    c. Face preparation was often the focus of crews rather than barring to make safe. Rushing and taking shortcuts with barring due to perceived production pressures and the drive to obtain production bonuses, occurred frequently.

    d. The MOSH EE process was completed well where poor hanging wall conditions existed, in faulted or highly fractured ground as well as at areas with dyke intersections.

    Some crews perceive that certain days (when early shifts are completed by managers) are when MOSH EE should be done and done well. The workforce at Mining House D feels that they should focus less on barring thoroughly during the remaining shifts for the week, if it is completed thoroughly on the one day of the week.

2) Poor gasket usage was often observed as gaskets slid down pinch bars too easily. 'Wear and tear' appears to be the biggest cause of this. Low gasket availability was highlighted at Mining House D and it was common that no gaskets would be seen on any pinch bars observed in a panel.

3) The sequencing of watering down and then barring needs some focus at most mining houses and this is true across the industry still. Watering down in development ends is often done incorrectly with individuals travelling under unsafe/ uninspected hanging wall for many metres without actually making safe. Visual examination at these times cannot be considered adequate only. This is possibly done in an attempt to rush through the EE process.

4) Pinch bar condition was good at the majority of working places visited and Mining House E excelled at the frequency at which stores underground appeared to be replenished. However, this was in direct contrast to the availability of gaskets at this champion mine.

5) Positioning was a concern at the gold mines as well. Often persons barring were standing too close to where rocks would fall when barred.

6) Geotechnical environment played a slightly different role in gold as compared to platinum mines with some key areas for consideration:

    a. The deeper mining environments where high stresses and extensive fracture zones occur indicate the need for a marginally longer time spent barring in order to make safe.

    b. Lava hangingwall has a propensity to form extensively fractured zones displaying what may be described as 'shark teeth formation'. Observing barring in these areas showed that one could bar for as long as one wished to. Experienced workers indicated that they have learnt to gauge what extent of loose rocks would fall during their shift and thus only bar the immediately hazardous loose rocks.

7) Training initiatives have large scope for improvement, particularly the use of computer based training and mock mining environments for barring training, which has been less prevalent than in platinum and coal mines.

8) Leadership factors and behaviours were highlighted on numerous visits and these manifested in the following ways. Transformation is clearly needed or radical change to increase the effectiveness of barring programmes, as well as other OHS programmes implemented by leaders.

a. Leaders that are not effective are overruled by strong crews who refuse to take direction even with regard to safety initiatives for their benefit e.g. Crews entering panels without miners.

b. Even miners got complacent about making safe and seemed uninterested in correcting wrong practices (Mining House D).

c. Women in mid-tier management and leadership roles (underground personnel) have challenges perceived to be greater than their male counterparts, who share better rapport with their crews. There were also some remarkable exceptions to this, showing that personality and positive leadership can transcend gender stereotypes. There is a perception that women cannot bar underground but perhaps even more concerning is that very few women were observed actually barring.

d. Worrying opinions by leaders included “Barring is fine and interventions complicate things”. This led to “Let’s not complicate and confuse people.” Whilst there is some validity in this statement on its own, observations clearly show that practices are not fine at this mining house and any focus placed on barring would benefit the company.

10.2.3 Coal

1) Sounding and barring was often completed diligently during visits. It is suggested that this is possibly due to visitor presence. The lack of evidence of sounding marks on the roof in certain areas indicates that perhaps barring was not done as thoroughly during shifts prior to the visits. This would not be ascertainable for shifts post the application of stone dust.

2) Production pressures and the drive for first sump were indicated by many workers as the primary reasons for entry exam not being completed thoroughly on many occasions. As personnel are left at machines in the sequence through sections, the remaining personnel and miner often have no challenges that should hinder them from making the entire section safe throughout the shift. Good crews across all the coal mining houses showed adherence to the process as miners and remaining personnel would complete making safe of the entire section at a steady pace.

3) Isolated cases showed that personnel seem to get complacent easily, due to the lack of barring accidents and do not complete the barring process adequately. One interviewee said “We just carry the sounding stick only as we hardly ever use a pinch bar. When we really need it, then we’ll fetch it.”

4) Rib sides/ Stick sides are sometimes overlooked as focus is placed on the roof.

5) The length of pinch bars and sounding sticks posed a challenge to successful barring in excavations that were higher than planned, due to poor cutting or geotechnical considerations.

6) Fibreglass combination sticks and hollow steel pinch bars which are lighter to carry show consistent equipment modifications by suppliers to improve barring and sounding.

7) Fixed steel or hard plastic gaskets on the middle of pinch bars made the use of gaskets a non-issue as compared to gold and platinum mines. A fixed gasket was suggested but may not be applicable for hard rock stoping environments due to low excavation heights. Barrers are closer to falling rocks in-stope than in high excavations and their hands are more exposed to injuries. This is a practice that could be possibly used for 3m long pinch bars only in hard rock development ends where rocks are potentially deflected off the pinch bar before it reaches the employee's hand.

8) Poor ground conditions are often experienced in areas of dyke and fault intersections, friable shale roof and areas with burnt coal. Geotechnical environment varies only slightly in the Highveld area between roof conditions for the different seams. This does not require changes in the barring process or focus. The coal roof in Kwa-Zulu Natal shows that personnel there may indeed bar for longer time periods than their Highveld counterparts to achieve safer roof conditions.

10.3 Quotable Quotes

The following responses are from underground respondents on barring, and particularly their answers when asked – "How do you think we can make barring safer?" Whilst all suggestions may not be feasible, the list below is intended to show that workers are keen to discuss barring and often suggest the most practical solutions. When respondents felt comfortable, particularly open and truthful discussions ensued:

UNFAVOURABLE/ CONCERNING:

- *'Most of the time people don't search, they just go inside.'*
- *'People don't bar – They think barring is a waste of time. If they start barring, they will knock off late."*
- *'The use of safety nets has made people complacent about barring and the need to bar.'*
- *'Sometimes you may get a choice in the language you want to learn in – but the problem is we are not all the same. Fanakalo is still most dominant. It is preferred even by young people.'*
- *'As soon as we get in the section, all we are concerned with is doing the job and finishing…for the production bonus.'*
- *'People skip entry examination because of production pressures.'*

- *'Not all the time, the behaviour of certain people causes us to not bar.''*
- *'Long travelling time to workplaces, we don't get enough time to complete our job so we have to hurry.'*
- *'The barring rules don't work all the time. Our stope is different.'*
- *'Because it is hard, even the shift boss can come point out some rocks that may be barred.'*
- *'Sometimes there is pressure and we usually visually inspect only… what they need the most is the blast!'*
- *'Because of time, people take short-cuts because they want to knock off early.'*
- *'People are concentrating on the production. Some people don't bar. Only after injuries they bar but then after a few days they leave it and concentrate on production again.'*
- *'There is no underground training here, only training at mock mines. They need to do it underground rather than just getting an off-day.'*
- *'We forget our English because we have to speak Fanakalo.'*

INTERESTING/ INSIGHTFUL:

- *'Someone should only work on barring and making safe and should get money for doing that job.'*
- *'We need to fight to get the attitude of the people right – People see bad conditions and don't bar.'*
- *'Paint the pinch bar with fluorescent paint to make them more visible.'*
- *'Implement full mechanised scaling."*
- *'Pinch bar should be lighter.'*
- *'I would prefer a bigger gasket.'*
- *'I cannot see how a machine can bar. Even a roof bolter needs to bar first.'*
- *'We need machines to bar; life is more valuable than machines.'*
- *'How you bar, depends on where you are.'*
- *"Train and give people the attitude to use it properly. Coaching and motivating other people with negative attitudes can be done."*
- *'The rules are fine, even the pinch bar. Just ensuring we do it properly every day. As the miner, I will supervise more.'*
- *'New recruits need more understanding. Something like computer training for barring, right-wrong things and they will see what underground is like and what can happen.'*
- *'We need more understanding of rocks.'*
- *"We must get more training – people must be confident to bar.'*

- *“Training on barring every month - 30 minutes so that we will get used to it.”*
- *‘Focus on positioning the most. You really should be in the right position!’*
- *‘Bring back incentives to reward those people doing a good job and to inspire those people who aren’t doing a good job.’*

The most frequent response when we asked people how they think barring can be improved was “People just need to follow the rules”. This is a resounding indication that worker attitude and behaviour at times is what contributes most to causing barring accidents. Secondary to this, underground workers always suggested more training and more frequent training to promote the understanding of barring by their fellow colleagues.

11 Introduction to Root Cause Analysis Methodology for the Study

The Root Cause Analysis (RCA) exercises have been undertaken using the international standard method of analysis, the Root Cause Analysis Technique (RCAT). The benefits of using this system are that it guides the investigator through the key steps of the investigation process, and has a comprehensive listing of causes so the appropriate issues are investigated, assuring that investigators will identify underlying or root causes.

Shown below in Figure 2 is an excerpt from the well-known and widely used root cause analysis technique. The initial steps (1 to 3) determine the type of the incident, the consequences/ losses of the incident, the type of contact and the general agencies.

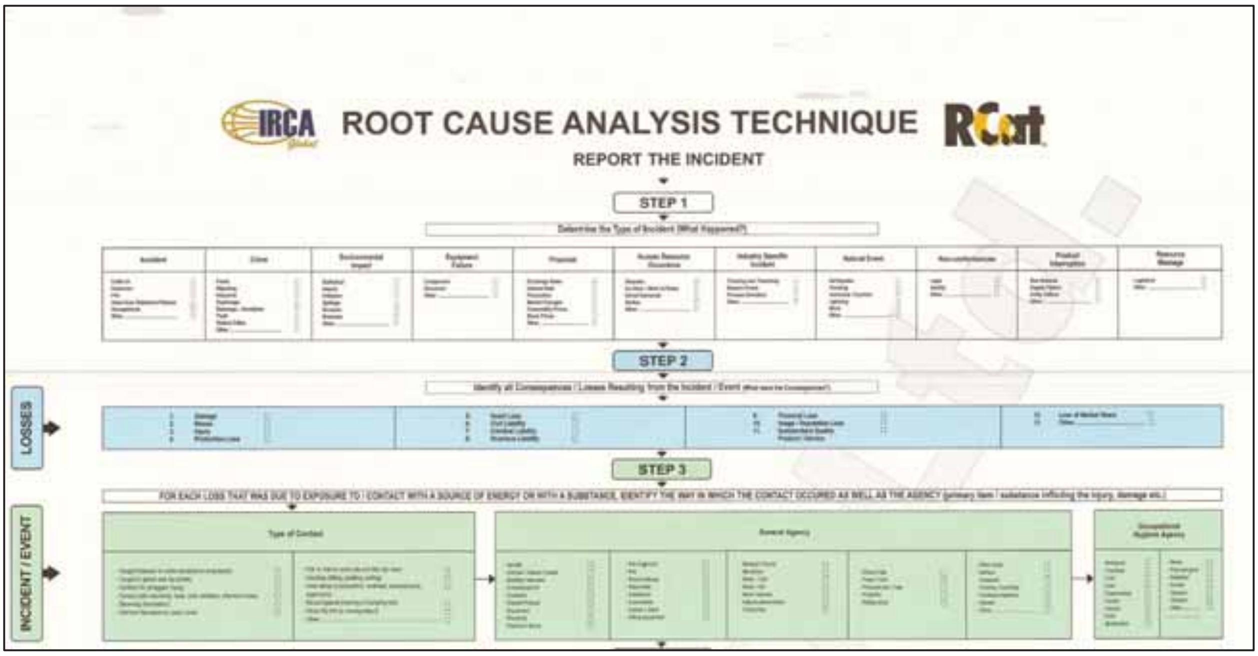

Figure 2: Initial Steps of the Root Cause Analysis Technique (RCAT)

Step 4 and 5 (Figure 3) involve risk assessment and evidence gathering, as well as identifying the immediate causes. Immediate causes are comprised of either substandard acts ('at risk' behaviour) or substandard conditions ('at risk' conditions). Examples of these vary from improper use of equipment, deviation from following standards, improper decision making to defective equipment or inadequate workplace layout.

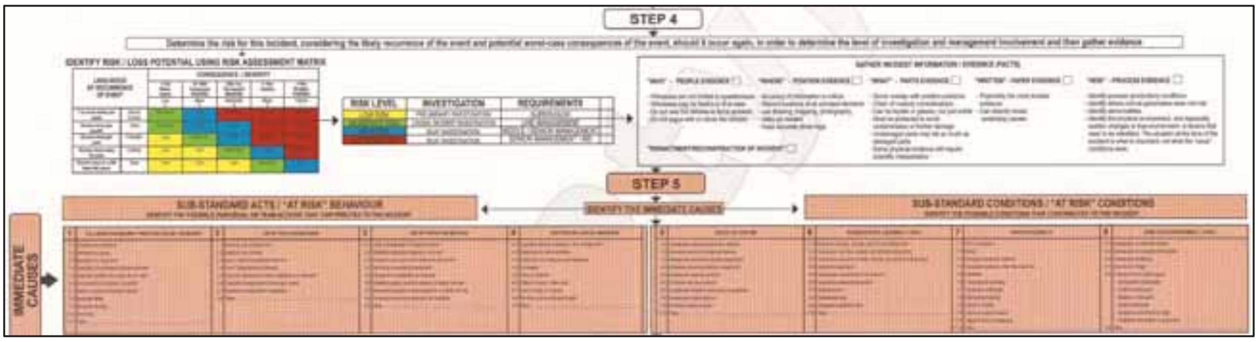

Figure 3: Step 4 and 5 of RCAT

Identifying the Root / Basic Causes (Figure 4 below) involves establishing either the possible human factors or workplace factors that contributed to the immediate cause. The RCat workflow is detailed enough that it includes all possible causes to any incident that may have happened. Some examples of the behavioural human factors in the comprehensive listing of root causes are:

- Improper performance is rewarding (by either saving time or effort, avoiding discomfort or gaining attention)
- Improper supervisory example
- Inappropriate aggression
- Improper use of production incentives
- Employee perceived haste
- Habit/ Personal preference
- Similarly, root causes are varied for other broad categories such as inadequate physical capability, mental stress, inadequate mental state, inadequate training and inadequate supervision. Listed below are some examples of workplace factors that may be the root cause of accidents:
- Inadequate training effort
- Inadequate identification of worksite/ job hazards
- Inadequate technical design

- Improper handling of materials
- Lack of PSP (Policies, Standards and Procedures) for the task
- Various forms of inadequate communication

Figure 4: Identifying the Root (Basic) Causes according to RCAT

Step 7 of the process (shown in Figure 5), identifies the system deficiencies that contributed to the existence of root causes. By understanding what corrective actions need to be implemented, RCat succeeds in finding and identifying which cause to eliminate for the incident in question.

Figure 5: Final Step (7) of RCAT-Identifying System Deficiencies

The analysis of the barring related accidents have been completed using the technique shown above. The entire RCAT process can be termed a reverse of the Loss Causation Model (shown in Figure 6). The investigation begins with the accident indicated by the loss on the extreme right of the diagram. The investigator then aims to work backwards to find the immediate causes followed by the root causes and ultimately identifies where the lack of control or system lies.

Figure 6: Loss Causation Model

The five key factors in the sequence are:

a) Lack of Control: Management

b) Basic Causes: Origins

c) Immediate Causes: Symptoms

d) Accident: Contact

e) Injury-Damage: Loss

Lack of management control is the most critical domino in accident causation. If systems are not reliable to prevent accident occurrence, this inability would lead to multiple accident recurrences. This loss causation model is the basis for the root cause analysis technique that is used. One should note that this is a sequential model that has been highly favoured as it allows focus on the view that accidents happen in a linear way. A leads to B which leads to C and the chain of events is examined between many causal factors often displayed in sequence from left to right (Safety Institute of Australia, 2012). There are numerous models available in the Safety field for causal analysis and this is one of the more complex linear models available.

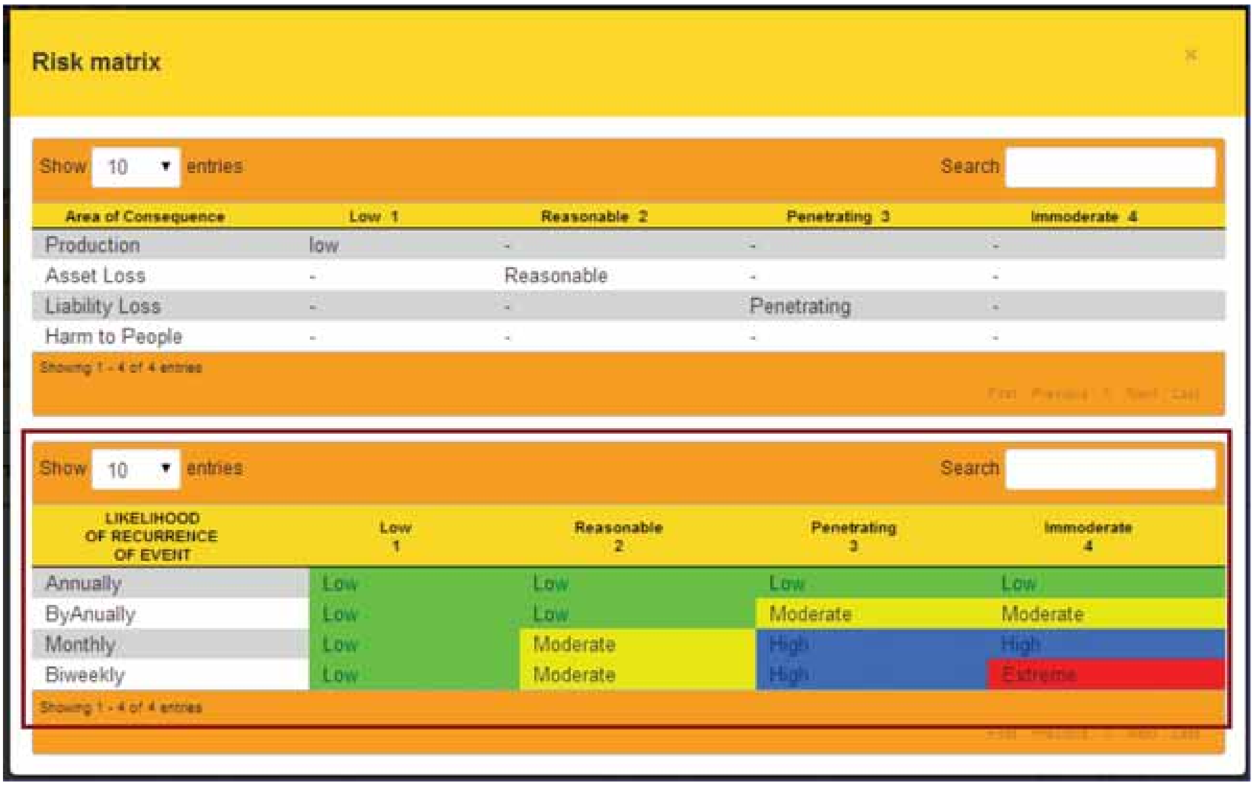

Figure 7: Risk Matrix used in RCAT's web based software

During the root cause study, the actual champion mine names will not be quoted, in order to:

- Protect the confidentiality of the sensitive information obtained.
- Eliminate bias from the reader of the research.

- Allow the root causes to be clear rather than placing focus on specific good and bad practices at each mining house.

12 Root Cause Analysis of Barring-Down Related Accidents from On-Site Data - Platinum

This chapter represents the final outcome of Milestone 2 of the study, being a root cause analysis of barring related accidents from data obtained directly from the champion mines that have volunteered for the study. Three mining houses with eleven mines/ shafts are the platinum champion mines for the project. Years 2011 and 2012 have been considered for the analysis. Root Cause Analysis (RCA) seeks to ultimately identify the basic cause of an incident or accident, and then to address the cause to ultimately prevent recurrence of such accidents.

12.1 Relevant Data

Shown below is the number of reports obtained per mine during the data collection phase (Table 4).

Table 4: Accident reports - Platinum

	Total number of reports obtained	**Total number of relevant reports**	
	All years	**2011**	**2012**
Mine/ Shaft 1	6	0	0
Mine/ Shaft 2	46	1	0
Mine/ Shaft 3	109	3	1
Mine/ Shaft 4	1	0	0
Mine/ Shaft 5	6	4	1
Mine/ Shaft 6	0	N/A	N/A
Mine/ Shaft 7	18	3	3
Mine/ Shaft 8	34	0	1
Mine/ Shaft 9	63	2	7
Mine/ Shaft 10	46	0	3
Mine/ Shaft 11	22	0	0

Only a few accidents were found to be relevant to the scope of this study after multiple readings of the reports. The key differentiator being that the accident needed to take place during the act of barring (during entry examination or pre-task barring). It should also be noted that these may not be the total or actual number of barring accidents that occurred at these operations during the periods considered.

- This may be due to a large number of contributory factors such as:
- All the shafts per champion mine were not visited.
- Data obtained may be incomplete data sets due to poor record keeping.
- High staff turnover has resulted in information loss over the years.

Some mines/ shafts did not provide any information for root cause analysis and thus were omitted from the Root Cause Analysis phase. Other relevant data from that mine has used for leading practice and underground assessments.

Twenty-nine barring related accidents occurred at the eleven champion mines during the years 2011 and 2012. These accidents took place during the act of barring and not due to a lack of barring. A previous lack of barring may have contributed to the accident taking place. However, the focus of this study is to identify where the act of barring can be improved. Thirteen accidents took place during 2011 with a slight increase in the number during 2012 when sixteen barring accidents occurred. The details of the accidents will be explained further, below.

12.2 Root Cause Analysis - Platinum

Twenty-nine barring accidents were analysed for their root causes. Shown below (d in the death of the employee.

Table 5) is the number of accidents that resulted in injuries (both minor and serious combined) as well as the one accident which resulted in the death of the employee.

Table 5: Distribution and severity of barring accidents (Platinum) during the study time period

	2011		2012		Total
	Injuries	Fatalities	Injuries	Fatalities	
Mining House A	4	0	1	0	5
Mining House B	8	1	12	0	21
Mining House C	0	0	3	0	3
Total	12	1	16	0	29

The dominant type of contact for the accidents analysed is “Struck by” (Figure 8). 93% of incidents are the ‘struck by’ occurrence where the person has been contacted abruptly and forcefully by an object in motion. It is known that the object is a rock that is dislodged from either the hanging wall or the sidewall underground. One incident was caused by over-exertion during the act of barring. This resulted in the injured person spraining his back.

The ‘caught-between’ occurrence is one where a person has been pinched, crushed or otherwise caught between either a moving object, a stationary object or between two moving objects. The one accident with this type of contact resulted in the injured person’s hand being caught between a pinch bar and a rock when he fell.

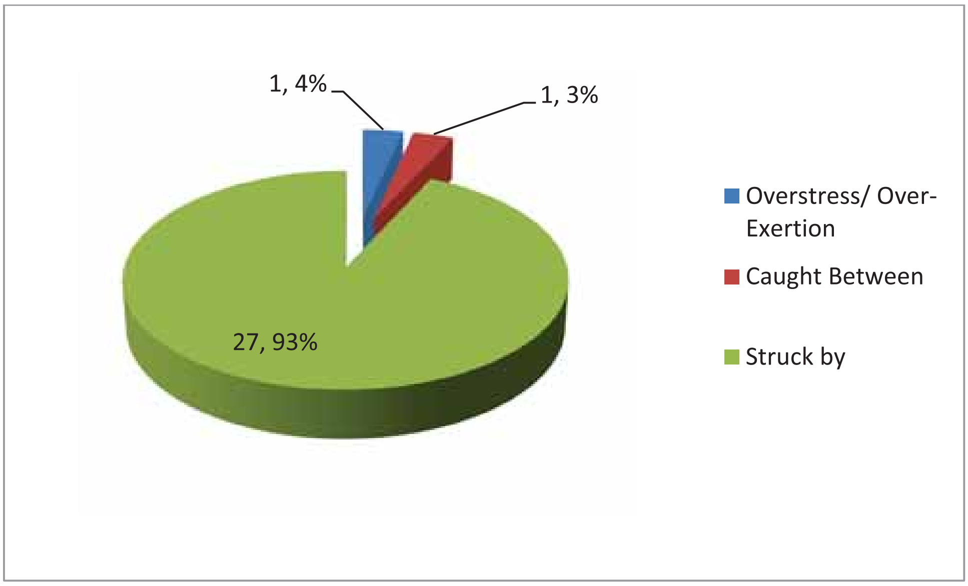

Figure 8: Type of Contact of Barring Accidents

The natural assumption when considering barring accidents is that the most common agency responsible for injuries is falls-of-ground (FOG) and this is what is reflected upon analysis of the data set. 76% of the accidents were caused by FOG (shown in Figure 9) whereas only 4% is caused by projectile rock which shattered and struck the person after a FOG. 10% of the accidents (3 out of 29) were caused by rolling rock and material handling.

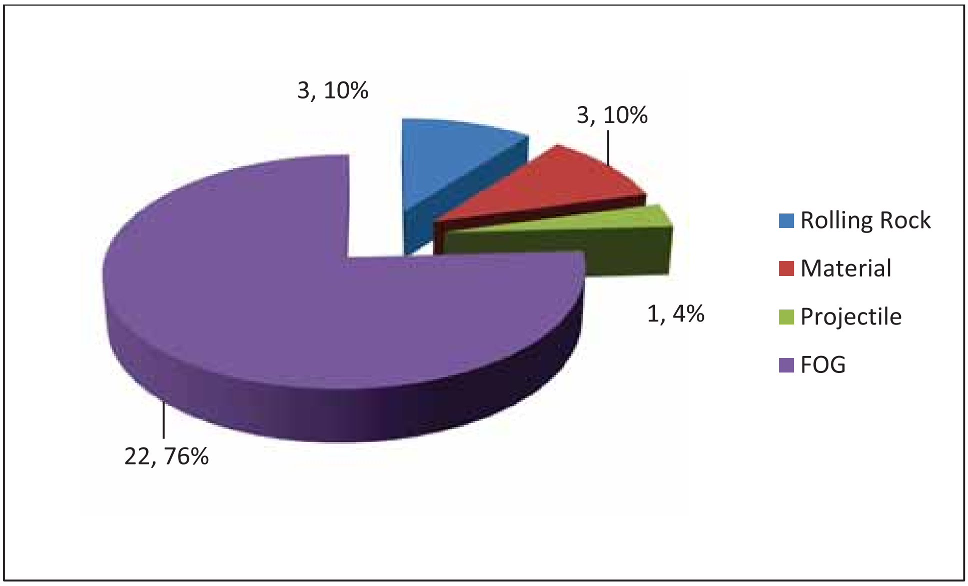

Figure 9: Agency of Barring Accidents

The next step in the root cause investigation led to identifying the consequence of each accident as well as the likelihood that there would be a recurrence of such an event. When the likelihood of recurrence is moderate, then a causal investigation is typically recommended. However, if the likelihood is high that a similar accident will recur, then a full RCAT investigation is recommended. It should be noted that a full investigation was completed for all accidents being investigated in this study.

Only two out of twenty-nine accidents had a moderate likelihood of recurrence classification, indicating that the risk of barring accidents happening once again is high. All other accidents (27) had a high likelihood of recurrence. This shows that the occurrence of accidents during the act of barring is common. Whilst these may not translate to serious injuries, the number of incidents if reliably reported would show the immense need for focus on improving the safety of the act.

Figure 10 shows the areas of the mine where the accidents took place. The stope face and advance stope gullies (ASG's) dominate as problem areas with eleven accidents (38%) taking place at the face whilst nine accidents (31%) occurred in the vicinity of the advanced strike gullies. Two accidents occurred in boxes whilst one occurred at the ledge face. The slusher gully was the locality of one accident with the remainder taking place in development cross cuts.

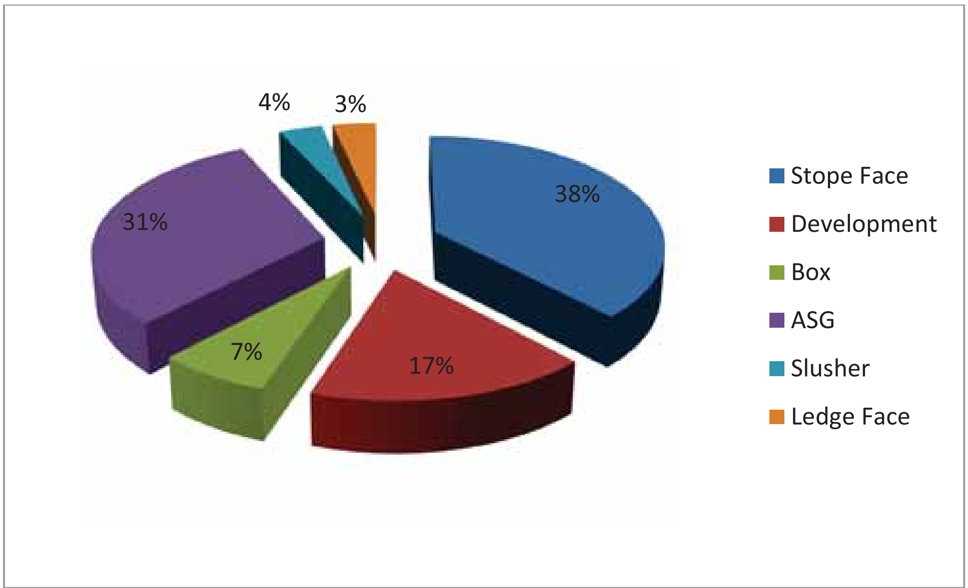

Figure 10: Area of excavations underground where accidents took place

Table 6 gives brief descriptions of the actual barring accidents and the circumstances contributing to them.

Table 6: Brief description of accidents - Platinum

Accident number	Brief description	Preliminary assessment of contributory immediate causes based on evidence in investigation
1	Deceased entered the area between the last line of support and the face, FOG during entry examination, Pinch bar found under FOG.	Deceased entered no-go zone and was barring alone.
2	Injured sprained his back whilst barring.	Injured chose to over exert himself whilst barring.
3	Whilst injured was barring, a rock dislodged and struck him on his upper lip.	Injured did not stand in a safe position.

4	Whilst the injured was barring, a rock dislodged from the face onto the footwall and rolled onto her ankle (Training cadet).	Incorrect length i.e. short pinch bar was used.
5	Whilst the injured was busy barring pre bolting, he was struck by a rock that dislodged from the hanging wall.	The injured was not concentrating completely on the task at hand due to stresses such as industrial action.
6	Whilst the injured was barring the side wall, a rock dislodged, rolled onto a pile of barred rocks and struck him on his right foot.	The injured did not ensure a clear escape way prior to barring.
7	The injured was barring when a FOG occurred and struck him on the leg	Incorrect positioning contributed to the cause. Miner and Shift Boss were also present and they did not correct this.
8	The injured was barring hanging ore in a box when the pinch bar got stuck in the chute. When the loco operator moved forward after the injured instructed him to do so, the pinch bar tilted and struck him on the thigh.	Wrong positioning as well as poor judgement contributed to this accident.
9	Whilst the crew was barring on the Eastern side wall of a cross cut, the injured was struck by a rock which dislodged from the Western side wall.	Awareness and positioning contributed to this injury. Reports indicate inconsistencies in investigation leading to the attitude of the injured and crew being questioned.
10	Whilst injured was barring and installing temporary support, he was struck by a rock which dislodged from the hanging wall.	Poor barring had been done and the injured was standing under loose rocks to continue barring.
11	Whilst crew was barring, the injured entered the panel from the advanced stope gully and was struck by a FOG.	The injured was possibly in the no-go zone and did not carry out early entry examination with the crew as he is a winch driver.
12	The injured was struck by a rock that dislodged in the north siding whilst barring adjacent to the advanced stope gully. The rock slid into the advanced stope gully trapping the injured person's foot against the side wall.	The injured did not identify the geological features present and also used a pinch bar that was too short.
13	A rock dislodged from the advanced stope gully face and struck the injured person's hand whilst barring.	Inadequate investigations as no causes were revealed.
14	The miner was busy barring the hanging wall at the top of panel during entry examination. He asked the injured who was sitting in the vent holing to move away. A rock dislodged from the sidewall of the advanced stope gully and struck the injured on the shoulder and foot.	Poor behaviour on the part of the injured as he did not take a safe position even after being instructed to do so.
15	A machine operator was struck by a rock from the side wall whilst barring in the advanced stope gully.	The injured never reported the incident to the miner leading to the conclusion of some wrong-doing on his part.
16	A machine operator was struck by the rock on his lower back while barring the hanging wall near the tip area and the ledge face.	The injured did not identify loose slabs in the hanging wall.
17	The injured was conducting entry examination in the advanced stope gully when a rock slab dislodged from the hanging wall above him and struck him on his upper arm fracturing his humerus.	The injured did not identify the loose slab immediately above him.
18	The injured was busy barring in the advanced stope gully when a rock dislodged from the hanging wall and struck him.	Incorrect positioning of the injured and reef in the hanging wall contributed to poor conditions.
19	The injured was barring when a rock dislodged from the side wall and struck him on the ankle.	Incorrect pinch bar length i.e. too short.

20	A barring assistant was struck on his wrist by a rock from the hanging wall whilst busy watering down the face.	Incorrect watering down procedure thus incorrect positioning under hanging wall that has not been barred.
21	The injured barred down a loose rock from the side wall, and as the rock struck the ground it broke into small pieces which flew and hit him on his left cheek.	Injured used short pinch bar, was not standing on solid ground and the area was not watered down adequately which could have helped him identify the large rock.
22	The injured entered the workplace without the miner's permission and started barring the side wall when he was injured.	Short pinch bars were used without gaskets.
23	The injured was hit by a rock that was attached to a rig chain whilst barring in the advanced stope gully.	The injured did not identify that the rock would swing towards him.
24	The injured was struck by a rock that dislodged from the sidewall when he was barring.	Incorrect positioning without a buddy barer
25	The miner was busy barring in a slusher when he was struck on his face by a rock that dislodged from the hanging wall.	Incorrect positioning
26	The injured was busy barring the west side panel when he was struck on his shoulder by a rock which dislodged from the hanging wall.	Incorrect positioning
27	The injured was struck on his right hand by a rock which dislodged from the hanging wall during visual examination after barring.	Inadequate hazard awareness in a confined space.
28	The injured was struck by a rock which dislodged from the hanging wall during the act of barring with a shovel. He was struck on his big toe.	Incorrect usage of equipment placing the injured too close to the area where rocks would fall.
29	Whilst the injured was barring a rock dislodged from the hanging wall. He lost his balance and fell resulting in his hand being caught between the pinch bar and a rock.	Lack of secure footing

The Root Cause Analysis was completed using IRCA's technique on the information present in each accident report made available by the champion mines. Even though there are many contributory and possible root causes for an accident, the main root/ basic causes are listed per accident (Table 7). For each root cause and system deficiency that is identified, the reasons why they were chosen are stated in the table.

Table 7: Root Cause Analysis of Platinum Barring Accidents

Accident number	Immediate Causes	Root Causes	System Deficiencies	Reasons for Identification of Root Cause and System Deficiency
1	Deviation by individual	Inadequate Leadership (inadequate safety promotion)	Planning and Implementing	Entry examination was not carried out to standard. Immediate supervision was not aware of injured person's actions. Panel classification system was not adhered to.
2	Improper decision making	Inadequate identification of critical safe behaviours.	Training Program Effectiveness	Very little information is given. Training on the buddy barring system may have prevented this accident.

3	Deviation by individual	Inadequate recall of training material	Training Program Effectiveness	Hazards were clearly identified but they were not treated adequately. Positioning was also a problem. Remedial steps included retraining on barring and the completion of PTO's leading to inadequate recall of training material being the root cause.
4	Deviation by individual	Inadequate recall of training material	Planning and Implementing (leadership)	Trainee was a new employee who did not use the correct length of pinch bar to bar and thus was positioned too close to the area being barred. Sufficient pinch bars were available. Injuring oneself whilst training could have been prevented by proper leadership. Training was identified by the mine as one of the controls.
5	Improper decision making	Mental Stress (Preoccupation with problems)	External relations	Poor concentration led to the injured not identifying a hazardous condition.
6	Deviation by individual	Inadequate recall of training material	Training Program Effectiveness	Investigation lacked detail citing human factors and poor training as root causes. Disciplinary action was also recommended.
7	Deviation by individual	Inadequate Leadership	Management Commitment	Incorrect positioning taken in the presence of leaders who should have corrected the injured person.
8	Improper decision making	Inadequate tools and equipment usage	Training Program Effectiveness	The system control that could prevent the incorrect usage of tools is training. It is clear that some training has been done thus the effectiveness of the training needs to be ascertained.
9	Inattention to footing and surroundings	Habit/ personal preference	Employee Orientations/ Awareness	Poor hazard identification and treatment. It appears that this may happen often and suggests that the injured employee has a habit of not following the steps of barring. Simple re-training would not have shown the employee the need for increased awareness in his environment.
10	Deviation by individual	Inadequate Leadership	Management Commitment	The geologically complex environment warranted the emphasized need for

				adherence and understanding of the panel classification system. The Rock Engineering and Geology departments were not requested to assist timeously. When exploring what could have prevented the accident, it is clear that immediate supervision should have made requests for assistance at the panel.
11	Exposure to mechanical hazards	Inadequate Leadership (safety promotion)	Management Commitment	According to the MOSH EE procedure which may not have been implemented at the time, the entire crew should have been involved in EE. Promoting safe behaviour would have been a proactive strategy.
12	Lack of knowledge of hazards present	Inadequate training effort	Competency and training needs identified	Multiple sub-standards evident and tampering with the scene is indicated. The immediate cause of the presence of a domal joint contact plane and steeply dipping fault that was not identified could have been addressed by a detailed strata control course. Thus the root cause indicated is inadequate training effort.
13	Unknown	Unknown	Unknown	Investigations revealed only that the correct pinch bar was used with two gaskets yet it is unknown how the injured person still hurt his hands. Proper drilling control and adhering to barring standards were listed as remedial measures taken.
14	Improper decision making	Habit/ personal preference	Employee Orientations/ Awareness	Injured person was warned to take a safe position and failed to examine his own surroundings leading to his injury. Employee needed to be sensitized to his environment as complacency may have contributed.
15	Deviation by individual	Inadequate Leadership (visibility)	Management Commitment	Though not stated in the investigation it is clear that the injured was standing too close to the area being barred allowing slabs to fall

				close to his body. Crew members including the miner denied witnessing any FOGs and it is apparent that more visible leadership and correction of poor practices may have prevented this accident.
16	Lack of knowledge of hazards present	Inadequate training effort	Management Commitment	Whilst attempting to bar thoroughly, the injured person failed to identify a loose slab that would also fall if he barred. The slabs at the edge of a slump/ pothole were not identified hence the root cause of the accident is inadequate training effort.
17	Deviation by individual	Inadequate training effort	Competency and training needs identified	There was a failure to identify and assess the potential risk of falling slabs or rock blocks associated with the targeted barring. This knowledge can be transferred to individuals with an improved training effort. The current training system is visual and thorough with regards to the panel classification system but it appears to be failing in teaching personnel how to identify critical geological structures.
18	Deviation by individual	Inadequate training effort	Competency and training needs identified	Failure to bar loose slabs that needed to be barred down. Individual could not decide on treatment of hazard. A greater training effort on the response required after panel classification is required.
19	Deviation by individual	Habit/ personal preference	Management Commitment	Incorrect length of pinch bar used, FOG was not reported timeously and panel classification was not adhered to. Multiple deviations indicate a propensity for the individual and team to not work to standard. Management commitment to strive to change this work ethic and attitude would be required.

20	Deviation by individual	Habit/ personal preference	Management Commitment	Due to the ease of watering down completely (prior to barring) many individuals do not water down from a safe position in order to save time. This was observed to be a habit of many individuals and leads to non-adherence to the barring standard. Management commitment to a SHEQ program is essential and can be displayed in a multitude of ways.
21	Deviation by individual	Habit/ personal preference	Planning and Implementing	Multiple contributory factors and poor discipline had been allowed to exist. Top management should display a commitment to their Safety initiatives to inspire mind-set change from ingrained personal habits.
22	Deviation by individual	Habit/ personal preference	Management Commitment	In addition to short pinch bars being used, no gaskets were available. However, the correct lengths of pinch bars were present. This indicates that it is likely that barring with a shorter pinch bar happens often even when 3m long pinch bars are available.
23	Inadequate skill level	Inadequate training effort	Competency and training needs identified	Skill is a combination of knowledge and ability. As the individual undoubtedly has the ability to perform the task, his knowledge and ultimately skill level can be increased by re-training or PTO's on barring. Whilst there is currently some training effort in place, it had failed to achieve the necessary knowledge transfer.
24	Deviation by individual	Inadequate recall of training material	Training Program Effectiveness	Injured did not choose a safe position and did not have a buddy barer with him. Training being reinforced on-the-job or a higher re-training frequency would promote better recall.
25	Deviation by individual	Inadequate recall of training material	Training Program Effectiveness	Emphasis on correct positioning during re-

				training or PTO's was required.
26	Deviation by individual	Unknown	Unknown	It cannot be ascertained from the brief report why the injured person stood in the incorrect position.
27	Lack of knowledge of hazards present	Inadequate performance of skill	Training Program Effectiveness	Hazard awareness (of abnormal geological features) was poor. Also, a 3m pinch bar could not be used effectively in the environment. Appropriate training measures ensuring the required skill level would not have permitted the root cause to exist.
28	Shortcuts	Improper performance is rewarding (saves time)	Management Commitment	The individual chose to bar with an incorrect tool i.e. the shovel as fetching a pinch bar may have been perceived as too time consuming.
29	Deviation by individual	Inadequate performance of skill	Training Program Effectiveness	It is decided that whilst the individual may have been trained, he may not have performed the act of barring consistently enough to practice sound footing. Training Program Effectiveness is one of many systems that may have failed in this instance.

Figure 11 shows the immediate causes of the barring accidents. By far, the dominant and most frequent cause is deviation by the individual. This is indicated by all the evidence given as per the investigation report. 'Deviation by individual' is defined as one person fully aware that he was taking a risk but still deciding to do the job that way. The one accident (accident 26) immediate cause shown as 'unknown' is due to a lack of information available in the report. As a result, it could not be decided what caused this accident or even the basic/ root cause. Improper decision-making means that the situation was wrongly judged and a wrong decision was made.

Three accidents had an immediate cause of a lack of knowledge of hazards present. Knowing that the area was not normal, the injured person had no knowledge of the geotechnical conditions and thus the hazards that were present in their environment. The immediate causes appear to be the point where investigation of the accident usually stops. All investigations should delve into the deeper and root causes of these deviations by individuals. When this is done, the focus shifts from what the employee did wrong to how the injured person was allowed to behave in this manner.

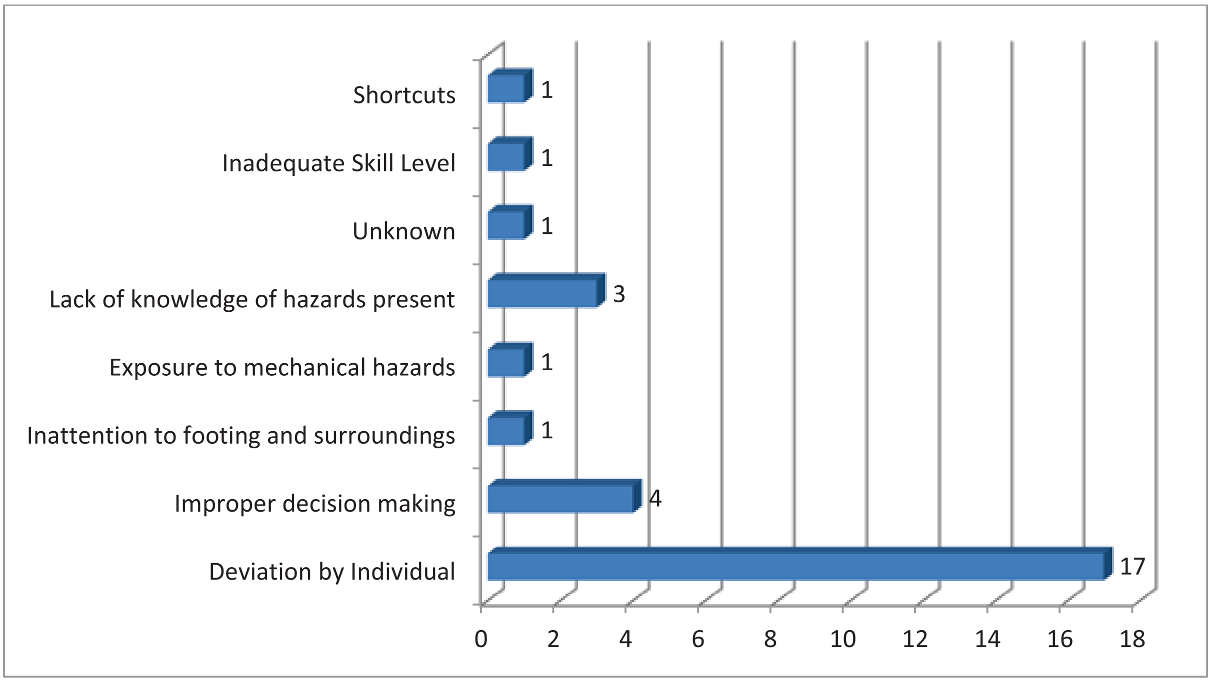

Figure 11: Immediate Causes of Barring Accidents - Platinum

It is interesting to note how varied the root causes of these barring accidents are. Figure 12 shows Habit/ Personal Preference to be a major contributor to barring accidents. This is caused by the employee's settled or regular tendency or practice, which is hard to give up. The decision to assign this root cause was taken after much discussion and deliberation over the available information leading to the root cause for the corresponding accidents.

Equally significant root causes are inadequate training effort, inadequate recall of training material and inadequate leadership. Inadequate training effort indicates that some training was conducted but it failed to be successful in transferring the knowledge required. Inadequate recall of training material is different in that a well-developed training initiative is evident but recall of the material is lacking. This may be due to training/ coaching not being reinforced on-the-job. Where corrective actions were Planned Task Observations (PTO's) or it was evident that the injured person did not have a PTO on barring done; then the root cause of inadequate recall of training material was chosen.

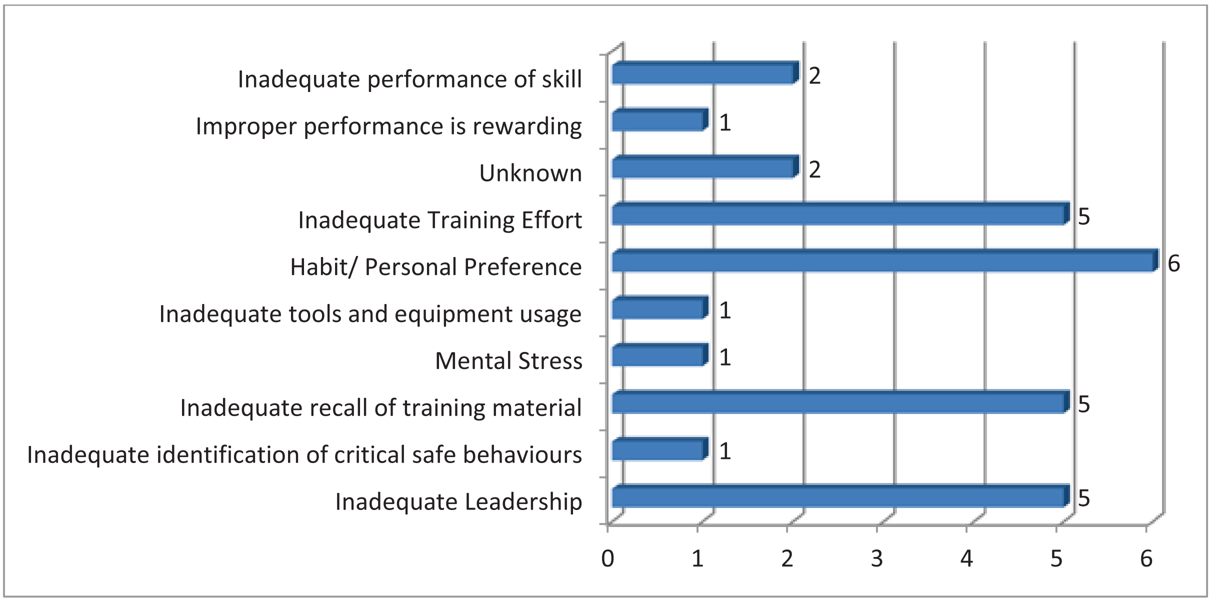

Figure 12: Root Causes of Barring Accidents - Platinum

Inadequate Leadership is a broad category and the various sub-divisions applicable to these accidents are visibility and safety promotion, or the lack there-of. What this implies is that the person assigned with the responsibility for safety had not carried out their responsibility to the degree necessary for safe work. This includes particular lax standards of performance being tolerated.

Whilst it does appear that emphasis has been placed on human factors, this is only the case because of the evidence provided in the investigation reports. Where technical detail on the influence of geotechnical environment and equipment usage is lacking, no presumptions were made about these historical accidents. It is not possible to visit the sites of the accidents that have occurred in the past. Discussed below are the ten key areas identified to be crucial to a proper root cause assessment for the barring act. It will be observed that many correlations can be drawn to the root cause assessment.

12.2.1 Risk Assessment

Barring is a task that needs to be quickly and internally risk assessed by the person who intends to bar down. Apart from the issue-based risk assessment for the critical task of barring, the crew should conduct a continuous risk assessment for tasks that are deemed extremely hazardous.

Analysis of the accident reports shows that only 52% of the investigations were thoroughly completed to include the existence of a risk assessment (Figure 13). The risk assessment may have comprised various forms such as a panel risk assessment, a Stop-Look-Assess-and-Manage (SLAM) process or even a Trigger Action Response Plan (TARP) system such as the Hazard Identification Treatment System (HITS or ABS-P) or Team Supervisor Management system (TSM). At some mines, both a pre-work assessment and a safe declaration are also completed.

For 48% of the accidents, it is unknown whether a risk assessment had been completed prior to the task being undertaken. It is also likely that the investigator may not have enquired about the risk assessment. Yet another possibility is that the completion of a risk assessment was not mentioned in the report. It is very concerning that one can only be certain that risk assessments were completed for 10% of the barring accidents that occurred in the data set being studied.

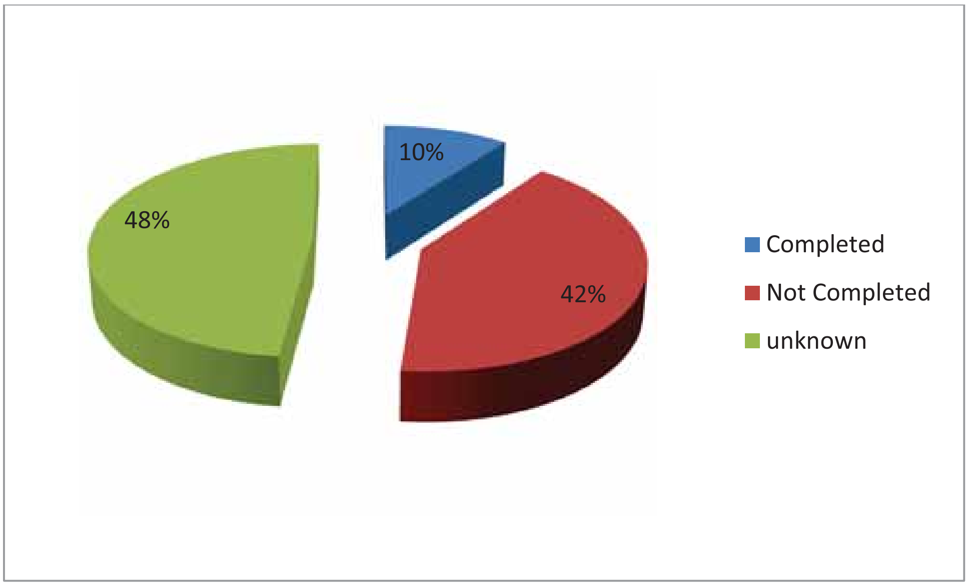

Figure 13: Risk Assessment status for Barring Accidents - Platinum

The need for better reporting of the accidents is evident as one cannot be certain that risk assessments were completed for a large percentage of the accidents.

12.2.2 Skills

A skill is a combination of ability, knowledge and experience that enables a person to do something well (Boyatzis, 1995). A workshop held as part of this project, on the 31st of March 2015 at Golder Associates offices in Midrand was well attended by Rock Engineering personnel and selected safety personnel from the various champion mines for the project. There was consensus by various people that barring is a physically demanding task that cannot be taught by training only. It is a skill that needs to be practiced so that the muscle memory can be instilled. This could also be termed procedural knowledge.

When analysing whether injured persons had the necessary skill to complete the task of barring, it is concerning to note that once again investigators failed to convey in their assessment whether the employees possessed the skill required to bar.

38% of accidents cannot be classified according to skills as this remains an unknown factor from the data obtained (Figure 14). Where the individual's years of experience did indicate that he should possess the skill of barring, an assumption was made that the skills required were present.

Only 14% of the injured persons possessed the skill to bar. This leads to a direct need for the iterative practice of barring by individuals with ability to do the task. Only this can assist in the development of the skill. Knowledge can be addressed by training.

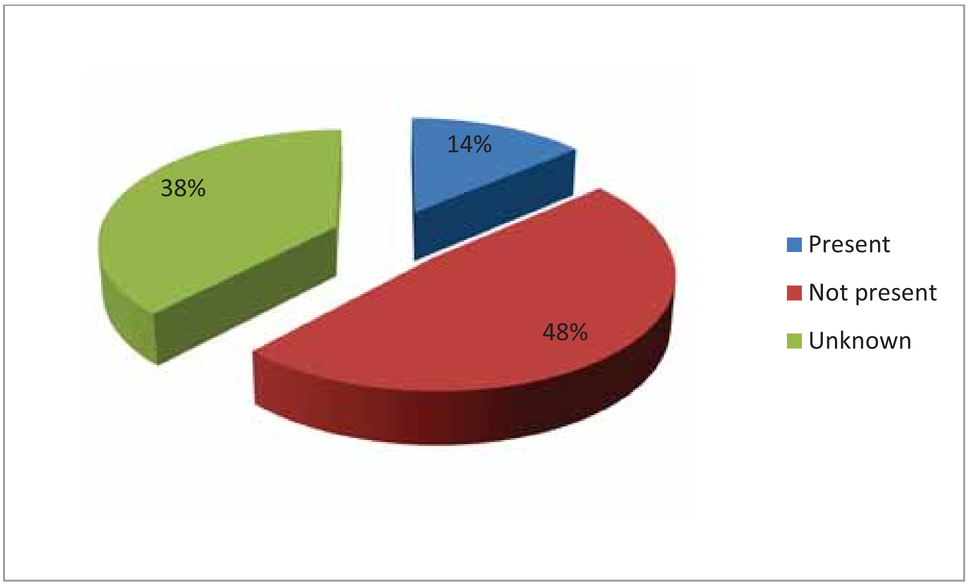

Figure 14: Presence and Lack of Skills required - Platinum

12.2.3 Training

14 of the 29 accidents (Figure 15) showed the need for training, refresher training or on-the-job coaching. This means that 48% of accidents occurred where the injured person did not receive/ undergo barring training that he could recall or the training received did not adequately transfer the required knowledge to the person. From 35% of the investigation reports, it is unknown whether the persons involved in the accident had sufficient training.

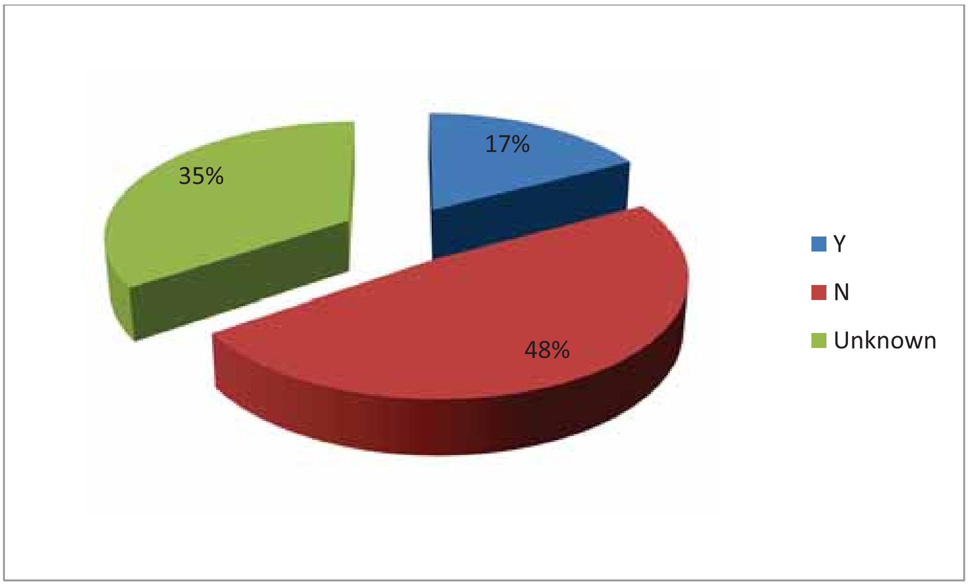

Figure 15: Presence and Absence of Training - Platinum

Only five accidents in the data set recorded that the training received by the employee was good. Training is needed to directly transfer the required knowledge of certain tasks/ processes to the individuals who will need to perform them.

It should be noted that the analyses completed were totally dependent on the information supplied within the investigation reports. The current training material and competency assessments will be assessed independently as these systems may not have been used at the time of these accidents. It is positive to note however, that all champion mines train according to the MQA standard MnH-G538 – Make Safe a Workplace by means of barring. The methods of training vary across operations with classroom and facilitator being favoured on surface and an underground practical training portion being common.

From the root cause analysis it is evident that training is one of the system deficiencies at a few mines. 'Inadequate training effort' and 'Inadequate recall of training material' are two major root causes of barring accidents in the platinum industry. The training material that is being developed as part of this project is innovative and will be developed in alignment with study findings and to address the root causes of barring accidents.

12.2.4 Equipment Selection

Correct equipment selection is vital to the successful completion of any task. The incorrect use of tools and equipment may contribute to the immediate cause of an accident in the following ways (IRCA, 2009):

- The improper use of equipment: where equipment was used for activities for which it was not designed.
- The use of defective equipment: knowing that the equipment was defective and still going on with the work.
- Improper placement of tools, equipment or materials: equipment is placed in a potentially hazardous position.

The barring accidents reviewed show that equipment selection was not the main cause of the accidents that occurred. However, even though some other factor contributed more to the accident occurrences, when the correct equipment selection was established for each accident, it was unexpected that the incorrect equipment or defective equipment was used for 31% of the accidents

(Figure 16) Examples include where the incorrect length of pinch bar was used and where a shovel was used to bar.

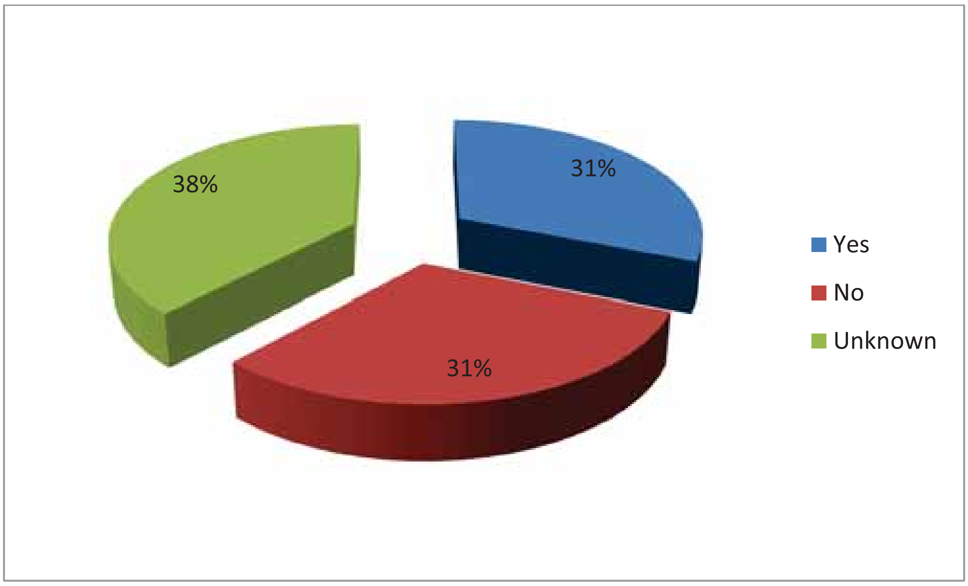

Figure 16: Correct Equipment Selection during barring accidents - Platinum

Of the eleven champion mines visited, only one was a fully mechanized mine. One other shaft visited had hybrid mining production sections but the rest of the shafts were conventionally mined. Even in mechanized mining sections, mechanical barring is used seldom where drilling booms are used to scale the hangingwall and sidewall of development faces. The most used tool to bar remains the steel pinch bar.

All barring standards include rules or steps that stress the checking of the equipment/ pinch bar. They are worded typically as follows: “Select the correct length of pinch bar to be used, examine the condition (not bent and sharp at ends), and ensure it is fitted with a gasket. It is even more concerning then that during the act of barring; the correct equipment was selected for only nine out of twenty nine accidents.

Once again, the unavailability of complete investigations shows that it is unknown whether the correct equipment was selected for 38% of the accidents that took place. The following pictures taken at the various platinum champion mines show various aspects of equipment selection for conventional barring processes (Figure 17 to Figure 22).

Figure 17: Typical entry examination board displaying the tools needed to bar (Mining House C)

Figure 18: Incorrect usage of a drill steel gasket which does not fit tightly onto the pinch bar (Mine 6)

Figure 19: Example of gasket used at Mining House C (this type is well favoured by users)

Figure 20: Complete view of gasket/ hand guard

Figure 21: 3m long Fiberglass pinch bar used at a development end at Mine 8

Figure 22: Incorrect usage of pinch bar for a task not intended for the equipment (Mine 11)

12.2.5 Geotechnical Environment

Shown below in **Table 13** are the local geotechnical aspects prevalent at the scene of the accidents and whether they made any contribution to the cause of the accident. Five accident investigations did not reveal whether geotechnical conditions contributed to the accident. Similarly, five accidents were not influenced by the presence of geological structures or other features particularly prevalent in the platinum mining environments of South Africa.

The differentiation between broad geotechnical mining environments where conditions are similar over a large areal extent to local Ground Control Districts (GCD) per mine/ shaft is detailed in the Code of Practice (COP) to combat Rockfall and Rockburst Accidents. Strategies such as minimum support requirements per area are also detailed in the COP.

The Platinum mining environment in South Africa lies in the various lobes of the Bushveld Complex (BC). The underground visits to the champion mines were concentrated on the western lobe of the BC. Alternating chromitite, pyroxenite, norite and anorthosite layers were typically observed. The two economic ore bodies of the Merensky Reef and the UG2 Chromitite layer are mined here with the following major geological features dominating the area:

- Joints: These occur in sets of similar orientation. Ryder and Jager (2002) indicate that in the western limb of the BC, three major joint sets occur throughout the region with varying prominence. The sporadic occurrence of low inclination planar joints also exists. Curved joints known locally as cooling joints also occur in certain areas. These comprise a system of concentric joints taking the shape of an upturned basin.

- Faults – both normal and reverse faults are encountered, with the latter being the most common. Fault planes generally extend through to surface and are associated with stress perturbations that can take the form of increases in horizontal stress. Faulting is of a lower intensity than is typically the case for the Witwatersrand goldfields.

- Dykes are more prevalent than sill-type structures. Two types of dykes are encountered, namely dolerite and lamprophyre. Dolerite dykes are generally strong (UCS more than 200 MPa) and the shear strength of the dyke / host rock contact is typically also considerable. These dykes are generally blocky and excavations located within the dyke experience localised stability problems. Lamprophyre dykes are significantly weaker (UCS from 0 to 60 MPa) and occur more frequently than dolerite dykes. The lamprophyre dyke / host rock contact has a very low strength. Lamprophyre material weathers rapidly and these dykes generally become self-mining when exposed to water. Diabase and syenite dykes are also present but are less prevalent.

- Potholes are structures where the reef has "slumped" into the footwall rocks. They occur throughout the western Bushveld area in an entirely random fashion. Due to their geological complexity and associated strata control problems, they are generally not mined. Where the hanging wall layers dip down into the pothole, deterioration in ground conditions is experienced. On certain shafts losses due to potholes represent significant percentages of the available mining area, especially for the UG2 reef horizon. The amount of reef remaining in pothole losses impacts on rock engineering design, particularly small pillar behaviour. As mining approaches the pothole edge a general increase in hanging wall disturbances (jointing and doming) coupled with a thinning of the hanging wall pyroxenite, results in an increased fall of ground (FOG) hazard, which becomes progressively worse as mining approaches the pothole edge.

- Iron-rich ultramafic pegmatoid (IRUP) has replaced the original igneous rocks in some areas. An IRUP may be in the form of a vertical pipe-like body, a sheet or an irregular body and can cause dramatic changes in dip and strike of the reef as well as the partial or total replacement of the reef. Generally, the presence of IRUP bodies creates weak zones that are not cohesive, increasing the risk of falls of ground when mining in or near these bodies.
- Shear zones are zones of closely spaced, approximately parallel faults or dispersed displacements. They often contain rock that has been crushed and brecciated by the many parallel fractures. Typically a shear zone is a type of fault, but it may be difficult to place a distinct fault plane into the shear zone. Shear zone widths vary from only centimetres wide up to several metres. Usually, the presence of shear zones creates weak zones that are not cohesive, increasing the risk of falls of ground when mining in or near these zones.

Table 8 shows the clear influence of some of the geological structures listed above. Most noticeable is the influence of jointing on hanging wall condition. Knowledge and understanding of these features will lead to a greater awareness of the surrounding area when crew members are undertaking barring and/ or entry examination. This indicates a need for training material on basic strata control practices. Some mining houses have strata control courses that are extremely impactful and the knowledge transfer was clearly observed during visits underground. Mining House C set a leading example in this type of training initiative.

Table 8: Contribution of geotechnical environment to the cause of the accident

Accident number	Year	Mine/ Shaft	Depth below surface of working place	Reef and Hanging Wall/ Side Wall type	Contribution of geotechnical environment to the barring accident
1	2011	5	Unknown	UG2 with Pyroxenite	Faults and low angle joints. Investigation showed that a dome structure was exposed by the FOG that occurred.
2	2011	5	Unknown	UG2 with Pyroxenite	Unknown
3	2011	5	Unknown	UG2 with Pyroxenite	Prominent jointing (dipping at 75°)

4	2011	5	Unknown	UG2 with Pyroxenite	Did not contribute to accident
5	2012	5	Unknown	UG2 with Pyroxenite	Approximately 20cm thick calcite vein present - Did not contribute to accident
6	2011	7	Unknown	Unknown	Unknown
7	2011	7	311m	Unknown	Poor ground conditions in ASG. Pothole observed on-plan.
8	2012	7	Unknown	Unknown	N/A
9	2011	7	771m	Reef N/A but rock type is Norite	N/A
10	2012	7	336m	Merensky with Norite	Low angle joints (with talc infilling) and brows present; 0.5m thick lamprophyre dyke, possible dome (low angle joint structure in the hangingwall, and possible reef roll (reef in footwall from the centre of the panel to the top).
11	2012	7	806.8m	Merensky with Lamprophyre	Edges of Lamprophyre dyke and jointing within the dyke. Jointing had mud infill.
12	2012	8	569m	UG2 with Pyroxenite	Domal joints and steeply dipping fault
13	2011	9	706.4m	UG2 with Harzburgite	Flat non-persistent serpentinite filled joints intersecting with vertical jointing
14	2011	9	628m	UG2 with sidewall Harzburgite	Vertical joints
15	2012	9	781m	UG2 with sidewall slab of UG2 (chromitite)	High abutment pillar stresses leading to scaling
16	2012	9	343m	UG2 with Pyroxenite	Slabbing due to slump, pegmatite veins. Additionally, a large sized Merensky pillar is present 40m above the area.
17	2012	9	655m	UG2 with Pyroxenite-Harzburgite	HW laminations in Pyroxenite-Harzburgite, vertical jointing and the area is over-stoped on Merensky.
18	2012	9	448.4m	UG2 with Pyroxenite	Slabs in Pyroxenite HW. Steeply dipping joints
19	2012	9	467m	Reef N/A Sidewall Norite	Calcite filled joints in sidewall Norite
20	2012	9	505m	UG2 with Pyroxenite	Exposure of Harzburgite
21	2012	9	249m	Reef N/A Anorthosite	Slabbing Anorthosite
22	2012	10	Unknown	Reef N/A Rock type is unknown	Low angle jointing
23	2012	10	Unknown	Unknown	N/A

24	2012	10	Unknown	Unknown	Lamprophyre dyke
25	2011	3	Unknown	Unknown	Friable hanging wall, closely spaced joints and multiple faults
26	2011	3	Unknown	Unknown	Unknown
27	2011	3	898m	UG2 in Box hole	Multiple joints
28	2011	2	Unknown	Unknown	Unknown
29	2012	3	Unknown	Unknown	Did not contribute to accident

As the depths of working areas are often not stated in the accident report, many fields of the table are indicated as 'unknown'. The available data shows that barring accidents are most common where UG2 is the reef type and where pyroxenite is present in the hanging wall.

Shown below (Figure 23 to Figure 25) are various examples from the champion mines of typical geological structures.

Figure 23: Jointing and layering observed in pillar (Mine 5)

Figure 24: Fall-out due to dome feature and associated low angle joints (Mining House C)

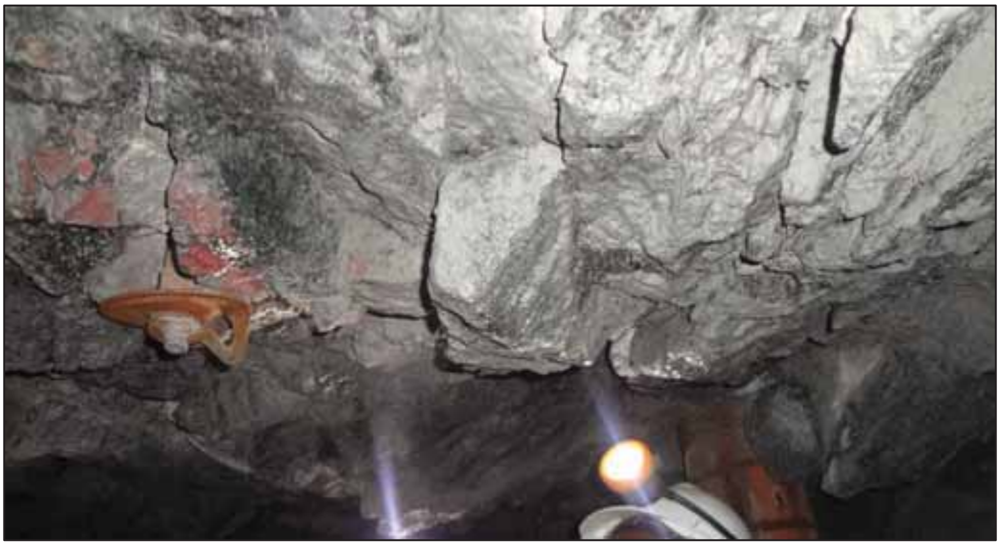

Figure 25: Prominent Hanging Wall Jointing (Mine 10)

12.2.6 SIZE OF EXCAVATION

Figure 26 shows that sixteen accidents occurred in excavations where the height did not exceed two metres. This indicates that the majority of barring accidents took place in stoping environments (Figure 27) at the face area and in the vicinity of advanced stope gullies. Ten of the accidents occurred in development ends where the height of excavations is typically 3m (Figure 28). Box holes were the location for two accidents with the exact height of one excavation being unknown.

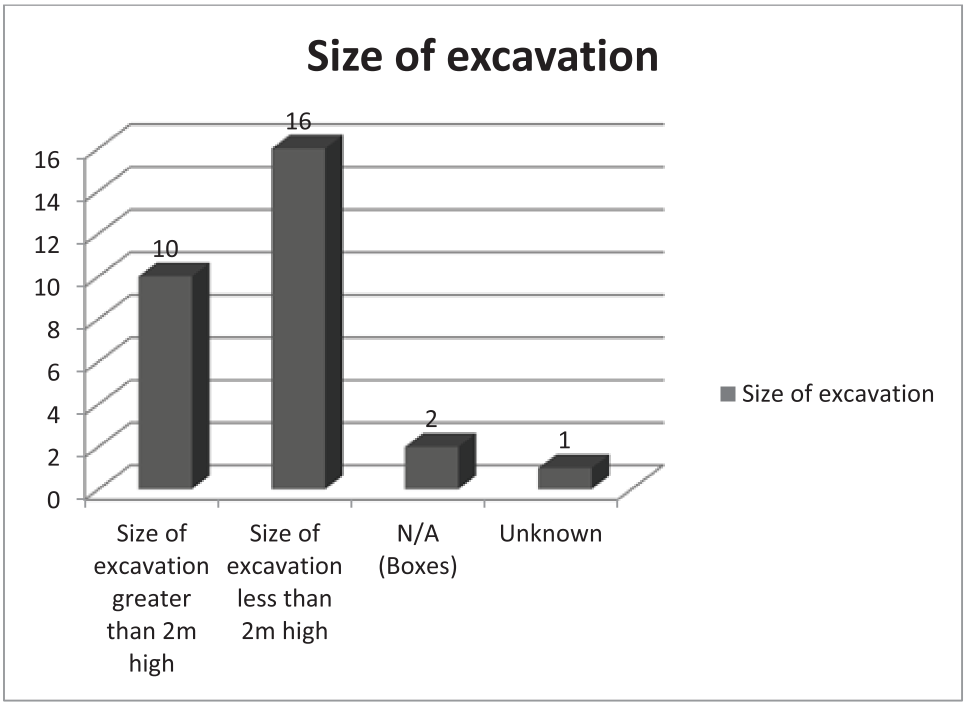

Figure 26: Sizes of excavations where accidents occurred

Conventional barring strategies in excavations of varying heights necessitate the use of different lengths of pinch bars. 3m long pinch bars are typically made of lighter materials such as aluminium and fiberglass to reduce the weight of the bar. Steel pinch bars are used in-stope and vary with lengths of 1m, 1.2m, 1.5m and 1.8m long bars used in gully areas. Thus, the choice of equipment is directly influenced by the height of the excavation that the barrer is working in. The task must be performed from a safe distance but also from a distance such that the required leverage can be obtained.

Shown in Figure 27 and Figure 28 below is a typical stope and cross cut.

Figure 27: Typical conventional stope where height of excavation is less than 2m (Mine 8)

Figure 28: Development excavation greater than 2m high with poor hanging wall conditions and overhanging side wall (Mine 9)

Where excavation heights exceed 3m, platforms may be required to be built in order to bar and support the excavation effectively. Excavations of these heights are mostly long-term bulk and fridge chambers where secondary support will be installed and the need to bar continuously will be removed.

12.2.7 Leadership

Analysis of the platinum specific accidents showed 'leadership' or the lack of good leadership being a factor that contributes to the occurrence of the barring accidents. Eighteen of twenty-nine accidents clearly took place in environments where poor leadership was evident (Figure 29). The level of leadership present could not be determined for four accidents from investigation reports. Two of the accidents arose because of extremely poor leadership. Leadership was fair for five of the accidents but this is still not acceptable.

Good leadership comprises visible felt leadership principles and ensures that supervisors and managers show the required promotion of safe behaviours.

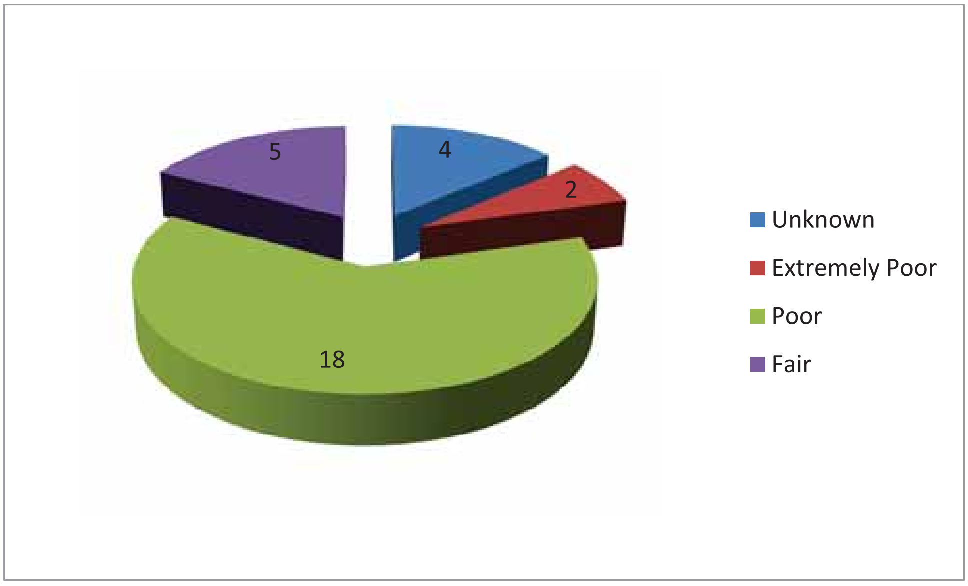

Figure 29: Contribution of leadership to barring accidents

12.2.8 Human Behaviour

In determining whether the injured person's or any employee's behaviour caused an accident, the following questions may be asked:

- Is improper performance rewarded?
- Are supervisors not giving a proper example to people working in the organisation?
- Are critical safe behaviours identified?
- Is there sufficient reinforcement of critical safe behaviours?
- Are people aggressive in the actions and decisions that have been taken?
- Have production incentives created an incentive to ignore safety requirements?
- Do supervisors imply that haste in completing work is more important than safety considerations?

- Do employees perceive that haste is necessary in the completion of work which is more important than safety considerations?
- Does an employee have a settled or regular tendency or practice that is difficult to give up?
- Did the employee wilfully cause malicious damage to property, process or the environment?

In asking the above questions, it was found that eighteen of the accidents were caused by poor human behaviour and eight accidents were caused by extremely poor human behaviour e.g. supervisors present whilst an individual deviates from performing a standard (Figure 30). Fair to normal behaviour was demonstrated at three accident occurrences.

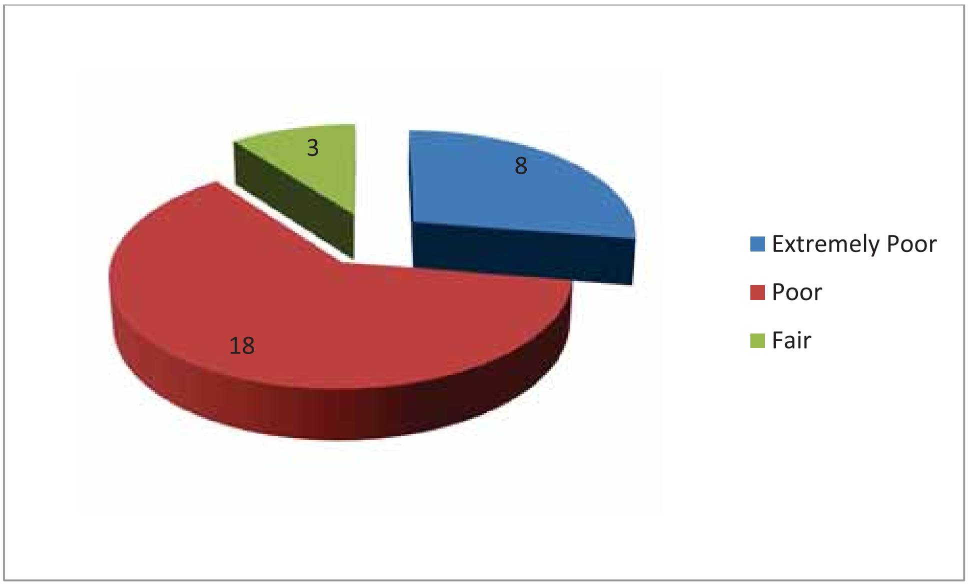

Figure 30: Contribution of human behaviour to barring accidents

12.2.9 Communication

Poor communication is evident in most of the environments where the accidents took place. Only one instance occurred where communication was good (Figure 31). Communication considered for this key area is that between crew members and from supervisor to crew level.

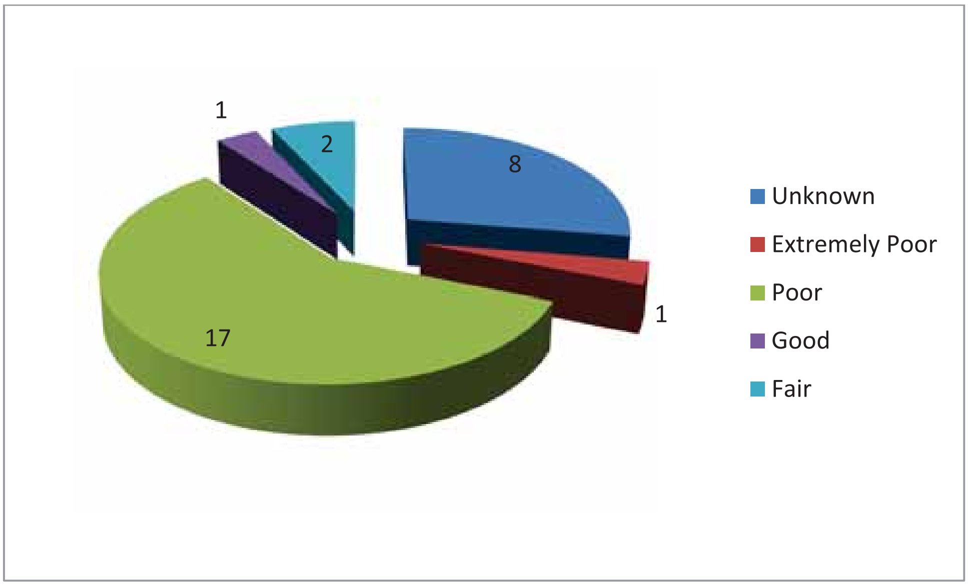

Figure 31: Contribution of Communication to barring accidents

Skoldeberg et al. (2011) suggested a practical guide to using communication to support sustainable development and some of the points are particularly relevant for the operational mining environment. They are:

- Know your audience and the influencers within them
- Find more opportunities to listen
- Align communications between various levels in the organisation
- Improve ways to measure what matters
- Invest in your employees
- Embrace digital dialogue
- Activate more industry cooperation
- Conduct regular self-diagnostics

12.3 Milestone Observations

- Most barring investigation reports received had insufficient detail to find out the root cause of the accidents of these platinum accidents. A lot of inference had to be made in order to arrive at the dominant root causes.
    - Where root causes were given, they were often immediate causes or the conditions present that led to the accident taking place.

    - A blame culture is still apparent as disciplinary action is often still recommended, even where the root cause is not due to a human factor.
    - The investigation reports supplied placed a lot of emphasis on the influence that the injured person contributed to the accident.
- Many technical aspects such as the contributing factors of the environment (ground condition, geological structures and the influence there-of) and equipment usage are lacking in detail.
- Corrective actions are fair to mostly poor as they often do not seem to be geared to prevent recurrence of such barring accidents.
- Most common corrective actions taken post an accident include re-training and the completion of PTO's.
- Rock Engineering and Safety department investigations and reports may be improved to explore the human factors that contribute to an accident more. This is even more applicable when the deviation of the individual is apparent.
- Features of poor investigations that were completed, show that they are directed away from systems. The analysis above attempts to re-classify the evidence given, to expose where system deficiencies obviously exist. In attempting to identify the correct systems to be targeted, the research project can further advance to eliminating such system causes. The analysis of the platinum barring accidents shows the need for training improvements, interventions and perhaps a greater emphasis on refresher training. The training aspects related to barring will be explored in more detail in future milestones of the study. In particular, strata control training and the use of mock-ups will be analysed. Training material from the champion mines have been obtained and has been reviewed. It can be noted that all mines that were visited use the MQA standard for making safe.
- Incorrect equipment usage contributed to two of the twenty-nine accidents and this appears to a problem that can easily be addressed by planning, risk assessments and training.
- The deeper UG2 mining environment appears to have more barring accidents occur than when mining the Merensky reef. Pyroxenite is the hanging wall type that has more prolific jointing and unfavourable geological structures that contribute to poor ground condition. Thus, the likelihood of barring accidents is higher here due to unraveling of the hanging wall parting planes.
- The lack of knowledge of key geological structures prevalent in the platinum environment is concerning. Whilst some attempt is being made at the various mines to train personnel in strata control practices, some mines achieve the required knowledge transfer better than others.

12.4 Milestone Conclusions and Recommendations

This root cause analysis has considered twenty nine relevant barring-related accidents from the platinum champion mines and the following recommendations can be made:

It is evident that the quality of the mine accident reports could be improved to include more details of the accidents, in order to allow a more thorough root cause analysis to be carried out. In addition, human behaviour factors should be included in the reports to allow a better understanding of why workers may have deviated from the accepted barring practices.

Systems to establish appropriate corrective actions need to be established within the mines so that continual barring related training is undertaken in order to ensure that recurrence of the accidents are prevented.

The following recommendations are made to address the findings of this phase of the study:

- Accident investigations must be undertaken by trained teams. Basic identification is lacking from many reports of the location, and root causes so teams need to improve on the data collection and overall reporting of accident details.
- The investigations should consider not only the person's involvement in the accident but also the system failures by the organization that permitted the accident to occur.
- More effective training of the production teams on hazard identification is needed.

13 Root Cause Analysis of Barring-Down Related Accidents from On-Site Data - Coal

This chapter represents the final outcome of Milestone 3 of the study, being a root cause analysis of barring related accidents from data obtained directly from the champion mines that have volunteered for the study. Four mining houses with eleven mines/ shafts are the coal champion mines for the project. Years 2011 and 2012 have been considered for the analysis, but due to the limited number of barring accidents, year 2013 is included for this analysis.

13.1 Relevant Data

Shown below is the number of reports obtained per mine (Table 9). Note that it is largely due to feedback from the champion mines that no barring related accidents had occurred at these shafts.

Table 9: Accident reports

	Total number of reports obtained	Total number of relevant reports	
	All years	2011	2012
Mine/ Shaft 1	0	N/A	N/A
Mine/ Shaft 2	0	N/A	N/A
Mine/ Shaft 3	0	N/A	N/A
Mine/ Shaft 11	1	0	1

Mine/ Shaft 4	1	0	0
Mine/ Shaft 5	0	N/A	N/A
Mine/ Shaft 6	0	N/A	N/A
Mine/ Shaft 7	0	N/A	N/A
Mine/ Shaft 8	No data received		
Mine/ Shaft 9			
Mine/ Shaft 10	0	N/A	N/A

Only two accidents were found to be relevant to the scope of this study after review of the reports. The key differentiator being that the accident needed to take place during the act of barring (during entry examination or pre-task barring). There were multiple requests to many of the shafts visited but data was not provided by two shafts. All other shafts visited indicated that no barring related accidents has occurred at these operations in the time period being considered.

It should also be noted that these may not be the total or actual number of barring accidents that occurred at these operations during the periods considered. This may be due to a large number of contributory factors such as:

- All the shafts per champion mine were not visited.
- Data obtained may be incomplete data sets due to poor record keeping.
- High staff turnover may have resulted in information loss over the years.

Two barring related accidents occurred at the eleven champion mines during the years 2011 to 2013. These accidents took place during the act of barring and also due to a lack of barring. The focus of this study is to identify where the act of barring can be improved.

13.2 Milestone Results

Two barring accidents were analysed for their root causes. Shown below (Table 10) is the number of accidents that resulted in injuries (both minor and serious combined). It should be noted that barring related fatalities were not present in this data set.

Table 10: Distribution and severity of barring accidents (Coal) during the study time period

	2012		**2013**		**Total**
	Injuries	Fatalities	Injuries	Fatalities	
Mining House F	1	0	0	0	1
Mining House G	0	0	1	0	1
Total	1	0	1	0	2

The dominant type of contact for the accidents analysed is “Struck by” .Both are the ‘struck by’ occurrence where the person has been contacted abruptly and forcefully by an object in motion. It is known that the object is a rock that is dislodged from either the roof or the rib-sides underground.

The natural assumption when considering barring accidents is that the most common agency responsible for injuries is falls-of-ground (FOG) and this is what is reflected upon analysis of the data set. Both accidents were caused by FOG.

The next step in the root cause investigation led to identifying the consequence of each accident as well as the likelihood that there would be a recurrence of such an event. When the likelihood of recurrence is moderate, then a causal investigation is typically recommended. However, if the likelihood is high that a similar accident will recur, then a full RCAT investigation is recommended. It should be noted that a full investigation was completed for both accidents being investigated in this study.

Both accidents had a high likelihood of recurrence, indicating that the occurrence of accidents during the act of barring is common. Whilst these may not translate to serious injuries, the number of incidents if reliably reported would show the immense need for focus on improving the safety of the act. Equally as important is the practice of the act of barring as this eliminates many more accidents that would have occurred.

Figure 32 shows the areas of the mine where the accidents took place. It is interesting to note that the panel faces did not dominate as a problem area. The sounding and barring of old areas (Back-bye/ Out-bye) should be focused on more.

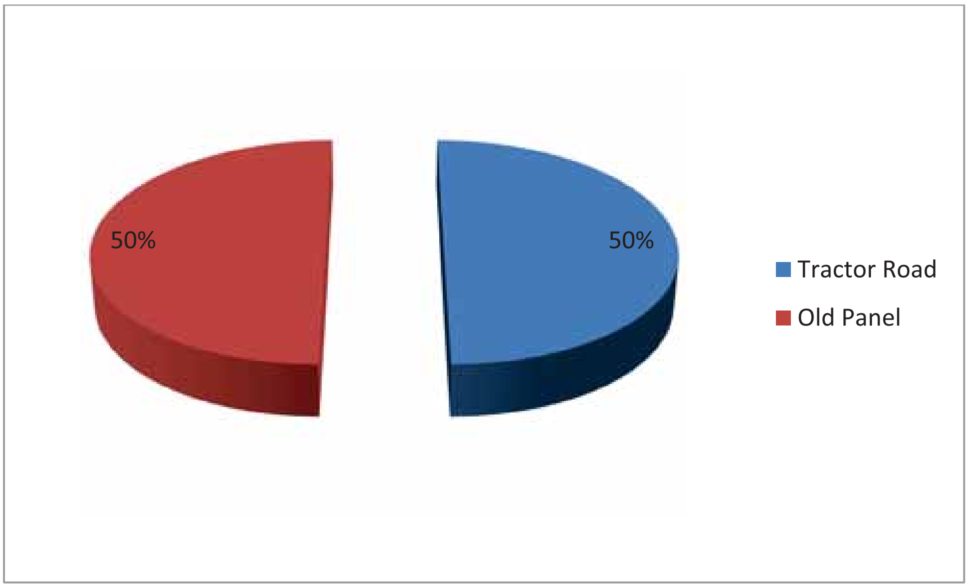

Figure 32: Area of excavations underground where accidents took place

Table 11 gives brief descriptions of the actual barring accidents and the circumstances contributing to them.

Table 11: Brief description of coal commodity barring-related accidents

Accident number	Brief description	Preliminary assessment of contributory immediate causes based on evidence in investigation
1	FOG occurred during the barring process, prior to support installation. The injured was struck on his face when he attempted to bar down a slab of shale.	Improper hazard identification as the area is known to have previous FOG's due to a dyke intersection. Loose slabs and sympathetic jointing were also present.
2	Whilst inspecting the area, a piece of frozen coal dislodged from the roof and hit the injured on her right shoulder.	Inadequate barring was done; the injured person was a new employee and did not undergo a thorough initial training. Sub-standard lighting in the area exacerbated the conditions that led to the injury.

13.3 Root Cause Analysis

The Root Cause Analysis was completed using IRCA's technique on the information present in each accident report made available by the champion mines. Even though there are many contributory and possible root causes for an accident, the main root/ basic causes are listed per accident (Table 12). For each root cause and system deficiency that is identified, the reasons why they were chosen are stated in the table.

Table 12: Root Cause Analysis of Coal Barring Accidents

Accident number	Immediate Causes	Root Causes	System Deficiencies	Reasons for Identication of Root Cause and System Deficiency
1	Deviation by group	Inadequate performance of skill	Competency and training needs identified	The area that the injured person was working has intersected a dyke and there was a previous FOG occurrence there. There were visible loose slabs of shale in the roof. The act of barring the loose slab proceeded without proper hazard identification and the injured could not predict where the rock would fall. It follows from the corrective measures taken that re-training was necessary.
2	Improper decision making	Inadequate training (initial)	Employee Orientations/ Awareness	The job factor of inadequate lighting in the area must be mentioned but the basic cause still remained that there was inadequate induction or orientation given to a new

				employee. Examination was a new skill for this employee and she did not have practice before working. It is also clear that she was not given an initial training underground.

Figure 33 shows the immediate causes of the barring accidents. One immediate cause is the deviation by the individual. This is indicated by all the evidence given as per the investigation report. 'Deviation by individual' is defined as one person fully aware that he was taking a risk but still deciding to do the job that way. Improper decision making to continue with examination when the hazards were clearly not perceived is the immediate cause of the second accident.

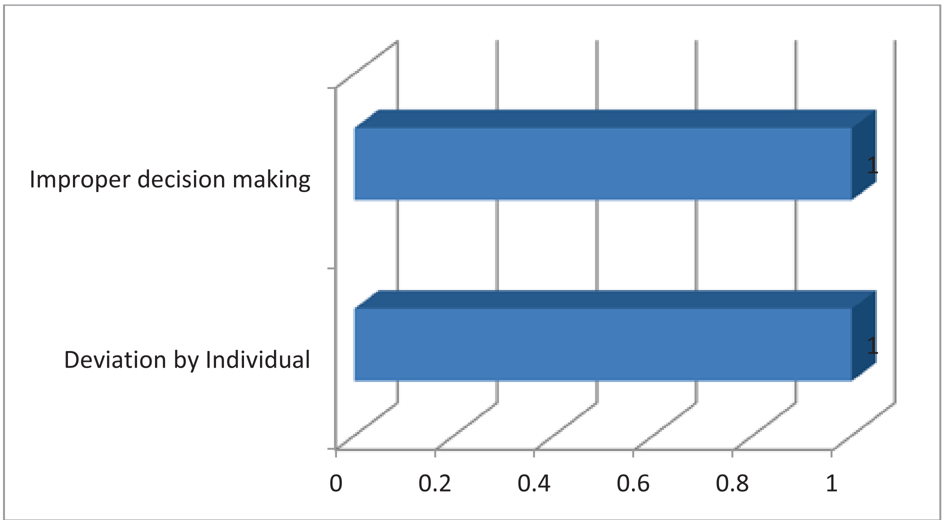

Figure 33: Immediate Causes of Barring Accidents

Figure 34 shows inadequate performance of skill as a root cause of an accident. The injured employee had undergone the necessary training and was well equipped to bar safely.

Equally significant as a root cause is inadequate training effort. Inadequate training includes initial training that requires improvement to increase the awareness of employees. Specifically, this accident highlighted the need to have employees orientated to the underground mining environment during training.

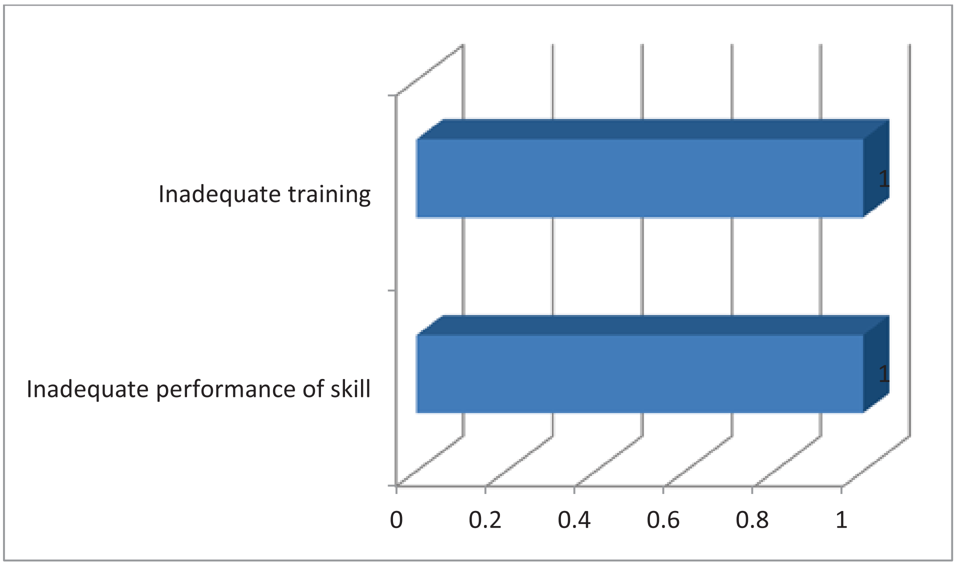

Figure 34: Root Causes of Barring Accidents

Both these investigation reports were completed well, as all contributory causes to the accident were identified and highlighted so that the corrective actions that followed were appropriate. Technical detail on the influence of geotechnical environment is concise where this factor contributed to the occurrence of the accident.

Discussed below are the ten key areas identified to be crucial to a proper root cause assessment for the barring act. It will be observed that many correlations can be drawn to the root cause assessment.

13.4 Discussion of the ten key identified areas

13.4.1 Risk Assessment

Barring is a task that needs to be quickly and internally risk assessed by the person who intends to bar down. Apart from the issue-based risk assessment for the critical task of barring, the crew should conduct a continuous risk assessment for tasks that are deemed extremely hazardous. Analysis of the accident reports shows that neither accident included the completion of a risk assessment. This is thoroughly unacceptable as both accidents could have been avoided through proper hazard identification.

The risk assessment may have comprised various forms such as a panel risk assessment, a Stop-Look-Assess-and-Manage (SLAM) process or even a Trigger Action Response Plan (TARP) system such as the Hazard Identification Treatment System or Team Supervisor Management system (TSM). At some mines, both a pre-work assessment and a safe declaration are also completed. Had risk assessments been completed (even visually) of the areas being worked in, it is believable that both of these accidents could have been prevented.

13.4.2 Skills

When analysing whether injured persons had the necessary skill to complete the task of barring, it is clear that the requisite skills to bar was not present. In the first accident analysed, the individual's years of experience did indicate that he should possess the skill of barring. On the other hand, it was also clear that the new employee did not have the experience needed to possess this skill.

13.4.3 Training

100% of the accidents (Figure 35) showed the need for initial training, refresher training or on-the-job coaching. This means that one accident occurred where one injured person did not receive barring training or initial underground training that adequately prepared the employee for the job she was to perform. The other employee clearly requires re-training or a refresher of the concept of hazard identification.

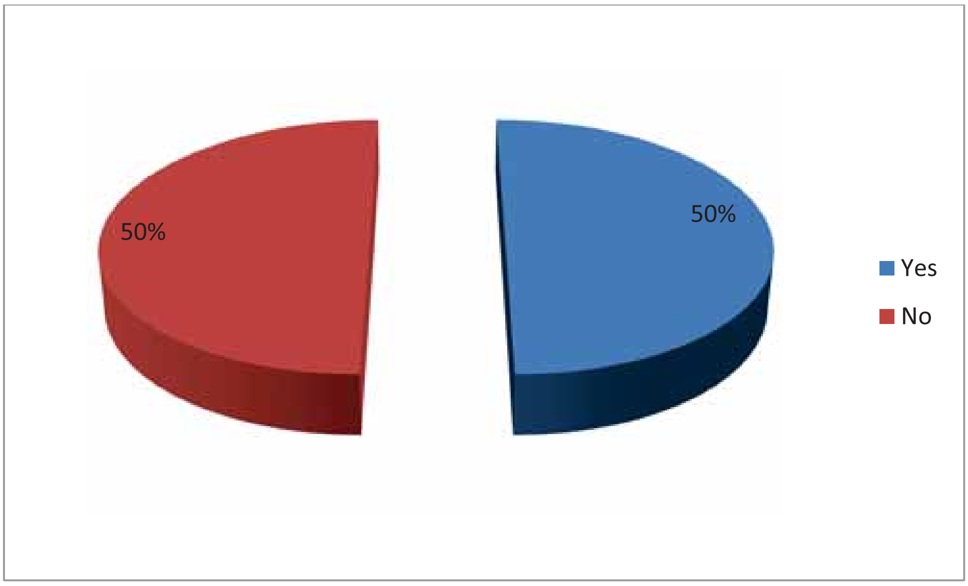

Figure 35: Presence and Absence of Training

The training material that is being developed as part of this project is innovative and will be developed in alignment with study findings and to address the root causes of barring accidents. Positive coaching will be present throughout the program and will show the power of leadership via the story. Hazard identification will also comprise a module within the training material. There is substantial evidence from both the root cause analysis and the underground visits to indicate that a large number of underground employees cannot differentiate and identify typical geological structures present in their environment. Questionnaire respondents (5% of total number of respondents) indicated that they cannot differentiate between various rock types and would like to learn how to do so.

13.4.4 Equipment Selection

Correct equipment selection is vital to the successful completion of any task. The incorrect use of tools and equipment may contribute to the immediate cause of an accident in the following ways (IRCA, 2009):

- The improper use of equipment: where equipment was used for activities for which it was not designed.
- The use of defective equipment: knowing that the equipment was defective and still going on with the work.
- Improper placement of tools, equipment or materials: equipment is placed in a potentially hazardous position.

The barring accidents reviewed show that equipment selection was not the main cause of the accidents that occurred.

All barring standards include rules or steps that stress the checking of the equipment/ pinch bar. They are worded typically as follows: “Select the correct length of pinch bar to be used, examine the condition (not bent and sharp at ends), and ensure it is fitted with a gasket.

The following pictures taken at the various coal champion mines show various aspects of equipment selection for conventional barring processes (Figure 36 to Figure 41).

Figure 36: Fibre-glass combination pinch bar with sounding stick on one side and pinch bar on the other (Mining House G)

Figure 37: Opposite end i.e. Sounding stick side with copper end (Mine/ Shaft 7)

Figure 38: Traditional wooden sounding stick with copper end – Note that the copper end does not cover the flat end of the stick. Suppliers are currently being contacted to ascertain the reasons for this – Mining House H.

Figure 39: Barring with a conventional hollow steel tube pinch bar with the secured steel gasket (Mining House F)

Figure 40: Mechanical Scaler used in Out-bye area (Mine 10)

Figure 41: Discarded old and bent pinch bars on surface (Mine/ Shaft 3)

13.4.5 Geotechnical Environment

Shown below in **Table 13** are the local geotechnical aspects prevalent at the scene of the accidents and whether they made any contribution to the cause of the accident. Roof failure in the South African coal mines is mostly controlled by the frequency of laminations in the roof. A number of tools assist in the planning of mining areas to assess the hazards prevalent. These include ground condition ratings, ground hazard plans or ground control districts.

The differentiation between broad geotechnical mining environments where conditions are similar over a large areal extent to local Ground Control Districts (GCD) per mine/ shaft is detailed in the Code of Practice (COP) to combat Rockfall and Rockburst Accidents.

As the champion collieries extended from the Witbank area to the coal fields of Northern Kwa-Zulu Natal, geotechnical considerations specific to both areas and then to each seam will be listed below. The conditions prevalent in the mining of the top and bottom seam in Kwa-Zulu Natal include:

- Roof and floor conditions that are generally moderate to poor and require a higher level of roof support.
- Pillar sidewall and corner deterioration over time is expected where the full mining height is exploited.
- There are numerous dykes intersecting the coal seam, with random strike orientation.
- Geological anomalies in the form of slips and joints sympathetic to intrusions are expected to intensify in close proximity to the dykes.

Typical geotechnical considerations when mining the 2 and 4 Seam in the Witbank area are:

- 2 Seam - In areas where the roof shales are not slickensided or fractured, roof conditions are generally good. Where mining does not extend to the top of the seam, the residual roof or top coal also forms a stable roof in most cases.
- 4 Seam - In certain areas, intra-seam partings comprising siltstone, shale and occasionally sandstone, occur. The floor, comprising largely sandstone or a sandstone/siltstone combination is expected to be reasonably competent. The immediate roof, however, consists of an interlaminated unit of shale and siltstone and may present roof stability problems.
- Other structural influences include:
    - Dolerite dykes ranging in thickness from 0.5 to 3.5m in thickness are commonly encountered underground. Burning associated with dykes and the thickness of this zone varies considerably. Also, it may not relate to the thickness of the dykes.
    - Jointing is more prolific near intrusions and fault zones.
    - Dominant horizontal stress directions and local variations associated with large structures.

Table 13: Contribution of geotechnical environment to the cause of the accident

Accident number	Year	Mine/ Shaft	Seam and Roof	Other conditions
1	2012	11	2 Seam with Shale Roof	Presence of dyke, sympathetic jointing and numerous loose slabs in roof
2	2013	4	4 Seam (Roof is unknown)	

Shown below (Figure 42 to Figure 44) are various examples from the champion mines of typical geological structures that influence the mining of the seams.

Figure 42: Sandstone parting in 4 Seam (Mine 7)

Figure 43: Typical slabbing and fall outs in a dyke area of Top Seam (Mine/ Shaft 3)

Figure 44: Scaling of rib-sides (Mining House I)

13.4.6 Size of Excavation

Figure 45 shows that both accidents occurred in excavations where the height exceeded two metres. This is normal in the coal mining environment where roadways typically range from 3.5m high to 4m high.

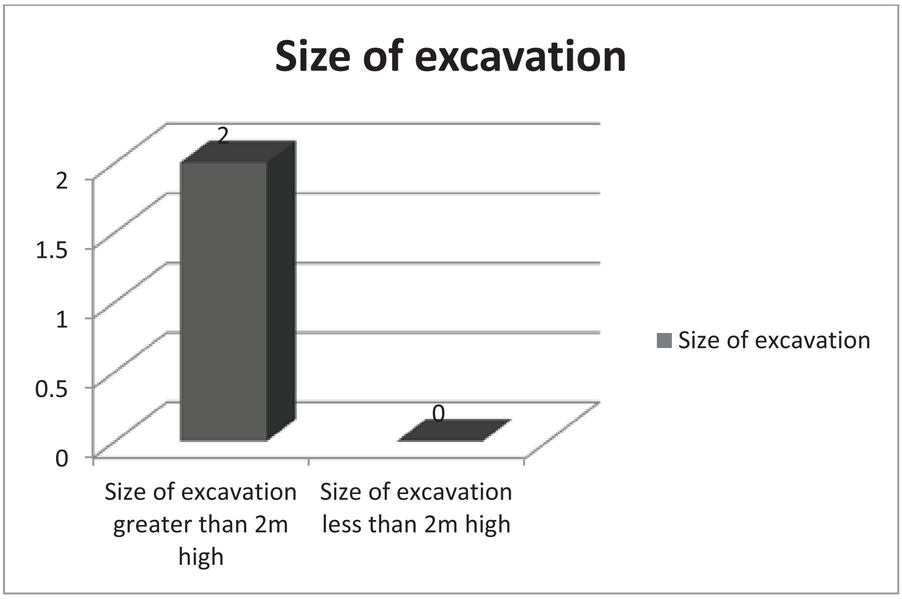

Figure 45: Sizes of excavations where accidents occurred

Conventional barring strategies in excavations of varying heights necessitate the use of different lengths of pinch bars. 3m long pinch bars are typically made of lighter materials such as hollow steel tubes and fiberglass to reduce the weight of the bar. Thus, the choice of equipment is directly influenced by the height of the excavation that the barer is working in. The task must be performed from a safe distance but also from a distance such that the required leverage can be obtained.

It is typically recommended by most mine standards that both the sounding stick and the pinch bar should be at least 0.5m shorter than the height of the excavation that you are working in. Where excavation heights exceed 3.8m, underground workers stress the importance of having a variety of pinch bars of varying lengths.

13.4.7 Leadership

Analysis of the coal accidents showed the lack of good leadership being a factor that contributed to one of the accident occurrences (***Figure 46***).

Good leadership comprises visible felt leadership principles and ensures that supervisors and managers show the required promotion of safe behaviours. The findings of the social study provide a good insight into why leaders are not perceived to be succeeding in promoting safe behaviours.

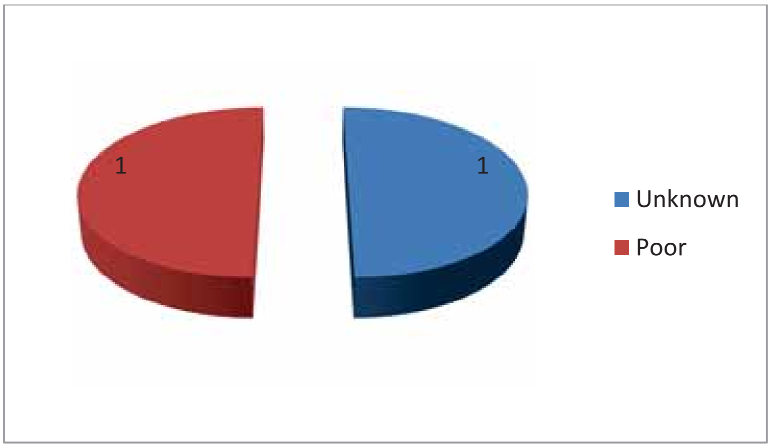

Figure 46: Contribution of leadership to barring accidents

13.4.8 Human Behavior

In determining whether the injured person's or any employee's behavior caused an accident, the following questions may be asked:

- Is improper performance rewarded?
- Are supervisors not giving a proper example to people working in the organisation?
- Are critical safe behaviours identified?
- Is there sufficient reinforcement of critical safe behaviours?
- Are people aggressive in the actions and decisions that have been taken?
- Have production incentives created an incentive to ignore safety requirements?
- Do supervisors imply that haste in completing work is more important than safety considerations?
- Do employees perceive that haste is necessary in the completion of work which is more important than safety considerations?

- Does an employee have a settled or regular tendency or practice that is difficult to give up?
- Did the employee willfully cause malicious damage to property, process or the environment?

In asking the above questions, it was found that both accidents were caused by poor human behavior.

13.4.9 Communication

Poor communication is evident in most of the environments where accidents do take place (Figure 47). Communication considered for this key area is that between crew members and from supervisor to crew level.

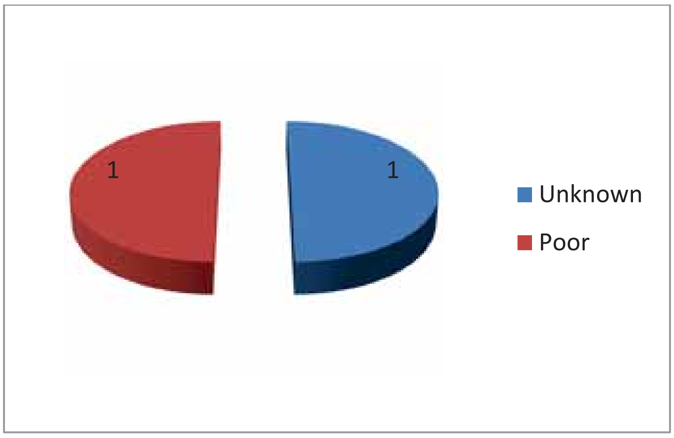

Figure 47: Contribution of Communication to barring accidents

13.5 Milestone Observations

- Coal mining appears to experience less barring related incidents and accidents than platinum or gold mining. This is due to smaller crew sizes and the mechanised mining environment which generally places operators out of harm's way at the panel faces. Barring in still mostly performed manually leaving opportunities to improve the safety of this practice. The small number of accidents that have occurred at the champion mines over the past few years is positive and shows that training alone may alleviate the reoccurrence of such accidents.
- Corrective actions are fair as they address the causes of the accidents and seem to be geared to prevent recurrence of such barring accidents.
- Most common corrective actions taken after an accident include re-training and the completion of PTO's, adherence to barring and entry examination standards.
- Initial employee training was changed to be completed in the underground environment rather than on surface.
- Lighting in an area was improved post an accident.

- Training improvements, interventions and perhaps a greater emphasis on refresher training is required. The training aspects related to barring will be explored in more detail in future milestones of the study but it is clear from site visits at the collieries that hazard identification needs to be focused upon.

13.6 Milestone Conclusions and Recommendations

This milestone report has analysed coal barring-related accidents some recommendations can be made.

It is evident that the quality of the coal mine accident reports are good as they correctly identify root causes of the accidents being investigated.

14 Root Cause Analysis of Barring-Down Related Accidents from On-site Data - Gold

This chapter represents the final outcome of Milestone 4 of the study, being a root cause analysis of barring related accidents from data obtained directly from the champion mines that have volunteered for the study. Two mining houses with sixteen mines/ shafts are the gold champion mines for the project. Years 2011 and 2012 have been considered for the analysis. Root Cause Analysis (RCA) seeks to ultimately identify the basic cause of an incident or accident, and then to address the cause to ultimately prevent recurrence of such accidents.

The sixteen mines/shafts visited include Hlanganani, Masakhane, Rethabile, Bambisanani, Khomanane, Ya Rona and Pitseng shafts at Sibanye Gold's Driefontein operations. Ikamva, Manyano and Hlalanathi were visited at Kloof Gold mine. In completing the Sibanye gold contribution to the study, Cooke's 1 and 3 shafts were visited. Mponeng and Tautona were volunteered by Anglogold Ashanti as champion gold mines and important observations were made at these operations.

The gold mine data collection phase encompassed many underground shifts (early shifts) undertaken by three Golder personnel (reducing to one person towards the second half of the site period) to observe the act of barring during entry examination in order to identify leading practices for the activity, and determine what practical solutions could be suggested.

Shown below is the number of reports obtained per mine (Table 14). All reports were reviewed to find those accidents most relevant to the study.

Table 14: Accident reports

	Total number of reports obtained	**Total number of relevant reports**	
	All years	**2011**	**2012**
Mine/ Shaft 1	-	N/A	N/A

Mine/ Shaft 2	28	0	0
Mine/ Shaft 3	15	0	1
Mine/ Shaft 4	15	0	1
Mine/ Shaft 5	25	1	0
Mine/ Shaft 6	-	N/A	N/A
Mine/ Shaft 7	-	N/A	N/A
Mine/ Shaft 8	-	N/A	N/A
Mine/ Shaft 9	-	N/A	N/A
Mine/ Shaft 10	-	N/A	N/A
Mine/ Shaft 11	12	2	0
Mine/ Shaft 12	23	1	1
Mine/ Shaft 13	10	1	0
Mine/ Shaft 14	31	1	0
Mine/ Shaft 15	16	1	6
Mine/ Shaft 16	3	0	1

Only a few accidents were found to be relevant to the scope of this study after multiple reviews of the reports. There were multiple requests to many of the shafts visited, but data was not provided by many.

Some mines/ shafts did not provide any information for root cause analysis and thus were omitted from the Root Cause Analysis phase. Other relevant data from that mine have been used for leading practice and underground assessments.

Seventeen barring related accidents occurred at the sixteen champion mines during the years 2011 and 2012. These accidents took place during the act of barring and not due to a lack of barring. A previous lack of barring may have contributed to the accident taking place. However, the focus of this study is to identify where the act of barring can be improved. Seven accidents took place during 2011 with a slight increase in the number during 2012 when ten barring accidents occurred. The details of the accidents will be explained further, below.

14.1 Root Cause Analysis - Gold

Seventeen barring accidents were analysed for their root causes. Shown below (Table 15) is the number of accidents that resulted in injuries (both minor and serious combined). It should be noted that no barring related fatalities were present in this data set.

Table 15: Distribution and severity of barring accidents (Gold) during the study time period

	2011		**2012**		**Total**
	Injuries	Fatalities	Injuries	Fatalities	
Mining House D	6	0	3	0	9
Mining House E	1	0	7	0	8
Total	7	0	10	0	17

The dominant type of contact for the accidents analysed is “Struck by” (Figure 48). 94% of incidents are the ‘struck by’ occurrence where the person has been contacted abruptly and forcefully by an object in motion. It is known that the object is a rock that is dislodged from either the hanging wall or the sidewall underground. One accident was caused by falling from elevation to a lower level during the act of barring. This accident occurred in a box hole where the injured person was not wearing a safety harness.

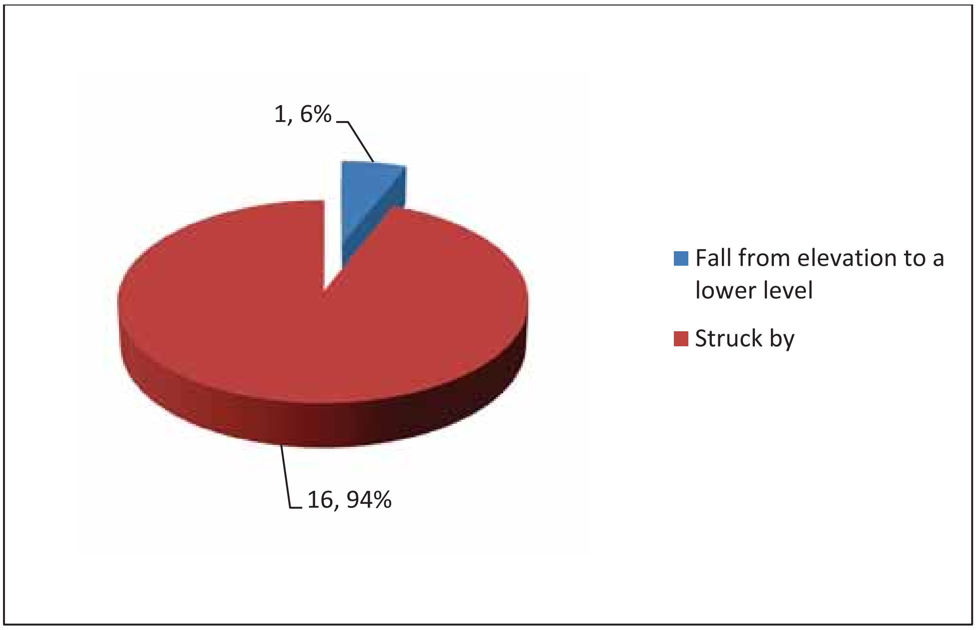

Figure 48: Type of Contact of Barring Accidents

The natural assumption when considering barring accidents is that the most common agency responsible for injuries is falls-of-ground (FOG) and this is reflected upon analysis of the data set. 82% of the accidents were caused by FOG (shown in Figure 49). The data set also comprised one rolling rock accident, a slip and fall accident as well as an injury during barring caused by a seismic event.

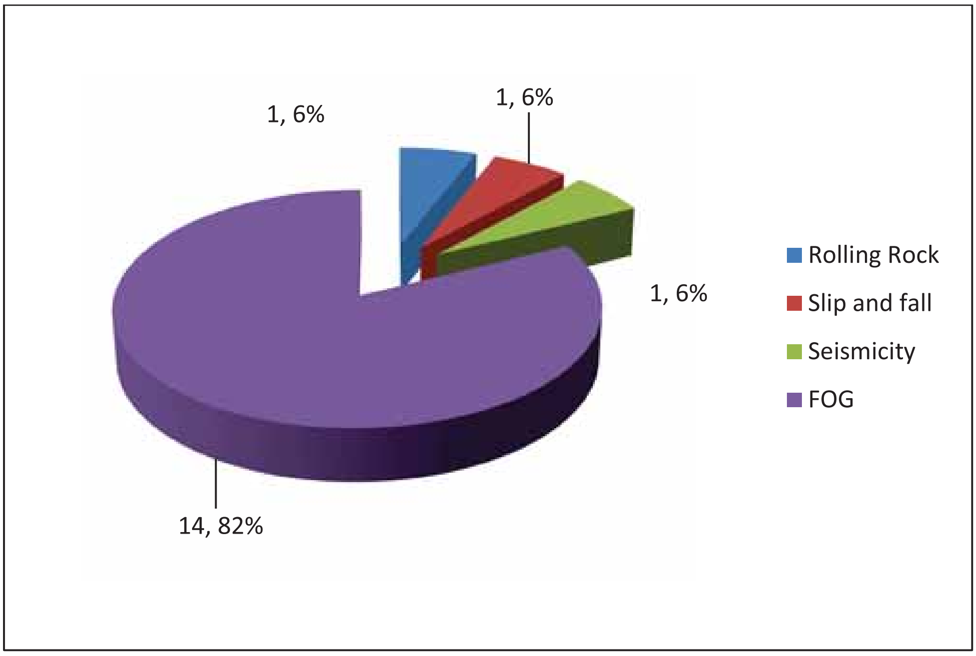

Figure 49: Agency of Barring Accidents

The next step in the root cause investigation led to identifying the consequence of each accident as well as the likelihood that there would be a recurrence of such an event. When the likelihood of recurrence is moderate, then a causal investigation is typically recommended. However, if the likelihood is high that a similar accident will recur, then a full RCAT investigation is recommended. It should be noted that a full investigation was completed for all accidents being investigated in this study.

Only five out of seventeen accidents had a moderate likelihood of recurrence classification, indicating that the risk of barring accidents happening once again is high. All other accidents (11) had a high likelihood of recurrence, indicating that the occurrence of accidents during the act of barring is common. Whilst these may not translate to serious injuries, the number of incidents if reliably reported would show the need for focus on improving the safety of the act. Equally as important is the practice of the act of barring as this eliminates many more accidents that would have occurred.

Figure 32 shows the areas of the mine where the accidents took place. The stope face dominates as a problem area with ten accidents (59%) taking place at the face whilst only three accidents (17%) occurred at development ends.

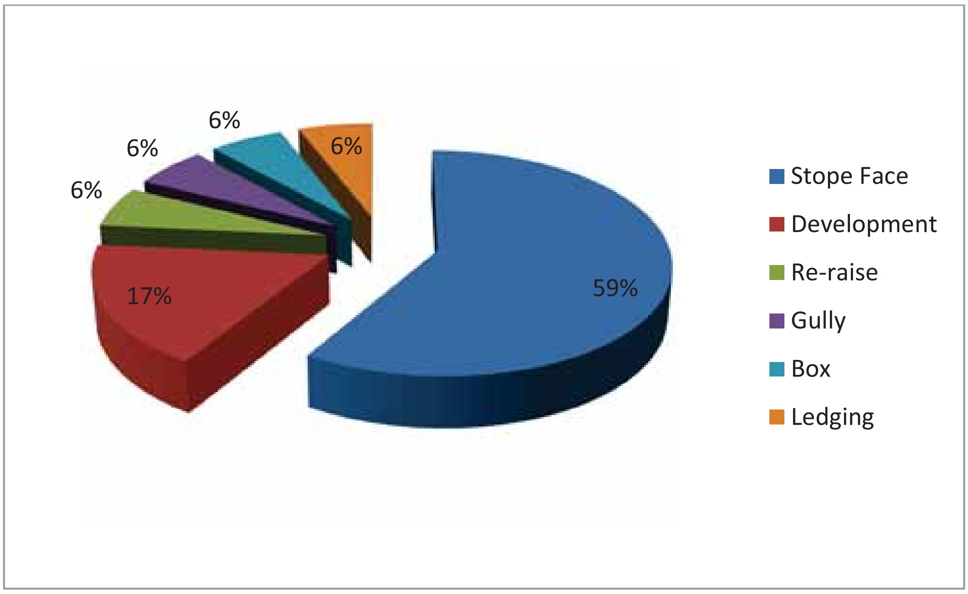

Figure 50: Area of excavations underground where accidents took place

Table 16 gives brief descriptions of the actual barring accidents and the circumstances contributing to them.

Table 16: Brief description of gold commodity barring-related accidents

Accident number	Brief description	Preliminary assessment of contributory immediate causes based on evidence in investigation
1	During barring operations, a rock dislodged from the hanging wall and struck the miner on his right foot.	Entry into the no-go zone without the installation of temporary support. Hanging wall condition is compromised due to inadequate support spacings. Incorrect positioning is a direct cause.
2	Whilst the team leader was barring loose rock from the face, a rock dislodged and struck a fellow employee.	Entry into the no-go zone took place and there was a failure to determine poor drilling and blasting discipline. The poor discipline led to the existence of poor ground conditions at the panel.
3	Whilst the team leader was removing rocks from barring on the face, a rock dislodged from the hanging wall and struck him on his right wrist causing a laceration.	It is probable that barring was not completed well. Also, nets were available but had not been used.
4	A rock drill operator was struck by a rock from the hanging wall, while barring.	Barring procedure was not followed - deduced that incorrect positioning was taken. Injured was within a metre from installed support. Insufficient information to ascertain root cause.
5	A rock from the top of the face dislodged and struck the injured person on his right foot. No continuous barring was done whilst collaring holes.	No continuous barring had been completed during drilling operations. Crew had only trained on the golden rules of barring and not on continuous barring.
6	The injury occurred when the stoper was doing re-entry examination. A rock dislodged from the hanging wall and struck the person.	Inadequate barring was done at the area. Complacency contributed to the

		lack of barring procedures being adhered to.
7	Whilst the injured was barring, a piece of rock dislodged from the hanging wall and struck him on his hard hat and then his left shoulder.	Non adherence to barring procedure i.e. barring from an unsafe position.
8	Whilst the Rock drill operator was busy drilling, his assistant barred a piece of loose rock from the hanging wall. The rock struck the drilling machine and deflected on to the injured person's left shin causing a laceration.	Poor judgement including failure to warn contributed to this accident.
9	Whilst barring at the face of the panel, a strain burst occurred and a rock struck him on top of his right foot.	Seismic
10	A rock drill operator was busy barring when a rock dislodged from the hanging wall and struck him on his left leg resulting in a fracture.	The injured positioned himself under uninspected hanging wall. A short pinch bar was used.
11	Whilst barring the face, a rock dislodged and struck the injured on his right foot.	It is likely that incorrect positioning led to this accident.
12	Whilst barring, the injured paused to remove something from his glove, when a rock dislodged from the hanging wall and struck him on his left hand causing a deep laceration.	Poor ground conditions resulted after mining through a dyke and the support standard was adhered to.
13	While resting in the dip gully whilst barring, the injures was struck by a rock dislodging from the hanging wall	Lack of awareness by the individual and inadequate barring by him of the hanging wall above himself.
14	Whilst barring in a box hole, a rock dislodged from the hanging wall and fell onto the platform which caused the injured to fall off the platform. This caused an injury to his right shoulder.	Not wearing a safety harness even after the injured was instructed to do so, led to this accident occurring.
15	Whilst the injured was busy with barring operations in the panel, a rock from the face was barred down and struck him on his chest and he fell over and bumped his head against the footwall. He sustained a contused chest and punch wound to his head.	Wrong positioning in that the injured was standing on the down dip side when barring was being carried out. Did not follow buddy-buddy procedure.
16	The injured was pulling a water jet hose at the top of the panel. His colleague who was barring up dip of him barred some loose rocks which rolled down to the injured and struck him on his right forearm.	Failure to warn as well as not adhering to the barring standard. Being positioned down dip of the person barring led to the occurrence of this accident.
17	Whilst clearing barred rocks from the rails, a piece of hanging wall dislodged and struck the injured on the head and back.	Failure to react quickly enough. The injured was warned by his buddy.

The Root Cause Analysis was completed using IRCA's technique on the information present in each accident report made available by the champion mines. Even though there are many contributory and possible root causes for an accident, the main root/ basic causes are listed per accident (Table 12). For each root cause and system deficiency that is identified, the reasons why they were chosen are stated in the table.

Table 17: Root Cause Analysis of Platinum Barring Accidents

Accident number	Immediate Causes	Root Causes	System Deficiencies	Reasons for Identification of Root Cause and System Deficiency

1	Deviation by group	Inadequate Leadership - standards of performance not enforced	Planning and Leadership (lack of accountability)	Many individuals were allowed to deviate from carrying out standard procedures as required e.g. substandard support installation and entry into no go zones. It is suggested that this became an accepted norm over time for this crew, indicating a lack of leadership.
2	Failure to warn	Improper supervisory example	Inspections	Inadequate workplace visits by supervisors as poor drilling and blasting practices needed highlighting prior to the accident occurring, hanging wall condition was permitted to deteriorate.
3	Deviation by group	Inadequate identification of critical safe behaviours	Competency and Training needs identified	Refresher training or some type of focus on barring is needed for the crew where this accident took place.
4	Deviation by individual	Unknown	Unknown	Insufficient information contained within report. Thus, the root cause could not be determined.
5	Improper decision making or lack of judgement	Inadequate training (initial)	Competency and Training needs identified	Investigation report clearly indicates that this team required training on continuous barring. It is likely that this training may have eliminated such an accident.
6	Deviation by individual	Inadequate leadership - inadequate safety promotion	Planning and Leadership (inadequate involvement)	The remedial actions taken here indicate that the lack of barring discipline was allowed to continue. It is an extreme measure to stop production in an entire section to bar all areas till solid. There was obviously a need for this action showing that for times preceding the accident, there was not enough of a focus on barring.
7	Deviation by individual	Supervisor implied haste	Planning and Leadership (management commitment)	Production pressure is stated as a contributory cause in the investigation report.
8	Inattention/ lack of awareness of surroundings	Inadequate communication (between peers)	Competency and Training (employee orientations/ awareness)	Lack of awareness and complacency should be addressed with timely refresher training sessions or a dynamic initial orientation program.

9	Work exposure to seismicity	Inadequate Risk Assessments	Management of Operational risk	An adequate risk assessment may have identified a seismically active geological structure and appropriate mitigation measures should have been made.
10	Lack of knowledge of hazards present	Inadequate training effort	Competency and training needs identified	Very basic errors in not following the barring standard shows a need for training or a competency assessment to be undertaken.
11	Deviation by individual	Inadequate leadership - standards not enforced	Planning and Leadership	Evidence in the investigation leads to the discovery that many sub-standards were condoned including non-compliance to the barring procedure.
12	Deviation by group	Inadequate leadership (work-site walk through)	Inspections	Mining at a dyke area necessitated changes in support spacings. This was not adhered to. Inspections and visible felt leadership underground may have picked up on these deviations, or influenced compliance.
13	Inattention/ lack of awareness of surroundings	Inadequate practice of skill	Training program effectiveness	This individual had not developed barring as a skill at the accident time. An optimized training program could do this by allowing time for the skill to develop.
14	Deviation from individual	Habit/ Personal preference	Corrective and Preventative Action Systems	This is a behavioural accident but some type of preventative system can be put in place.
15	Deviation by individual	Employee perceived haste	Corrective and Preventative Action Systems	Communication on prevention of such incidents 'may' have influenced the injured person's perceptions.
16	Deviation by group	Inadequate communication (between peers)	Competency, Training and Communication	Multiple deviations from standard. Communication between peers should have developed.
17	Defective safety devices i.e. damaged WML	Poor reaction time	Inspections	The human error could have been prevented by timely inspection of the workings.

Figure 51 shows the immediate causes of the barring accidents. By far, the dominant and most frequent cause is deviation by the individual. This is indicated by all the evidence given as per the investigation report. 'Deviation by individual' is defined as one person fully aware that he was taking a risk but still decided to do the job that way. Deviation by group occurred in four out of seventeen accidents and this is one step more severe than a deviation by individual as there is now a group deciding to do a job in a way where they are knowingly taking a risk.

Two accidents had an immediate cause of a lack of attention to one's surroundings.

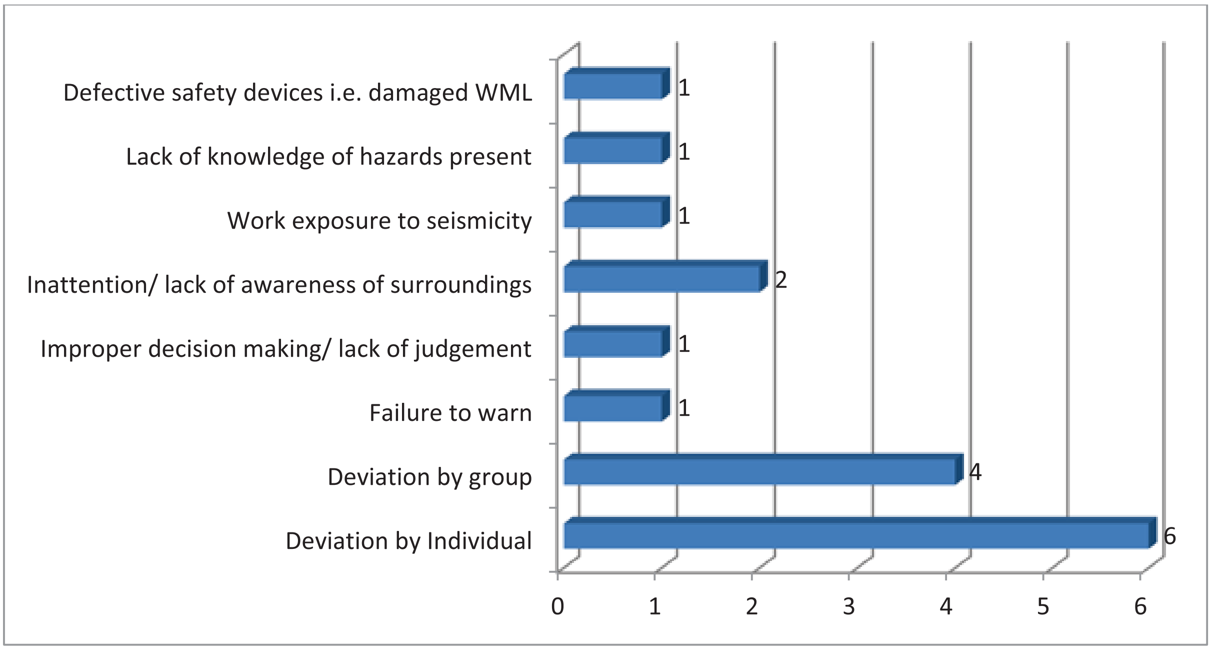

Figure 51: Immediate Causes of Barring Accidents

It is interesting to note how varied the root causes of these barring accidents are. Figure 52 shows inadequate leadership to be a major contributor to barring accidents. This varies from crews where standards of performance are not enforced to inadequate safety promotion to inadequate work-site walk through.

Equally significant as a root cause is inadequate training effort. Inadequate training includes initial training that requires improvement to increase the awareness of employees.

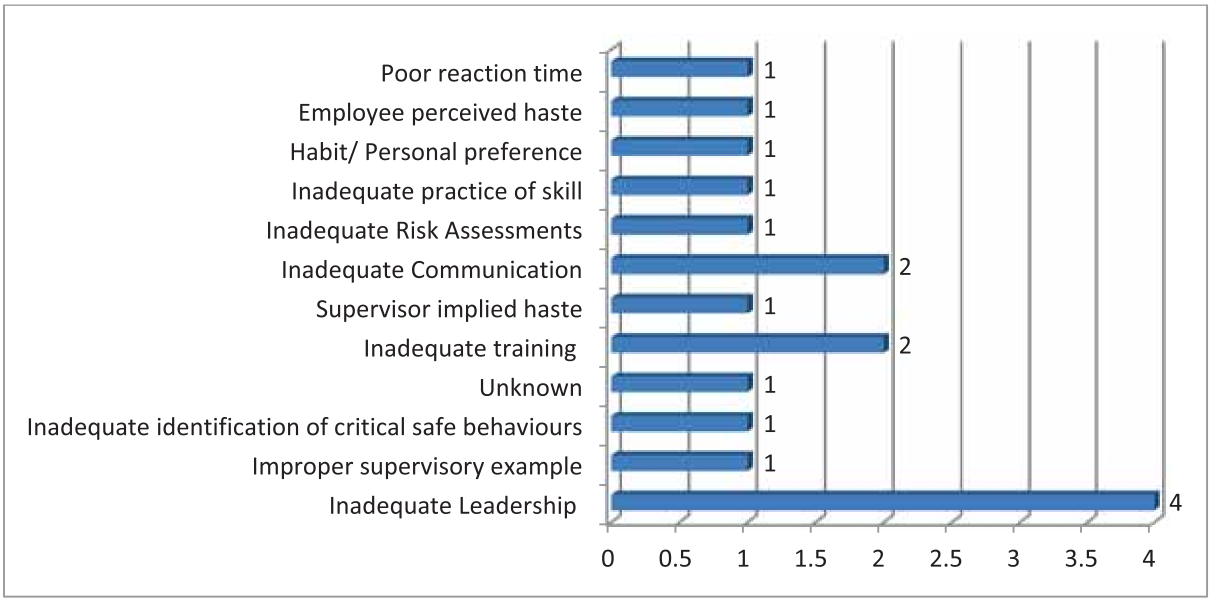

Figure 52: Root Causes of Barring Accidents

Inadequate Leadership is a broad category and the various sub-divisions applicable to these accidents are visibility and safety promotion, or the lack there-of. What this implies is that the person assigned with the responsibility for safety had not carried out their responsibility to the degree necessary for safe work. This includes particular lax standards of performance being tolerated.

Whilst it does appear that emphasis has been placed on human factors, this is only the case because of the evidence provided in the investigation reports. Technical detail on the influence of geotechnical environment and equipment usage is lacking from almost all investigation reports and no presumptions were made about these historical accidents.

Discussed below are the ten key areas identified to be crucial to a proper root cause assessment for the barring act. It will be observed that many correlations can be drawn to the root cause assessment.

14.1.1 Risk Assessment

Barring is a task that needs to be quickly and internally risk assessed by the person who intends to bar down. Apart from the issue-based risk assessment for the critical task of barring, the crew should conduct a continuous risk assessment for tasks that are deemed extremely hazardous.

Analysis of the accident reports shows that only 18% of the investigations were thoroughly completed to include the existence of a risk assessment (Figure 53). This is extremely low and thoroughly unacceptable. The risk assessment may have comprised various forms such as a panel risk assessment, a Stop-Look-Assess-and-Manage (SLAM) process or even a Trigger Action Response Plan (TARP) system such as the Hazard Identification Treatment System (HITS or ABS-P) or Team

Supervisor Management system (TSM). At some mines, both a pre-work assessment and a safe declaration are also completed.

For 23% of the accidents, it is unknown whether a risk assessment had been completed prior to the task being undertaken. It is also likely that the investigator may not have enquired about the risk assessment. Yet another possibility is that the completion of a risk assessment was not mentioned in the report. It is very concerning that risk assessments were not completed for 59% of the barring accidents that occurred in the data set being studied.

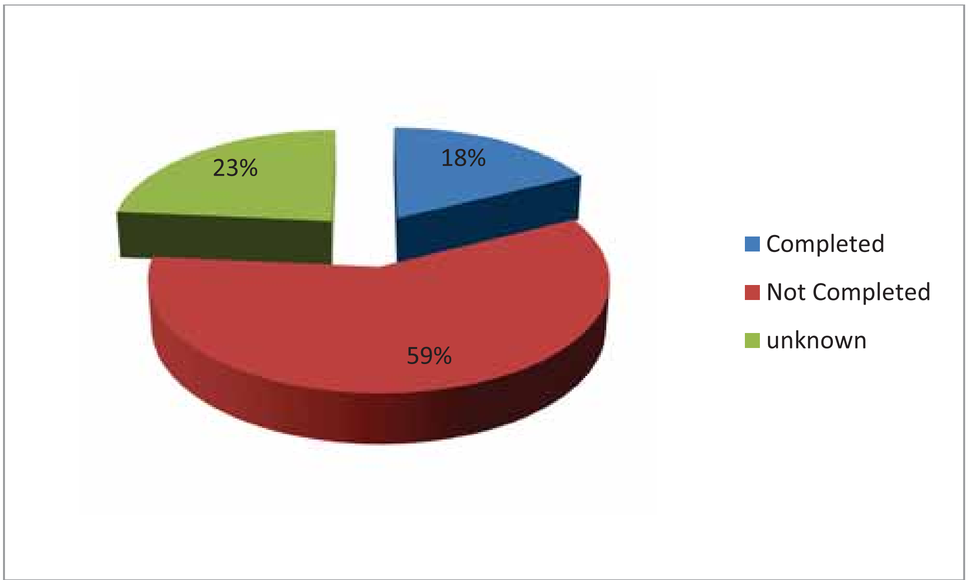

Figure 53. Risk Assessment status for Barring Accidents

The need for better reporting of the accidents is evident as one cannot be certain that risk assessments were completed for a large percentage of the accidents. However, had risk assessments been completed (even visually) of the areas being worked in, it is suspected that many of these accidents could have been prevented.

14.1.2 Skills

A skill is a combination of ability, knowledge and experience that enables a person to do something well (Boyatzis, 1995). The workshop held as part of this project, and mentioned in Section 12.2.2 concluded that barring is a physically demanding task that cannot be taught by training only. It is a skill that needs to be practiced so that the muscle memory can be instilled.

When analysing whether injured persons had the necessary skill to complete the task of barring, it is concerning to note that once again investigators failed to convey in their assessment whether the employees possessed the skill required to bar. 12% of accidents cannot be classified according to skills as this remains an unknown factor from the data obtained (*Figure* ***54***). Where the individual's years of experience did indicate that he should possess the skill of barring, an assumption was made that the skills required were present.

41% of the injured persons possessed the skill to bar. However, 47% do not possess the skill leading to a direct need for the iterative practice of barring by individuals with ability to do the task. Only this can assist in the development of the skill. Knowledge can be addressed by training.

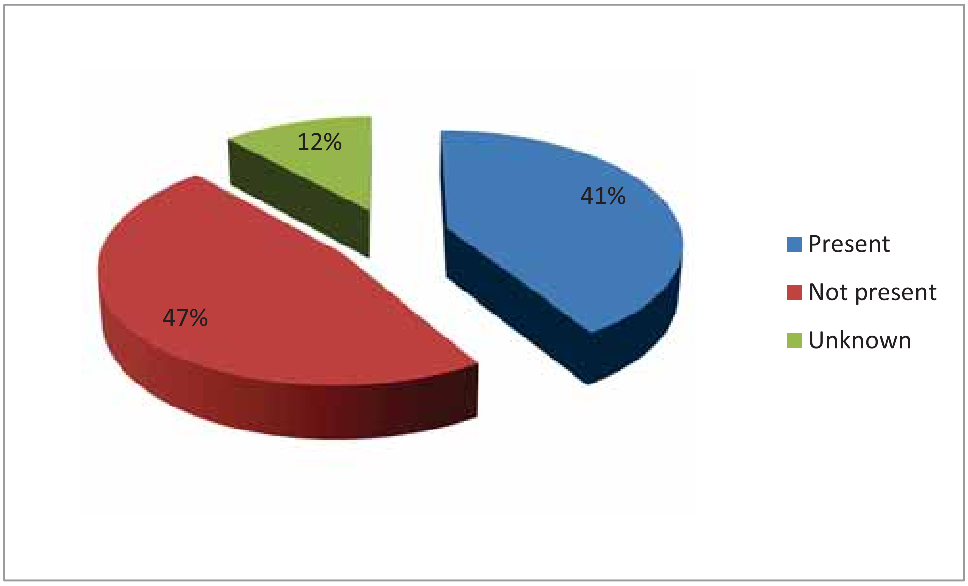

Figure 54: Presence and Lack of Skills required

14.1.3 Training

29% of the accidents (Figure 55) showed the need for training, refresher training or on-the-job coaching. This means that some accidents occurred where the injured person did not receive/ undergo barring training that he could recall or the training received did not adequately transfer the required knowledge to the person. From 12% of the investigation reports, it is unknown whether the persons involved in the accident had sufficient training.

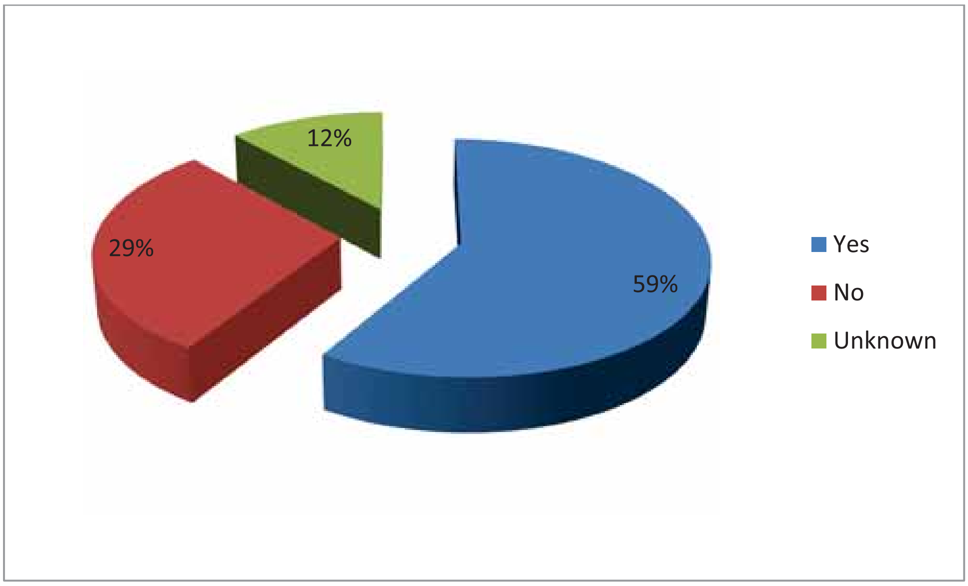

Figure 55: Presence and Absence of Training

It is positive that 59% of the reports showed that training was received by the employee. Training is needed to directly transfer the required knowledge of certain tasks/ processes to the individuals who will need to perform them.

It should be noted that the analyses completed were totally dependent on the information supplied within the investigation reports. The current training material and competency assessments will be assessed independently as these systems may not have been used at the time of these accidents. It is positive to note however, that all champion mines train according to the MQA standard MnH-G538 – Make Safe a Workplace by means of barring. The methods of training vary across operations with classroom with facilitator being favoured on surface and an underground practical training portion being common. Mock mines are also prevalent at most of the operations visited. Currently, most champion mines that previously used computer systems with visual training material to give additional value; have decided to use other approaches for many reasons such as budget, complexity of maintenance systems and quality assurance of the training.

From the root cause analysis it is evident that a lack of leadership is one of the system deficiencies at a few mines. The training material that is being developed as part of this project is innovative and will be developed in alignment with study findings and to address the root causes of barring accidents. Positive coaching will be present throughout the program and will show the power of leadership via the training story.

14.1.4 Equipment Selection

Correct equipment selection is vital to the successful completion of any task. The incorrect use of tools and equipment may contribute to the immediate cause of an accident in the following ways (IRCA, 2009):

- The improper use of equipment: where equipment was used for activities for which it was not designed.
- The use of defective equipment: knowing that the equipment was defective and still going on with the work.
- Improper placement of tools, equipment or materials: equipment is placed in a potentially hazardous position.

The barring accidents reviewed show that equipment selection was not the main cause of the accidents that occurred. It was unexpected that the investigations would choose to ignore equipment usage as much as they have done. 82% of the investigations have no information on the pinch bars used, the quality there-of or even the presence or absence of hand guards/ gaskets. Incorrect equipment i.e. a short pinch bar was used and contributed to causing one accident (Figure 56).

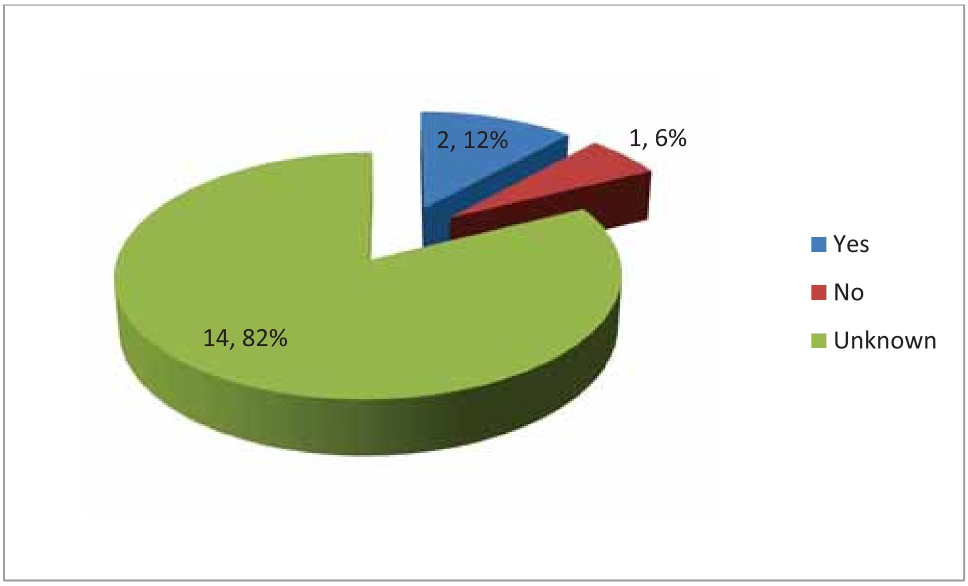

Figure 56: Correct Equipment Selection for the Barring Accidents

All barring standards include rules or steps that stress the checking of the equipment/ pinch bar. They are worded typically as follows: “Select the correct length of pinch bar to be used, examine the condition (not bent and sharp at ends), and ensure it is fitted with a gasket.

Once again, the unavailability of complete investigations shows that it is unknown whether the correct equipment was selected for 82% of the accidents that took place. The following pictures taken at the various gold champion mines show various aspects of equipment selection for conventional barring processes (Figure 57 to Figure 62).

Figure 57: Pinch bar with gasket (Mining House D)

Figure 58: Worn/ Old pinch bar with blunt end (Mine 1)

Figure 59: Pinch bars being used with and without hand guards/ gaskets at Mine 8

Figure 60: Absence of gasket/ hand guard due to it easily sliding off the bar (Mining House D)

Figure 61: 3m long Aluminium pinch bar used at a mock mine (Mine 12)

Figure 62: Pinch bar ready to be used for barring with no gasket fitted on (Mine 7)

14.1.5 Geotechnical Environment

Shown below in Table 18 are the local geotechnical aspects prevalent at the scene of the accidents and an assessment of whether they made any contribution to the cause of the accident. Five accident investigations did not reveal whether geotechnical conditions contributed to the accident. Two accidents were not influenced by the presence of geological structures or other features particularly prevalent in the gold mining environments of South Africa.

The differentiation between broad geotechnical mining environments where conditions are similar over a large areal extent to local Ground Control Districts (GCD) per mine/ shaft is detailed in the Code of Practice (COP) to combat Rockfall and Rockburst Accidents. Strategies such as minimum support requirements per area are also detailed in the COP.

Most noticeable is the influence of fractures (either stress induced or from blasting) on hanging wall condition. Knowledge and understanding of these fractures will lead to a greater awareness of the surrounding area when crew members are undertaking barring and/ or entry examination.

Table 18: Contribution of geotechnical environment to the cause of the accident (Gold)

Accident number	Year	Mine/ Shaft	Depth below surface (m)	Reef/ Geotechnical Environment
1	2011	5	1509	Middelvlei Reef with minor HW damage
2	2011	13	2315	Main Reef
3	2012	4	1972	Middelvlei reef
4	2012	3	1300	Carbon Leader
5	2011	11	-	Unknown
6	2011	11	-	Unknown
7	2011	14	-	Quartzite
8	2011	12	-	Unknown
9	2012	12	-	Unknown
10	2012	15	3391	Steep reef rolls and blast damage to hanging wall
11	2011	15	-	Unknown
12	2012	15	3394	Presence of cross fractures including multiple quartz veins. Presence of dyke.
13	2012	15	3093	Poor ground conditions - multiple joints and blocky.
14	2012	15	-	Box hole - Did not contribute to accident
15	2012	15	3313	Highly fractured zone - steeply dipping
16	2012	15	-	Did not contribute to accident occurring
17	2012	16	3538	Transition zone of Jeppestown shales to Maraisburg quartzites

As the reef type was not always specified, it would not be appropriate to suggest which geotechnical environments are more prone to barring accidents.

Shown below (Figure 63 to Figure 65) are various examples from the champion mines of typical geological structures.

Figure 63: Layering and fractures in lava hanging wall (Mine 8)

Figure 64: Steeply dipping joints in hanging wall lava (Mining House E)

Figure 65: Minor faulting in VCR (Mining House D)

14.1.6 Size of Excavation

Figure 66 shows that twelve accidents occurred in excavations where the height did not exceed two metres. This indicates that the majority of barring accidents took place in stoping environments (Figure 67) at the face area. Four of the accidents occurred in development ends where the height of excavations is typically 3m (Figure 68). A box hole was the location of one accident.

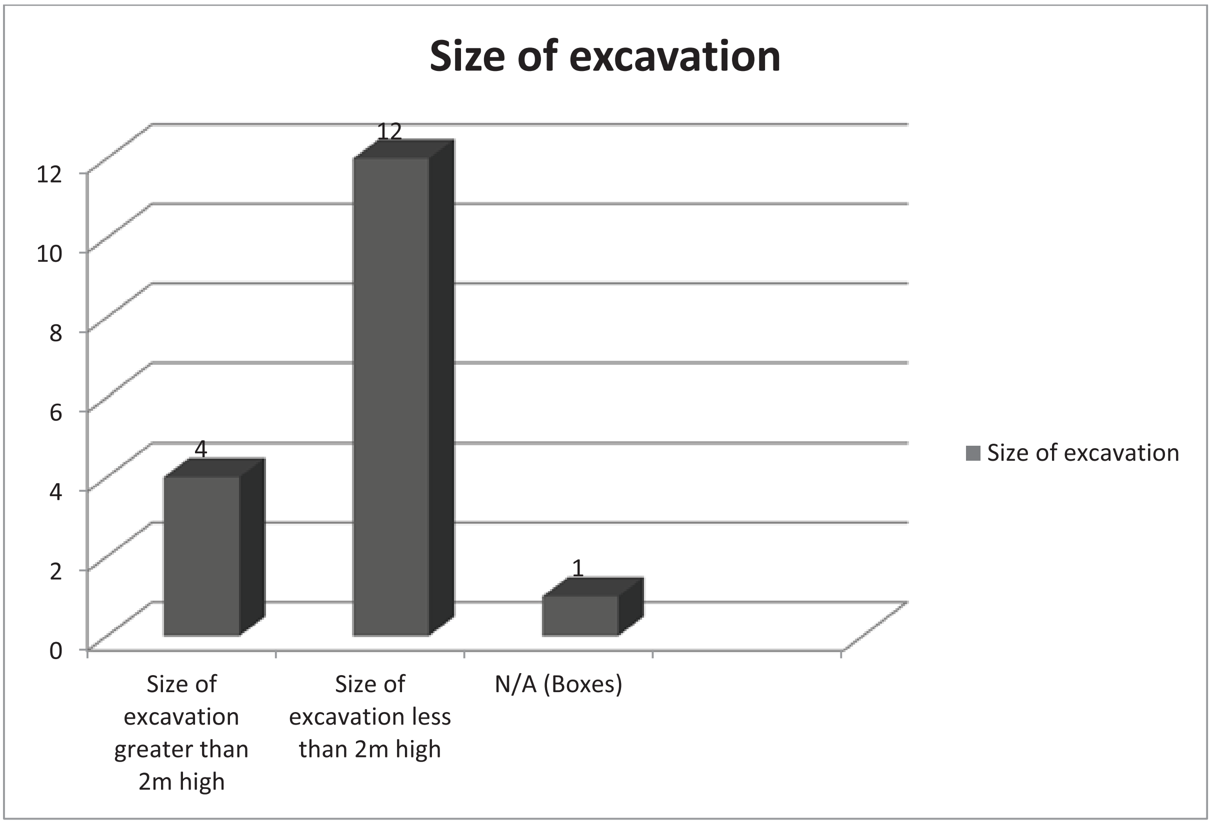

Figure 66: Sizes of excavations where accidents occurred

Conventional barring strategies in excavations of varying heights necessitate the use of different lengths of pinch bars. 3m long pinch bars are typically made of lighter materials such as aluminium and fiberglass to reduce the weight of the bar. Steel pinch bars are used in-stope and vary with lengths of 1m, 1.2m, 1.5m and 1.8m long bars used in gully areas. Thus, the choice of equipment is directly influenced by the height of the excavation that the barer is working in. The task must be performed from a safe distance but also from a distance such that the required leverage can be obtained.

Shown in Figure 67 and Figure 68 below is a typical stope and cross cut.

Figure 67: Typical conventional stope where height of excavation is less than 2m (Mine 8)

Figure 68: Development excavation greater than 2m high with poor hanging wall conditions and overhanging side wall (Mining House D)

Where excavation heights exceed 3m, platforms may be required to be built in order to bar and support the excavation effectively. Excavations of these heights are mostly long-term bulk and fridge chambers where secondary support will be installed and the need to bar continuously will be removed.

14.1.7 Leadership

Analysis of the gold accidents showed 'leadership' or the lack of good leadership being a factor that contributes to the occurrence of the barring accidents. Ten of the seventeen accidents clearly took place in environments where extremely poor leadership was evident (Figure 69). Seven of the accidents arose because of poor leadership.

Good leadership comprises visible felt leadership principles and ensures that supervisors and managers show the required promotion of safe behaviours.

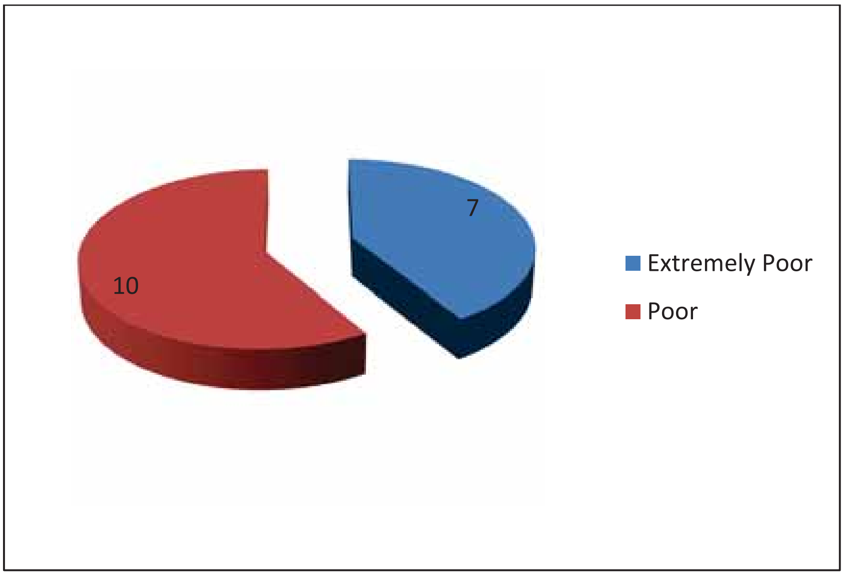

Figure 69: Contribution of leadership to barring accidents

14.1.8 Human Behaviour

In determining whether the injured person's or any employee's behaviour caused an accident, the following questions may be asked:

- Is improper performance rewarded?
- Are supervisors not giving a proper example to people working in the organisation?
- Are critical safe behaviours identified?
- Is there sufficient reinforcement of critical safe behaviours?
- Are people aggressive in the actions and decisions that have been taken?
- Have production incentives created an incentive to ignore safety requirements?
- Do supervisors imply that haste in completing work is more important than safety considerations?
- Do employees perceive that haste is necessary in the completion of work which is more important than safety considerations?
- Does an employee have a settled or regular tendency or practice that is difficult to give up?
- Did the employee wilfully cause malicious damage to property, process or the environment?

In asking the above questions, it was found that four of the accidents were caused by extremely poor human behaviour and nine accidents were caused by poor human behaviour e.g. supervisors present whilst an individual deviates from performing a standard (Figure 70). Fair behaviour was prevalent at four accident occurrences.

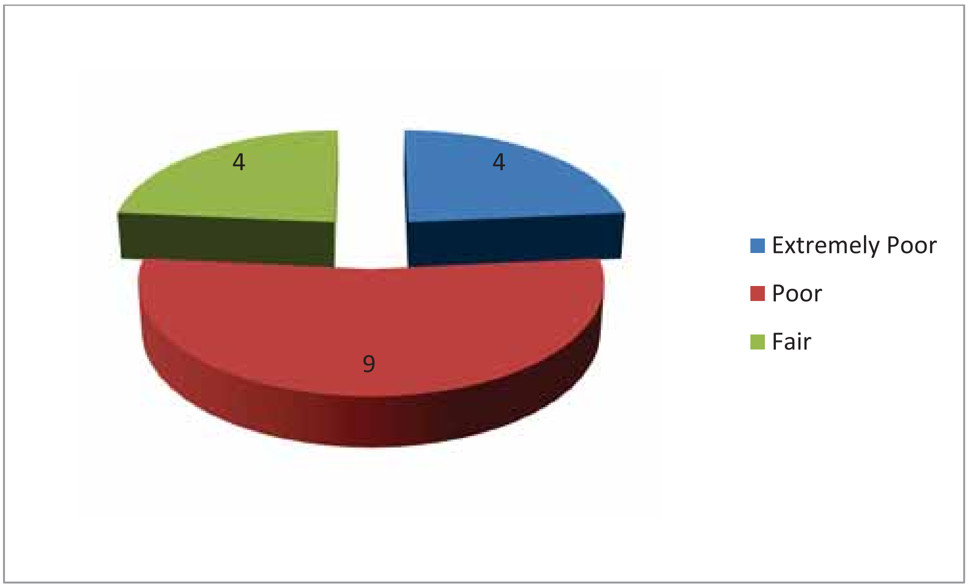

Figure 70: Contribution of human behaviour to barring accidents

14.1.9 Communication

Poor communication is evident in most of the environments where the accidents took place. Only one instance occurred where communication was fair (Figure 71). Communication considered for this key area is that between crew members and from supervisor to crew level.

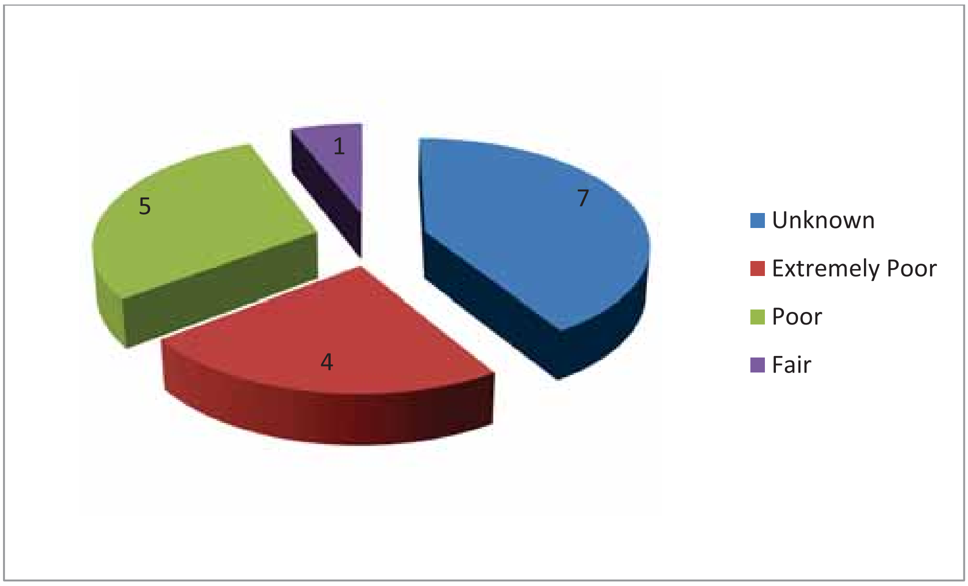

Figure 71: Contribution of Communication to barring accidents

14.2 Milestone Observations

- Most barring investigation reports received had insufficient detail to find out the root cause of the accidents. A lot of inference had to be made in order to arrive at the dominant root causes.
- Where root causes were given, they were often immediate causes or the conditions present that led to the accident taking place.

- The investigation reports supplied placed a lot of emphasis on the influence that the injured person contributed to the accident.
- Many technical aspects such as the contributing factors of the environment (ground condition, geological structures and the influence there-of) and equipment usage are lacking in detail.
- Corrective actions are fair to mostly poor as they often do not seem to be geared to prevent recurrence of such barring accidents.
- Most common corrective actions taken post an accident include re-training and the completion of PTO's, adherence to barring and entry examination standards.
- Rock Engineering and Safety department investigations and reports may be improved to explore the human factors that contribute to an accident more. This is even more applicable when the deviation of the individual is apparent.
- Features of poor investigations that were completed, show that they are directed away from systems. The analysis above attempts to re-classify the evidence given, to expose where system deficiencies obviously exist. In attempting to identify the correct systems to be targeted, the research project can further advance to eliminating such system causes. The analysis of the gold barring accidents shows the need for leadership improvements and leaders to promote safety in a better manner than they currently do. Without this visible felt leadership, it is clear that complacency seems to set in.
- Training improvements, interventions and perhaps a greater emphasis on refresher training is required. The training aspects related to barring will be explored in more detail in future milestones of the study. In particular, strata control training and the use of mock-ups will be analysed. Training material from the champion mines have been obtained and will be reviewed. It can be noted that all mines that were visited use the MQA standard for making safe.

14.3 Milestone Conclusions and Recommendations

This milestone report has analysed seventeen relevant barring-related accidents from the gold champion mines and some preliminary recommendations can be made.

It is evident that the quality of the mine accident reports could be improved to include more details of the accidents, in order to allow a more thorough root cause analysis to be carried out. In addition, human behaviour factors should be included in the reports to allow a better understanding of why workers may have deviated from the accepted barring practices.

Systems to establish appropriate corrective actions need to be established within the mines so that continual barring related training is undertaken in order to ensure that recurrence of the accidents are prevented.

The following recommendations are made to address the findings of this phase of the study:

- Accident investigations must be undertaken by trained teams. Basic identification is lacking from many reports of the location and root causes, so teams need to improve on the data collection and overall reporting of accident details.
- The investigations should consider not only the person's involvement in the accident but also the system failures by the organization that permitted the accident to occur.
- Leadership drives and interventions are clearly needed in the gold industry. This recommendation is aided by the perceptions that have arisen from the social studies undertaken. Lack of discipline can be attributed to the felt absence of leadership and mentorship.

15 Root Cause Analysis Summary of On-site Data Collection

Figure 72 below shows that there was an increase in the number of barring accidents that took place at the champion mines from 2011 to 2012.

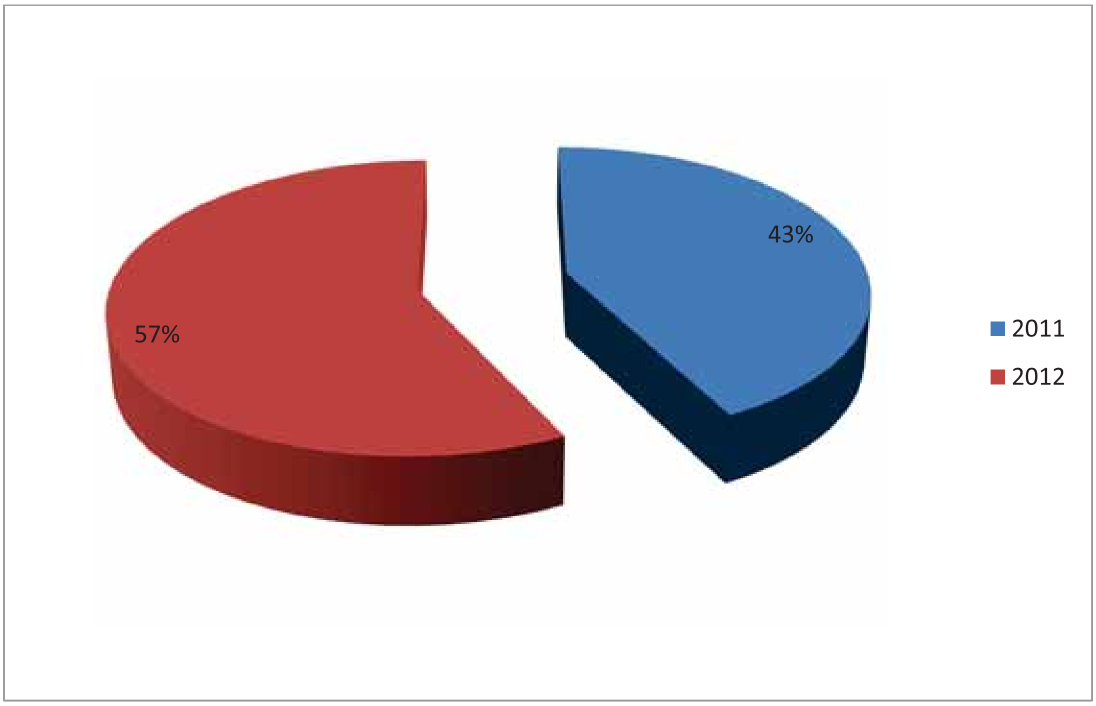

Figure 72: Percentage of total accidents per year

Mining House B of the platinum commodity had the highest number of barring accidents in this data set. It follows that 60% of the accidents took place at the platinum champion mines. Gold barring accidents made up 37% of the data set with only 4% of the accidents analysed taking place at the coal champion mines. Mining House D and E which represent the gold champion mines showed a similar number of accidents for the study period.

Figure 73 shows the immediate causes of the barring accidents. 50% of the accidents analysed showed that the immediate cause was "deviation by individual". As defined previously, this means that the injured employee was fully aware that he was taking a risk but he/ she had still decided to complete the task in that manner.

This indicates that risk and hazard awareness levels are poor and will need to be developed in employees, with a focus on the champion mines in the hard rock environment. Perceptions of exposure to risk need to be more attuned to the reality of the working environments. Thus, a basic hazard identification training module is being developed as part of the training program for this Simrac project. In addition to this, the storyline being developed around certain characters in the training will attempt to make the effects of such deviations more tangible by the impact of the visual animations.

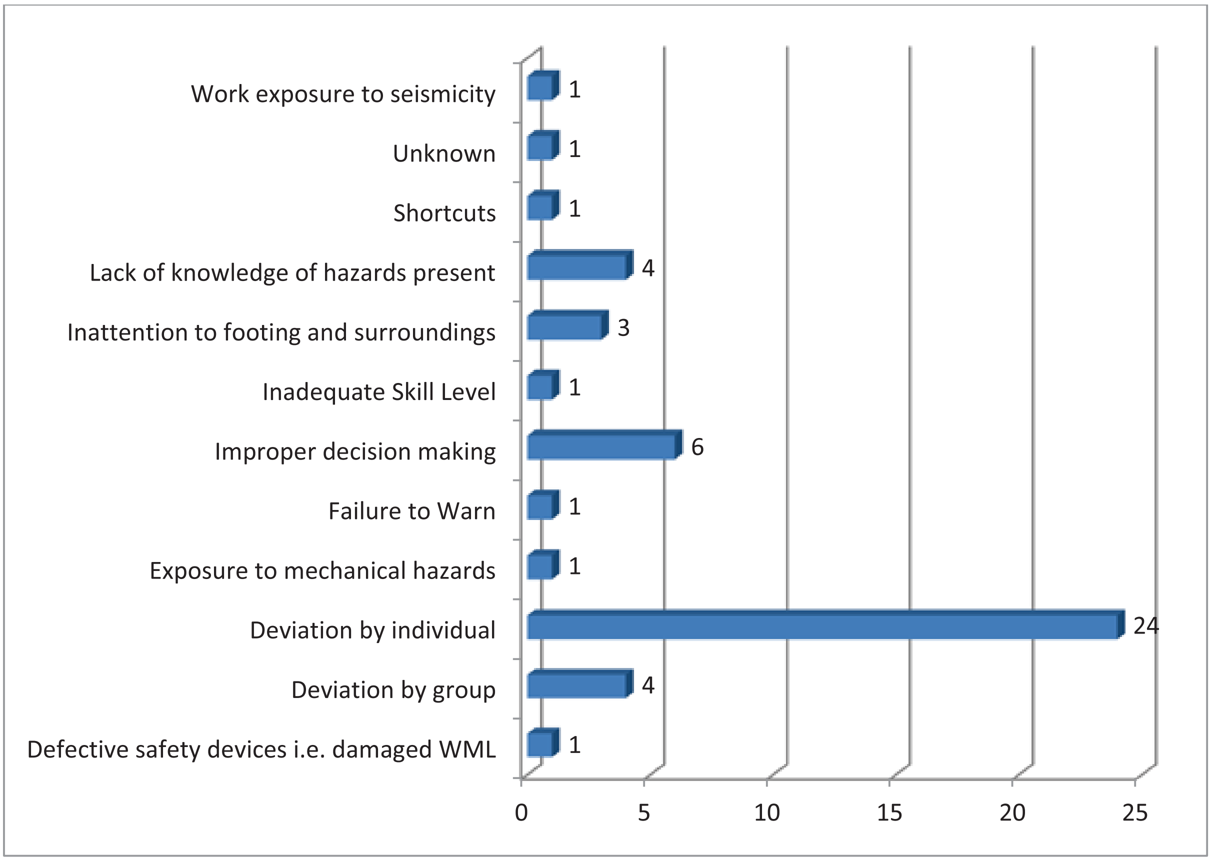

Figure 73: Summary of Immediate Causes of Barring Accidents (All commodities)

Figure 74 shows a summary of the various root causes identified. Inadequate training and inadequate leadership are broad descriptions but each accident can show specific ways in which these systems failed to prevent these accident occurrences. Inadequate leadership in these accidents showed in a multitude of ways manifesting by leaders not showing that they promote safety adequately, standards not being enforced, no visibility of leaders or inadequate work site walk-throughs. Likewise inadequate training as a root cause for eight accidents is comprised of an inadequate recall of the training material by the employee, inadequate training effort by the mine and inadequate initial training or orientation/ awareness training for new employees.

15% of accidents have a root cause of habit or personal preference and this is worrying as it shows that numerous employees have a settled or regular tendency to practice risky behaviour by not barring correctly, not barring at all or even taking up an unsafe position during the act.

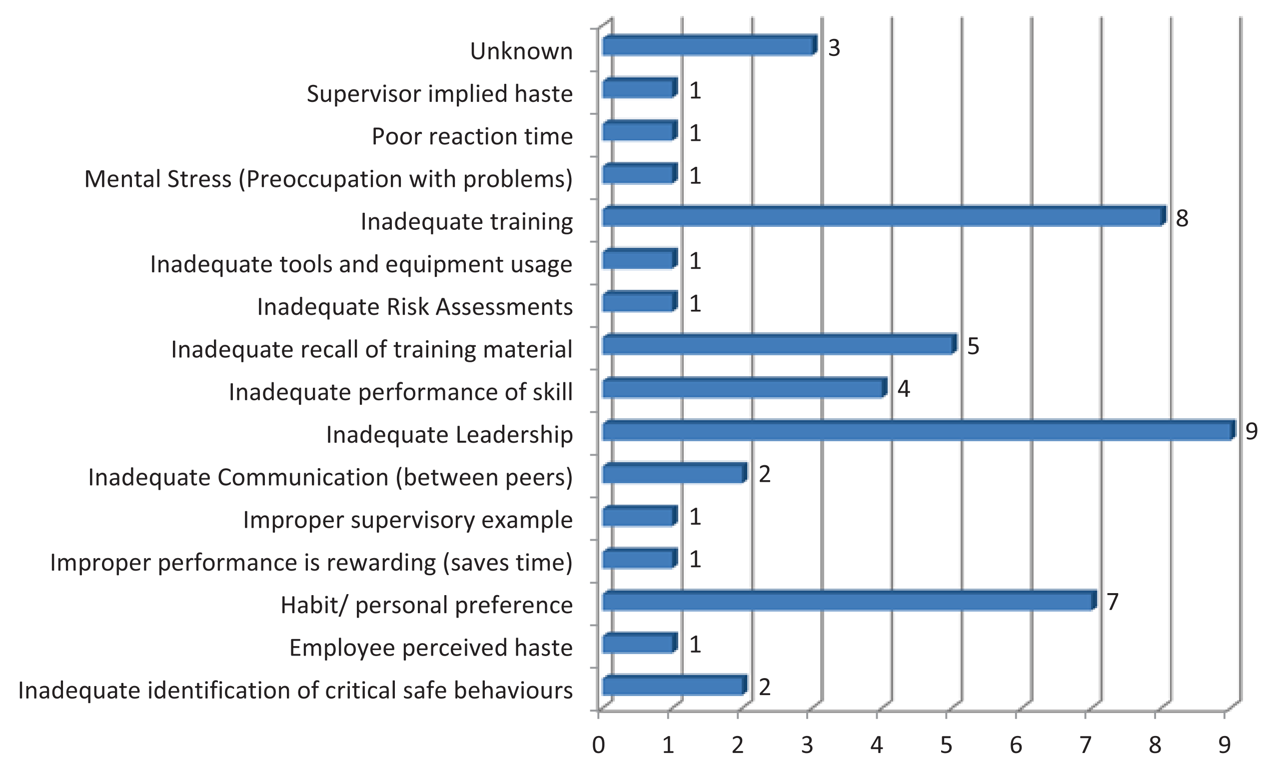

Figure 74: Root Causes of Barring Accidents (All commodities)

16 Root Cause Analysis of Barring-Down Related Accidents from DMR data

This report represents the final outcome of Milestone 6 of the study, being a statistical and root cause analysis of the reportable accidents that form the basis of the DMR SAMRASS database.

16.1 Milestone Results

16.1.1 DMR Accident Statistics

In terms of the requirements of the Mine Health and Safety Act (MHSA) regulations, employers must report certain accidents and dangerous occurrences that occur at a mine to the Regional Principal Inspector of Mines. The data is then captured onto the South African Mines Reportable Accidents Statistical System (SAMRASS), from which the information can be analysed.

The basis of the SAMRASS system is a number of forms that must be completed for each reportable accident. SAMRASS Form 1 requires the following information:

- Section A: Employer Details
    - 01-Name of Mine
    - 02-DME Mine Code
    - 03-Main Commodity
- Section B: Accident or Dangerous Occurrence Details
    - 01-Mine Accident or Dangerous Occurrence Number
    - 02-Number of Persons Killed
    - 03-Number of Persons Totally Disabled
    - 04-Number of Persons Inured
    - 05-Date of Accident or Dangerous Occurrence
    - 06-Time of Accident or Dangerous Occurrence
    - 07-Location of Accident or Dangerous Occurrence
- Surface Operations
- Underground
- Opencast
- Surface Mining
- Aquatic Mining
    - 08-Name of Working Place
    - 09-Depth Below Surface (m)
    - 10-Section

    - 11-Description of Accident or Dangerous Occurrence
    - 12-Accident Classification Code
- Fall of Ground
- Machinery, tools and equipment
- Transportation and mining
- General
- Conveyance accidents (shaft/winze)
- Electricity (not causing fires)
- Fires
- Explosives and accessories
- Subsidence or caving
- Occupational Diseases (non-diving)
- Heat Sickness
- Diving Sickness
- Miscellaneous
    - 13-Dangerous Occurrence Classification Code
    - 14-Did accident occur during normal hours or overtime
    - 15-Did accident occur at normal workplace
    - 16-Average number of persons working during previous month
- Section C: Responsible Persons
- Section D: For use by DME
    - 01-Regional Accident Number
    - 02-Date Reported
    - 03-Type of Accident or Dangerous Occurrence
    - 04-Accident or Dangerous Occurrence Registered By

    - 05-Inquiry Type
    - 06-Probable Cause of Accident or Dangerous Occurrence
- Training or Placement Factors
- Personal Factors
- Job Factors

Most of the sub-sections of the above form have a number of codes or category numbers that can be used to more specifically sub-define each category.

SAMRASS Form 2 requires details of the employee, and details of the injuries. Other SAMRASS forms must be completed depending on the type of accident that occurred – fall of ground, fires, etc.

16.1.1.1 Accidents per Commodity

An *Excel* spreadsheet "*Rates per ACCR 1984-2012.xls"* was provided by the DMR Pretoria office. This contained the official mine accident data (number of fatalities and injuries) for the period 1984 to 2012, plus the provisional figures for 2013. The data was available as a combined number for all the mines within South Africa, plus for the main commodities gold, platinum, coal, diamonds, chrome, copper, iron ore and manganese.

The accident data was provided as raw numbers (number of fatalities or injuries), plus as ratios of the number of accidents per 1000 persons at work within the various commodities, and as the number of accidents per million hours worked within each commodity. Because the number of hours worked within the mining industry has only been accurately determined since 1999, it is only possible to present the data in that format for the period 1999 – 2013.

In the past, accident figures have been quoted as raw numbers of injuries or fatalities, but it has been realised that these numbers do not allow comparative statistical analysis to be carried out because they do not take into consideration the number of people employed within the mining industry, which has generally decreased over the past twenty years. Since 1984 the mining accident data has also been quoted per 1000 workers employed per year in order to overcome this problem. However, it has subsequently been realised that data in this format does not allow risk determinations to be carried out. The international standard for quoting accident rates has become the number of casualties per million man hours worked, and this has been adopted by the mining industry of South Africa since 1999.

Table 19 and Table 20 present the DMR accident data for the 2006 to 2013 period, and Figure 75 to Figure 77 show the combined accident data for all the commodities for the period 1984 – 2013, with the accident data represented as raw numbers, accidents per 1000 workers, and accidents per million hours worked, for the period 1999 - 2013. It is clear from these graphs that there has been a dramatic reduction in fatalities (774 to 93) and injuries (15745 to 3126) during the period studied. Figure 78 shows the accident data per million hours worked within the gold mining industry for the period 1999 – 2013. The number of fatalities have dropped from 0.45 per million hours worked to 0.14 per million hours worked. Similarly, the injury rates have fallen from 9.04 to 4.66 per million hours worked.

Figure 79 shows that during the same period, the number of fatalities per million hours worked within the platinum mining industry has fallen from 0.21 to 0.07. However, the number of injuries has not shown a significant reduction, but has varied between 2.9 and 4.0 injuries per million hours worked.

The accident data for the coal mining industry is presented in Figure 80. The number of fatalities has fallen from 0.23 to 0.08 per million hours worked, whilst the injury rate has varied between 1.4 and 2.4 per million hours worked.

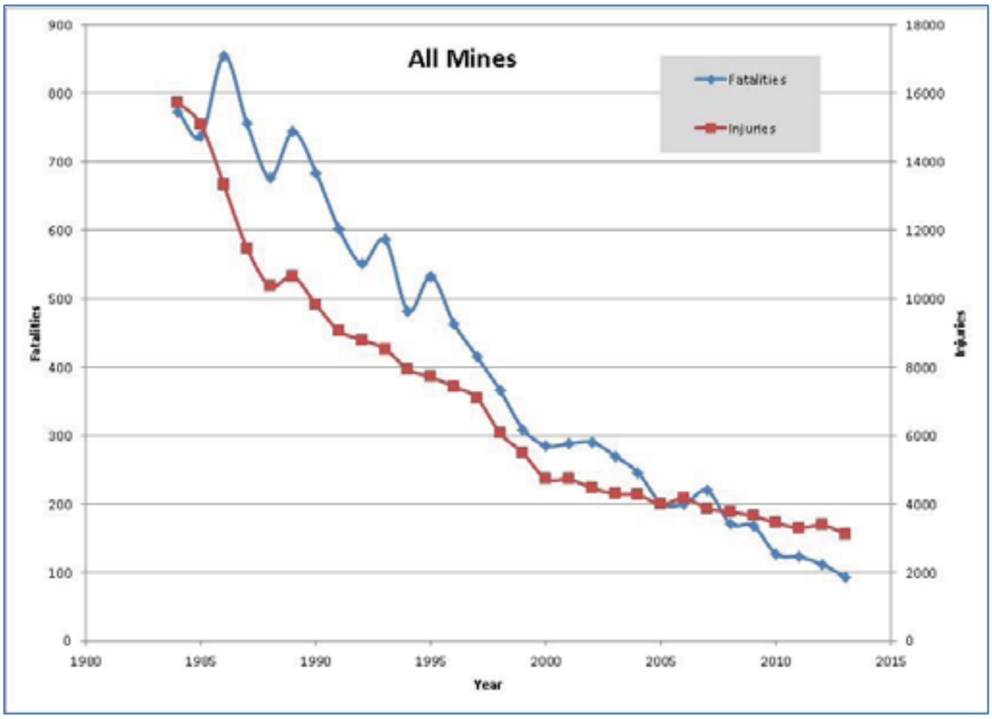

Figure 75: Accident Statistics - All Mines: 1984 - 2013 – Raw Numbers

Table 19: Fatalities per Commodity

Commodity	2006		2007		2008		2009		2010		2011		2012†		2013†	
	Number	Fatality Rate*	Number	Fatality Rate	Number	Fatality Rate	Number	Fatality Rate	Number	Fatality Rate	Number	Fatality Rate	Number	Fatality Rate	Number	Fatality Rate
All Mines	200	0.20	220	0.21	171	0.21	168	0.16	127	0.12	123	0.11	112	0.10	93	0.09
Gold	114	0.35	115	0.34	85	0.25	81	0.25	62	0.20	51	0.18	51	0.18	37	1.14
Platinum	40	0.11	53	0.14	36	0.09	41	0.11	34	0.09	37	0.09	28	0.07	27	0.07
Coal	20	0.16	15	0.12	20	0.15	18	0.12	12	0.07	12	0.16	11	0.06	7	0.04
Diamonds	3	0.07	12	0.28	6	0.15	3	0.11	4	0.15	3	0.11	2	0.07	0	0.00
Copper	2	0.23	1	0.12	1	0.12	1	0.14	1	0.14	1	0.14	1	0.15	1	0.15
Chrome	2	0.12	4	0.19	4	0.15	3	0.13	3	0.09	5	0.14	4	0.10	7	0.17
Iron ore	2	0.11	4	0.13	2	0.07	3	0.10	3	0.06	0	0.00	2	0.09	0	0.00
Manganese	0	0.00	0	0.00	0	0.00	1	0.09	1	0.08	2	0.13	0	0.00	0	0.00
Other	17	-	16	-	17	-	17	-	7	-	12	-	13	-	14	-

* Fatality rate per million hours worked

Table 20: Injuries per Commodity

Commodity	2006		2007		2008		2009		2010		2011		2012†		2013†	
	Number	Injury* Rate	Number	Injury Rate	Number	Injury Rate	Number	Injury Rate	Number	Injury Rate	Number	Injury Rate	Number	Injury Rate	Number	Injury Rate
All Mines	4169	4.14	3867	3.62	3763	3.34	3650	3.43	3438	3.25	3299	3.00	3377	3.03	3126	2.88
Gold	2316	7.04	2239	6.67	1938	5.65	1756	5.36	1379	4.36	1498	5.07	1478	5.13	1252	4.66
Platinum	1344	3.74	1180	3.05	1221	2.95	1299	3.50	1515	4.08	1283	3.20	1360	3.43	1344	3.53
Coal	253	2.08	183	1.44	332	2.42	295	1.97	273	1.73	241	1.44	267	1.51	263	1.41
Diamonds	45	1.04	54	1.24	35	0.84	46	1.66	50	2.04	42	1.58	48	1.78	19	0.64
Copper	19	2.22	19	2.21	22	2.51	19	2.59	19	2.61	19	2.66	13	1.90	15	2.19
Chrome	52	3.13	53	2.48	58	2.12	60	2.00	84	2.78	71	1.99	77	1.96	91	2.27
Iron ore	25	1.40	17	0.55	12	0.44	15	0.49	18	0.44	20	0.39	20	0.39	34	0.75
Manganese	0	0.00	0	0.00	16	1.91	11	1.03	17	1.36	13	0.82	15	0.80	14	0.65
Other	115	-	122	-	129	-	149	-	83	-	112	1.12	99	0.90	94	-

* Injury rate per million hours worked

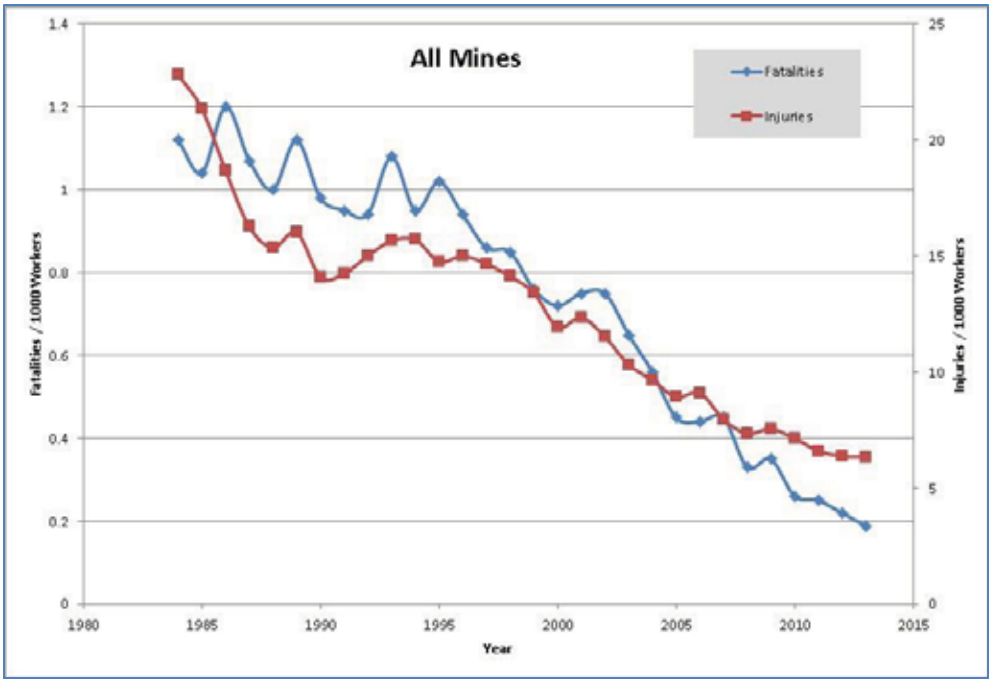

Figure 76: Accident Statistics - All Mines: 1984 - 2013 - per 1000 Workers

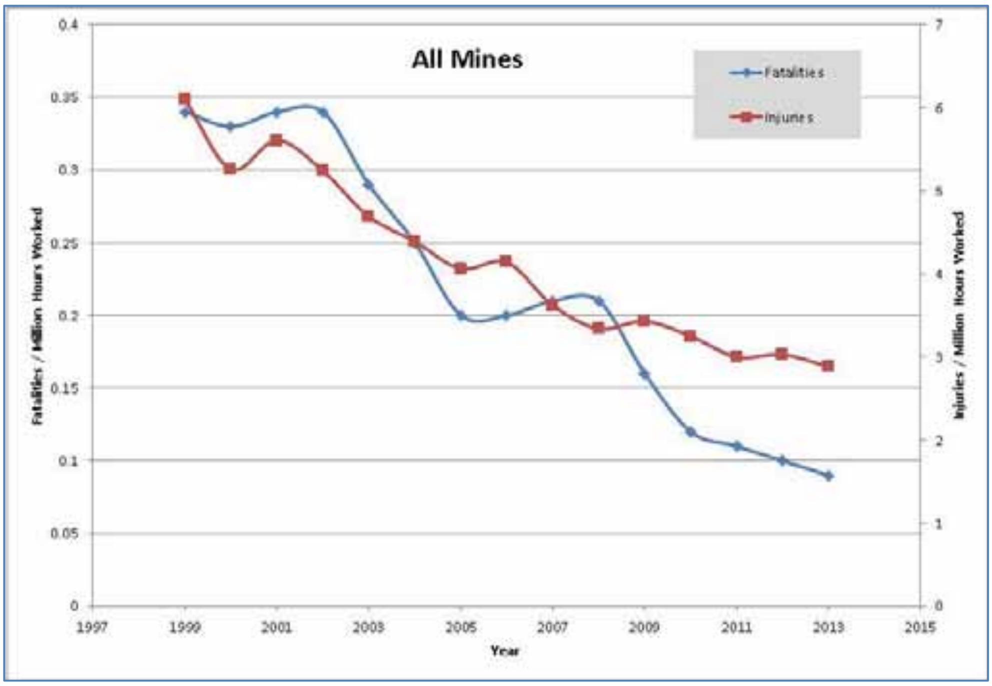

Figure 77: Accident Statistics - All Mines: 1984 - 2013 - per Million Hours Worked

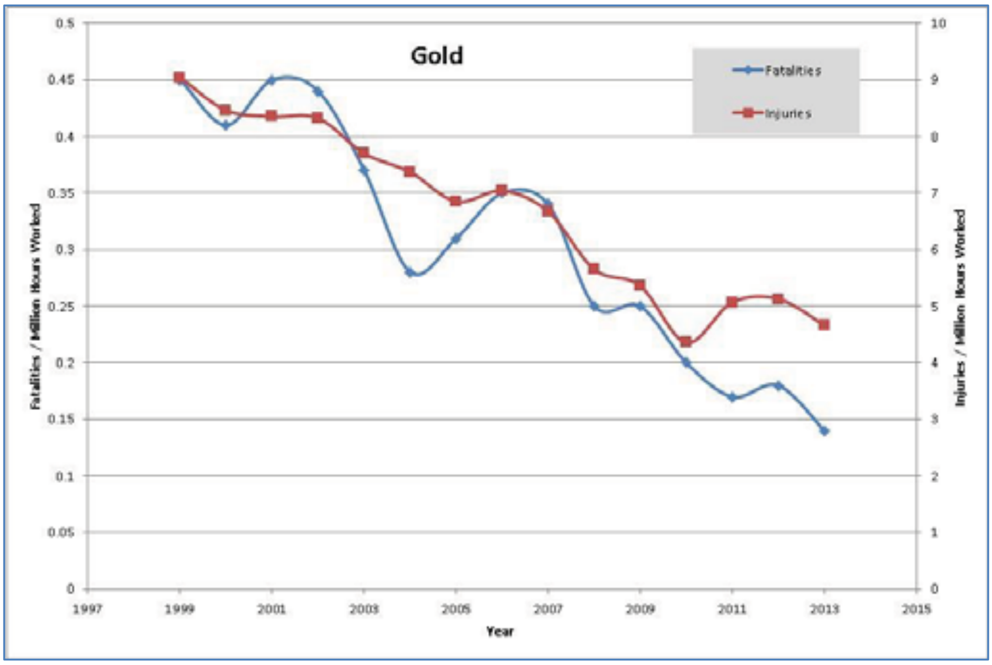

Figure 78: Accident Statistics - Gold Mines: 1984 - 2013 - per Million Hours Worked

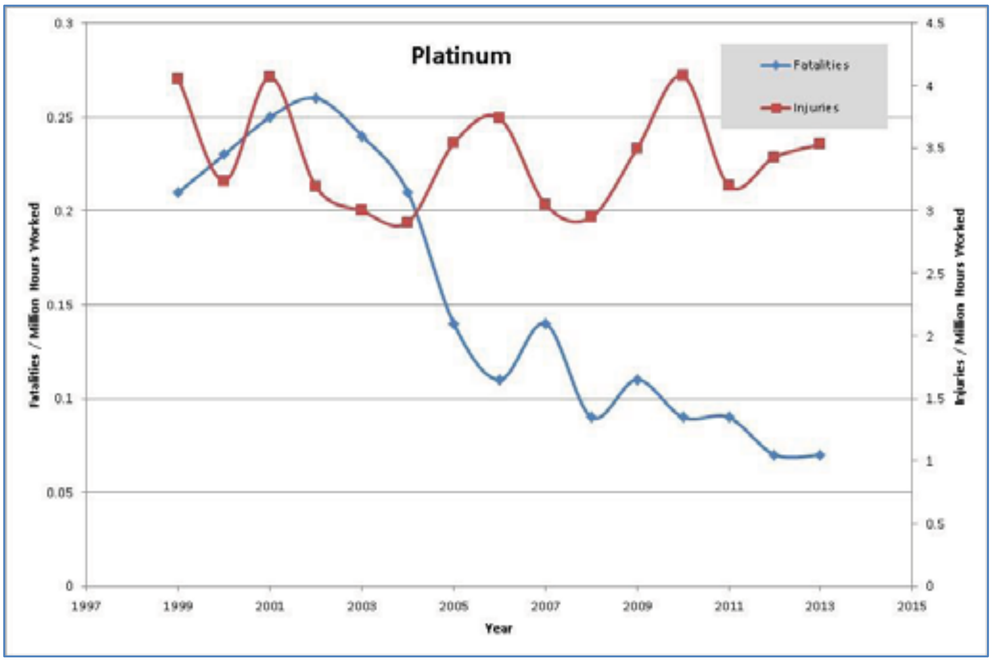

Figure 79: Accident Statistics - Platinum Mines: 1984 - 2013 - per Million Hours Worked

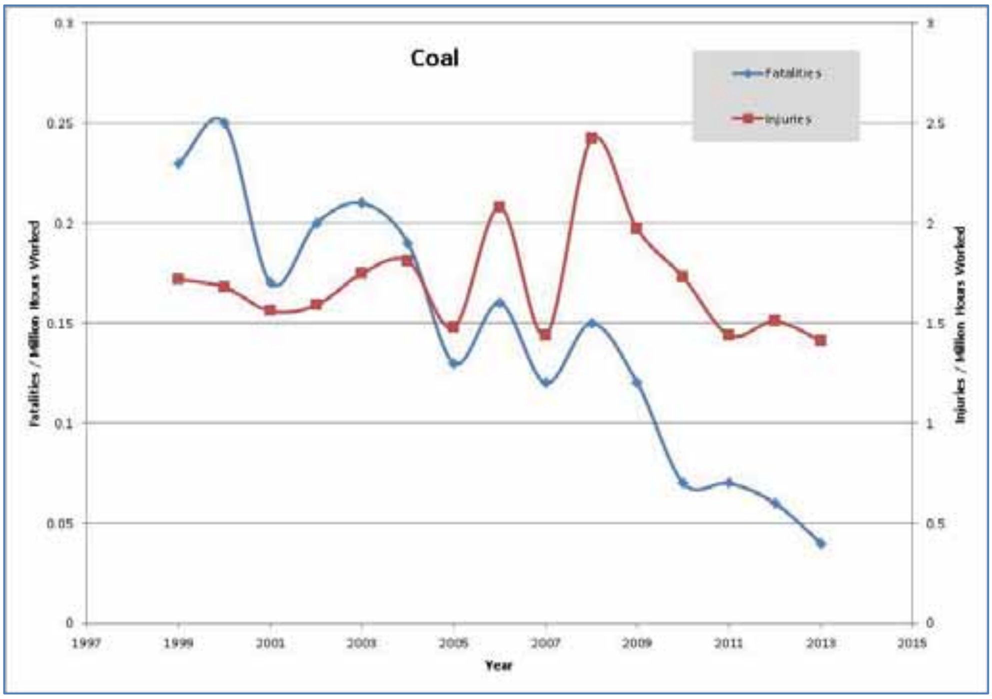

Figure 80: Accident Statistics - Coal Mines: 1984 - 2013 - per Million Hours Worked

16.1.1.2 Accidents per Classification

The number of accidents within the South African mining industry is also collected and correlated by the DMR per type of broad accident classification, as presented in Table 21 and Table 22. This data has been obtained from the published DMR annual reports for the period 2006 to 2011, as raw numbers and number per million hours worked. The figures for 2012 and 2013 should be regarded as provisional since they are based on currently available data, and may be subject to change. The data represents the number of accidents for the combined mining industry, with no published figures of the data being broken down into the various commodities mined. The main DMR accident classifications are:

- Fall of Ground;
- Machinery;
- Transportation and Mining;
- General;
- Conveyance Accidents;
- Electricity;
- Fires;
- Explosives;
- Subsidence and Caving;

- Heat Sickness;
- Diving Sickness;
- Miscellaneous.

Figure 81 shows the raw number of fatalities per accident classification for the period 2006 to 2013, and Figure 82 shows the number of fatalities per million hours worked. Similarly, Figure 83 and Figure 84 show the raw number of injuries and number of injuries per million hours worked.
It is clear from the tables and figures that the number of fatalities related to falls of ground are far greater than the other accident classifications for the same period. There is a marked reduction in the number of fatalities (86 to 32, or from 0.9 to 0.3 per million hours worked) caused by falls of ground within the time period being considered. The number of injuries related to falls of ground are almost half those combined within the “general” accident classification, and they show such a reduction from 1 092 to 534 (1.09 to 0.49 per million hours worked) during the study period.

The fall of ground related accidents are analysed in more detail in subsequent sections of this report.

Table 21: Fatalities per Accident Classification

Accident Classification	2006		2007		2008		2009		2010		2011		2012†		2013†	
	Number	Fatality Rate*	Number	Fatality Rate	Number	Fatality Rate	Number	Fatality Rate	Number	Fatality Rate	Number	Fatality Rate	Number	Fatality Rate	Number	Fatality Rate
Fall of Ground	86	0.09	76	0.07	56	0.05	65	0.06	48	0.04	40	0.04	25	0.02	32	0.03
Machinery	15	0.01	19	0.02	4	0.00	8	0.00	3	0.00	5	0.00	9	0.01	3	0.00
Transportation and Mining	46	0.05	47	0.04	50	0.04	47	0.04	37	0.03	38	0.03	30	0.03	31	0.03
General	35	0.03	50	0.05	45	0.04	32	0.03	20	0.02	25	0.02	34	0.03	19	0.02
Conveyance Accidents	2	0.00	5	0.00	4	0.00	2	0.00	1	0.00	3	0.00	1	0.00	1	0.00
Electricity	6	0.01	4	0.00	5	0.00	5	0.00	3	0.00	3	0.00	5	0.00	2	0.00
Fires	0	0.00	0	0.00	2	0.00	0	0.00	5	0.00	0	0.00	0	0.00	0	0.00
Explosives	5	0.00	8	0.01	2	0.00	4	0.00	5	0.00	4	0.00	4	0.00	1	0.00
Subsidence or Caving	0	0.00	1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.00	0	0.00
Heat Sickness	0	0.00	1	0.00	1	0.00	4	0.00	2	0.00	2	0.00	1	0.00	0	0.00
Diving Sickness	0	0.00	1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Miscellaneous	5	0.00	8	0.01	2	0.00	1	0.00	3	0.00	3	0.00	2	0.00	4	0.00
Total	200	0.20	220	0.21	171	0.15	168	0.16	127	0.12	123	0.11	112	0.10	93	0.09

* Fatality rate per million hours worked

† Preliminary data values

Table 22: Injuries per Accident Classification

Accident Classification	2006		2007		2008		2009		2010		2011		2012†		2013†	
	Number	Injury Rate*	Number	Injury Rate	Number	Injury Rate	Number	Injury Rate	Number	Injury Rate	Number	Injury Rate	Number	Injury Rate	Number	Injury Rate
Fall of Ground	1092	1.09	950	0.89	781	0.69	833	0.78	720	0.68	655	0.60	623	0.56	534	0.49
Machinery	275	0.27	286	0.27	193	0.17	301	0.25	232	0.22	213	0.19	228	0.20	217	0.20
Transportation and Mining	871	0.87	787	0.74	728	0.65	694	0.65	667	0.63	634	0.58	579	0.52	569	0.52
General	1780	1.77	1671	1.56	1879	1.67	1617	1.52	1630	1.54	1611	1.46	1779	1.60	1535	1.41
Conveyance Accidents	22	0.02	28	0.03	24	0.02	19	0.02	20	0.02	28	0.02	24	0.02	31	0.03
Electricity	27	0.03	36	0.03	31	0.03	20	0.02	31	0.03	24	0.02	18	0.02	27	0.02
Fires	11	0.01	6	0.01	3	0.00	5	0.00	24	0.02	25	0.02	8	0.01	9	0.01
Explosives	25	0.02	37	0.03	39	0.03	37	0.03	18	0.02	17	0.01	16	0.02	9	0.01
Subsidence or Caving	1	0.00	0	0.00	2	0.00	0	0.00	1	0.00	0	0.00	3	0.00	0	0.00
Heat Sickness	2	0.00	12	0.01	27	0.02	74	0.07	16	0.01	7	0.01	4	0.00	4	0.00
Diving Sickness	0	0.00	0	0.00	0	0.00	1	0.00	2	0.00	0	0.00	0	0.00	0	0.00
Miscellaneous	62	0.06	54	0.05	55	0.05	70	0.07	76	0.07	85	0.08	81	0.07	80	0.07
Total	4169	4.14	3867	3.62	3762	3.34	3672	3.45	3438	3.25	3299	3.00	3377	3.03	3126	2.88

* Injury rate per million hours worked

† Preliminary data values

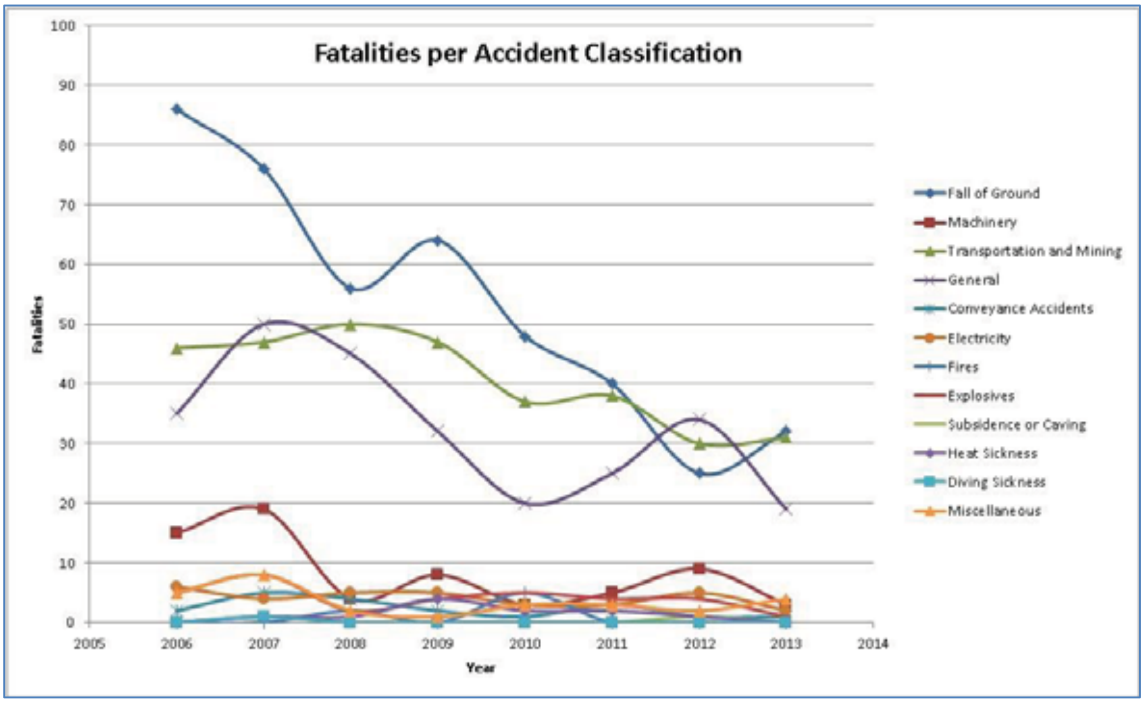

Figure 81: Fatalities per Accident Classification – All Mines: 2006 – 2013 - Raw Numbers

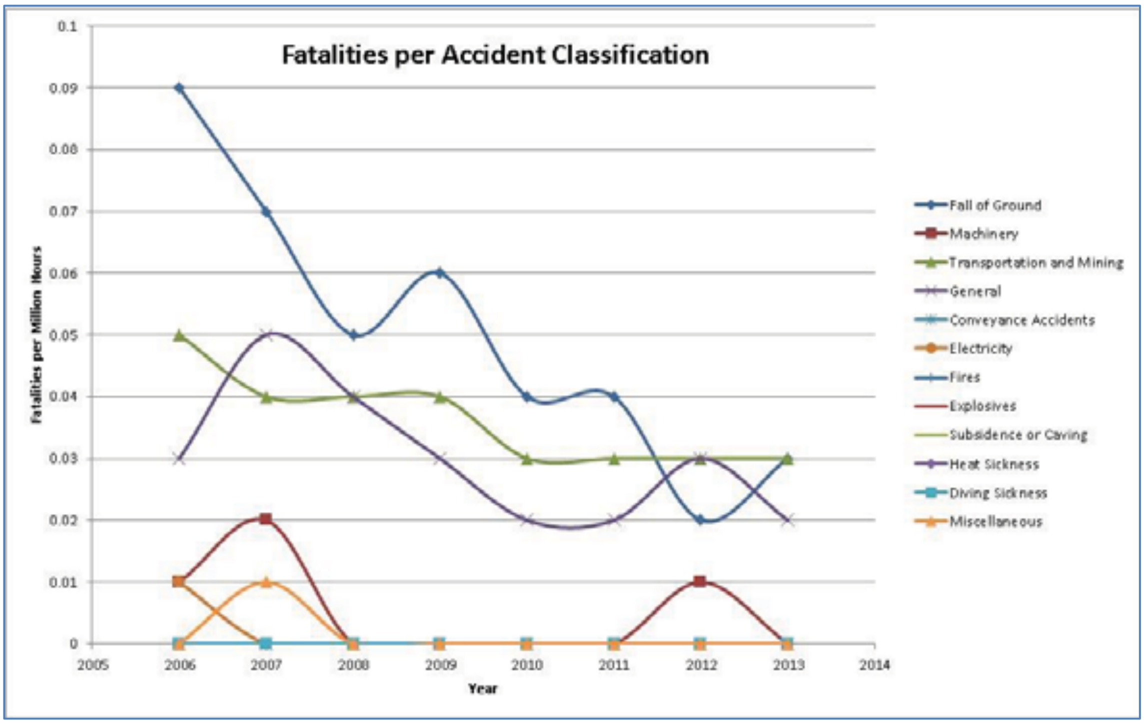

Figure 82: Fatalities per Accident Classification – All Mines: 2006 – 2013 - per Million Hours Worked

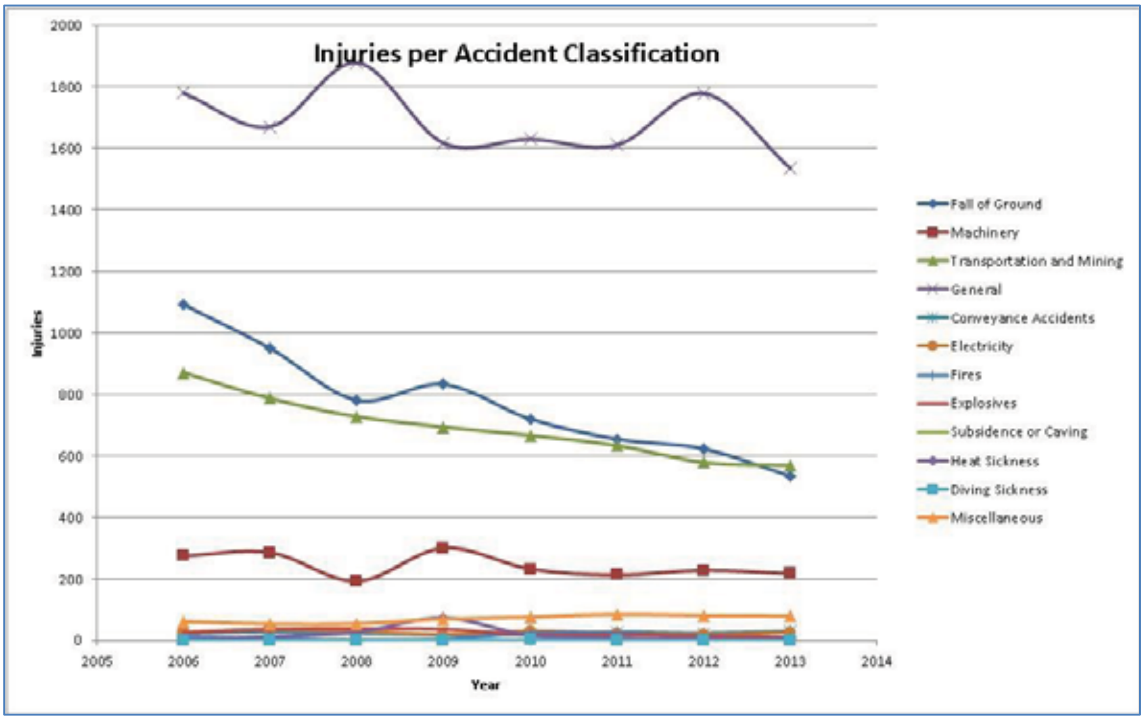

Figure 83: Injuries per Accident Classification – All Mines: 2006 – 2013 - Raw Numbers

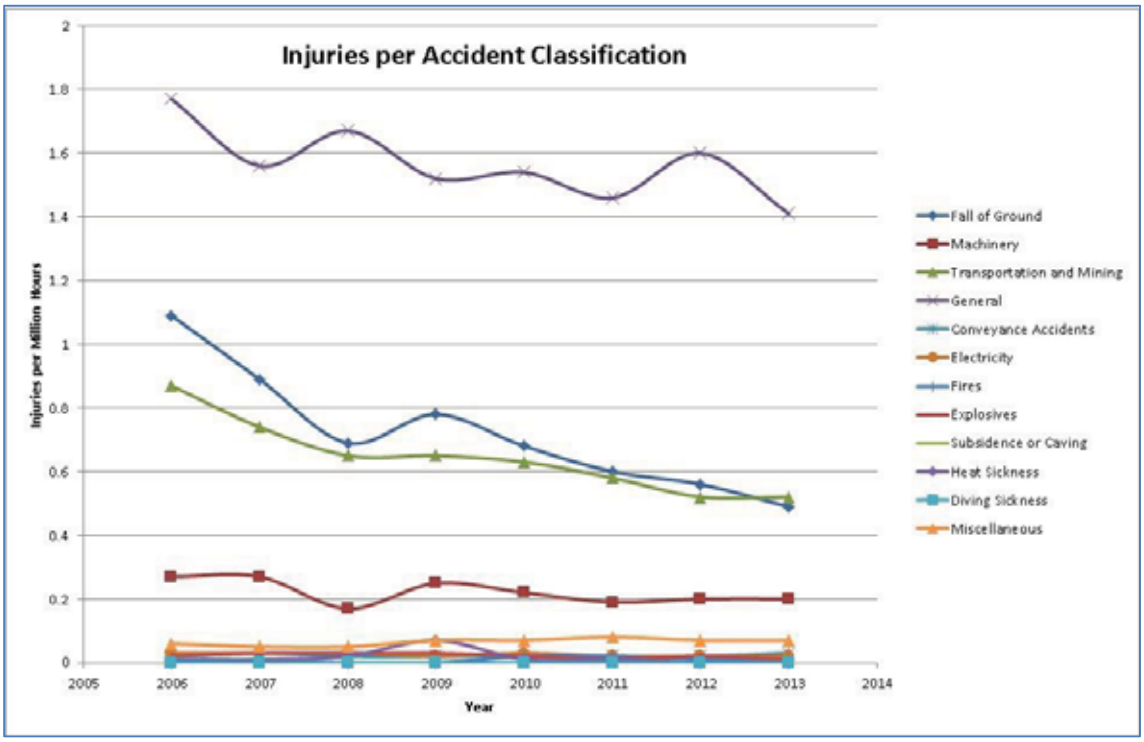

Figure 84: Injuries per Accident Classification – All Mines: 2006 – 2013 - per Million Hours Worked

16.1.1.3 Individual DMR Accident Records

The largest set of data obtained from the DMR Pretoria offices comprised the summary details of all the registered accidents and incidents that have been recorded from all South African mines for the 2010 to 2014 period. The data was provided as five comma separated values files (one for each year), that were combined together to form one large spreadsheet for subsequent analysis. The details of 17 263 registered accidents and incidents are recorded within these files.

The data collected in the spreadsheets comprises most of the information stipulated in the SAMRASS documentation (SAMRASS, 2007), including the following:

- Mine Information:
    - Year of Accident;
    - Region;
    - Regional Accident Number;
    - Type of Accident;
    - Mine Number;
    - Mine Description;
    - Commodity;
- Accident Information:
    - Date of Accident;
    - Date Reported;
    - Day of Week;
    - Number of persons killed, disabled or injured;
    - Location;
    - Casualty Classification;
    - Casualty Classification Description;
    - Cause of Accident;
    - Accident Description;
- Personnel Information:
    - Surname;

- Age;
- Years of Experience;
- Period Employed;
- Employment Status;
- Contracting Company;

- Details of Accident:
  - Nature of Injury;
  - Body part Injured;
  - Allocated days Lost;
- Accident Status.

16.1.1.4 QA/QC and Problems with the Data Set

Once the data from the five .csv files had been combined the data set was subjected to a rigorous QA/QC analysis to assess its veracity and suitability for purpose. Unfortunately, a number of problems were identified with various components of the data, which although not critically compromising the overall data set, does limit the statistical analyses that can be carried out on it.

Most of the QA/QC problems were associated with the personnel information of the accident victims. The age of the employees is recorded as varying from 5 to 99 years, which is clearly incorrect, and more than 2 200 accident victims having a recorded age of zero, or "**", presumably to indicate that the actual age was not known.

The years of work experience is recorded in a number of formats, including time formats such as H: M to represent years and months, and H: M: S to record similar information after "23 hours and 59 minutes" of the H: M format. The years of experience of employees is recorded as varying from 45 to 94 years, with a number of people having years of experience in excess of their stated age.

The period employed was also recorded in a number of formats, from a possible date of first appointment (although some of these dates were recorded as 2015), to a fraction such as 6 / 11, which since the second number never exceeded 11, could be interpreted as years and months.

The cause of an accident is recorded as a description, rather than the official SAMRASS "Probable Cause" codes listed in Item 6 of …… Unfortunately this can lead to confusion as to the actual cause because the description "*Other (specify)*" occurs as a possible option in seven different possible causes in the SAMRASS manual, and descriptions such as "*Wrong/sub-standard equipment*" and "*Available but not used*", etc. also appear in different possible causes in the SAMRASS manual.

The recorded "accident description" varies from a detailed account which allows one to easily gauge what went wrong to cause the accident, to a very generalised description which provides very limited information to determine the cause the accident. In some cases the accident description does not seem to coincide with the recorded "casualty classification" and "casualty classification description".

A registered accident that occurred at Impala Platinum mine in 2013 is recorded as having injured 103 workers. The accident description is that of a rolling rock (not fall of ground) that rolled down the central gully travelling way and injured the employees' right foot, resulting in a contusion bruise, and 14 allocated days being lost. There is presumably a simple data-entry error, but it is not known how many similar, but less obvious errors there may be in the DMR accident data set.

In order to standardize the above data it was decided to delete the lower and upper age extremes, so that the employee ages vary from 20 to 65, and to ensure that their years of experience or employment were not in excess of their age.

16.1.2 Statistical Analysis of DMR Accident Records

Figure 85 shows the age distribution of the personnel involved in reportable accidents, for all the mined commodities, plus gold, platinum and coal individually. As stated above, ages below 20 and above 65 have been removed from the data set because of their unreliability. It is evident that the distributions are approximately normal, with an average age of 40 years. The y-axis shows the relative frequency, expressed as a percentage, of the number (n) of personnel involved in an accident, for whom a valid age was recorded (n = 15 227 for all commodities, 6 552, 5 901 and 1 228 for gold platinum and coal respectively.

The graphs may indicate that there are more workers in the 40 to 50 year age bracket in the gold mining industry and that there is a general decrease in the number of older workers in the platinum and coal mining industries, but in general the distributions are very similar.

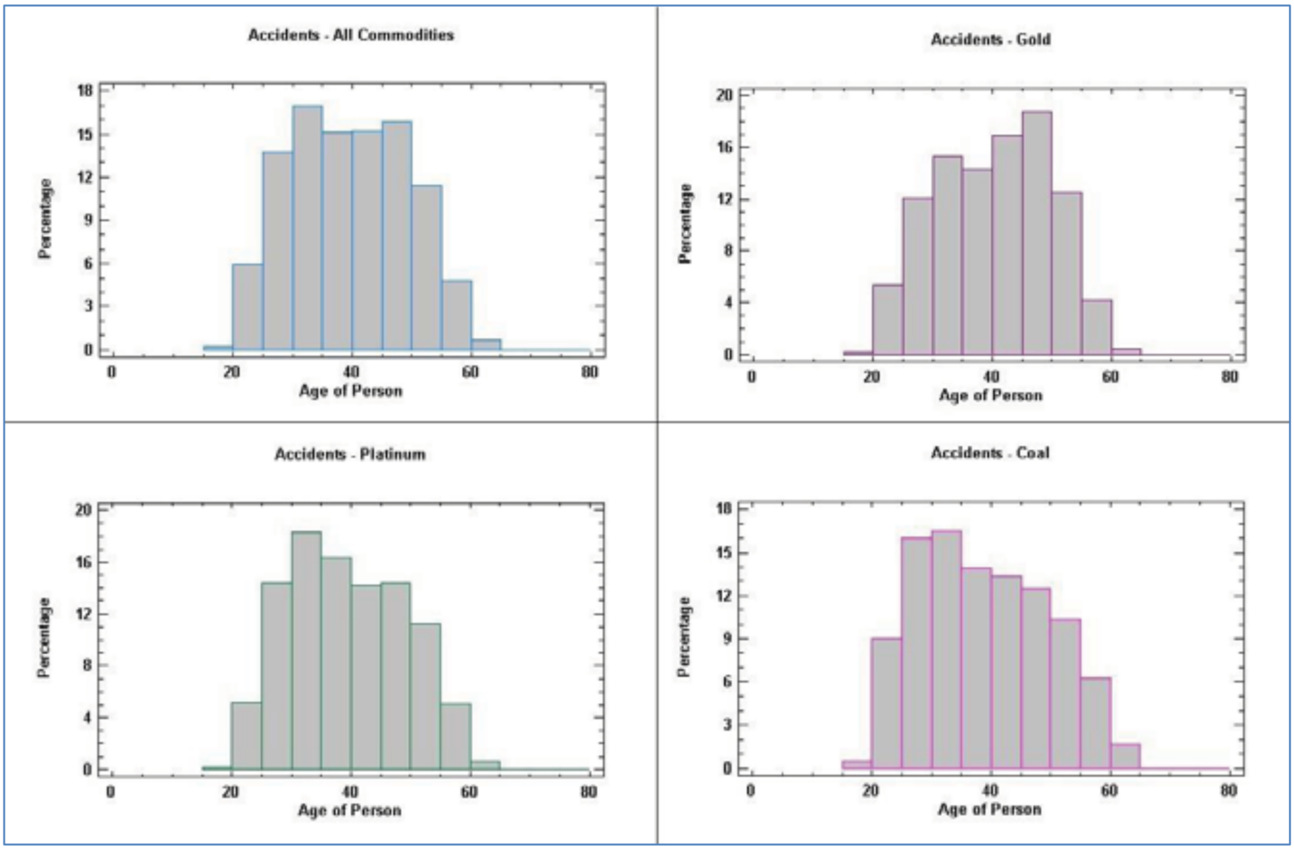

Figure 85: Age distribution of Personnel involved in Reportable Accidents

Figure 86 shows a graph of age versus years of experience of all personnel involved in reportable accidents. The green line represents the assumption that the workers are aged between 20 and 65, and the years of mining experience they have is 20 years less than their age. The blue circles represent the data points that fall within these assumptions, and the red circles show the data that does not (a 42 year old with 90+ years of experience, etc.).

Figure 87 is a similar graph of age versus years employed at the mine in which the personnel were working. It clearly shows that by far the majority of workers, of whatever age, have been employed less than 10 years at their current mine, with only a few of the older personnel having remained with their employer for more than 30 years. There appears to be only a limited number of employees with between 10 and 30 years continuous employment at the mine in which they were involved in an accident.

Figure 88 and Figure 89 show the number of fatalities and injuries (as relative frequencies) that occur per day of the week, for all types of accident causes, in the gold, platinum and coal sectors, plus for all the commodities mined. The total number of fatalities in all commodities, gold, platinum and coal are 517, 235, 137 and 52 respectively. The equivalent number of injuries are 15 076, 6 530, 5 851 and 1 254 respectively. There appears to be a uniform injury rate for all the commodities analysed from Monday to Thursday, with a small drop off on Friday, and then a significant reduction over the weekend.

The fatality rate per day appears to be more random in nature, with a general reduction over the weekend. However, there would appear to be a relatively higher fatality rate in the coal mining industry during the Friday to Sunday period when compared with the other commodities.

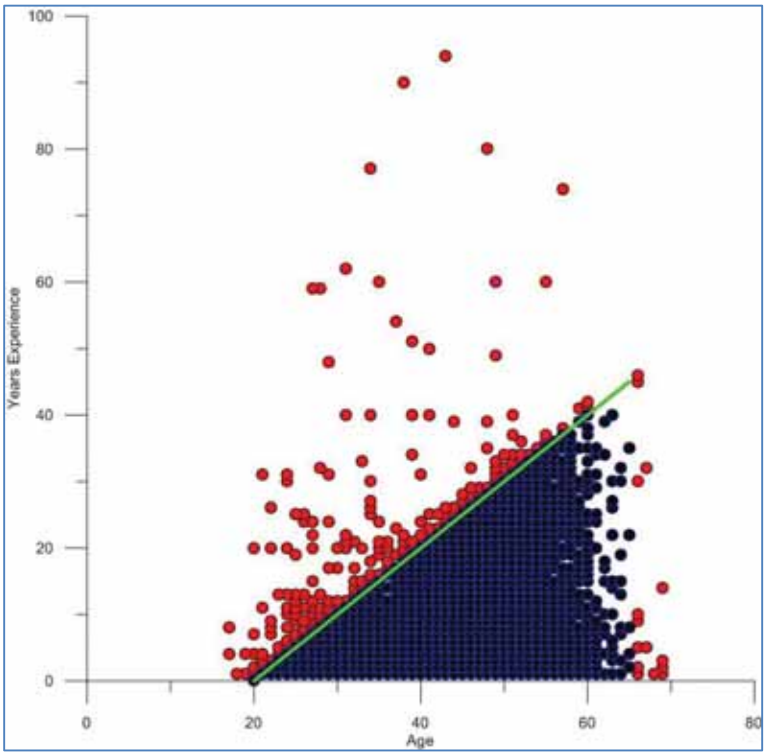

Figure 86: Age and Years of Experience of Personnel involved in Accidents

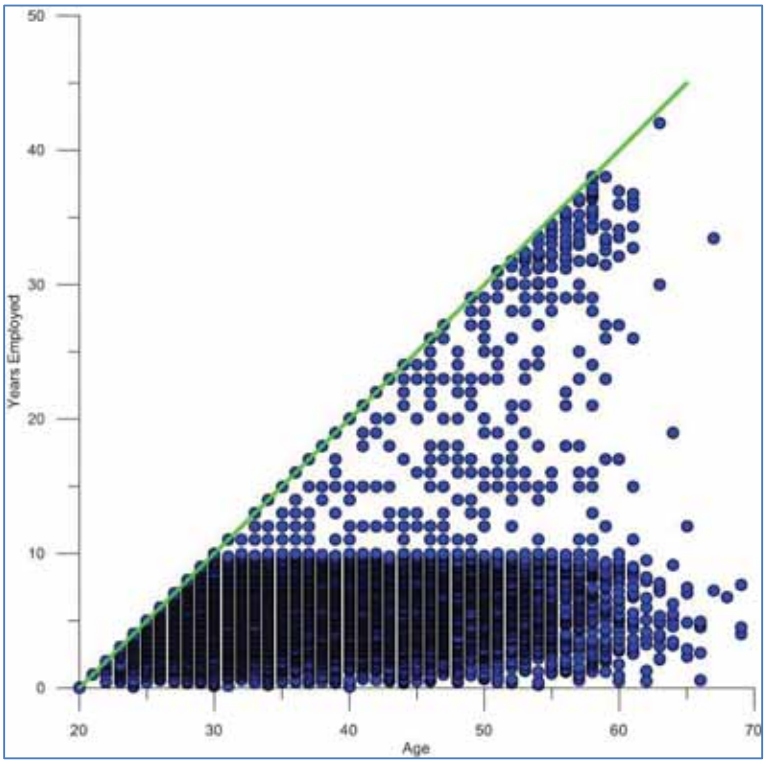

Figure 87: Age versus Number of Years Employed

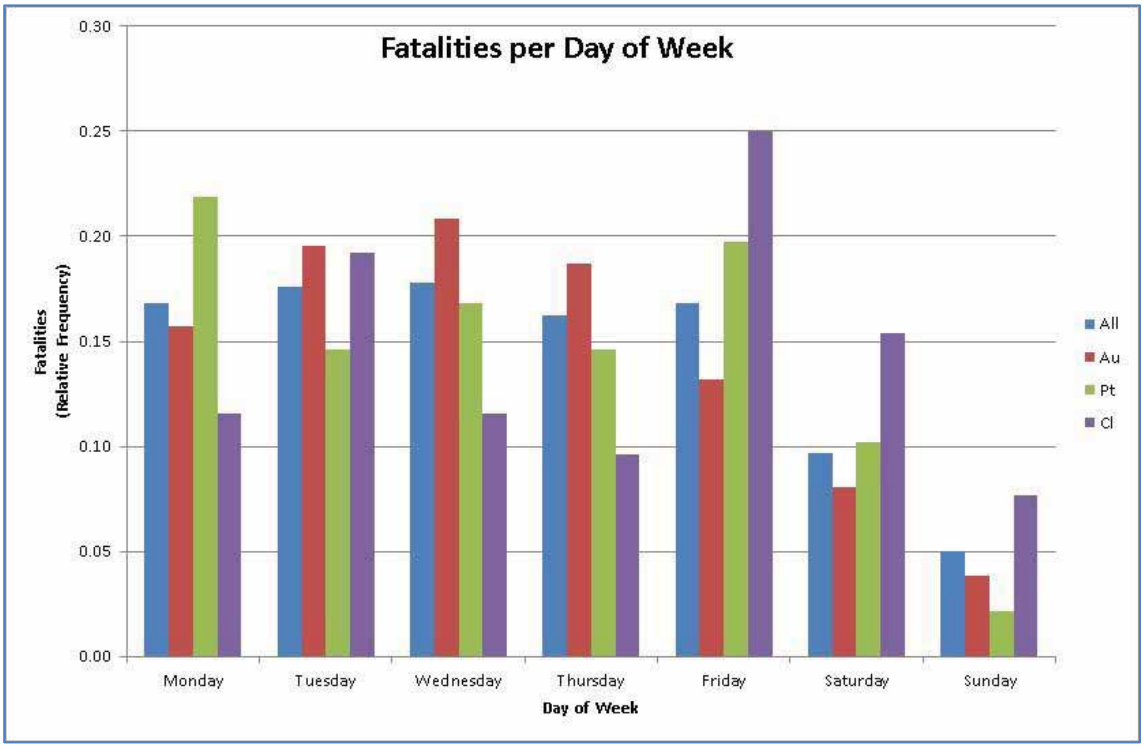

Figure 88: Day of Week versus number of Fatalities

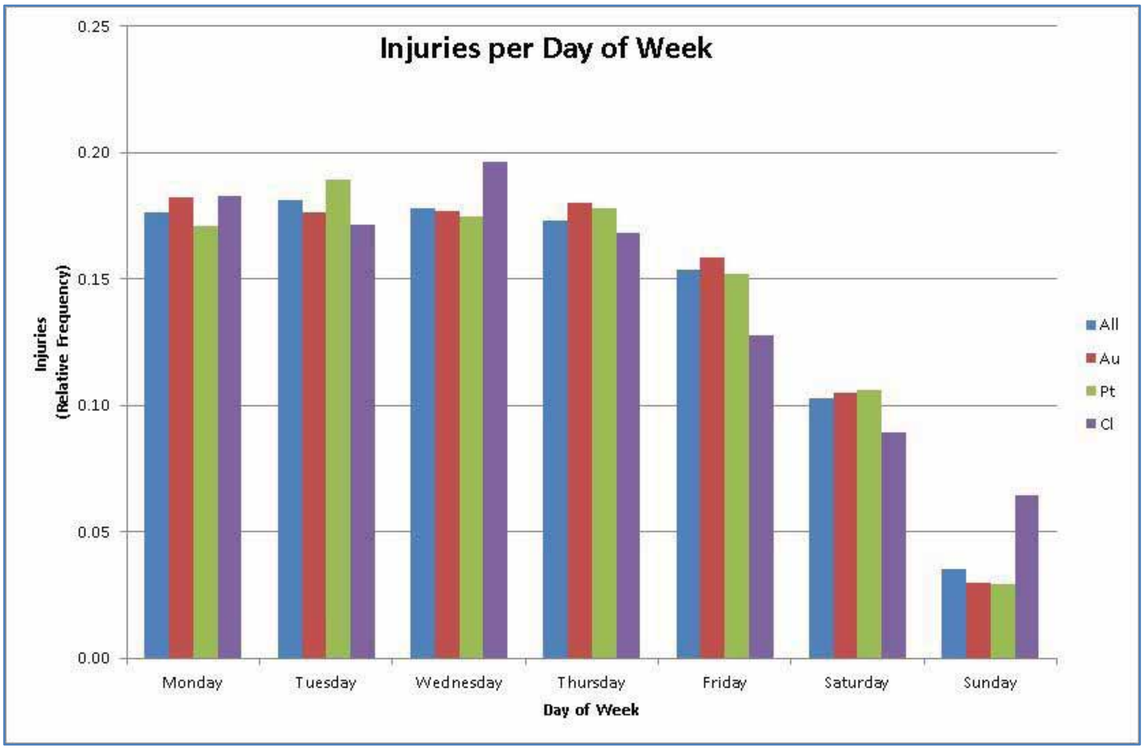

Figure 89: Day of Week versus number of Injuries

Similar trends can be seen in Figure 90 and Figure 91, which show the number of fatalities and injuries due to Falls of Ground, per day of the week. There appear to be a greater number of fatalities and injuries in coal mining on a Friday, compared to other commodities.

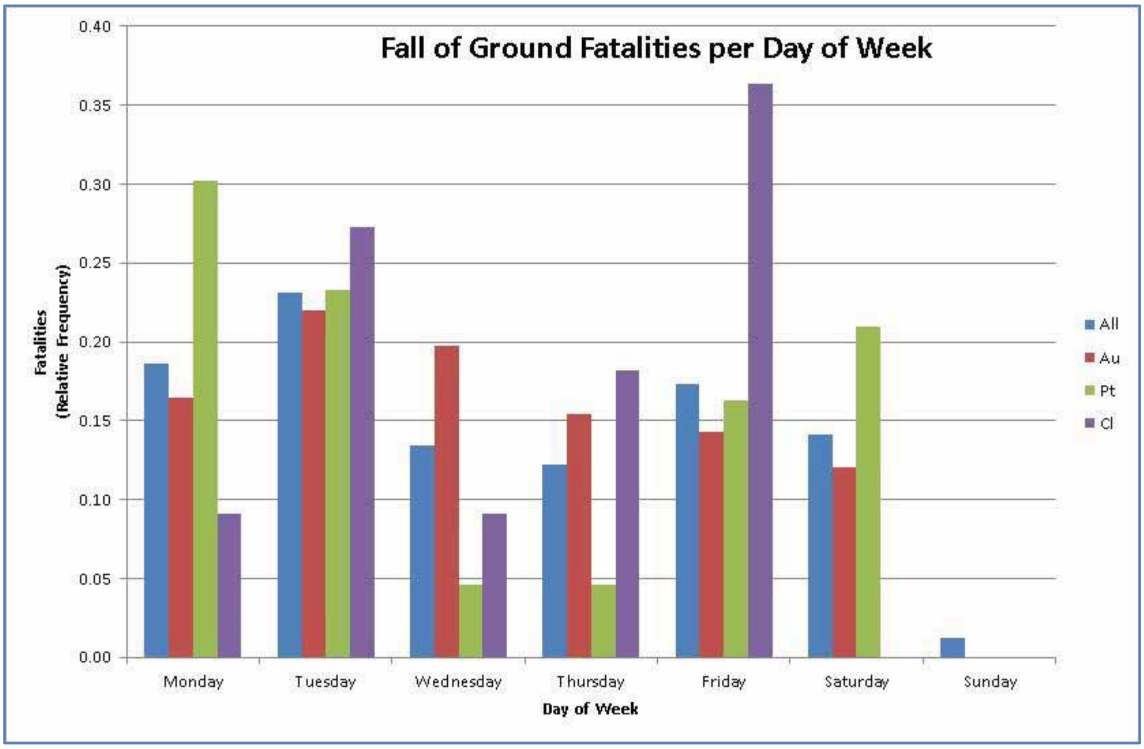

Figure 90: Day of Week versus number of Fatalities - Fall of Ground Accidents

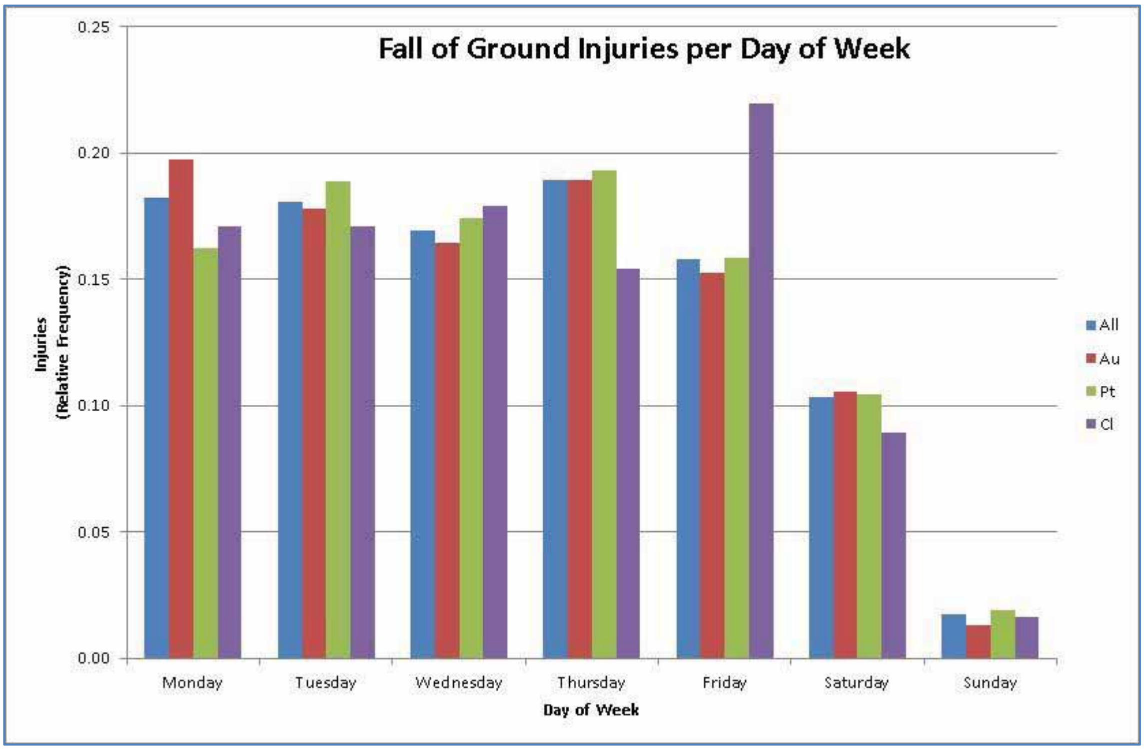

Figure 91: Day of Week versus number of Injuries - Fall of Ground Accidents

The DMR accident database records the employee type (casual, contractor and employee) of the workers involved in a reportable accident. By far the greater number of personnel are employees of the mining companies (13 218 employees, 2 076 contractors and 17 casual workers), so the accident statistics reflect this disparity, as shown in Figure 92 and Figure 93.

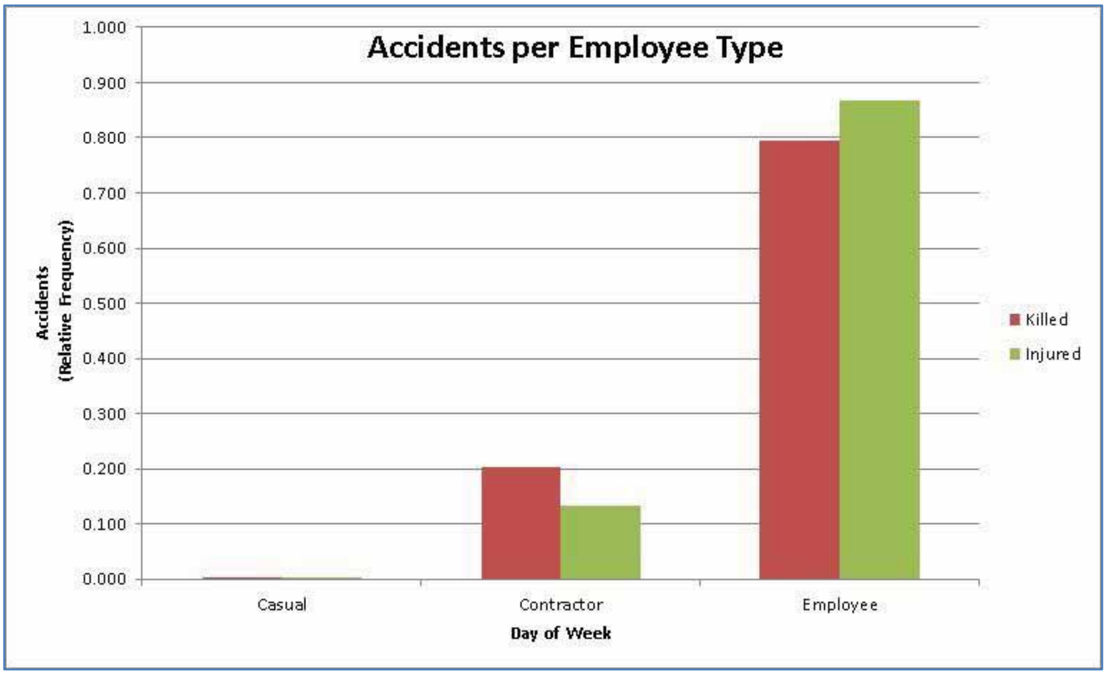

Figure 92: Accidents per Employee Type - All Accidents

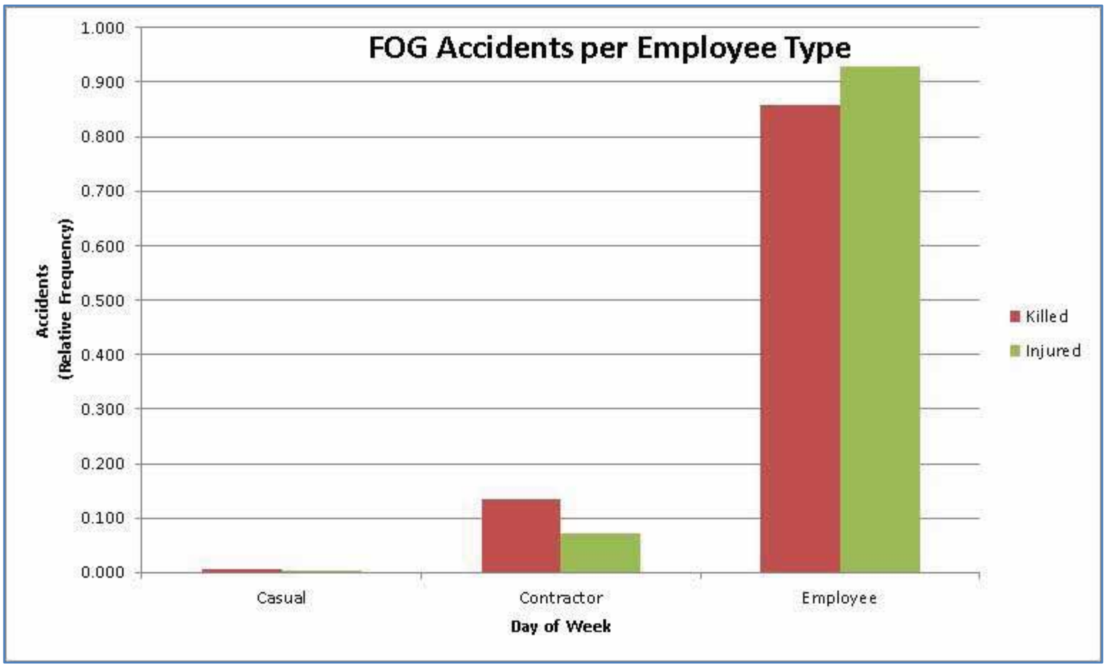

Figure 93: Accidents per Employee Type - Fall of Ground Accidents

The DMR database also records the nature of the injuries caused by the accidents. Figure 94 and Figure 95 show the injuries associated with all causes of accidents, for all the commodities, plus gold, platinum and coal individually. It is clear that crushing injuries, fractures and multiple injuries, plus amputation, asphyxiation, drowning and lacerations are responsible for most of the fatalities. The "*Other (specify)*" category is also widely used within the database, but no further specific details are provided.

The main non-life threatening injuries are shown to be amputation, contusion bruises, dislocation, fracture, laceration, multiple injury and sprain / strain. There does not appear to be any specific injury that is linked to mining a particular commodity.

The nature of the injuries associated with Fall of Ground accidents are shown in Figure 96 and Figure 97. Multiple injuries are the main cause of fatalities, and abrasion, amputation, contusion bruises, dislocation, fracture, laceration and multiple injuries are the causes of non-life threatening injuries.

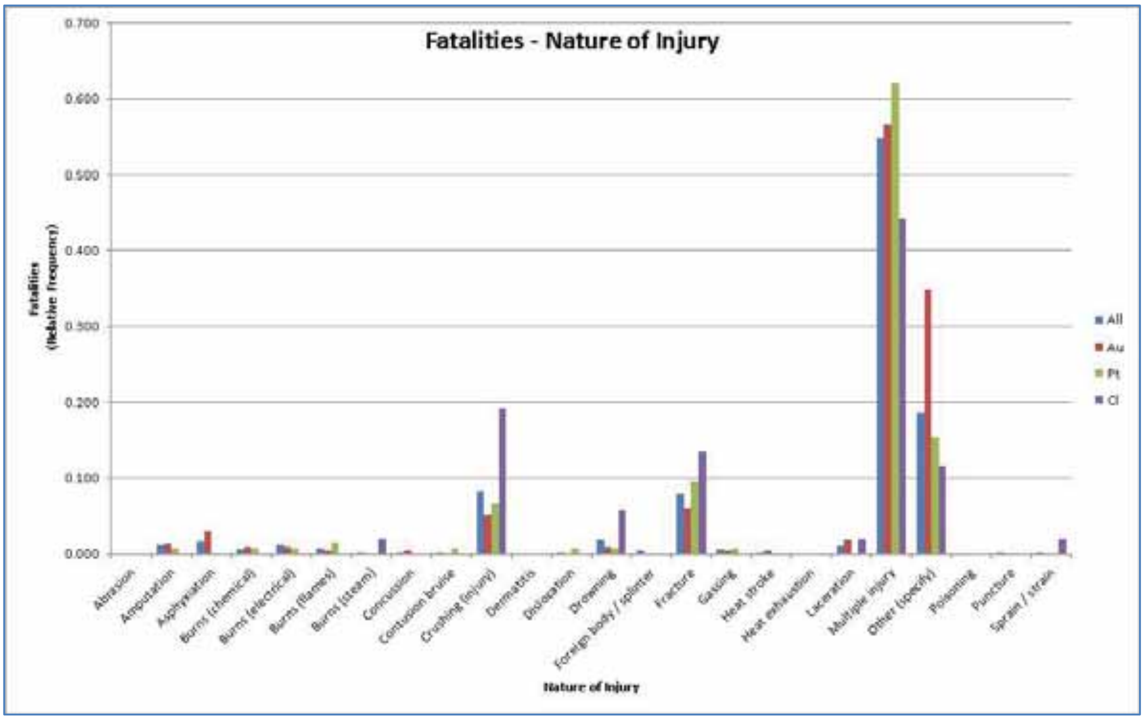

Figure 94: Nature of Injury - Fatalities

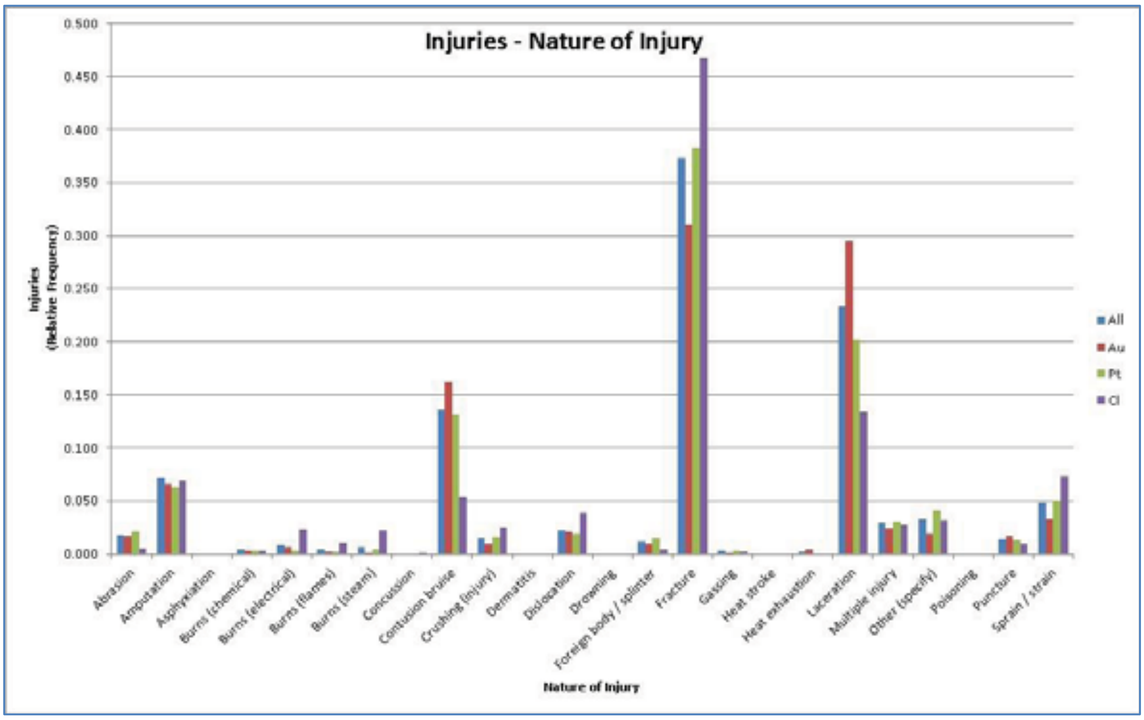

Figure 95: Nature of Injury – Injuries

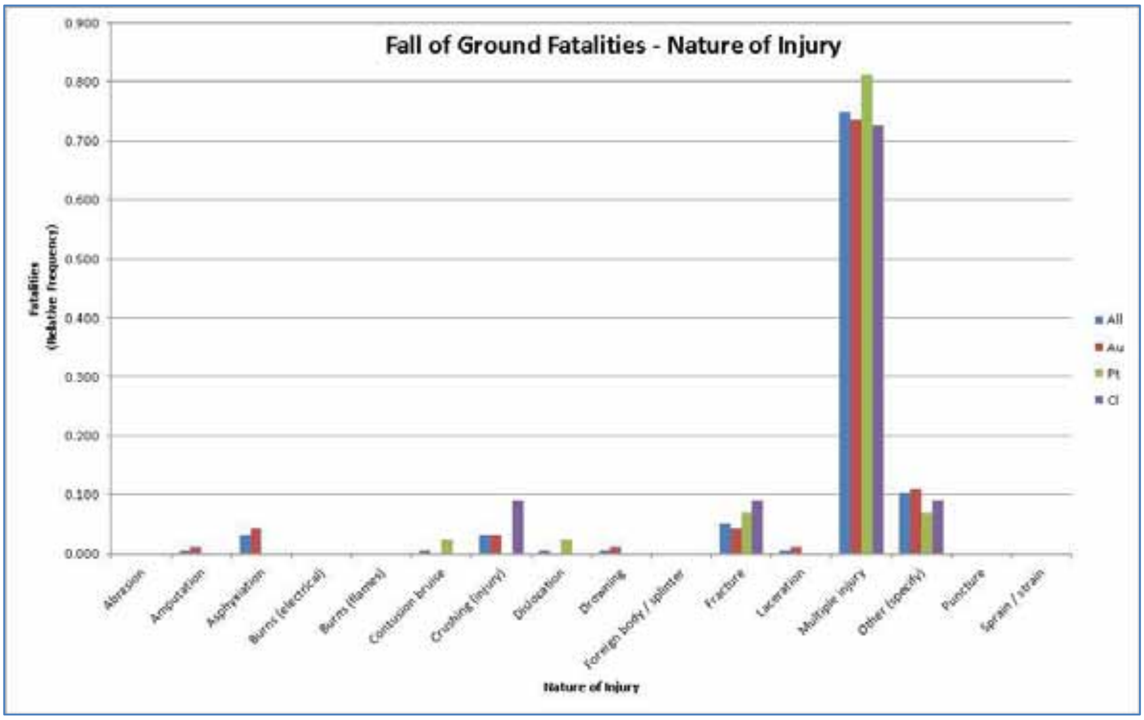

Figure 96: Nature of Injury - Fall of Ground Fatalities

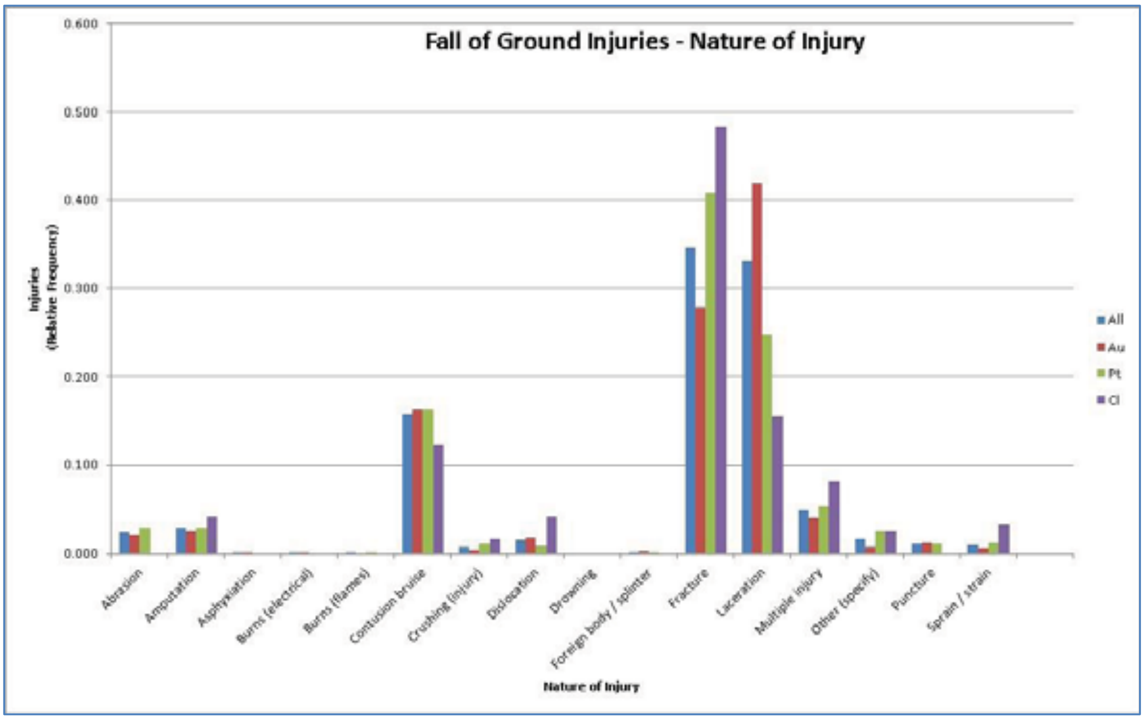

Figure 97: Nature of Injury - Fall of Ground Injuries

16.1.3 Root Cause Analysis of Fall of Ground Related Accident Records

This Simrac research project is involved with analysing barring-down related accidents in gold, platinum and coal mines for the period 2011 to 2012, with a view to improve safety. In order to do so it is necessary to analyse the available information on the causes of relevant registered accident data within the DMR SAMRASS database. This report concentrates on analysing the spreadsheet version of this database, obtained from the DMR offices in Pretoria, whilst subsequent milestone reports will analyse the more detailed individual accident reports from the DMR local offices and the related accident reports held at the mines.

The term "*barring*" only occurs twice in the SAMRASS Codebook for Mines (SAMRASS, 2007). Once as part of SAMRASS Form 2, Section F – Details of Injury, Item 1-Task: Person injured or killed while performing, where Barring (code 1A0702) appears as part of the item "*Making safe (includes barring)*" and once in the same section, Item 2-Activity (Injured or Killed while …), where Barring (code 2011) appears as one of those activities.

Unfortunately, neither of these items is captured within the SAMRASS accident spreadsheet obtained from the DMR Pretoria offices. The term "*barring*", together with the related terms "*fall of ground, entry examination, pinch bar and gasket*" are only found as part of the *Accident Description* information.

However, the Accident Classification Codes (Item 12 in Section B of Form 1) are contained within the SAMRASS accident spreadsheet. This includes the code 01 for Fall of Ground, which is subdivided into the following categories:

- 01-Fall of Ground
- Rockburst (bump)
- 01A001-Face
- 01A002-Hanging wall
- 01A003-Sidewall
- 01A004-Footwall
- Strainburst
- 01B001-Face
- 01B002-Hanging wall
- 01B003-Sidewall
- 01B004-Footwall
- Gravity

- 01C001-Face
- 01C002-Hanging wall
- 01C003-Sidewall
- 01C004-Footwall
- 01C005-Brow

These codes can be used to query the database and the relevant “*Probable Cause of Accident or Dangerous Occurrence*” (Item 6 in Section D of Form 1) can be retrieved. The main categories of the Probable Cause of Accident or Dangerous Occurrence are:

- Training or Placement Factors
    - 01-Inadequate Mental or Physical Limitations
    - 02-Lack of Knowledge
    - 03-Lack of Skill
- Personal Factors
    - 04-Stress – Physiological or Mental
    - 05-Improper Motivation
    - 06-Abuse or Misuse
    - 07-Inadequate Leadership and Supervision
    - 08-Engineering
- Job Factors
    - 09-Inadequate Purchasing
    - 10-Maintenance
    - 11-Equipment, Tools and Material
    - 12-Standards and Procedures
    - 13-Miscellaneous

Each of the above main categories are further subdivided into subcategories with specific reference numbers, as stipulated in the relevant pages (50 – 57) of the SAMRASS Codebook for Mines (SAMRASS, 2007).

The following figures (Figure 98 to Figure 110) show graphs of the Probable Cause of Accident or Dangerous Occurrence which have been recorded within the SAMRASS accident spreadsheet for each of the reportable accidents that have been categorized with the Accident Classification Code "*01 - Fall of Ground*". The graphs show the causes of the Fall of Ground accidents that have occurred for all the mining commodities, plus gold, platinum and coal mines separately. The numbers of injuries are shown as relative frequencies of the totals and the cause of accidents are shown as the DMR code numbers (Pages 50 – 57 of the SAMRASS Codebook for Mines).

Despite the number of injuries and fatalities caused by Falls of Ground (2 962 and 169 respectively), the graphs indicate that there are a total of approximately fifty probable causes listed for them. These are analysed further below.

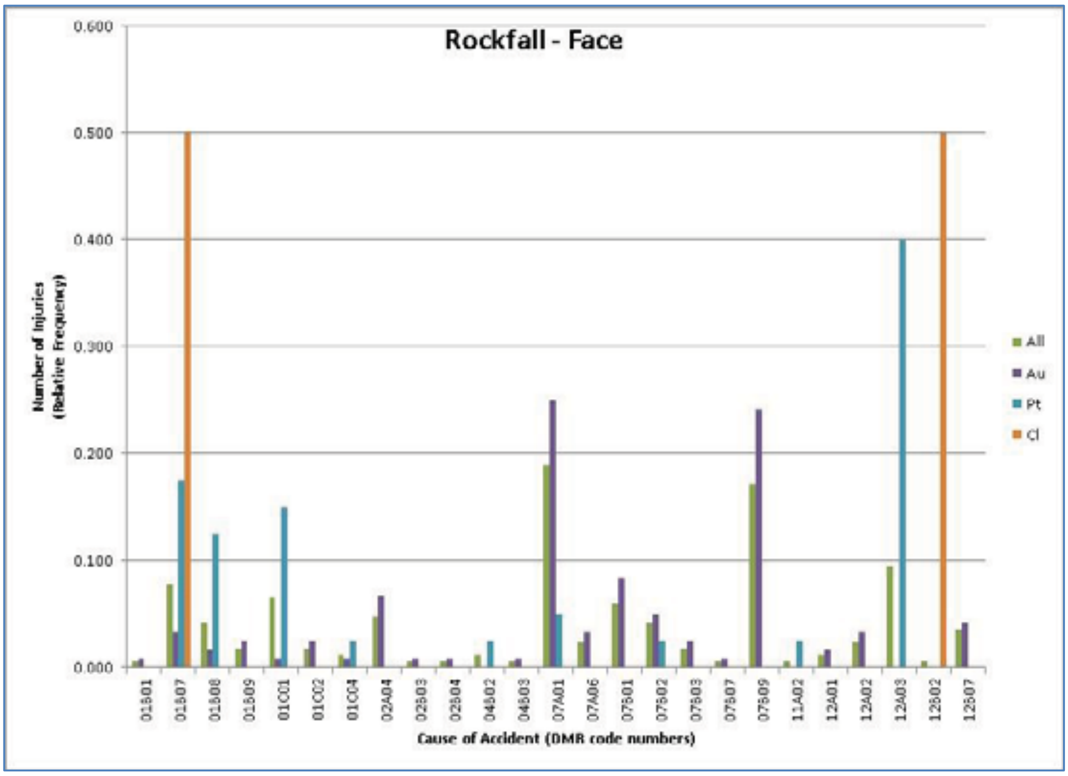

Figure 98: Probable Causes of Rockburst-Face Accidents

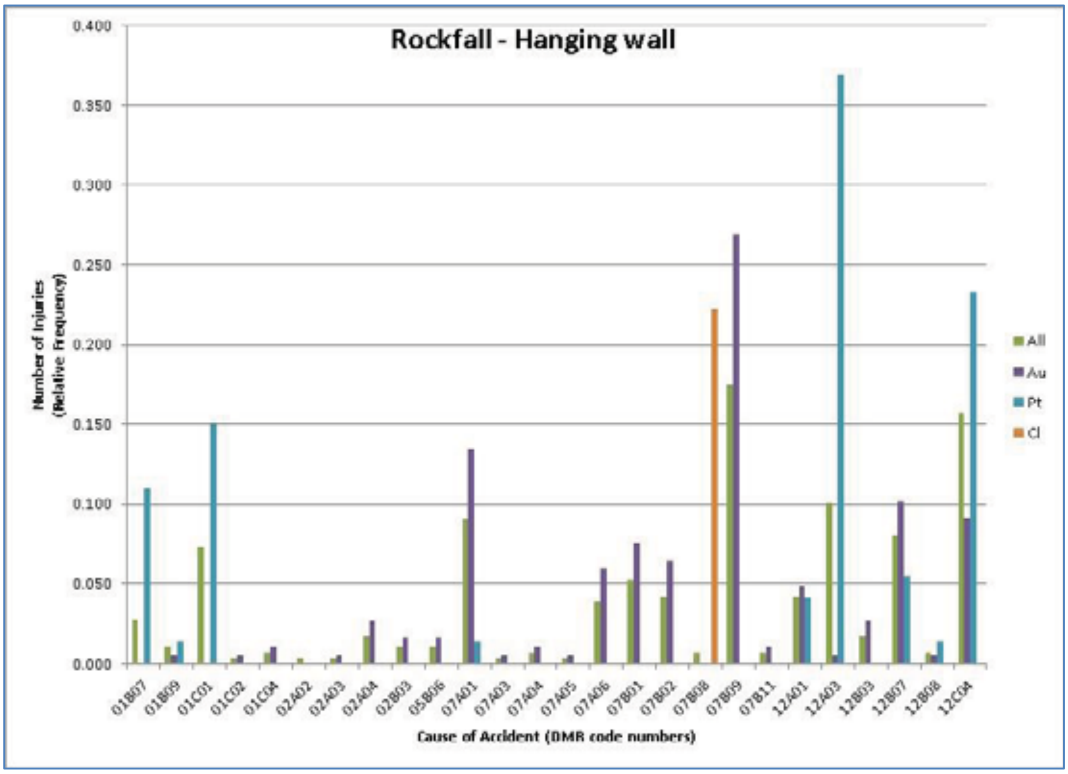

Figure 99: Probable Causes of Rockburst-Hanging wall Accidents

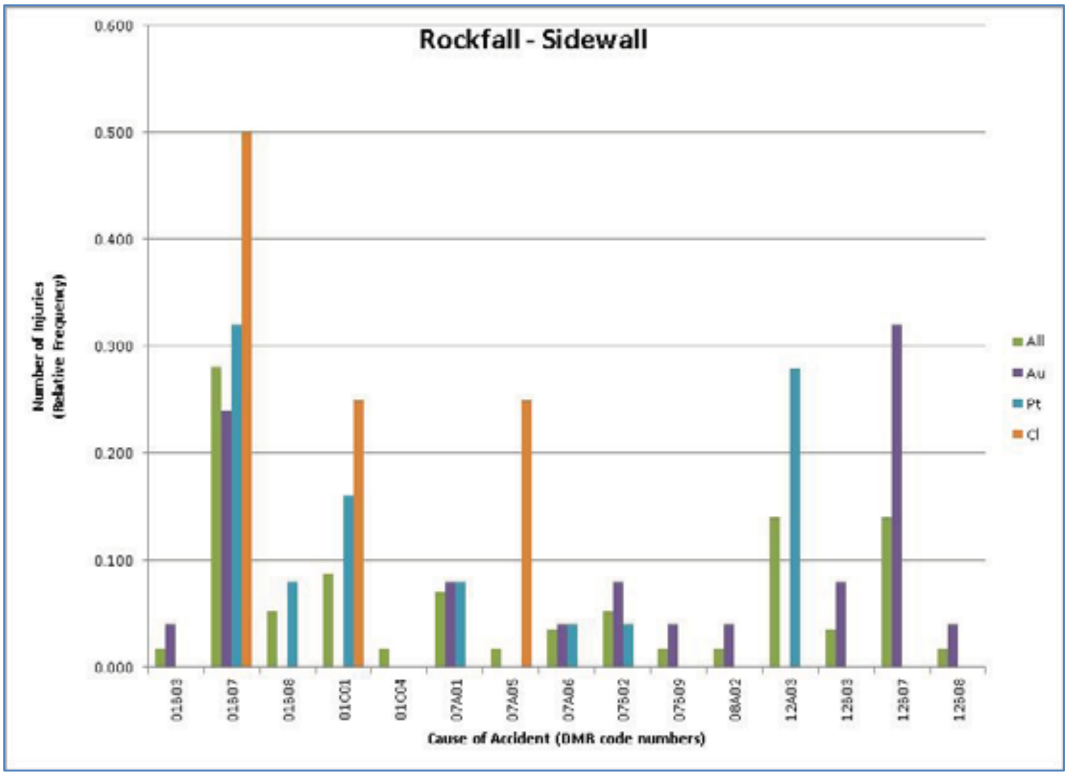

Figure 100: Probable Causes of Rockburst-Sidewall Accidents

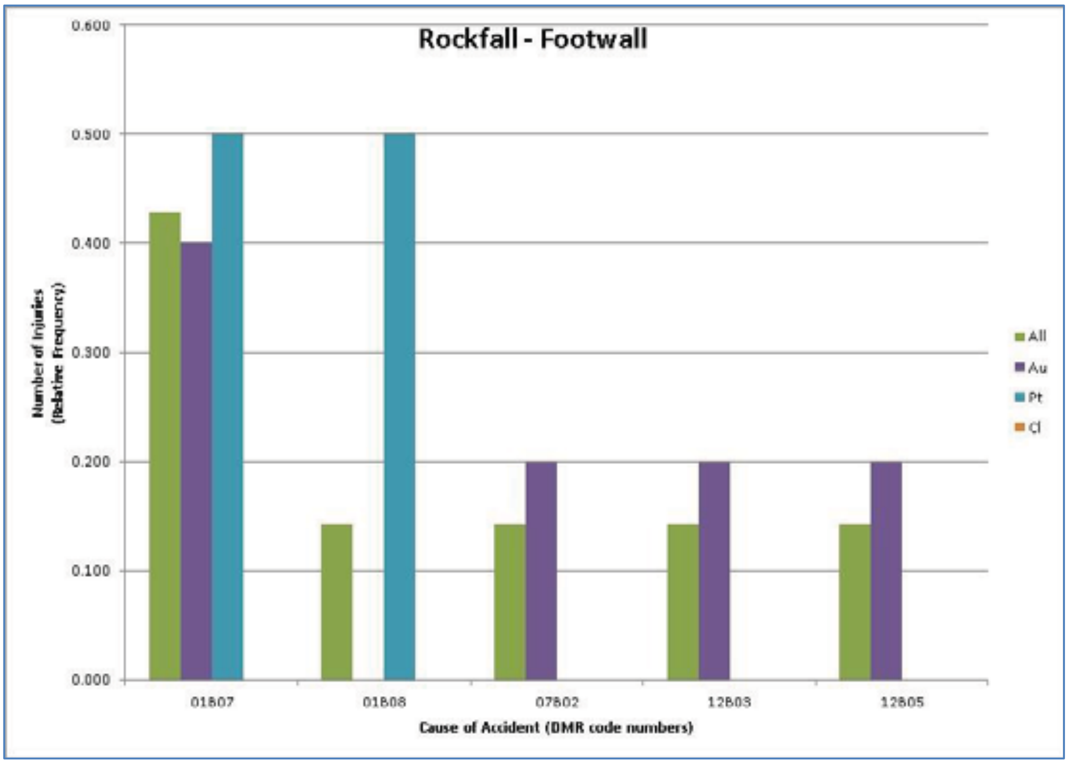

Figure 101: Probable Causes of Rockburst-Footwall Accidents

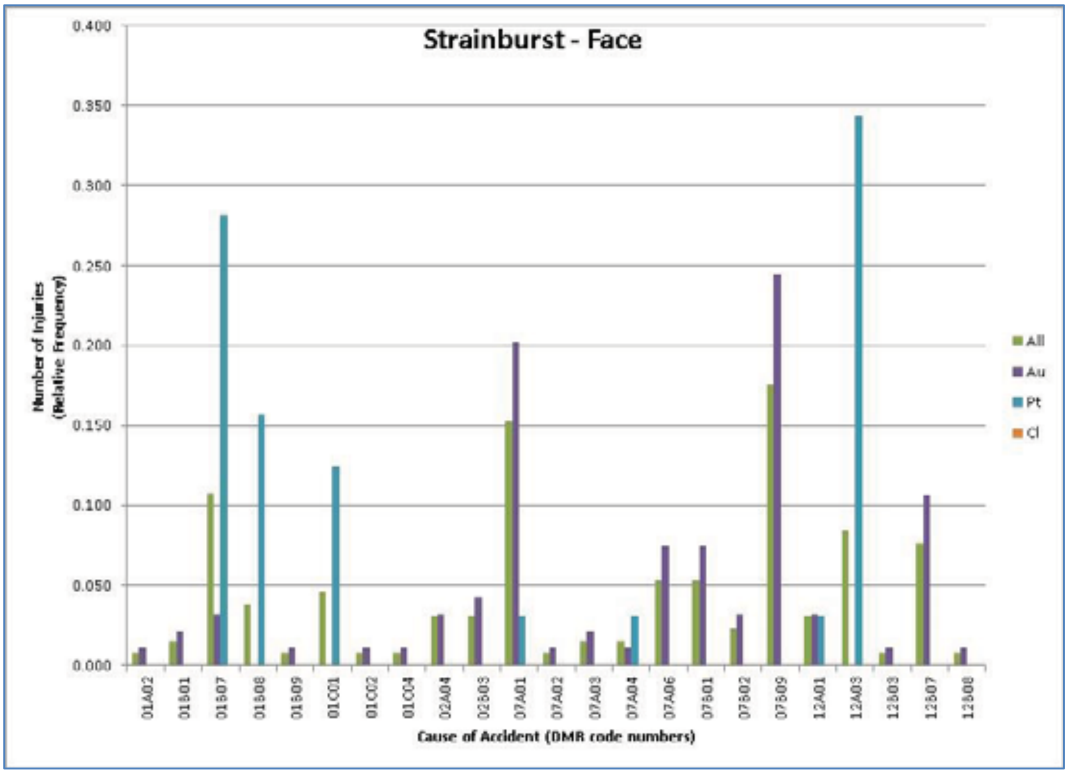

Figure 102: Probable Causes of Strainburst-Face Accidents

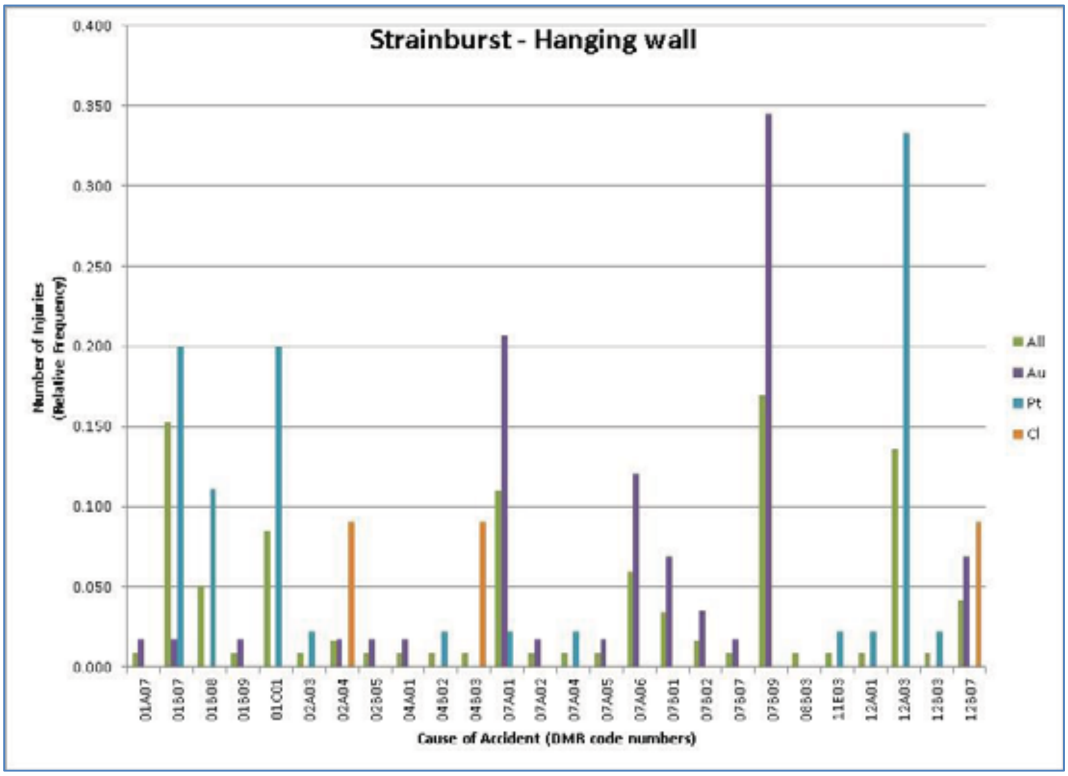

Figure 103: Probable Causes of Strainburst-Hanging wall Accidents

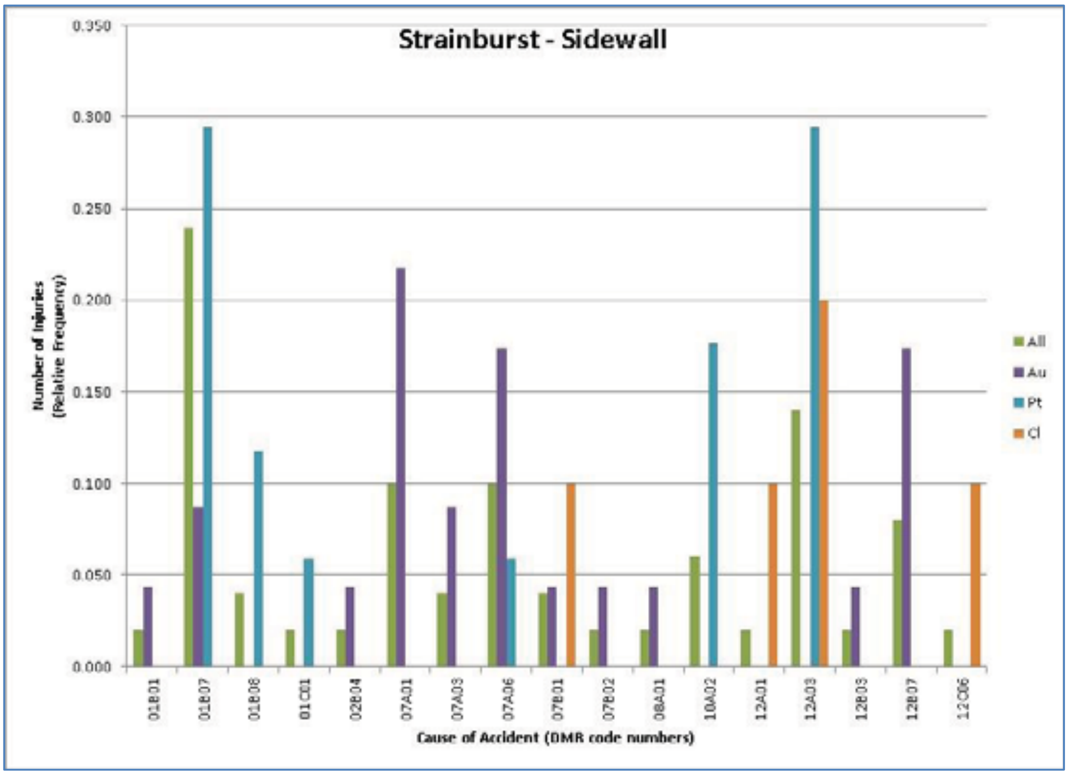

Figure 104: Probable Causes of Strainburst-Sidewall Accidents

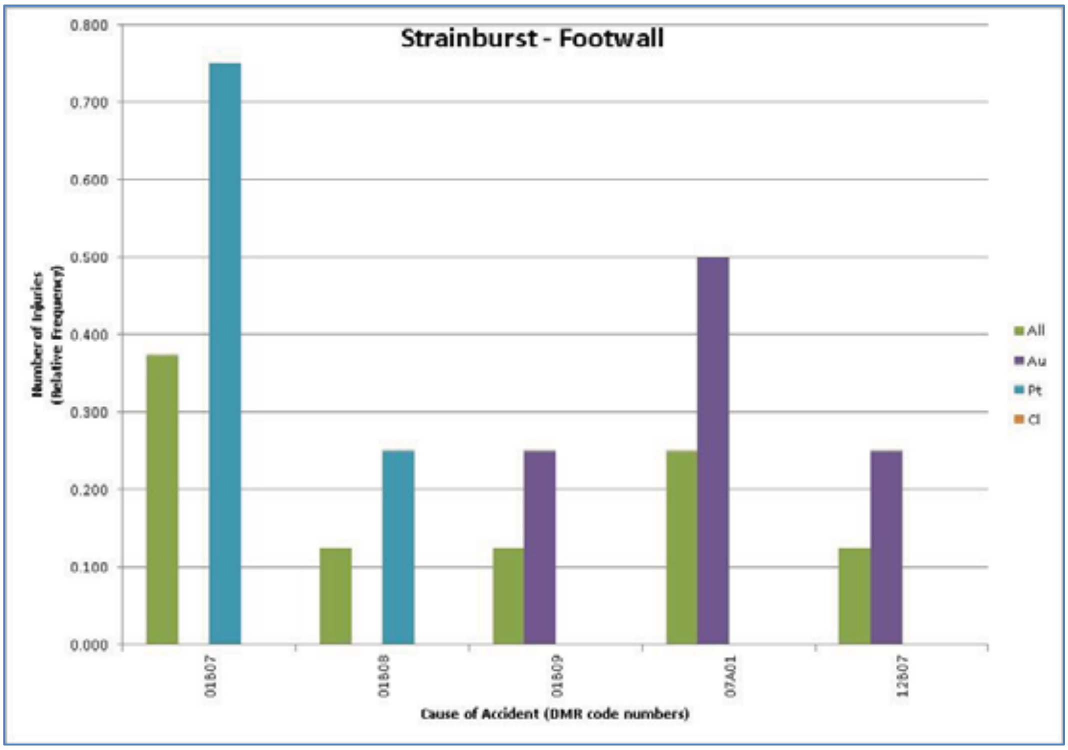

Figure 105: Probable Causes of Strainburst-Footwall Accidents

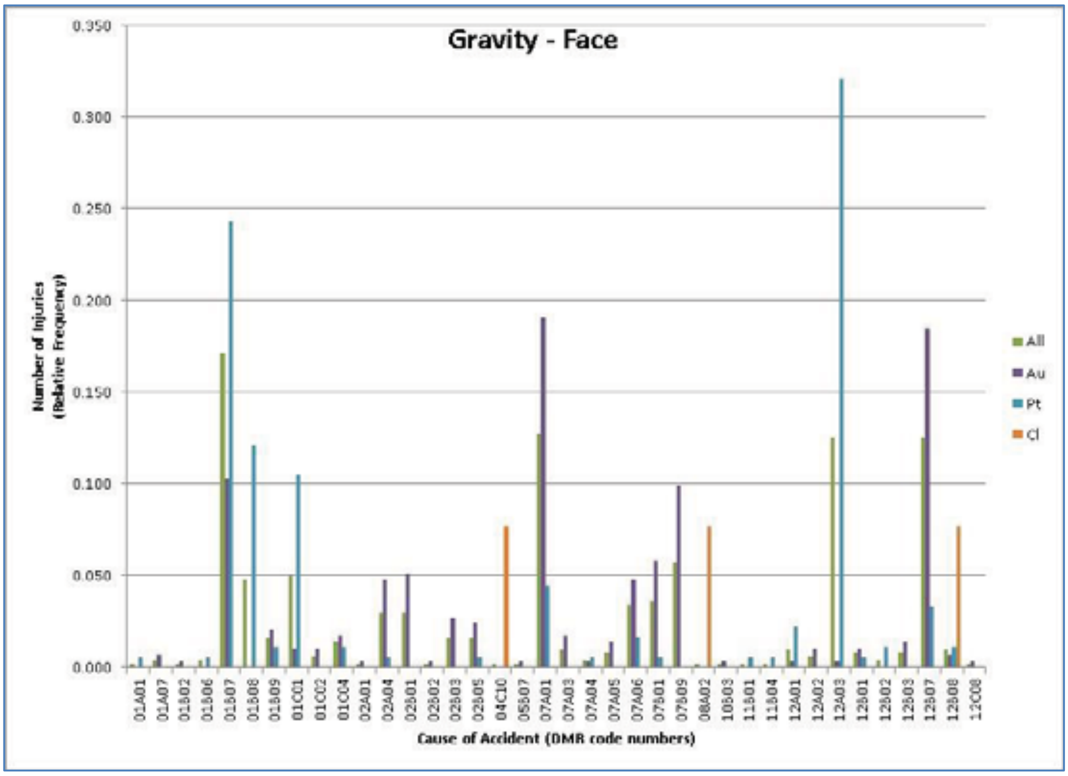

Figure 106: Probable Causes of Gravity-Face Accidents

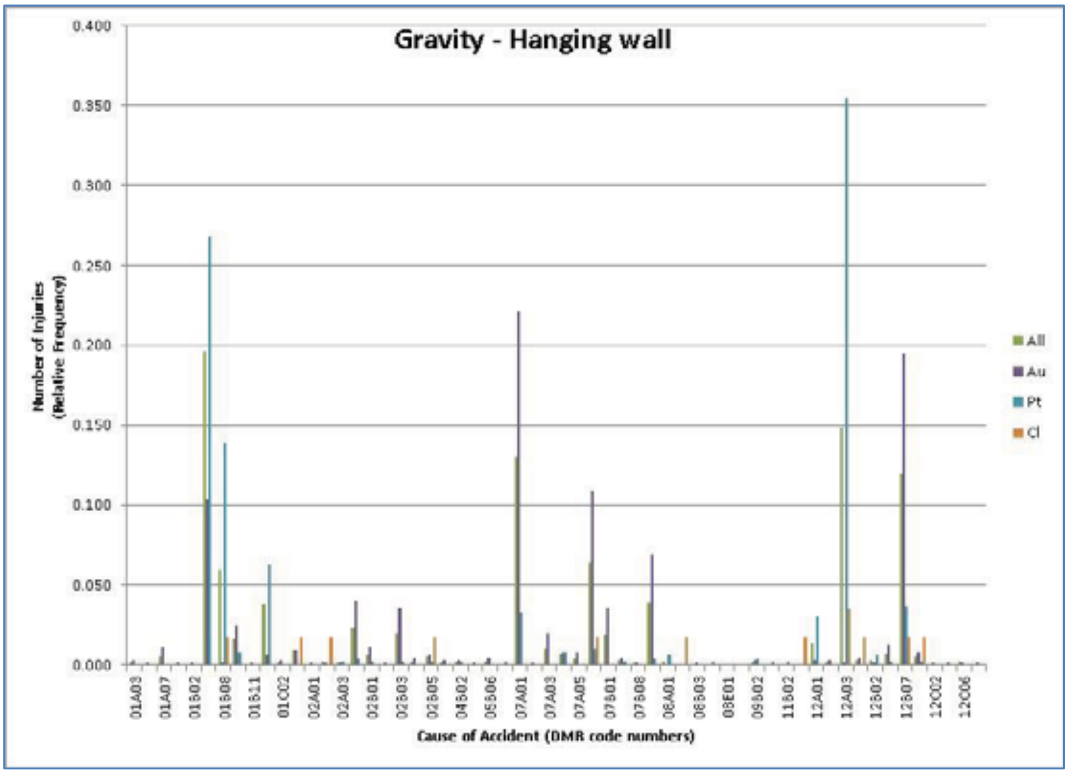

Figure 107: Probable Causes of Gravity-Hanging wall Accidents

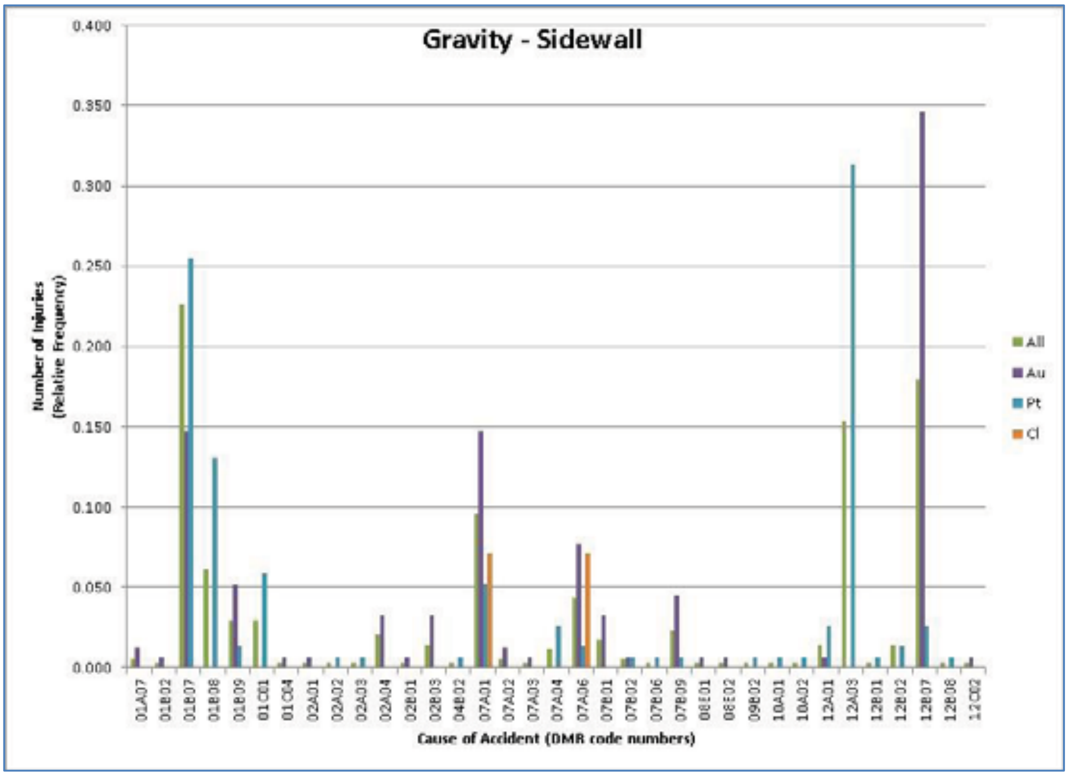

Figure 108: Probable Causes of Gravity-Sidewall Accidents

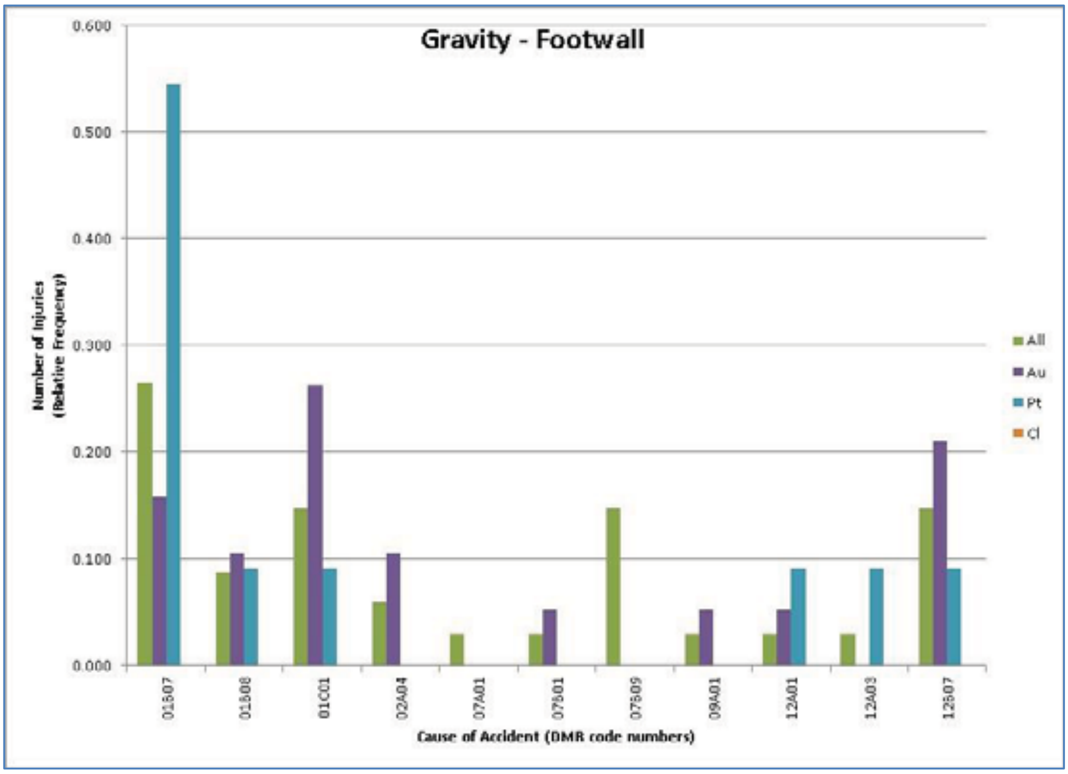

Figure 109: Probable Causes of Gravity-Footwall Accidents

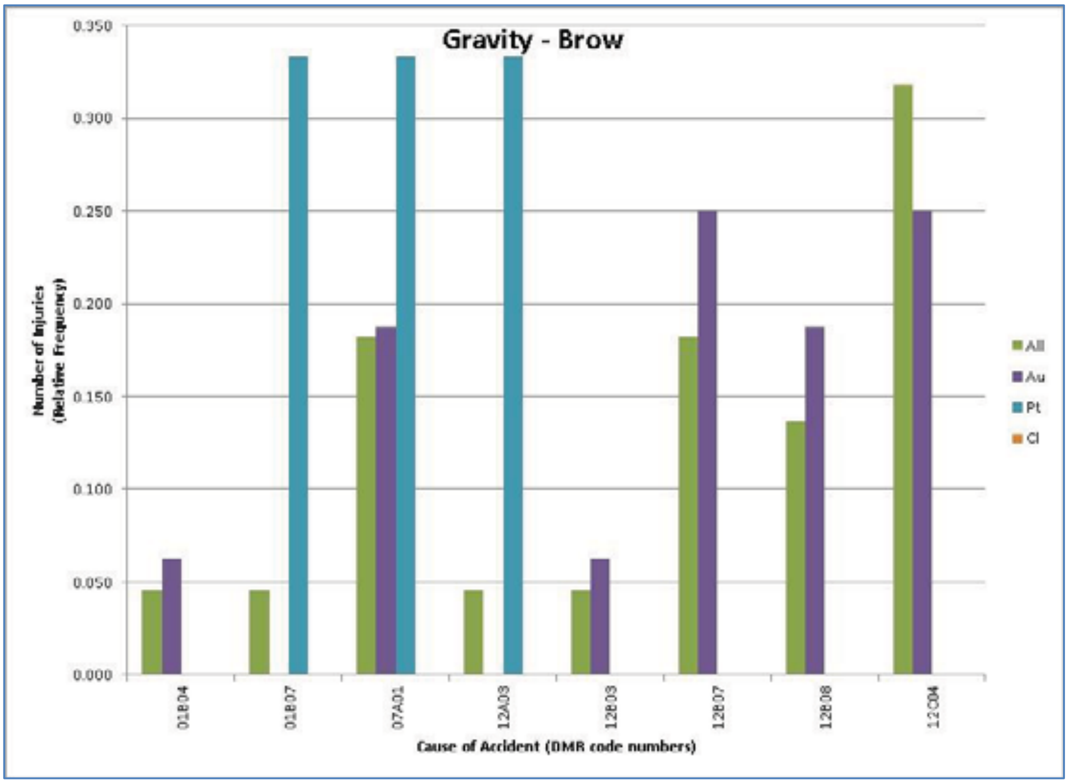

Figure 110: Probable Causes of Gravity-Brow Accidents

If the Fall of Ground accident data is re-analysed by combining the data together for all commodities, for each of the types of FOG accidents (face, hanging wall sidewall and footwall), the graphs shown in Figure 111 to Figure 114 can be created. The probable causes of the accidents for a variety of relative frequencies can be extracted to create a table, as shown in Table 23. This shows the probable causes of Fall of Ground accidents, for the various accident types, with the relative frequency of accidents highlighted for different values.

The causes of accidents that are responsible for greater than 10 % of FOG accidents are highlighted in red, and those responsible for 8 – 10, 6 – 8, and 4 – 6 % are highlighted in orange, green and blue respectively. Those not highlighted are responsible for 2 – 4 % of the FOG accidents.

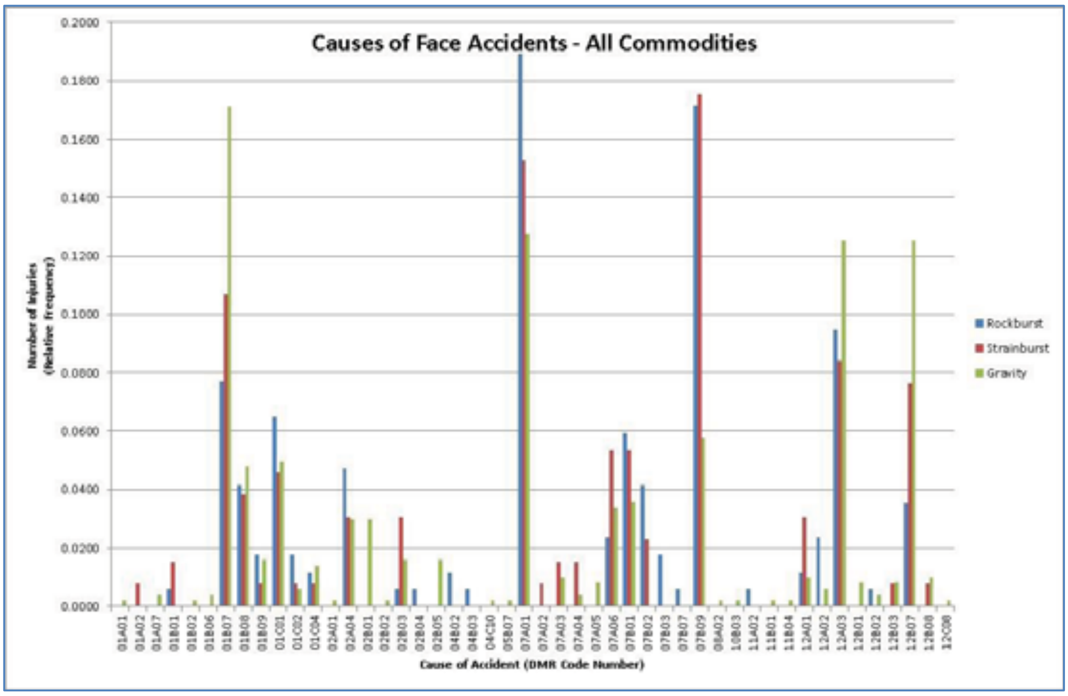

Figure 111: Probable Causes of Face Accidents - All Commodities

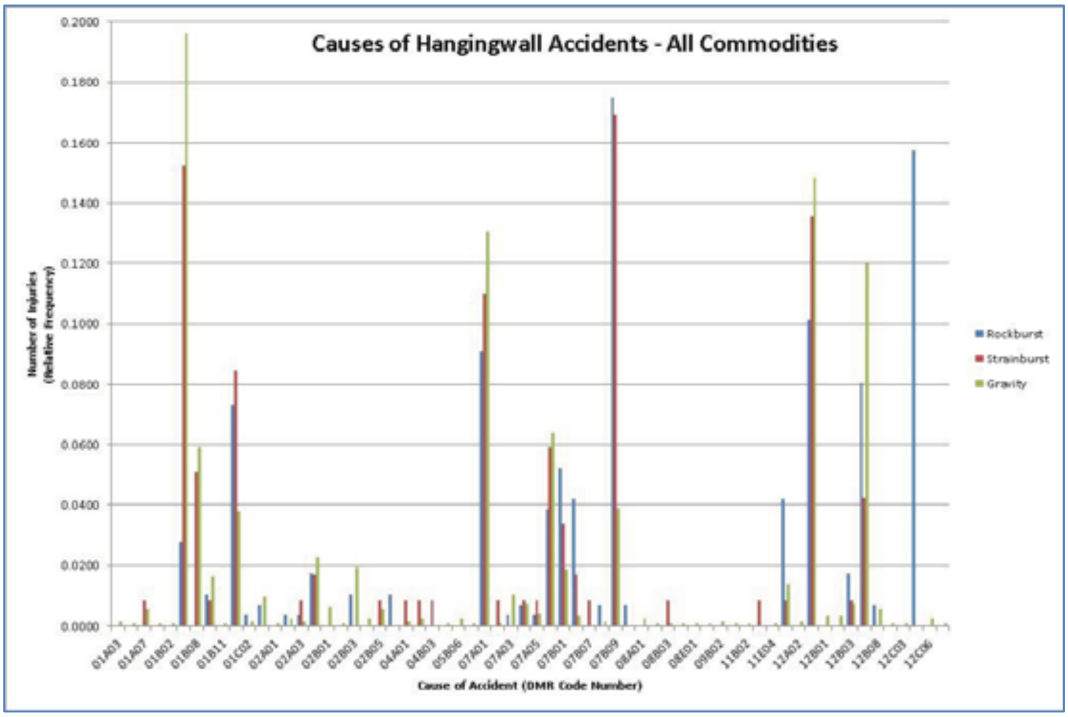

Figure 112: Probable Causes of Hanging wall Accidents - All Commodities

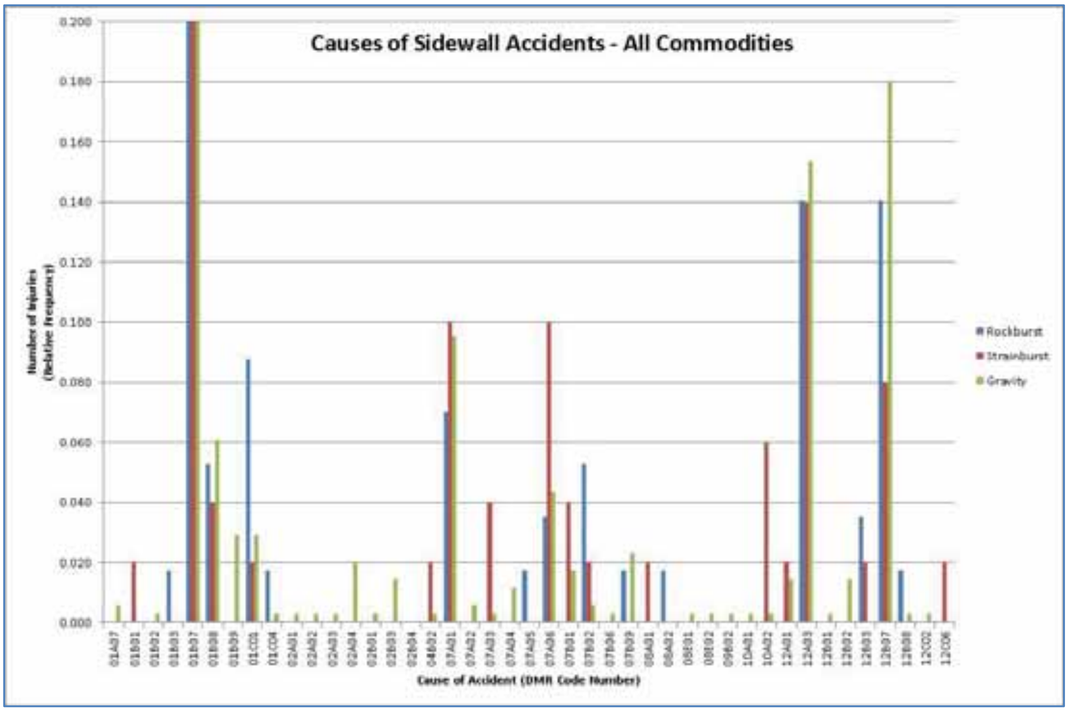

Figure 113: Probable Causes of Sidewall Accidents - All Commodities

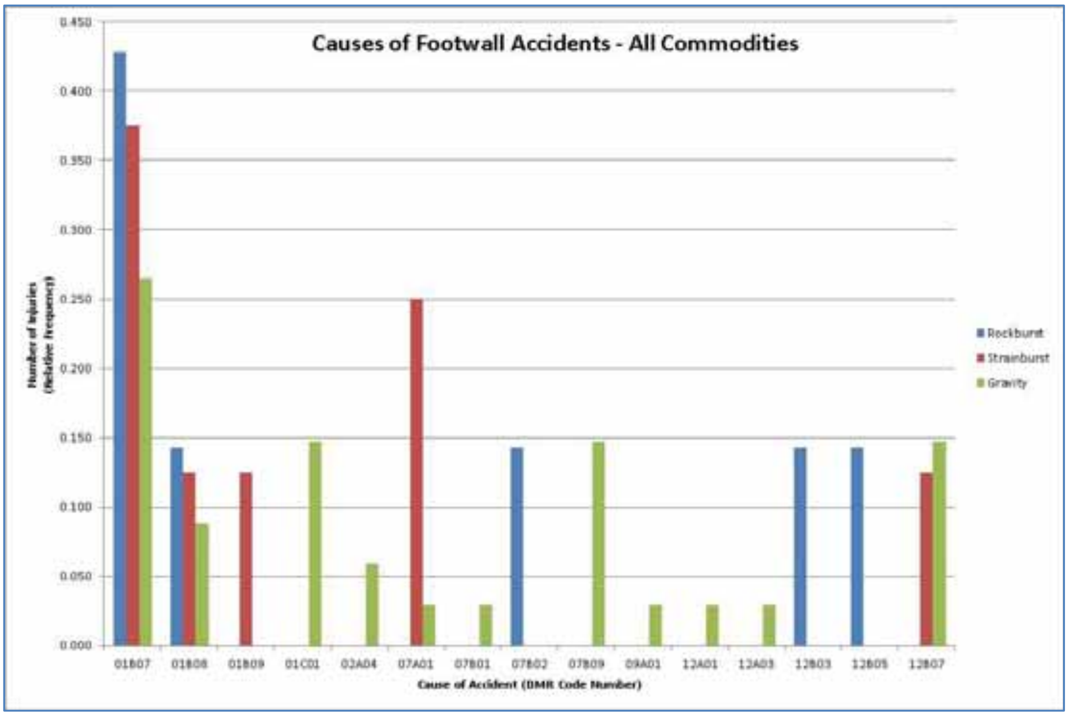

Figure 114: Probable Causes of Footwall Accidents - All Commodities

16.2 Milestone Conclusions

Table 23 indicates that the main probable causes of the Fall of Ground accidents are:

- Poor judgement (01B07)
- Inadequate maintenance of standards (12A03)
- Inadequate involvement/leadership to prevent injury (07A01)
- Inadequate method for hazardous task identification (12B07)
- Shortcomings in risk control system (07B09)
- Poor co-ordination (01B08).

Two of the above probable accident causes (01B07 & 01B08) fall within the SAMRASS group "*inadequate mental or physical limitations*", two (07A01 & 07B09) within the "*inadequate leadership and supervision*" group, and two (12A03 & 12B07) within the "*standards and procedures*" group.

Table 23: Probable Causes of Fall of Ground Accidents - All Commodities

Probable Cause of Accident		Relative Frequency											
		Face			Hanging Wall			Sidewall			Footwall		
Code	Description	Rockburst	Strainburst	Gravity	Rockburst	Strainburst	Gravity	Rockburst	Strainburst	Gravity	Rockburst	Strainburst	Gravity
01B07	Poor judgement	0.077	0.107	0.171	0.028	0.153	0.196	0.281	0.240	0.226	0.429	0.375	0.265
01B08	Poor co-ordination	0.041	0.038	0.048		0.051	0.059	0.053	0.040	0.061	0.143	0.125	0.088
01B09	Slow reaction time									0.029		0.125	
01C01	Workplace not modified to accommodate personal shortcomings	0.065	0.046	0.050	0.073	0.085	0.038	0.088		0.029			0.147
02A04	Lack of knowledge regarding safety aspects of job	0.047	0.031	0.030			0.023			0.020			0.059
02B01	No/inadequate training on task that lead to incident			0.030									
02B03	No/inadequate instructions given before task conducted		0.031										
07A01	Inadequate involvement/leadership to prevent incident	0.189	0.153	0.127	0.091	0.110	0.130	0.070	0.100	0.096		0.250	0.029
07A03	Too little authority								0.040				
07A06	Inadequate supervision task	0.024	0.053	0.034	0.038	0.059	0.064	0.035	0.100	0.043			
07B01	Lack of commitment and/or involvement in risk control programme	0.059	0.053	0.036	0.052	0.034			0.040				0.029
07B02	Inadequate work planning/programming	0.041	0.023		0.042			0.053			0.143		
07B09	Shortcomings in risk control system	0.172	0.176	0.058	0.175	0.169	0.039			0.023			0.147
09A01	Not researched												0.029
10A02	Frequency of maintenance								0.060				
12A01	Inadequate developments of standards		0.031		0.042								0.029
12A02	Inadequate communication of standards	0.024											
12A03	Inadequate maintenance of standards	0.095	0.084	0.125	0.101	0.136	0.148	0.140	0.140	0.154			0.029
12B03	No specific rule to control actions that lead to incident							0.035			0.143		
12B05	No signs/notices to reinforce rule										0.143		
12B07	Inadequate method for hazardous task identification	0.036	0.076	0.125	0.080	0.042	0.120	0.140	0.080	0.180		0.125	0.147
12C04	Practices				0.157								

Key to Relative Frequency
> 0.10
0.08-0.10
0.06-0.08
0.04-0.06
0.02-0.04

17 Social Research Findings

The social research component is investigations into the perceptions of underground mine worker's safety practices and contributes to the overall outcomes of the study.

17.1 Methodology

This social research study utilised a variety of qualitative research methodologies to collect data in order to gain an understanding of the current environment and perceptions of underground mine workers in relation to barring practices. Initial data collection was undertaken within these categories in the desktop review phase where background information was available for the study.

The social research study consisted of a desktop review, a fieldwork component, data analysis and the compilation of the report. The fieldwork component consisted of key informant interviews as well as focus group discussions at seven champion mines across South Africa within the platinum, gold and coal commodities. Fieldwork was conducted consecutively from March to August 2015.

17.2 Desktop Review

A desktop review of the existing barring environment documentation was undertaken. The documents and information which have been reviewed are included in the reference list at the end of this document. Internet research was conducted to gain an understanding of available reports, articles and papers on the following broad topics:

- South Africa's mine health and safety culture.
- Workers perceptions on safety procedures.
- What goes wrong underground which has increased the number of reported incidents?
- Culture-based behaviour.
- Leadership challenges.
- Automation of the "making safe" process.
- Mine safety training systems.

17.3 Fieldwork Component

Social research was undertaken at seven of the nine champion mining houses across the South African platinum, gold and coal sectors. Data collection was carried out on the surface, using social assessment tools in order to obtain qualitative data for the understanding of barring related incidents and accidents. These tools are:

- Focus group discussions.
- Key informant interviews.

17.3.1 Focus Group Discussions

Dr Anita Gibbs (1997) indicates that the main purpose of focus groups is to draw upon respondents' attitudes, feelings, beliefs, experiences and reactions in a way in which would not be feasible using other methods. The focus group discussions have been guided discussions involving a small number of crew workers (between 8 and 13) sharing a common characteristic (e.g. belonging to underground mining crews/gangs, being involved in barring training, activities and practices) (Gibbs, 1997). The discussion addressed topics of common concern to participants, and issues raised during discussion were recorded and subject to qualitative analysis.

A schedule of the focus group discussion at the champion mines is presented in Table 24 below. This fieldwork was undertaken from March to August 2015.

Table 24: Schedule of Focus Group Discussions

Mine	No. of focus group discussions	Commodity	Date
Mining House A	2	Platinum Group Metals	03/03/2015
Mining House B/Shaft 9:	2	Platinum Group Metals	17/03/2015
Mining House B/Shaft 9:	3	Platinum Group Metals	18/03/2015
Mining House D	2	Gold	19/05/2015
Mining House D	2	Gold	20/05/2015
Mining House C	2	Platinum Group Metals	11/06/2015
Mining House E	2	Gold	17/06/2015
Mining House E	2	Gold	18/06/2015
Mining House F/Shaft 2	0	Coal	04/08/2015
Mining House F/Shaft 1	1	Coal	05/08/2015
Mining House G	0	Coal	13/08/2015

17.3.2 Key Informant Interviews

Qualitative data was collected through semi-structured interviews, held with key representatives and managerial staff from each volunteer mine and commodity. This tool was used to validate the data obtained from focus group discussions. Similar questions from the focus group discussions were asked to individual participants whom operated in the following roles:

- Miners.
- Supervisors.
- Shift Bosses.
- Mine Overseers.
- Strata Control Officers.
- Rock Engineers.
- Relevant Head of Departments (HODs).
- Training Managers Etc.

The purpose of the interviews was to:

- Gain insight into the current situation at each mine with regard to barring activities and procedures.
- Ascertain the perceived issues related to barring and the underground physical environment.
- Understand the key issues and themes related to barring practices.

Table 25: Schedule of Key Informant Interviews

Mine	No. of key informant interviews	Commodity	Date
Mining House A	2	Platinum Group Metals	03/03/2015
Mining House B/Shaft 9:	2	Platinum Group Metals	17/03/2015
Mining House B/Shaft 9:	4	Platinum Group Metals	18/03/2015
Mining House D	3	Gold	19/05/2015
Mining House D	4	Gold	20/05/2015
Mining House C	4	Platinum Group Metals	11/06/2015
Mining House E	3	Gold	17/06/2015
Mining House E	4	Gold	18/06/2015
Mining House F/Shaft 2	8	Coal	04/08/2015
Mining House F/Shaft 1	3	Coal	05/08/2015
Mining House G/Shaft 4	8	Coal	13/08/2015

17.4 Data Analysis and Report Writing

The qualitative data collected through the key informant interviews and focus group discussions sought to determine specific pieces of information pertaining to the different issues and thematic areas involved in underground barring activities. The data was analysed using thematic content analysis to gain insight into worker difficulties and challenges underground. The reiteration of similar themes were grouped and presented to show percentage of frequency. Note that the resultant graphs and charts are a representation of the repetition of key issues in terms of frequency and are not designed to indicate statistical representation for the data collected.

The social research report was compiled based on the thematic areas stipulated in the MHSC terms of reference for this study. These are as follow:

- Skills
- Training
- Equipment selection
- Geotechnical environment
- Size of excavation less than 2m high and size of excavation greater than 2m high
- Leadership
- Human behaviour

- Communication

The report will also include recommendations as identified by the mine employees through focus groups and key informant interviews. It also identifies problematic areas which need to be addressed and in some cases suggests strategies to eradicate or reduce issues or problems related to underground barring activities.

17.5 Study Limitations

The following limitations were experienced during this study:

- Data collection for measuring people's perceptions and attitudes was undertaken through key informant interviews and focus group discussions, but these have limited utility when extrapolating this data to a larger population (http://dmeforpeace.org/discuss/dme-tip-measuring-attitudes-and-perceptions);
- At certain mines, undertaking focus groups was difficult as most of the participants were sourced from centralised training centres. In order to collect sufficient data from these mines, additional key informant interviews were held.

17.6 Background Research

In recent times, South Africa's mine health and safety culture has evolved from one based on mere lip service to one based on widespread acceptance that safety is a key component to the success of any mining operation. There is a strong industry focus to drive down the level of fatalities and lost time injury frequency rates, as the consequences of these events are far reaching with implications within the mining sector and broader mining communities throughout the country.

In his keynote address at the Southern African Institute of Mining and Metallurgy's 2015 MineSafe conference, Chamber of Mines of South Africa President, Mike Teke, urged industry stakeholders to continue working hard to improve on health and safety related matters to achieve the objective of zero harm at mining operations.

Teke noted improvements in the mining sector over the period 2012 to August 2015. "In 2012, the local mining industry recorded 112 fatalities, 93 in 2013 and in 2014 there were 84 fatalities recorded by the industry, which is a clear indication that great strides toward improving safety levels were being made." However, Teke also pointed out that, as of August 28, 2015, the industry had recorded 49 fatalities, which he stressed was a "very important reminder" that a lot more needed to be done to ensure zero harm was achieved. He emphasised the importance of the health and wellbeing of mine employees as well as the environmental impacts of mining operations.

In his 2013 BD Live article entitled Voice of Mining: Worker safety a mammoth task for SA's mining sector, Teke commended industry role players for the results achieved, noting what could be done when a broad base of industry stakeholders commit to the achievement of mutually beneficial objectives. What made these achievements so extraordinary was that they occurred in the deepest mines in the world and in operating conditions that are accepted as the world's toughest. Coupled with a workplace that is categorised by a critical skills shortage in some 30 significant occupations, low literacy levels and a national culture that tends to disregard safety imperatives, Teke states that these achievements are commendable (Teke, 2013).

Teke noted that among members of the Chamber of Mines, managing safety issues was elevated to the highest level with the establishment of the CEO Elimination of Fatalities Team in 2012. Comprising the CEs of a number of mining companies that produce a variety of different commodities, the team is specifically focused on leading collaborative safety initiatives from the top. Its initial primary target was falls of ground because these, historically, were the biggest cause of underground fatalities. The concentrated CEO attention on this traditionally dangerous phenomenon produced a 50% reduction in 2012 in fall of ground fatalities. This trend was sustained during 2013.

The focus of safety leadership was also echoed by Lance Bloch, Clinical Psychologist with Lance Bloch & Associates. Bloch, in his paper entitled 'The 4th Wave': culture-based behavioural safety, presented at the Southern African Institute of Mining and Metallurgy, Platinum 2012 Conference, notes that most mine safety initiatives in South Africa were historically centred around a focus on foreign health and safety concepts and systems that did not necessarily work in a South African context. These initiatives, according to Bloch, largely ignore the unique South African historical and cultural context, lacking a deeper appreciation for legacy issues that negatively impact on safety, production, and relationships. In addition, Bloch argues that existing methods based on safety engineering, policies and procedures, Behaviour-Based Safety have proven less effective than what is required by the current health and safety standards. Bloch advocates a method which focuses on culture-based behavioural safety, arguing that this method has proven to be more effective and appropriate for the safety and transformation issues being dealt with in mining today (Bloch, 2012).

Bloch cites the research of Professor Petri Schutte (Schutte, 2015) into hundreds of mines in South Africa which identified a clear correspondence between employees' perceptions of a lack of management caring about their welfare and happiness, and their willingness to work safely and productively. Similarly, Bloch notes that his own research has shown that a management supervisory style characterised by a lack of appreciation for black African culture coupled with a low EQ quotient on the part of the supervisor, can negatively affect employee job attitudes. He cites a study by Pesuric and Byham (1996) which showed that good emotional intelligence training for supervisors, including listening skills and techniques on how to empower workers. This in turn had a major impact on the reduction of grievances, and significantly improved productive capacity and profitability.

Bloch observed that a lack of constructive and caring engagement with employees by management and senior staff contributed to the widely held belief that production and profits come before health and safety. Bloch cited research by international safety consultancy SAFEmap (1999) which shows that the biggest increase in safety comes from an improvement in the belief that 'this company really cares about us'. He further quotes Jim Collins (2001), in his book "*Good to Great*", which shows that emotional commitment is essential to improving performance at all levels. He further notes the work of Jeffrey Pfeffer (1998) in his book The Human Equation which demonstrates that the biggest single increase in production comes from increased participation. For every increased one standard deviation in participation, production increases by 16 per cent. The impact of employee engagement and participation in any endeavour (including health and safety) should therefore not be ignored.

Bloch observes that despite the intentions of management, workers are still unhappy, feeling to be an unacknowledged part of a workplace culture that does not seem to engage, involve, or care about them. The low levels of emotional commitment and relatively high levels of frustration and disenchantment inevitably lead to consequences that sabotage management efforts to achieve the goal of zero harm.

A further factor that impacts greatly on achieving this goal, according to Bloch, is making every effort to include and take account of all significant role players in developing and implementing measure to build a viable safety culture. Role players include management and middle management, unions, workers, the community, and the DMR.

The importance of supportive leadership and inclusive broad based consultation regarding health and safety issues was also emphasised by Van Zyl in his paper entitled '*Progress with* *piloting of adoption for a leading practice*', presented at the Southern African Institute of Mining and Metallurgy, Hard Rock Safe Safety Conference 2009 (Van Zyl, 2009).

To demonstrate gains made in the industry, the successes of BHP Billiton in the implementation of a comprehensive culture change initiative is worth nothing. These initiatives were launched following two unfortunate incidents at Wessels Mine in 2010 and 2011. After a time of relative stability in terms of safety, the mine experienced two fatalities in quick succession in November 2010 and February 2011 (Cronje, J and Rajan, J, 2015).

Cronje (2015) notes that BHP Billiton leadership undertook a critical review of the leadership culture and organisational failures which led to these events. As a consequence, structural and behavioural changes were implemented at Wessels and Mamatwan Manganese Mines which focused on simplifying and entrenching existing safety systems and developing a leadership culture that modeled low tolerance for risk taking behaviour. This was achieved through, *inter alia*, building a reporting culture and requiring immediate response to addressing hazards. The result, Wessels Mine achieved 299 white flag days (without any injuries) on 30 July 2013 and had achieved a record of 445 recordable injury free days on 31 July 2013.

Cronje also notes that the Wessels approach aligned well with Casey's model (2012) which proposes eight behavioural dimensions which would provide employees with safety performance expectations and increase motivation to engage in safety beyond compliance.
It is interesting to note that strategies implemented at the above mine correspond with recommendations made in earlier research undertaken by SAFEMap for SIMRAC in 2005 (SAFEMap, 2005). Conclusions of this research are summarised below:

- Overall, the safety and health culture in the SA Mining Industry is significantly more not taken as seriously as that of the Australian and International benchmarks.
- All levels, except the specialist group record more negative trends than the benchmarks.
- The SA Mining Industry is driven primarily by a systems and compliance based culture.
- Mines with a more positive historical performance recorded a more positive safety and health culture than those mines with a poorer historical performance.
- Large differences in the safety and health culture between the mines exist.
- The Gold mining sector records a slight but statistically significantly negative trend when compared to the other sectors.
- Smaller mines recorded more positive trends in the safety and health culture than the larger mines.

With specific reference to ‘making safe’ or barring, this practice, although life-saving, is laborious, subjective and dangerous (Teleka, S.R; Green, J.J and Brink, S, 2011). Given the inherent dangers and the pressure that the barer is often subjected to, it is not surprising that critical decision making, even for an experienced barer, can be severely compromised. When combined with fatigue, inexperience, poor hearing ability, hot and humid underground working conditions and pressure to quickly execute the task, the risks of errors are multiplied.

Similarly, Green (2010) notes that while the exercise of barring is extremely important to the safety of miners, it is often rushed and carried out inefficiently due to the fact that production can only commence after the area has been declared safe. Miners carrying out this exercise are often under a lot of pressure to complete the process and declare the area safe in order for operations to begin (Green *et al*., 2010).

Another behavioural factor that impacts significantly on safety performance in underground mines is the abuse and use of drugs and alcohol among mineworkers. In a recent interview with Mining Weekly (2015), alcohol testing distributor ALCO-Safe director Rhys Evans noted that drugs are often used as a coping mechanism to deal with stress, unhappiness or the pressures of daily life. Evans explains that new drugs, such as Nyaope, a mixture of low-grade heroin, often cut with anticoagulant compounds (typically rat poison) or prescription antiretroviral medication, and Tik, a methamphetamine-based drug cocktail, are currently popular. The different types of drugs available have increased dramatically at different prices, and cheap recreational drugs are now easier to come by than ever before (Evans, 2015).

Evans notes that drugs have essentially become more affordable than alcohol, giving rise to increasing levels of abuse and addiction in the mining industry. He states that mining houses need to implement drug policies that include testing procedures to monitor employees. He notes that although alcohol testing in the workplace has become increasingly common, as the dangers and liabilities in many industries of employees being under the influence of alcohol can be significant, drug testing is less common, despite the consequences being equally severe and the same legislation governing the use of both substances.
Evans notes that alcohol and drugs impair judgement that can constitute a workplace hazard, particularly in environments that involve the operation of machinery. “Preventing substance abuse in the workplace is generally accepted to be best practice and regulated by the OHSA, which applies to not only dangerous environments but also any business in any industry” (Evans, 2015).

According to Ajani (2007), the prevalence of risky drinking among mine workers was found to be as high as 32% and the majority of affected employees were in unskilled or semiskilled occupations (Kews, 1994). In a South African gold mine the lifestyle of miners such as living apart from families for prolonged periods was found to encourage unhealthy alcohol consumption (Parry, CDH and Bennets, AI , 1998). Higher rates of alcohol use have been found among miners who have only ever worked underground compared to those who work above ground and among miners with a heavy workload (Ajani, 2007).

Factors, which may contribute to cannabis use, include the fact that it is inexpensive, easy to procure, prosecution is infrequently enforced, and is perceived by many not to be problematic (Bhana, A; Parry, CDH; Myers, B; Pluddermann, A; Morojele, NK; Flisher, AJ, 2000). Poverty, boredom, and inadequate health education, have also been associated with substance use (Parry, CDH and Bennets, AI , 1998).

Stressful working conditions as are found underground and heavy workloads may encourage alcohol and drug use, which may serve as a coping mechanism (San Jose, BN; Van de Mheen, H; Van Oers, JA; Mackenbnach, JP; Garretsen, HF, 2000). Stress, loneliness, and boredom have also been cited as reasons for alcohol use by South African mine workers (Kews,1994).

Regular cannabis use has been associated with impaired social and occupational functioning. Chronic effects include psychological dependence characterised by deterioration in psychosocial functioning; subtle cognitive deficits, particularly attention, learning, and executive functioning (organising and integrating of information); possible triggering of onset of schizophrenia; increased vulnerability to respiratory illnesses; impaired lung function; and precancerous changes in lung tissue (Myers, B and Parry, CDH, 2001).

It is thus clear that abuse of controlled substances in the work place and particular in the underground gold mine setup has far reaching consequences and impacts on efforts to achieve the goal of zero harm. However, it was not frequently reported in this study. This may have been more prevalent in the old mining era. With the new mine, health and safety standards, this issue has been regulated and mines implement alcohol and drug testing (cannabis).

17.7 Results from Fieldwork Data Collection

This social research study investigates the perceptions of mine workers on barring practice and worker safety and how these can be improved. The mining industry has improved on safety standards with the development and implementation of the Mine Health and Safety Act. Mine workers have developed a safety culture which refers to the formal safety issues in the company, dealing with perceptions of management, supervision, management systems and perceptions of the organisation (company) (SIMRAC, 2005). However, the number of underground incidents related to barring is still significant.

The SIMRAC (2005) study stated that employees have distinct perceptions of the typical or habitual behaviours in the organisation. A person's actions will be largely influenced by his/her perceptions of what behaviours are expected, permitted or even required. A person may perceive members of his/her group as "inclined to take risks", and this will have a strong influence on the person's own willingness to take short cuts in the job. A person will act without giving the (risk taking) behaviour much or any thought. It is therefore imperative that when measuring such perceptions, the process and technology of measurement should not be foreign, threatening or unnatural to the respondents.

Measuring workers perceptions and attitudes was undertaken through key informant interviews and focus group discussions. This section discusses the findings from each of the champion mines identified for this study. Results based on participatory observation and thematic analysis is provided for each mine with a summary of the comparative key issues in each of the commodities. Please note the graphs and pie charts presented in this section are merely a representation of the repetition of key issues. These graphs and charts are not designed to indicate statistical representation for the data collected.

17.8 Platinum Sector

The platinum sector in South Africa has experienced major impacts due to labour relations in the past year. The dissatisfaction of underground workers on their salaries, bonuses and working environments has triggered strike action and even violent protests against the mining companies in this sector. The mining sector underwent reduction in their labour force due to a decrease in the platinum prices and demand for high labour wages.

The underground environment is a challenge to work in and induction includes health and safety tests and full medical and heat tolerance screening in order to appropriately function underground. Data was collected from three mines within the platinum sector. Key informant interviews were conducted with the management and control officers at the mine as well as focus groups with the crews working underground, who undertake barring practices daily. There were common themes identified when comparing the responses from workers at these mines and these were analysed into key theme issues.

17.8.1 Mining House A

The main issues are presented in Figure 115 below. The main issues mentioned by respondents were workers attitudes, incorrect reporting procedures, lack of appropriate leadership and production pressure. These issues may be presented separately but each is linked and will be discussed in relation to the responses from the interviews and focus groups. There is a significant frequency of responses on worker attitudes as compared to the other main issues. The percentage representation indicated the frequency in which these issue themes were reported through the data collected.

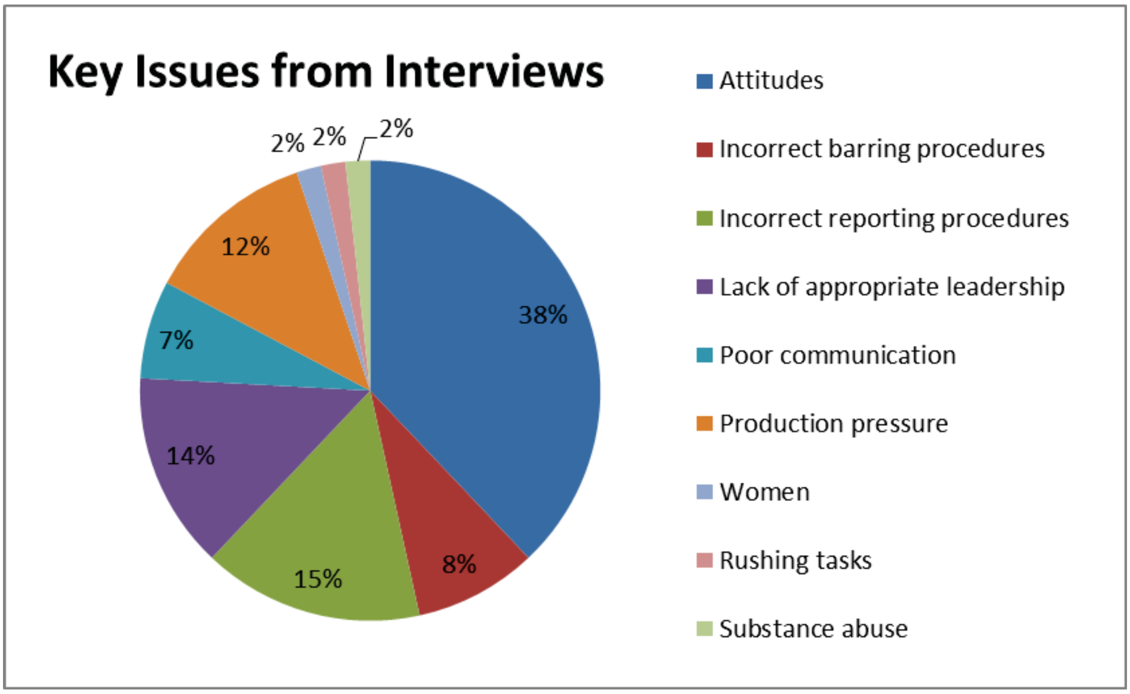

Figure 115: Key Issues from Informant Interviews

Worker Attitudes

Attitudes of the workforce develop over time due to extenuating factors which lends to the formation of an individual’s perception of their surrounding work environment, company and management. The various responses around workers attitudes are presented in Figure 116. Major attitudes are to do with workers choosing to follow incorrect procedures, lack of empowerment, complacency and feelings of being overworked, stressed and fatigued on the job.

It was reported that workers are sufficiently trained to undertake barring activities at Competent A and Competent B levels however, they choose to follow incorrect procedures based on other contributing factors. This was stated to be due to production pressure where they rush the safety procedures so that they can achieve production targets. The underground environment is not comfortable so workers take short cuts in order to exit shafts quickly at the end of shift. Unfortunately workers prioritise the production targets rather than safety procedures.

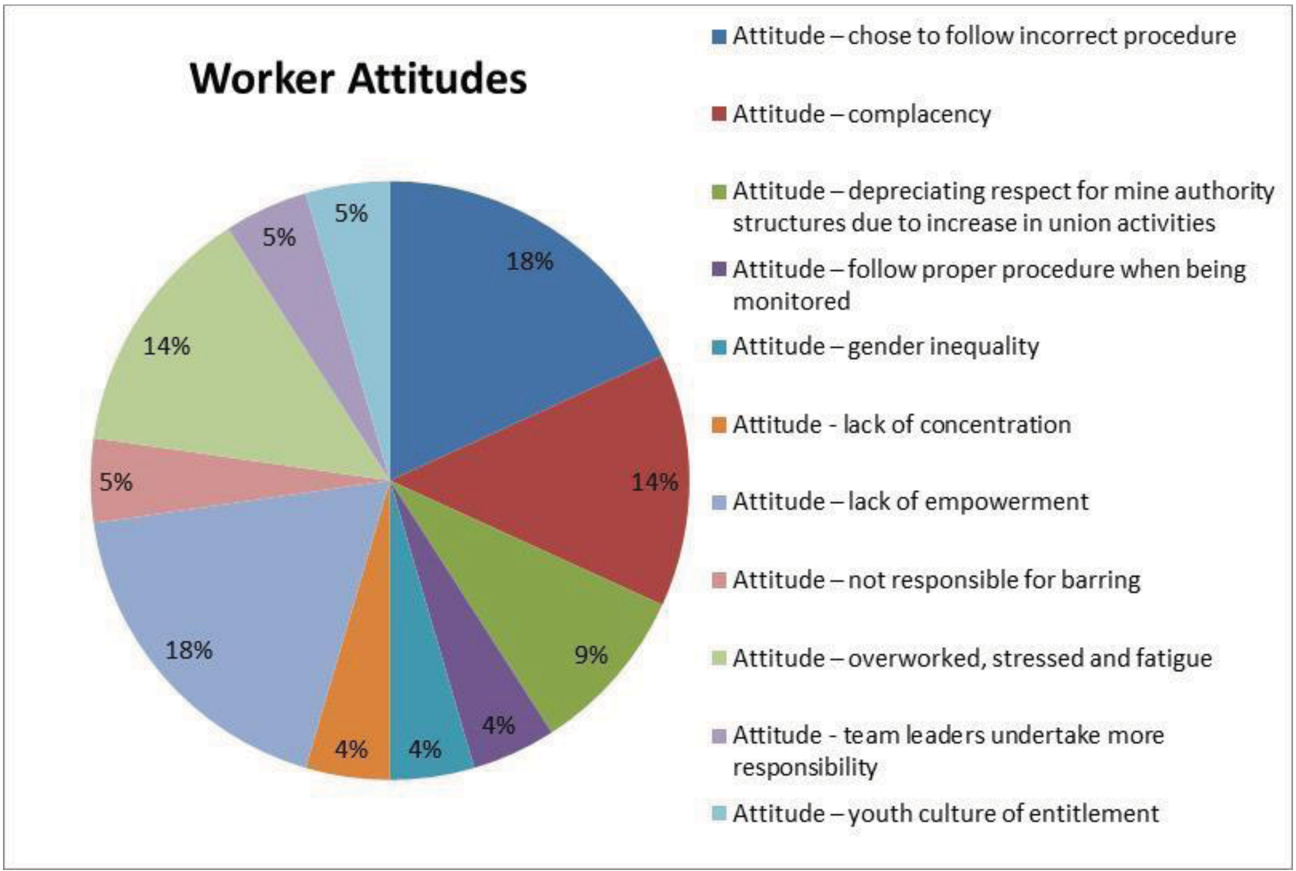

Figure 116: Workers attitudes

Employees experience a lack of empowerment based on lack of support from management and supervisors. They receive no affirmation of good work from leadership thus feel disempowered in their jobs. Supervisors reported the lack of presence of miners and the lack of support for the team leaders (Competent A) by the crew underground. The team leaders take on the responsibility of barring but lack the support from the Competent B workers in the crew. There are a small number of miners who are responsible for too many sections. The miners are not able to spend enough time at their sections during a shift in order to add value in terms of mentorship and coaching. This further disempowers the mine workers.

Managers at the mine stated that workers have developed an attitude of complacency. They have worked in the same sections for years without any occurrence of incidents so they take short cuts or fail to undertake the barring and safety procedures. There is a perception that the mine workers operate on autopilot in the tasks they undertake underground.

Respondents indicated that there was a lack of employees to undertake the necessary tasks to be completed in a shift. They stated that there was too much work for the existing workforce to complete in the time given. The workforce is pressured by management to reach their production targets which mean longer hours, which leads to increased fatigue and heat stress among mine workers underground. Fatigue increases the ability for human error to occur which could lead to incidents and potential injury.

Other things to consider are people's perceptions around taking responsibility for barring activities. The workers feel that they lack appropriate leadership and their team leaders take on more responsibility underground due to the lack of available miners, supervisors and shift bosses underground.

Incorrect Reporting Procedures

The reporting structure at the mine follows the tiered levels of the leadership and communication structure. So for daily reporting and inspections, the miner makes sure there is a team leader for the crew on a daily basis that will be responsible for reporting back on the shifts activities. There is also a safety representative in every crew to monitor that the area has been made safe. The responsible shift-supervisor signs off that the panel was risk assessed and the instructions given were carried out satisfactorily. The responsible mining overseer, rock engineer, technical services expert will sign off on the risk assessment and the area will be declared safe in a document for filling which is kept over a period of 3 months as reference.

Respondents indicated that workers incorrectly report safety incidents due to fear of the consequences from management. Less reported incidents means that the safety targets are met and bonuses are awarded. Respondents have indicated that they fear losing their jobs if they report incidents and the procedure is that they receive time off from work which they don't get paid for. Mine workers can't afford to be off work on sick leave so they tend to not report small incidents in order to stay at work and earn money. This indicates the number of reported incidents is low, thus the number of reported incidents on the mine may be inaccurate. The trend of failing to report incidents and workers fear of reporting incidents are the main causes of incorrect reporting procedures (refer to Figure 117 below). Workers also misrepresent the reasons for the incidents so it is unclear if incorrect barring procedures are always the cause for incidents occurring.

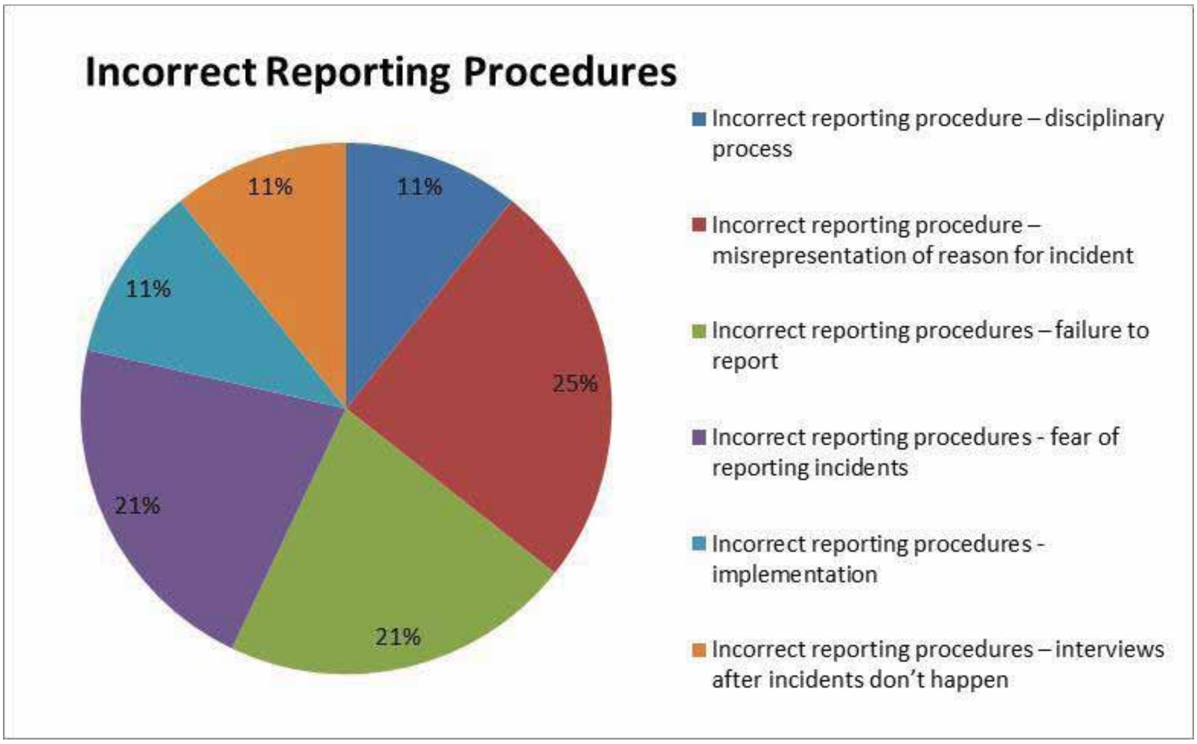

Figure 117: Causes of incorrect reporting procedures

As part of the reporting procedure, follow up safety interviews with the people involved are required. Respondents indicated that these follow up interviews were not taking place. Miners are production focused so they are satisfied to have the worker back on shift and on target rather than off sick as it is difficult to find replacement crew members. The worker is reportedly responsible for finding their own replacement which supports the behaviour of not reporting incidents correctly as finding replacements is a challenge due to the mine being understaffed.

Lack of Appropriate Leadership and Communication

The leadership and communication key issues were reported as an integrated issue where deficits in one affect the other. The leadership structure at the mine is a tiered structure which is also the structure for the flow of communication at the mine. The bottom up structure of the underground sections is described below:

- General crew workers
- Team leaders
- Miners
- Supervisors

- Shift bosses
- Mine overseer
- Mine Captain/Manager

It was reported by the crews at the general mine worker level that the people who hold management positions in the company may not be competent in the technical disciplines they manage. This was not reported through the interviews with respondents from the management levels, so this is a perception from the mine workers. The managers reported a lack of understanding instructions within the mine worker level. These differing responses are an indication of a communication system which isn't functioning.

Respondents reported issues with the leadership and communication within similar responses. There are few miners to manage the panels underground and team leaders take on the miner's responsibility in their panels with no support from management. Team leaders are not trained to blast but many do undertake these activities due to the shortage of miners and the pressure of production targets from each of the panels. There is no communication between the team leaders and miners so there is no knowledge of what happens in the panels as the miners and supervisors are not visible and actively managing.

The communication system at the mine follows the same tiered structure as the leadership mentioned above. The main break in communication occurs between the team leader and miner level. Respondents feel that the current communication system is not adequate and more effective strategies need to be put in place to facilitate better transfer of task instructions and information. There is a lack of discipline from workers in following the correct communication systems. It was reported that the system is adequate but is not being used appropriately.

Production Pressure

Production pressure is also an integrated issue which dictates workers attitudes toward health and safety policies. Pressure to meet production targets affects the way incidents are reported. Most commonly, workers rush their safety procedures in order to meet their daily production targets within their work shift. Workers indicated that the underground environment is not a comfortable place to work so they rush their work in order to exit the shift areas quickly at the end of the shift.

17.8.2 Mining House B/Shaft 9

The main issues arising from interviews were workers attitudes and incorrect barring procedures (refer to Figure 118). This is the perception from the management at the mine. Once again, the frequency of responses on worker attitudes as compared to the other main issues is significant.

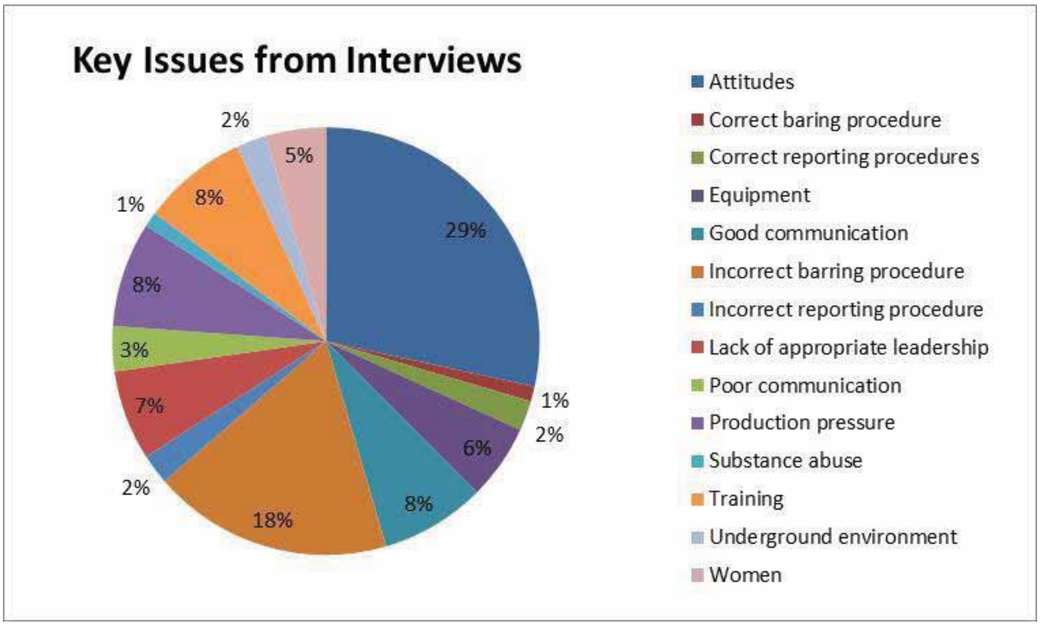

Figure 118: Results of key issues from interviews with management group

Responses of mine workers from the focus groups indicated that the main issues are workers attitudes, lack of appropriate leadership and training systems (refer to Figure 119).

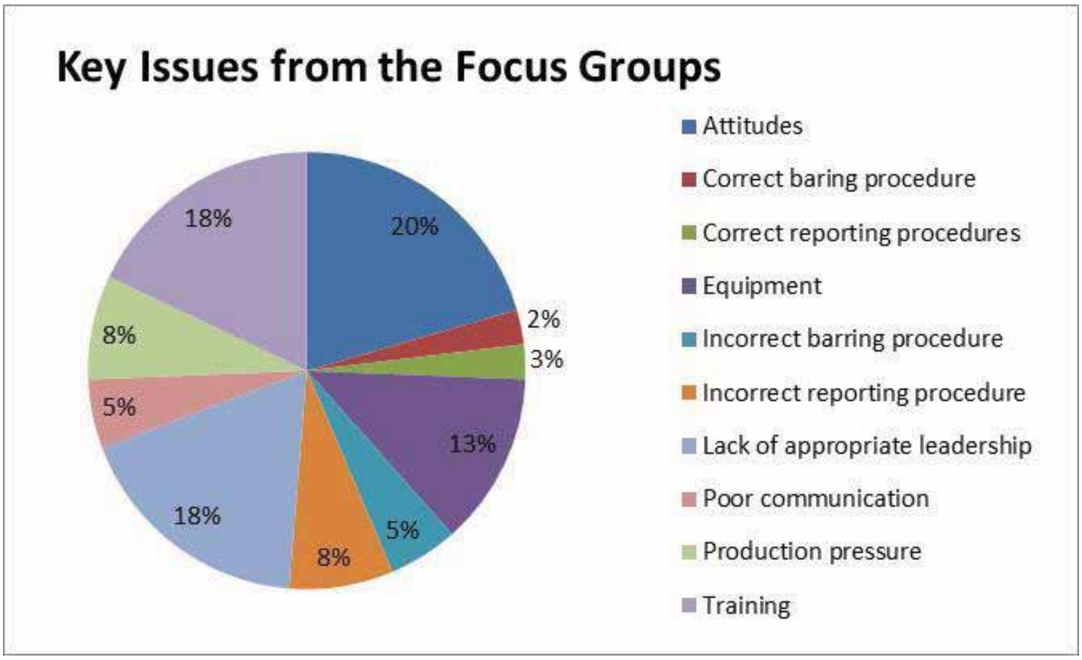

Figure 119: Results of key issues from focus groups with mine workers

Worker Attitudes

Respondents from interviews and focus group discussions indicated that worker attitudes are a main issue when it comes to implementing safety compliant barring activities underground. To indicate the perceptions experienced by management (through the interviews) and the mine workers (through the focus groups), Figure 120 represents the disparity of responses for the sub-issues related to workers attitudes.

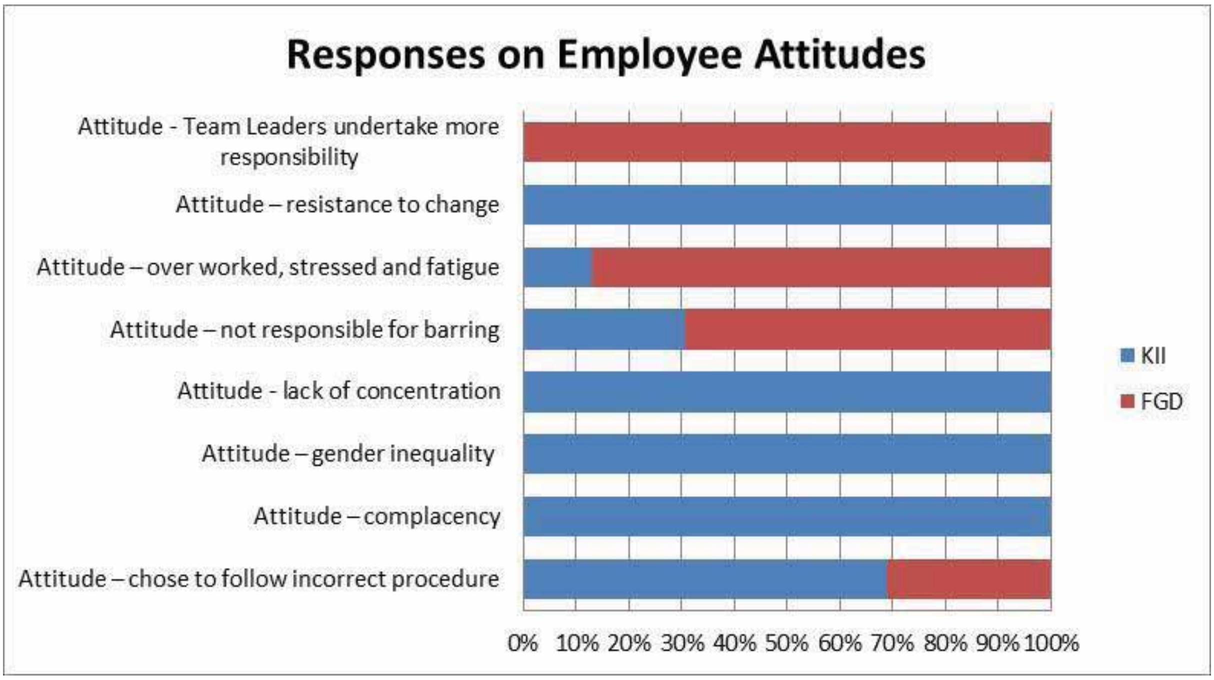

Figure 120: Responses from interviews and focus groups describing workers attitudes

The main issue of team leaders taking on more responsibility for underground work during a shift was reported by the crews through the focus groups. This additional responsibility on team leaders is due to a shortage of miners to manage the panels/working areas in the underground sections.

According to the management group responses, the attitude of workers is their resistance to change and their complacency when working underground. It was reported that the main causes of incidents underground is due to workers complacency and lack of concentration when conducting their work. Lack of motivation in their current jobs also leads to lack of attention or poor concentration on tasks which leads to injury.

Complacency on the job comes from workers undertaking the same activities in the same work areas for months with no incidents. This creates a sense of ease and workers tend to relax their safety practices. When workers are exposed to the underground environment for long periods of time, the heat can cause exhaustion which leads to lack of concentration and potential for injury.

Predominant attitudes of being overworked, stressed and fatigued come from the focus group respondents. The crews also have the perception that barring underground is not their responsibility. In the mine workers opinion, it is either the responsibility of the team leader or the miner to undertake the barring activities. There is not enough available pinch bars for everyone to bar so it is assumed that only the team leader and miners (if present) bars at the beginning of the shift.

Responses from management indicated an inequality of gender in underground crews. The nature of underground barring activities is physically demanding, coupled with the underground environment creates the perception that this is male dominated work. There are women who work underground and they have indicated that barring is very tiring. Women are partnered (buddy barring system) with men for barring activities and it was reported by the men that women can only bar for a short period and then rotate with their partner. So the male partners feel they are barring longer than their buddy (women) counterparts.

Responses from interviews and focus groups indicated that there is an attitude where workers choose to follow the incorrect procedure. This perception comes mainly from the management level but it was also reported from the mine workers. It was mentioned in an interview that the workers know the procedures and the safety rules but they simply choose to practice the incorrect procedure. The workers go against their training and their knowledge of what is right in order to take short cuts. This undertaking of incorrect procedures is especially practised when there is lack of supervision present during the shift.

Incorrect Procedures

Barring and reporting procedures have been raised as systems which are undertaken incorrectly. The reporting procedure follows the same tiered structure as the leadership and communication structure. Barring procedures at the mine are consolidated into 13 principles for safe and complaint barring as per the MOSH principles.

Incorrect barring is practised due to pressure to finish the work tasks during the shift and exit early so as to avoid the lengthy process of queuing to exit the shaft via the chair lifts. The constraint of exiting the shaft via the chair lifts was noted from the focus groups as a main reason for rushing through their work tasks during the shift. Rushing underground activities leads to carelessness when executing tasks and increases the probability for incidents.

There is a general attitude of non-compliance whereby the mine workers just don't follow the correct procedure. It was reported that the mine workers know the correct procedures and they have received training but they still choose to follow the incorrect procedures. This could be due to rushing through the tasks in a shift and choosing to prioritise the production targets rather than the safety procedures. It could also be attributed to the feeling of complacency in the underground environment.

Responses also indicated poor communication as a contributing factor to following the incorrect procedure. The communication of instructions from miners to the general workers was reported as poor although the team leaders' communication to their crews is good. Instructions may not be communicated adequately on the barring processes and lack of available supervision lead to incorrect barring procedures.

Incorrect reporting procedures are mainly due to the pressure to have a good safety record for the mine so workers fail to report any incidents or only report the serious incidents where injuries are significant. Workers reported experiencing pressure from management to meet safety targets of zero incidents so they report inaccurately or they misrepresent the reason for the incident. If it isn't logged as a barring incident, the safety targets remain good. Managers also mentioned that the reporting procedures involve a lot of paperwork and they don't have the time to complete everything correctly.

Lack of Appropriate Leadership

Leadership issues were raised mainly from the respondents in the focus groups which indicate that the mine workers are experiencing a lack of leadership. The main comment was the lack of presence of miners underground due to the miners having too many panels to manage within a shift. So there is a shortage of labour in that position which means team leaders take on the miner's responsibility for undertaking the day to day tasks during a shift. The miners entrust the team leaders to undertake these tasks although the team leaders may not have the sufficient qualifications or appropriate training for these tasks (for e.g. blasting). Due to the low number of miners per shift, there is also a lack of mentoring and training from that level of leadership underground. Some team leaders take on this role as well.

It was stated that the communication between team leaders and their crews are good and they also demonstrate good teamwork. Some crews have a good relationship with their miner, but some do not so the communication and teamwork should be improved those cases.

Responses from the focus groups indicated that there is abuse of authority from the upper level of management as they treat workers with favouring certain employees based on nepotism even if they don't have the right training for those tasks. There is also a lack of interest from management to improve and develop their subordinates.

Training

The current training system is a mixed method utilising both technical lectures and video/computer training followed by practical training at the training centre underground. The mine places high importance on training with adequate material in written (English and Fanakalo), visual and audio format. Responses indicated that the training system is good and that both technical and practical methods of training are being implemented (refer to Figure 121). It was also stated that the mine has re-training or refresher training for mine workers which keeps knowledge and techniques up to date with the constant changes in modern technology.

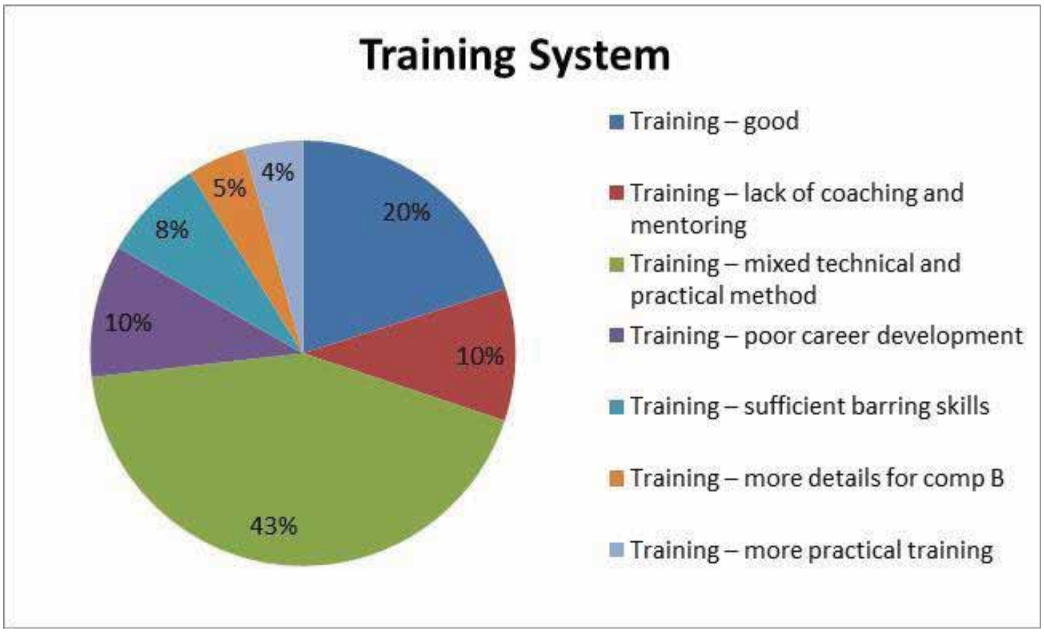

Figure 121: Responses on the Training System

There was a request through the data collection that Competent A and B workers should be taught how to identify rock types within the underground environment and be able to assess hazards. This is particularly important for the team leaders as they take on additional responsibility than their trained position. Respondents indicated that there is a lack of mentoring and coaching from seniors which is also linked to building an individual's career development at the mine.

Equipment

Equipment used for underground barring activities is the pinch bar. Pinch bars are generally steel bars fitted with a gasket which protects the users' hands when undertaking barring. There are different lengths of pinch bars to be used on the various heights of the excavated underground areas where barring needs to be conducted. It was reported that there are sometimes no gaskets on the pinch bars.

Respondents at the mine indicated that any issues with the pinch bar had to do mainly with the weight of the pinch bar. Heavy pinch bars limit the time a worker can accurately bar without feeling fatigued and lose concentration during barring. The second main issue with pinch bars is the availability of the correct length pinch bars in the panels underground. Respondents indicated that there aren't always pinch bars available and workers will use the incorrect length pinch bar instead of finding the correct length bar to use. It was even reported that workers would use whatever tool was available to bar and not necessarily a pinch bar. It was also mentioned that the hose which covers the sharper end of the pinch bar are unsuitable and workers injure themselves on this sharp end.

Other equipment relative to underground barring is the worker's PPE kit. Respondents had issues with the work gloves inhibiting their ability to bar. They also raised the issue of only being issued a set of overalls every 6 months. However, due to the nature of the work and the number of shifts the workers have, these do not last as long. Workers indicated that if they wash the overalls after every shift then it doesn't last long and they cannot request more.

An important point mentioned in the interviews with management is that workers do not bar areas where safety nets are bolted to the hanging wall. It is a perception that the safety nets are a suitable safety mechanism and there is no need to bar. However, this perception means that these hanging walls aren't maintained and when the nets are removed, the risk of fall of ground injuries is increased.

17.8.3 Mining House C

The main issues raised during the interviews with individuals in management positions were incorrect barring procedures, workers attitudes, production pressure and lack of appropriate leadership as presented in Figure 122 below.

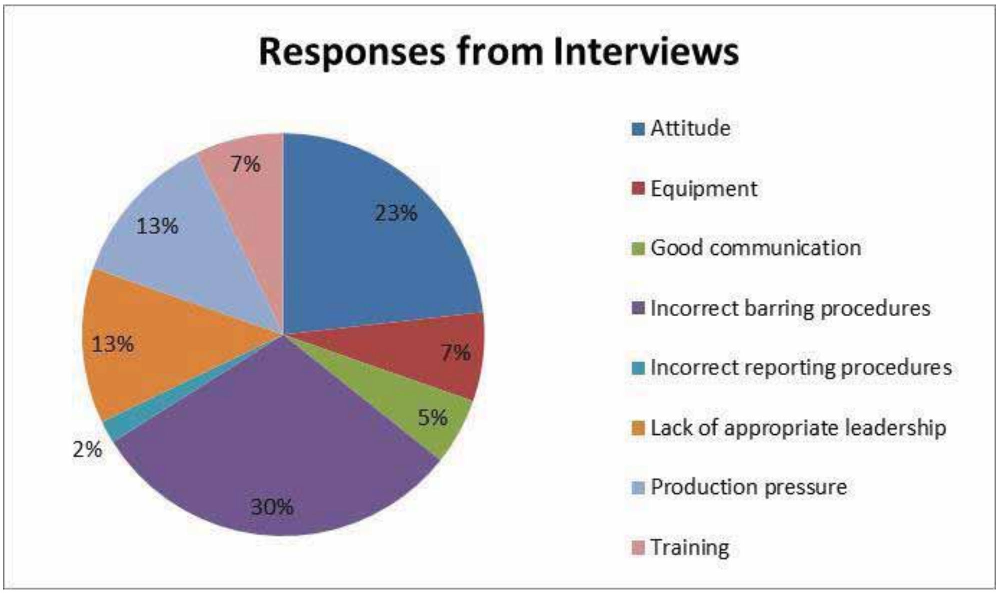

Figure 122: Key Issues from Interviews

The main issues raised from the focus groups with mine workers were worker attitudes, equipment and incorrect barring procedures as presented in Figure 123 below.

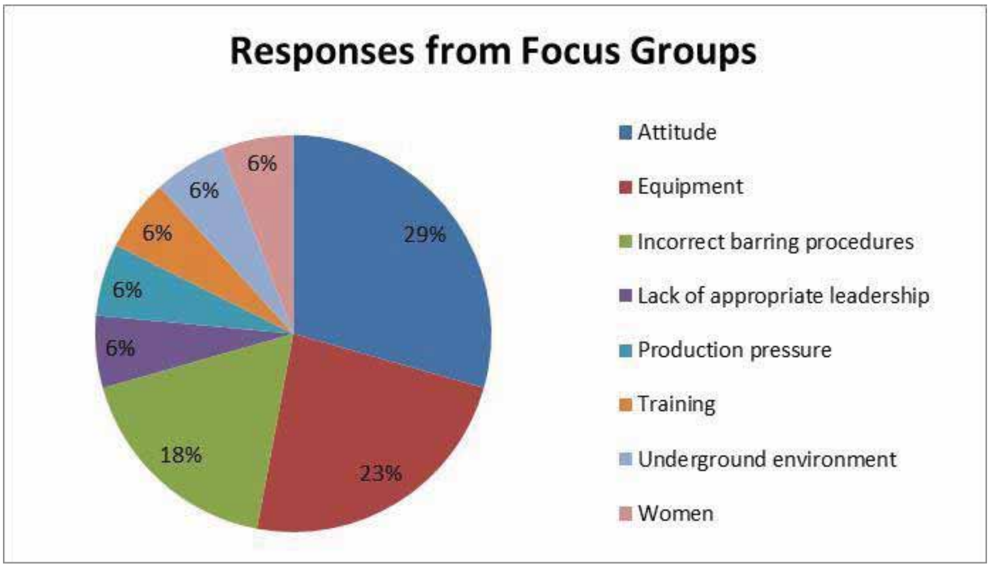

Figure 123: Key Issues from Focus Groups

Workers Attitudes

The main responses from the different perspectives of the mine workforce are presented in Figure 124 below. Mine workers generally are satisfied at work. Management feels that the workforce is highly driven by political agendas and union activities. This perception can lead to mistrust between these two groups of the workforce. There is already a perception that the union activities and messages have led to many mine workers questioning the instructions from management. This could potentially create a lack of respect for authority and leadership positions within the mine. Management also indicated that workers choose to follow the incorrect procedures. This is in line with the main reported issue from the management group being incorrect barring procedures. Mine workers will understand the consequences for not barring correctly but they will still choose to not comply with the rules.

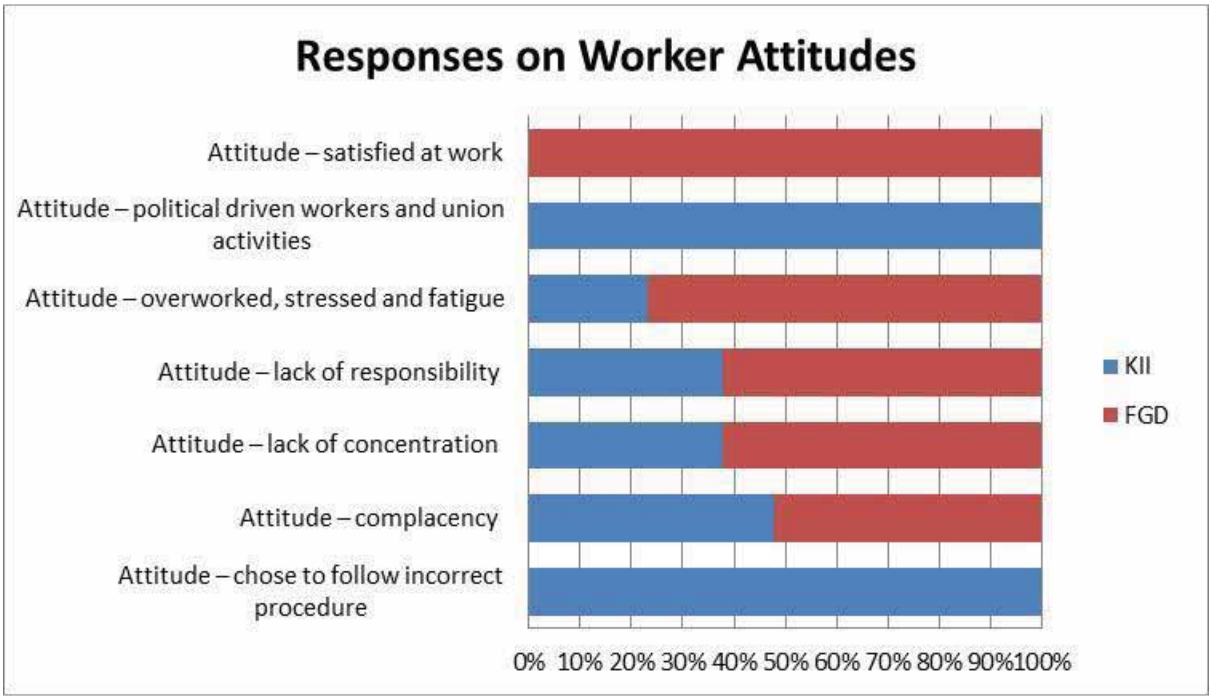

Figure 124: Responses from interviews and focus groups describing workers attitudes

Both interviews and focus groups response indicates the perceptions from the management and mine worker groups respectively concerning the following attitudes:

- Overworked, stressed and fatigued

Respondents indicated that there is a shortage of labour so there are fewer workers available to accomplish the required tasks within a shift. Workers spend longer time periods underground with few to no breaks so they are fatigued. The additional pressure of meeting production targets set by management creates a level of stress among the workforce and it becomes common place to take shortcuts in conducting underground activities.

- Lack of responsibility

It was reported that workers have a dependency on supervision in order to do their work. Constant supervision and review for workers on specific tasks gets the best results. Workers do not take responsibility for the tasks they are assigned, they do what they think they should do and not necessarily the correct task.

- Lack of concentration

This is linked to being overworked due to a shortage of labour. When an individual is fatigued it is probably that they will have more frequent lapses in concentration. When barring underground, a lack of concentration causes incidents. The heat in the underground environment conditions also plays a part in heat exhaustion which further impairs concentration.

- Complacency

The general attitude of complacency derives from doing the same activities in the same workplace without incident so workers feel they are safe in their work area. They become unaware of the dangers underground and are no longer vigilant in their daily activities. This form of complacency can also lead to incidents.

The responses about surface training systems were good and workers felt they had a good understanding of theoretical training. They also reported that even with the training there are still a lot of incorrect barring procedures being undertaken during the shift. This links to workers still choosing to follow incorrect procedures.

Incorrect Barring Procedures

This issue was the most reported issue by the management group as well as one of the key issues from the mine workers. Barring procedures are standard in the platinum sector so all mines would practice similar steps of barring. Some of the reasons for incorrectly barring are presented in Figure 125 below.

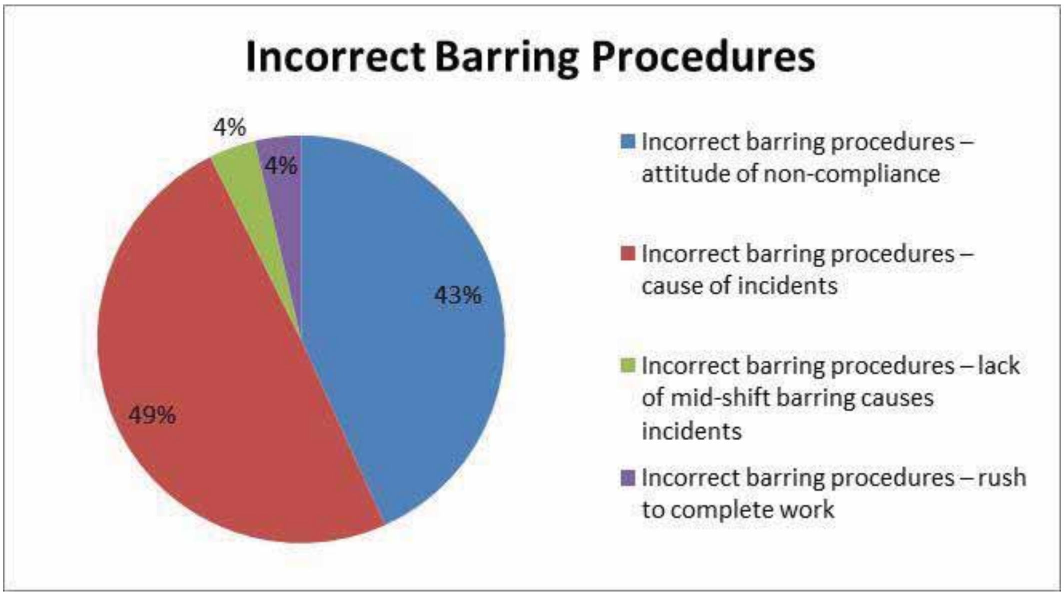

Figure 125: Incorrect barring procedures reported by workers

This issue is linked to worker attitudes described above as the behaviour to practice the incorrect procedure has become the norm. Workers take short cuts and those are with the barring procedures. There is a correlation between incorrect barring procedures and incidents or injuries. Where workers take short cuts is in the amount of time they spend barring at the beginning of the shift. The workers reported only barring at the beginning of the shift and not continuously throughout the shift.

Shortcuts are also taken because workers are under pressure to meet their production target so they rush to complete their tasks in the shift as barring procedures are seen to be time consuming. This rush to complete the tasks is also due to workers wanting to leave the underground environment as soon as shift is over. They feel they do not want to be underground longer than they are required to be.

It was noted from an interview with an engineer that the mine workers commenced early entry examination from the panel backwards to the waiting place areas instead of the correct way which is moving from the waiting place area toward the panel.

Production Pressure

This issue was reported mainly by the management group as there is pressure from the top down to meet the mine's production targets. Shortage of labour underground means that workers have the propensity to take short cuts whenever they can and the correct procedures are not being enforced. Generally these shortcuts are taken with the safety procedures as indicated by the highly reported incorrect barring procedures and the attitude of non-compliance. More priority is placed on production rather than on safety at the mine.

Equipment

This issue was mainly reported by the mine workers as they have to work with barring equipment on a daily basis. The equipment issues are described as follows:

- No gaskets being used when barring with a pinch bar. Where there are gaskets, workers place their hands over the gasket in order to have better control of the pinch bar but their hands remain unprotected.
- The pinch bars are not adequate. This means they are blunt or in poor condition.
- Pinch bars are not readily available. Workers would rather choose not to bar than try to find an adequate pinch bar.
- Weight of the pinch bars is too heavy so workers don't bar as often as they should.
- The length of the pinch bars is insufficient for the excavation area they are used in. In a 2m high or less excavation area, a 1.2m pinch bar should be used. A 1.8m pinch bar should be used in an excavation area greater than 2m. However, these protocols are not being adhered to.

Lack of Appropriate Leadership

Lack of appropriate leadership was reported from the management group which is interesting that they perceive the lack of leadership as a higher priority issue than the workers. Respondents reported that there are better results from the workforce with strict leadership and continuous supervision. It was also stated that with a stronger leadership system the correct barring procedures can be sufficiently enforced.

There are links to the perception that union activities are creating a distrust and lack of respect to authority or leadership positions at the mine. It was reported that workers constantly question the leaders underground and sometimes there is no time to explain properly but the tasks have to be completed. The leaders need the workers to follow their instructions in order to work efficiently together as a team.

Other Issues to Consider

- Training:

Focus group respondents indicated that there is a lack of practical training. Workers mentioned that the underground practical training is where they learn more experience and is the preferred method. The workers feel despondent as they don't receive career development opportunities. This could be an indication of poor communication about what benefits they can receive from the mine.

- Low level of literacy.
- Personal issues impacting a person's ability to work.
- Poor communication.

Communicating instructions get obscured by the different languages of the work force. Job instructions should be written as well as verbally communicated.

17.9 Gold Sector

According to Mining Weekly, South Africa's gold mines are the deepest and among the most dangerous in the world. Safety procedures need to be complied with in order to prevent incidents and injuries. Safety Induction includes health and safety tests, full medical and heat tolerance screening in order to appropriately function in the underground environment.

Gold was discovered in the Johannesburg area in 1886 and after 120 years of continuous operation, mining is currently approaching depths of 4 000 m. In spite of the challenges and risks that the industry has had to deal with including rock temperature, ventilation and water, one of the most feared hazards in the Witwatersrand basin has been the threat from the on-going occurrence of seismicity and rock bursts. The problem first manifested itself by way of the occurrence of tremors roughly 20 years after the commencement of mining operations. The work of research organisations over the years has addressed mining seismicity in terms of monitoring phases, mechanisms and mitigation strategies and is highlighted with a brief mention of current regulation strategies on the part of the mining inspectorate (Riemer and Durrheim, 2012).

Based on the current news, there is potential for unrest at gold mining sites during a potential strike by the Association of Mineworkers and Construction Union as they demand increased wages. Gold mines are labour intensive, employing over 40 000 people, so potential strike action creates a major impact to the industry. Similar to the platinum industry strikes last year (2014), a lengthy strike period affects the commodity prices as mines reduce or stop production because of the labour strikes and negotiations.

Data was collected from two mines within the gold sector. Key informant interviews were conducted with the management at the mines as well as focus groups with the crews working underground who undertake barring practices daily. There were common themes identified when comparing the responses from workers at these mines and were analysed into key theme issues.

17.9.1 Mining House D

The main issues raised from the interviews with management at the mine indicated that workers attitudes, training systems and lack of appropriate leadership (refer to Figure 126). There is once again the trend of a significant frequency of responses on worker attitudes is reported as compared to the other main issues.

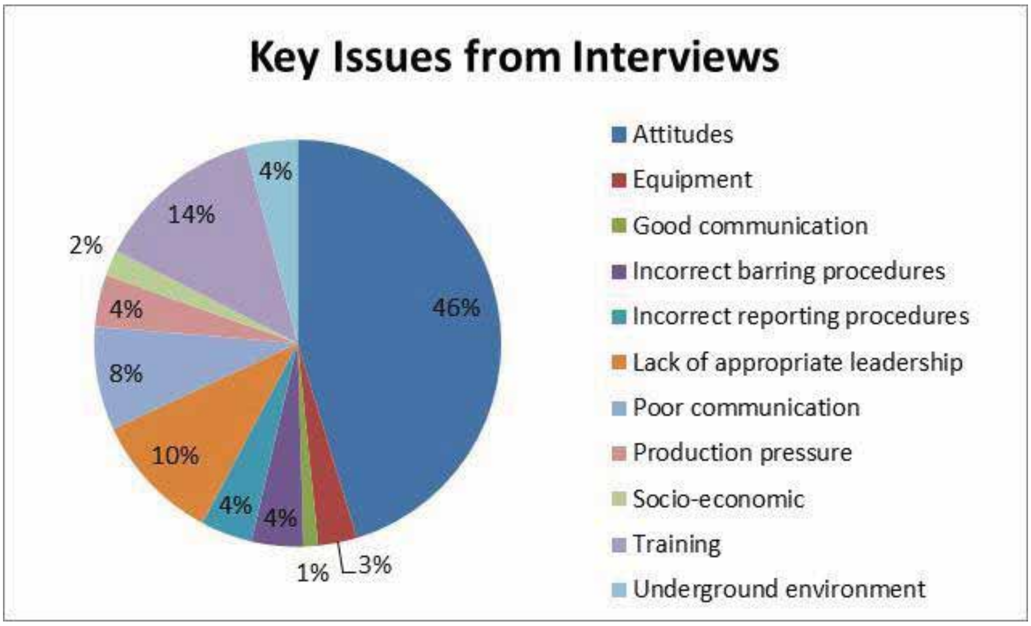

Figure 126: Key Issues raised from Interviews

The main issues raised from the focus groups with mine workers are worker attitude; equipment, incorrect barring procedures and the underground environment (refer to Figure 127).

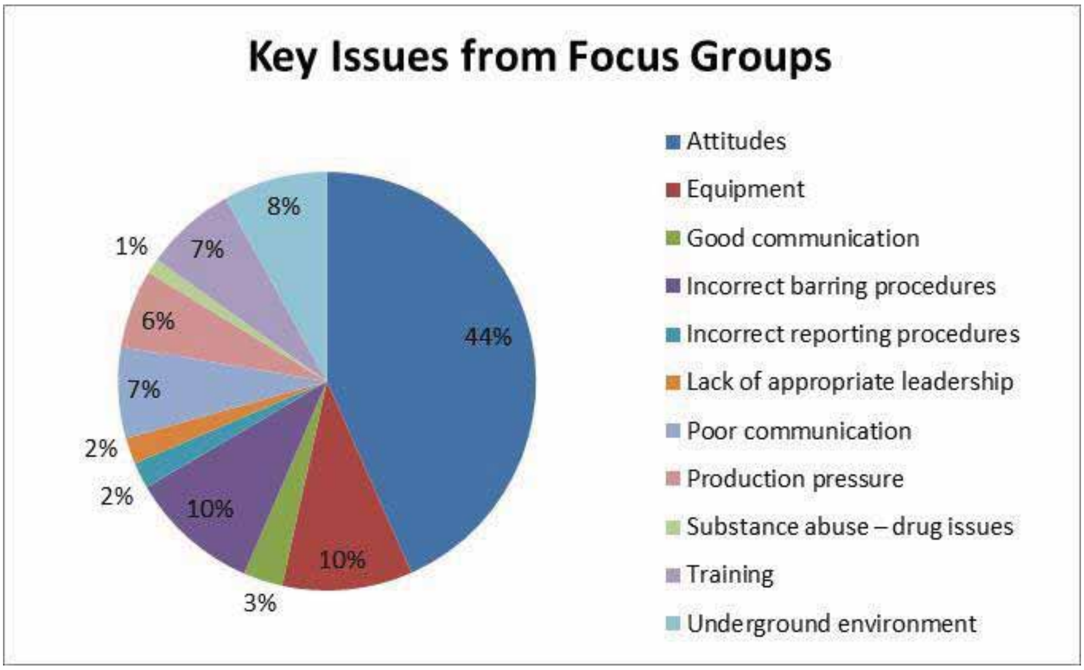

Figure 127: Key issues from the focus group discussions

Worker Attitudes

The responses from interviews and focus groups on workers attitudes were varied so the categories as described in Figure 128 below. The main attitude reported by both management and mine worker groups was being overworked, stressed and fatigued, followed by complacency of workers on the job. The respondents from the focus groups indicated an attitude to not take responsibility for barring activities and a lack of respect and trust for mine management.

Mine workers take no responsibility for barring as they view it as a position which was once held by a dedicated person whose sole task was to bar. The mine has subsequently dissolved that position due to budget constraints and reduction in the workforce. Now it is everyone from the crew’s responsibility to bar but there is still the perception from mine workers that they do not have to bar.

Responses only from focus groups were positive around a sense of teamwork among the crew and a safety focused attitude. They reported a lack of trust toward the company as well as lack of respect for people in authority positions. This was indicated from management interviews and could be instigated by the union activities at the mine.

Focus groups also indicated the presence of cultural differences in association with the distribution of white technical managers compared to the high number of black mine workers employed at the mine. This perception also comes from the mine worker group who feel these differences in the way instructions are issued and the tone in which they are spoken to.

Other attitudes which were mentioned from the management group through interviews were that the perceived incompetency (lack of experience and knowledge) of management was hidden when the mine was undergoing audits. Middle management groups also indicated they get no support from the upper levels of the mine management. It was also reported that workers were not respected and they have many personal issues which prevent them from undertaking their tasks underground.

There is reported tension between the youth and elderly generations working in the crews. The youth come from a mostly educated background and have demands on instant career development when they are employed at the mine. However, they lack on the job training and underground barring experience which the elderly have acquired through years of practical work experience. The elderly view these youth as wild and lacking discipline. It was also mentioned that the youth are also more involved in the union activities at the mine so the elderly generation fear that the youth will cause them to lose their jobs. The elderly also fear that the youth are not cautious when they work and may potentially increase the whole crew’s risk of an incident. The focus group responses also indicated that the elderly fear change more so than the youth.

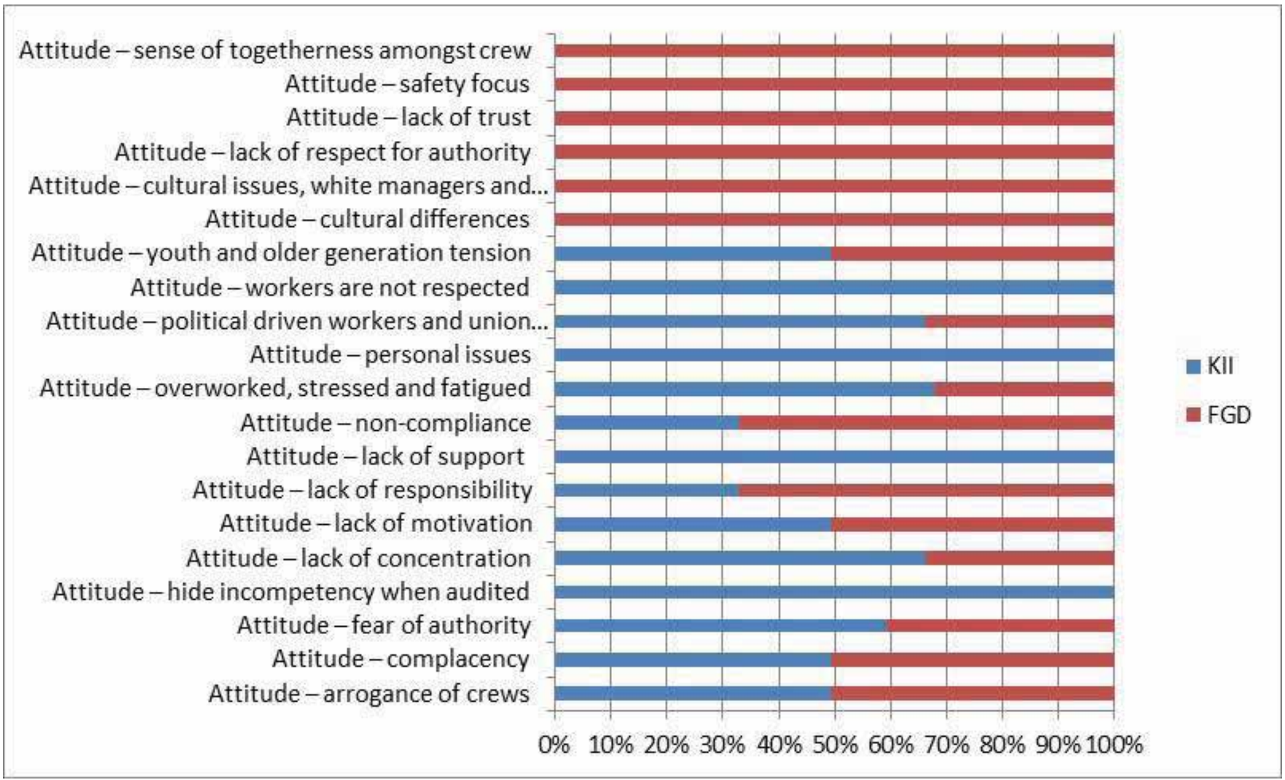

Figure 128: Distribution of responses from interviews and focus groups on worker attitudes

Responses mentioned in both interviews and focus groups that the relationship between supervisors (middle management) and the crews ranges from good to poor and has the following implications:

- Lack of respect for authority: If workers do not respect their leadership, they cannot feel motivated to work and adhere to safety procedures.
- Fear of authoritative figures: Workers fear leadership instead of respecting their leaders. There are reported scare tactics and intimidation methods being used by supervisors in order to manage the workforce to meet their production targets.
- Lack of trust and faith in management: Workers bypass supervisors and communicate directly with their union representatives.

Equipment

Responses around the equipment was mostly raised in the focus groups as the mine workers utilise the barring equipment on a daily basis. These responses are presented in Figure 129 below.

The main issue with the barring equipment is that there is no use of gaskets on the pinch bars. Workers indicated that they would like to redesign the gaskets to make it larger to cover a broader surface area. The other main issue is the pinch bar length is incorrect for the size of the area which has to be barred. Other challenges with the equipment are the lack of availability of pinch bars in work areas. Due to time constraints during a shift, workers don't leave the work area to find the correct length pinch bar but will bar with whatever pinch bar is available. The PPE gear which workers use includes safety goggles but workers don't use their goggles while they bar. It was reported that due to the heat underground, the goggles fog up and the workers visibility is impaired while they bar.

The 1.8m – 3m length pinch bars are heavier and barring becomes even more labour intensive. This increases the worker's fatigue and can lead to a lapse in concentration when undertaking barring activities. The results of this are barring incidents which may lead to serious injuries or even death.

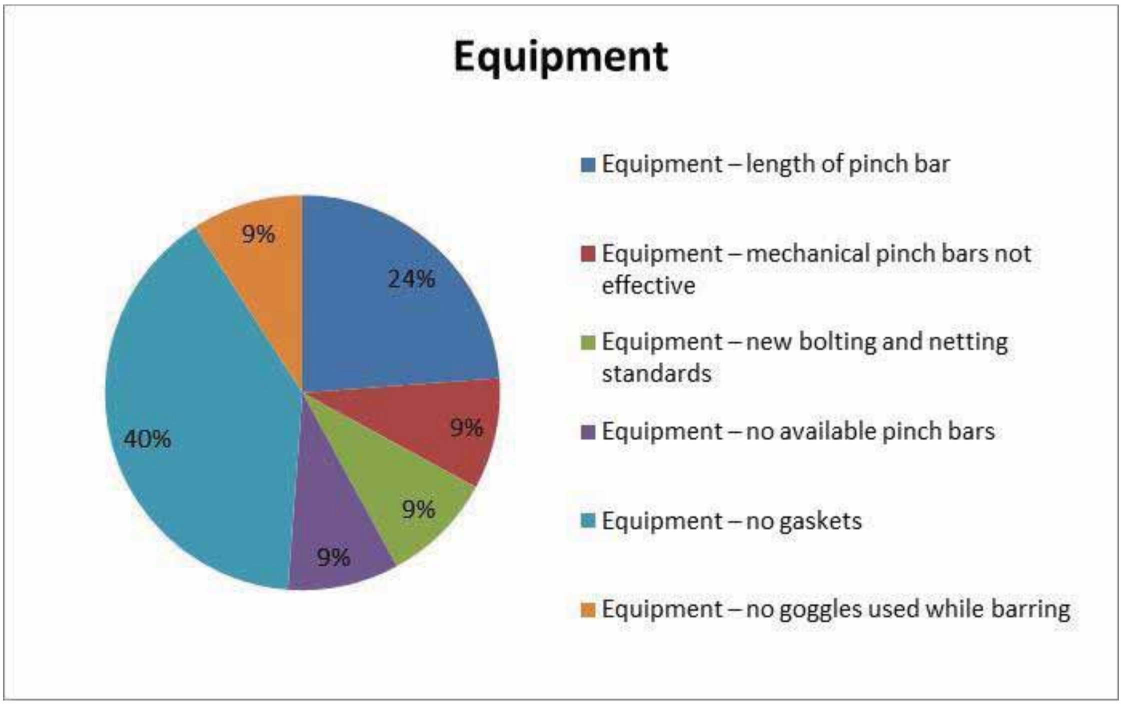

Figure 129: Responses on the Equipment Underground

Training Systems

The current training systems at the mine include technical surface training which includes classroom lectures and mock up. A mock up consists of man-made structures which closely resembles what the underground environment terrain is like and where workers will be spending the majority of their time.

There were also varied responses from interviews and focus groups on the training systems implemented at the mine (refer to Figure 130 below). The main challenge with the training is that the workers have a low literacy level so training has to be curtailed to suite these workers. Training materials should be more visual and auditory methods of training for the technical and practical modules. Currently it's reported that the training material is only available in English.

Responses from some of the participants indicated that the youth demand training opportunities when they start work without allowing time spent gaining underground experience. The elderly workers may lack the formal education but they have the years of practical experience. This disparity between the generation leads to tension among the crews. There is no knowledge sharing or communication between these generations as there is a lack of trust so on the job mentoring doesn't occur due to this tension.

They also reported lack of mentorship and coaching from leadership and an undefined career path within the company. Training involves skills development where individuals can progress up their chosen career path. The mine's training system should be reviewed to incorporate more focus on skills development through mentoring and coaching.

Figure 130: Responses on Training systems

Lack of Appropriate Leadership and Communication

There is a link between the leadership structure and the communication system. Both follow the tiered levels of the mines leadership structure. In mine workers perceptions, both issues relate to one another as well as the reporting structure which also follows the same tired level of reporting.

It was indicated through both interviews and focus groups that there is a lack of appropriate leadership at the mine which leads to a general lack of discipline among all levels of workers at the mine. The current roles of the leadership are viewed as weak due to a lack of people skills and the ability to manage and relate to many people at the same time.

It was reported that mine workers are receiving insufficient training and lack of mentoring and coaching provided by leadership. Respondents from the focus groups indicated that their superiors may not be sufficiently educated or experienced in the tasks they are managing. One response mentioned that supervisors did not work according to the Mine Health and Safety Act as they were too production orientated.

The mine also has too few miners who are able to manage the various sections/panels in the underground areas. The team leaders from the crews take on the responsibility of the miners in some cases. This lack of leadership presence underground could advocate the perception that the workers are unsupervised and increase the risk for potential incidents. It was mainly reported that there is very poor communication between the team leaders and miners. It was also indicated that the generational gap between the youth and the older workers plays a part in the poor communication.

Good communication has been reported from both interviews and focus groups with regards to the type of systems. The use of notice boards in the waiting places underground where information is presented in English and Fanakalo was reported as good. However, it was also stated that these notice boards aren't updated frequently. Workers also reported that they receive verbal communication once a week at the safety meetings and daily before commencing works in their section. The verbal communication helps the illiterate workers to understand the communications and job instructions.

Incorrect Procedures

There are specific barring procedures at the mine which have to be followed in order to effectively and safely undertake barring activities underground in accordance with the Mine Health and Safety Act. However, these procedures are not being followed or are being undertaken incorrectly by mine workers. The main factors for undertaking incorrect barring procedures is the general non-compliance attitude from the mine workers. The mine workers are risk takers and take short cuts in their tasks to finish their work within the shift. This incorrect barring leads to incidents or more serious accidents occurring underground.

Incorrect barring procedures refer to the way you hold a pinch bar while barring and how you position your body in relation to the pinch bar to make the activity of barring safe and efficient. Workers reported the wrong positioning of the body as a cause for barring incidents. Failure to 'wash' the hanging wall to reveal any cracks was also reported due to the lack of water underground. Workers bar without a buddy and this is against the safety rules and it was reported that they lack supervision while barring. Contrary to that comment, workers reported they receive correction through coaching if they show a lack of knowledge of correct barring procedures. Fatigue was also reported as playing a part in causing incorrect barring practices.

The reporting procedure is linked to the leadership and communication structure. It was mainly reported that workers fear reporting incidents correctly. Managers put pressure on workers to keep the safety targets at zero reported injuries. Thus workers would also choose not to report any incidents. Once an incident is reported, the process is to identify learnings from that incident to ensure it doesn't get repeated. Workers indicated that due to a lack of coaching and mentorship, the workers only receive corrective instructions after an incident has occurred.

There is also pressure from management to meet production targets per shift so workers focus is shifted away from safety and more on completing their work. It was even reported that some workers don't bar at all during a shift. Due to this focus on production target, training and coaching also get a lower priority.

Underground Environment

The underground environment is not a comfortable place to work. The main issue reported about the environment is the heat which workers are exposed to while undertaking barring and production (strenuous) activities during the shift. Over exposure to heat in certain shaft areas causes fatigue, exhaustion and a lack of concentration to undertake tasks which subsequently lead to incidents and injury.

The bolted and netted areas of the underground working areas have created a sense of security with workers. They feel they don't need to bar in these areas and develop an attitude of complacency to barring. Workers reported that the travel distance from the shaft access point to certain work areas is far to cover especially in the terrain of the underground environment. Some workers walk approximately 8km a day to and from their working areas. Workers indicated that they are tired by the time they reach their work areas at the start of the shift. Once again fatigue causes a lapse in concentration which in turn leads to incidents.

Other Issues

In a focus group, it was stated that the mine is understaffed and the workers are overworked. There is an issue around workers applying and taking leave, as it is their responsibility to find a replacement which they find difficult among already employed workers. The mine doesn't accept any replacement worker who isn't already an employee. So workers, who are unable to take sick leave, work in a compromised state which is a high risk for incidents occurring. Others would just not go to work so absenteeism is high, which results in the remaining crew members working harder and longer hours to compensate and meet daily targets.

17.9.2 Mining House E

The main issues derived from the interviews with management were workers attitudes; incorrect barring procedures and lack of appropriate leadership (refer to Figure 131 below).

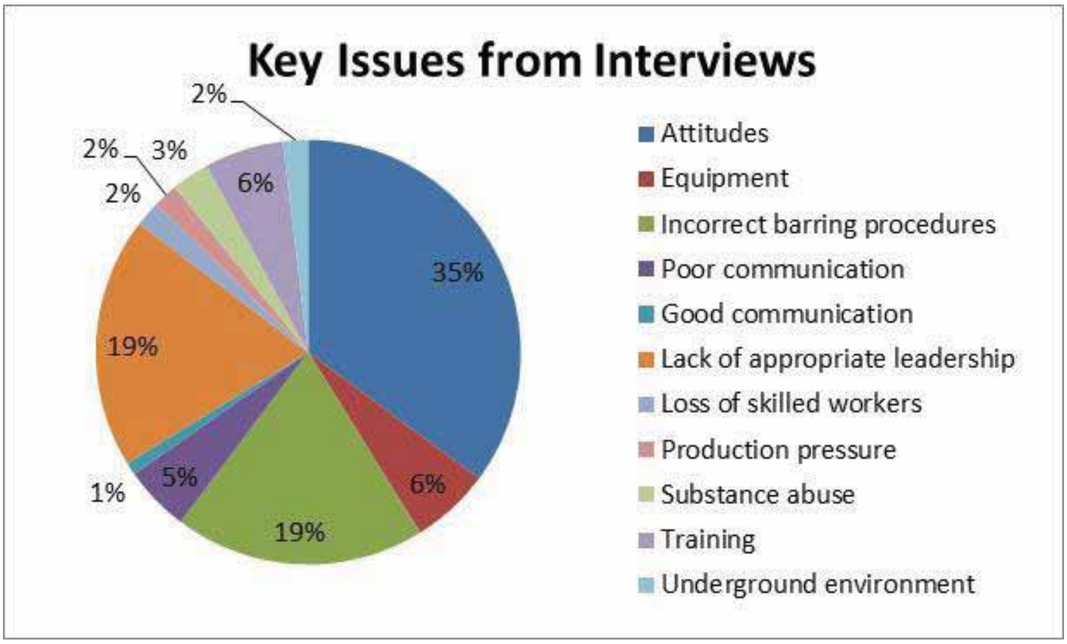

Figure 131: Key issues mentioned from interviews with the management group

The main issues indicated from the focus groups with the mine workers were workers attitudes and training (refer to Figure 132). Lesser issues which were mentioned and are of interest are the poor communication, production pressure and equipment.

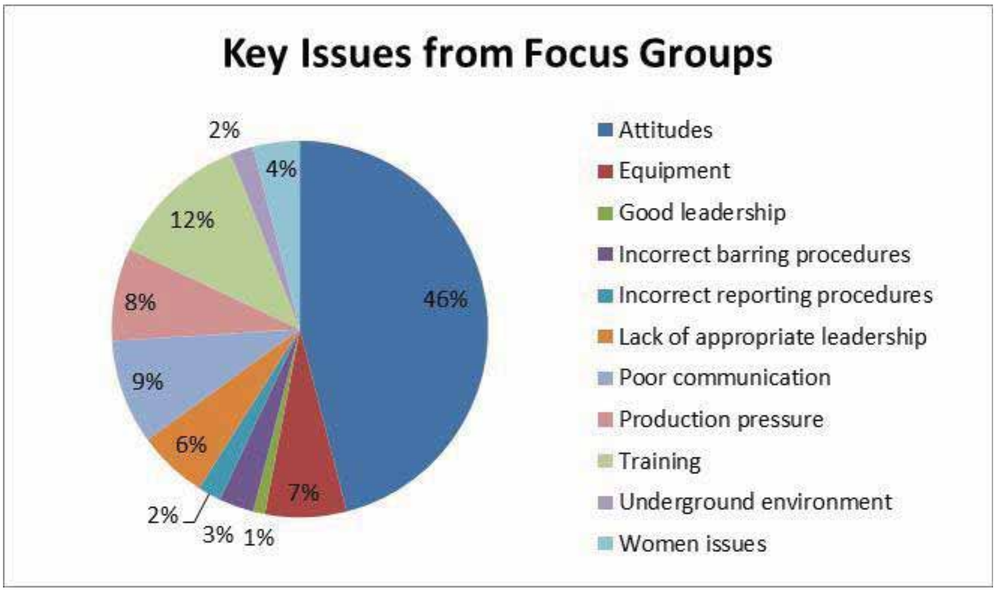

Figure 132: Key issues mentioned from focus groups with the mine workers

Worker Attitudes

The responses around worker attitudes were varied among the interviews and focus groups. The distributions of these attitudes are presented in Figure 133 below.

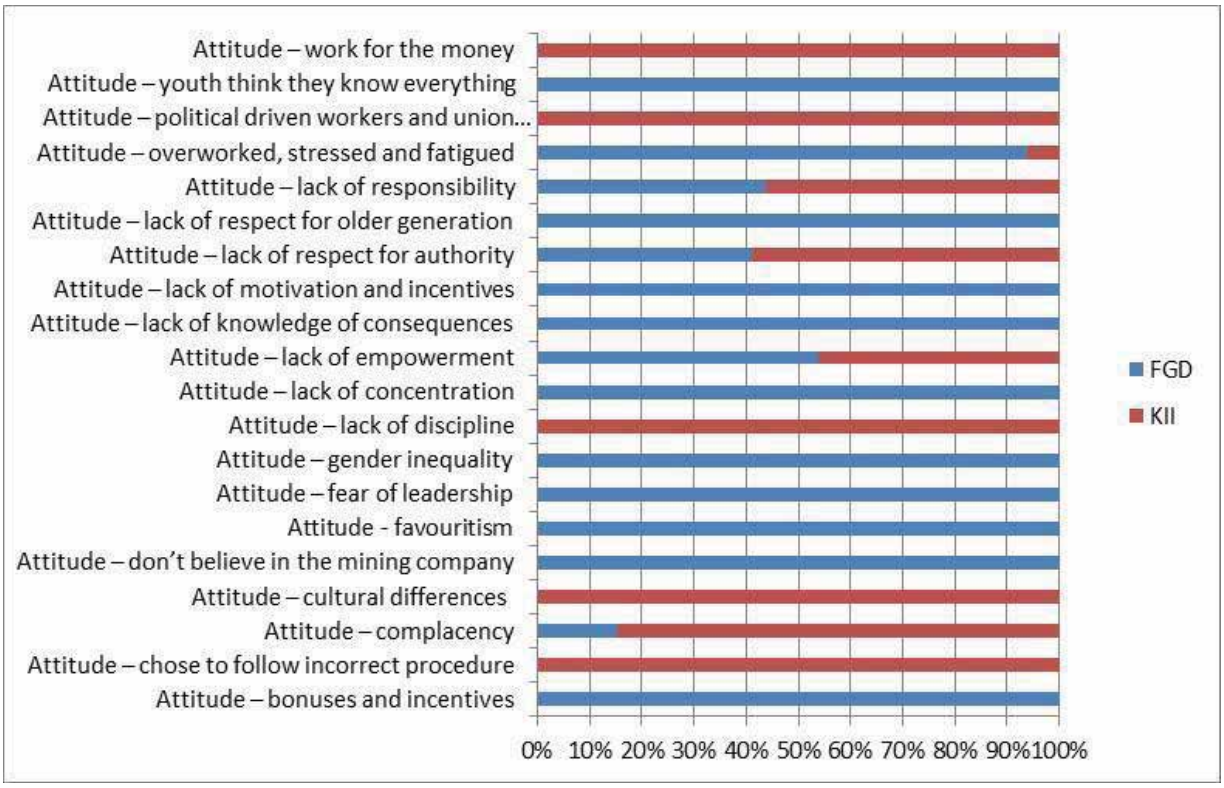

Figure 133: Distribution of responses on worker attitudes from interviews and focus groups

Most of the responses on workers attitudes came from the mine workers in the focus groups. They predominantly indicated that they are overworked, stressed and fatigued by the work they are undertaking underground. The long working hours and overtime are negatively impacting on workers family and personal lives. It was stated that they are underpaid and overworked, which is contributing to a dissatisfied workforce and lack of motivation. Being underpaid in correlation to the downturn on South Africa’s economy provides additional stress on workers who are trying to meet the increasing cost of living and this was evident in responses from focus groups. These additional external stress factors impede worker concentration and create a high risk for potential incidents and accident occurring.

Other aspects workers raised were the lack of bonuses and incentives provided for working the long shifts. Mine workers are disillusioned about the company and they lack trust and faith in the company management. Lack of trust combined with dissatisfaction with the functioning of the company has led to dissatisfaction among the workforce. Unfortunately due to the high rate of unemployment, workers feel they have no choice but to work for the company. It was reported that workers feel management are communicating false information and management make commitments which they don’t uphold.

Mine workers also mentioned the issue of gender inequality as the other main issue at the mine. The activity of barring is a challenge for everyone. It is physically exhausting and the pinch bars are heavy. Mine workers indicated that women bar for a shorter time than the men. It was reported from focus groups that there is an attitude of favouritism experienced where management favours a few workers and not everyone gets equal opportunity. Women are also favoured over men in terms of career progression to ensure that the Mining Charter targets are met.

Focus group responses also indicated that there is a fear of leadership at the mine especially when it comes to reporting incidents. Middle management (supervisors) utilise threat tactics to ensure workers meet production targets and zero safety incident target. This has instilled a culture of fear toward supervisors. Workers feel that they are pressured to not report barring related incidents as it impacts their safety bonus targets. Based on the dissatisfaction of current incentives, the pressure to meet bonus targets are from workers who need the money and from management who are pushing production targets. They indicated that there are misrepresented causes of injuries in the incident reports.

There is reported tension between the youth and elderly generations working in the crews. The youth come from a mostly educated background and have demands on instant career development when they are employed at the mine. They are perceived as having a sense of entitlement which creates an abrasive relationship when interacting with the older generation. The youth have also given the perception that they want the higher paid jobs but are not prepared to fulfill the job requirements for those positions. The older generation has reacted to this perceived behaviour by withholding knowledge and experience from the youth.

The youth lack on the job training and underground barring experience which the elderly have acquired through years of practical work experience. It was also mentioned that the youth are involved in the union activities at the mine. The elderly also fear that the youth are not cautious when they work and may potentially increase the whole crew's risk of an incident. The focus group responses also indicated that the elderly fear change more so than the youth.

Incorrect Barring Procedures

The main types of issues mentioned in the interviews and focus groups are workers attitudes of non-compliance (refer to Figure 134 below). The mine workers rush their safety procedures to meet their production targets so they take shortcuts. The behaviour of rushing through the barring procedures or leaving out steps or not even barring at all leads to incidents and develops an attitude of non-compliance to these procedures from the workforce. Incorrect barring leads to potentially hazardous incidents/injuries and sometimes death.

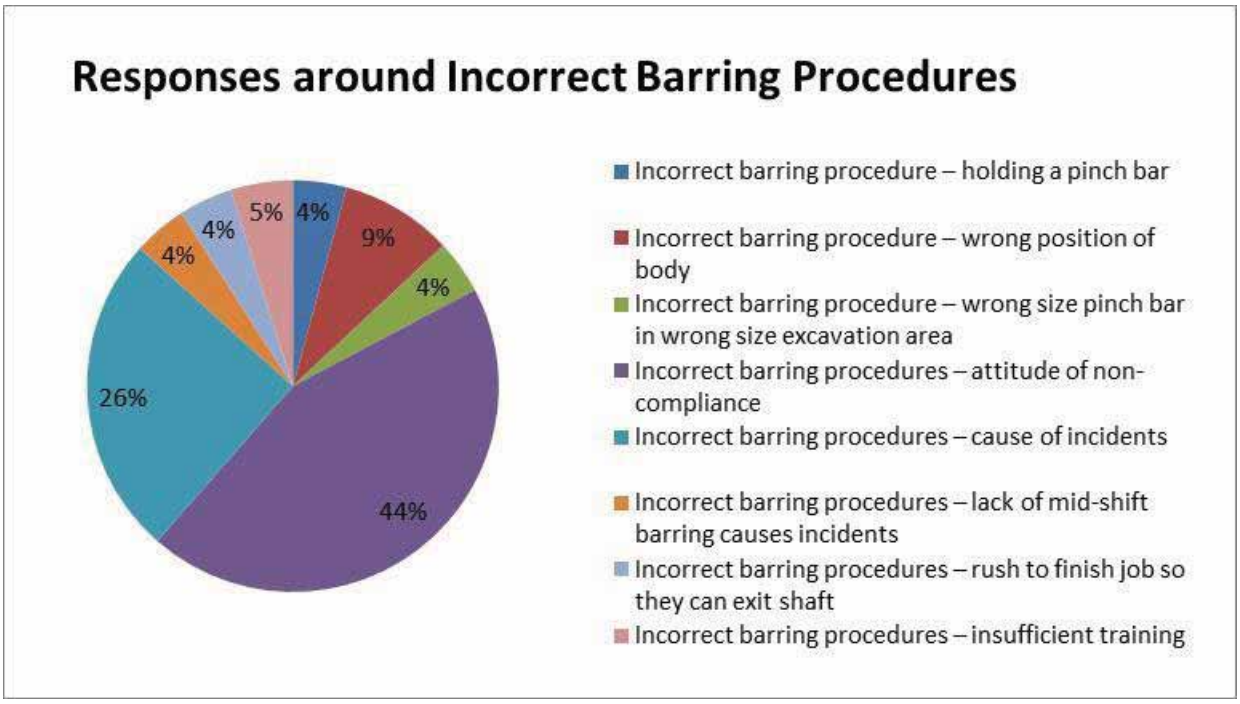

Figure 134: Responses related to Incorrect Barring Procedures

Other types of incorrect barring reported is the positioning of the body in relation to the pinch bar when barring, the use of the wrong length pinch bars in the wrong size excavation area and insufficient training when it comes to barring. Reporting procedures have been stated as inaccurate as the supervisors misrepresent the cause of incidents.

Lack of mid-shift barring is in contravention of the safety procedures which promotes continuous barring and hazard identification throughout a shift. In the gold mining environment with potential seismicity occurrences, it is vital to undertake continuous monitoring of side walls and hanging walls for potential changes in the rock structure. Reported fatalities in the last 5 years within the underground hard rock mining environment are mostly caused by fall of ground incidents.

According to Teleka's study, in an attempt to mitigate the prevalence of rock burst and FOG accidents, an assessment of the rock mass condition prior to entering a narrow tabular ore-body is carried out. This is usually carried out after blasting. Determining whether a narrow tabular ore-body is safe to mine in, is thus both dangerous and highly subjective. This is due to the fact that the process is currently influenced by, inter alia, human factors such as fatigue, inexperience, hearing ability and pressure to quickly execute the task. Errors arising from these human factors can be made while trying to accurately characterise the rock mass under assessment. The accurate assessment of the stability or possible instability of a hanging wall and proper alerts to the worker/miner are critical to the safety of miners working in a narrow tabular ore-body (Teleka, S.R; Green, J.J and Brink, S, 2011).

Lack of Appropriate Leadership and Communication

This issue was mainly reported by the middle management group which indicated that there is a lack of support and mentorship from the top tier management levels. Leadership structure at the mine follows the same process as the communication system. The management group indicated that the poor communication resides between the team leaders and the miners and the mine workers indicated the communication gap is between the youth and older generations. Overall it is indicated that respondents have a lack of trust with the leadership structure at the mine.

The mine workers also reported that the presence of miners and supervisors is lacking during a shift. The miners and supervisors are not taking responsibility for their crews and sections/panels. This could be because they are given too many sections/panels to manage within a shift and aren't able to provide adequate mentoring and support in all areas. It was reported that a strong, strict leadership regime would be beneficial to balance the lack of available mentoring and coaching from the miners and supervisors. This would also address the lack of discipline experienced in some crews which are due to the felt absence of leadership and mentoring from management.

The workers reported that the team leaders end up being the highest level of authority in the section/panels during the shift if the miners are not present. There were mixed reports around the team leaders taking responsibility for the task set for the miners. Some crews reported their team leaders are illiterate so they are not able to fulfill the higher responsibility role. A few respondents reported a good leadership role from their team leaders and even miners. Focus groups indicated that communication from the shift boss to the crews in the waiting places is done but the break in communication comes between the shift bosses and the miner. It was also observed that there is a general lack of responsibility of the crew members to undertake continuous barring activities.

Training Systems

The training systems at the mine include video learning, e-learning, lectures and practical training on surface through mock-ups and underground at the training centre. The mine has recently rolled out the "fit for purpose" training module which increases underground workers exposure to the realistic underground environment within a controlled setting.

The responses from interviews and focus groups on the training systems (presented in Figure 135 below) were predominantly the lack of practical experience displayed by the younger generations among the crews. The youth can be trained but they still lack the years of experience working in the underground environment and undertaking barring activities. They also do not receive adequate mentoring and coaching from leaders while undertaking their tasks during a shift.

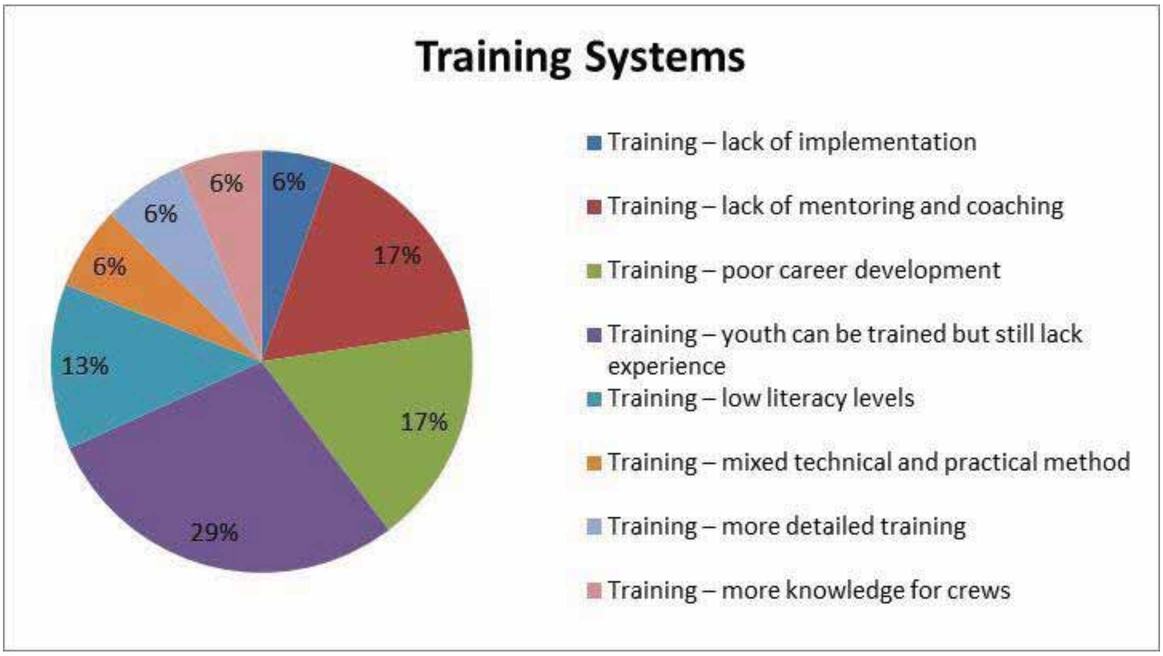

Figure 135: Responses on the mine's training system

The main issue with the training system reported was the poor career development opportunities for mine workers at the mine. It could be that the mine workers aren't aware of the potential training the mine offers or that there is more focus on production and less on the training and skills development of the workers. This perception of lack of career development is linked to the low level of literacy of the mine workers.

Focus group respondents requested additional training in strata control to identify hazards in the rock while barring. There is a need for more practical, on the job training that could be an indication of the current lack in coaching and mentoring for crew members.

Equipment

The predominant issue reported was the use of the wrong length pinch bar as presented in Figure 136 below followed by not using a gasket with the pinch bar while barring. This is linked to the third main issue of pinch bars and pinch bars with gaskets not being available. Workers use whatever pinch bar is available in their section regardless if it is the correct length for the size of the excavation area. Some may not have gaskets attached or workers remove them to get better leverage on the wrong length pinch bars. Workers should locate the appropriate equipment before barring however, this wastes time and there is pressure from leaders to meet production targets.

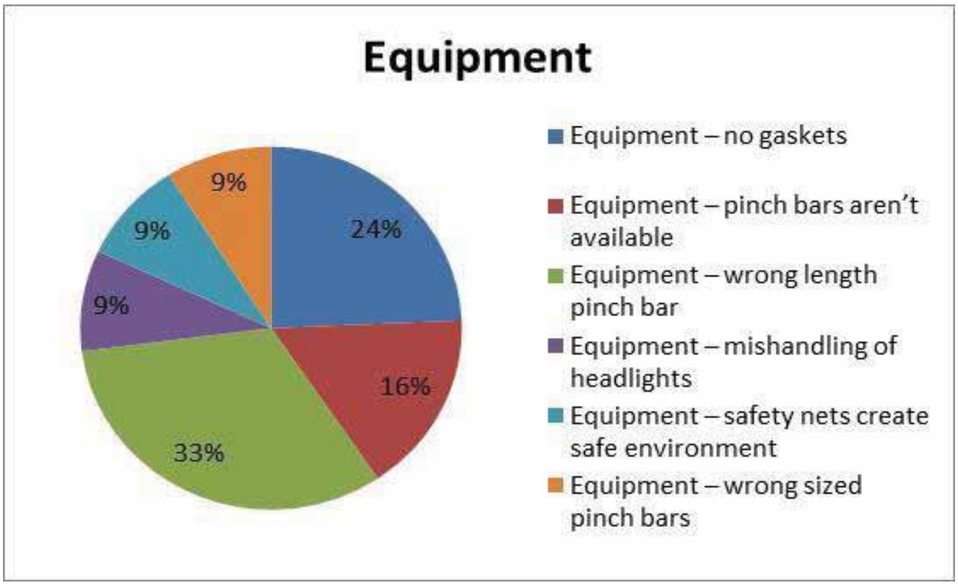

Figure 136: Responses on barring equipment

Other Issues to Consider

Other issues mentioned by both interview and focus group participants were:

- Production pressure

Workers rush to complete tasks during their shift and eventually are overworked and fatigued. There is always this competing pressure to meet production targets but also to prioritise safety procedures. Workers feel stressed that they work hard to finish their tasks because there is a shortage of labour.

- Women

The underground environment is a challenge to work in but more so for women. It was mentioned by the male focus group respondents that the privacy in the underground environment is lacking in terms of the bathroom facilities for women. It was stated in the discussion that women have to share the men's facilities which has led to incidents of rape. The male workers demonstrate a high level of concern for their female counterparts in attempting to work in the underground conditions. It was also mentioned that there is a perception of general lack of respect for women from mine management. Another reported issue regarding women is that management displays perceived inequality when employing women for underground work.

17.10 Coal Sector

The coal mining sector is a completely different type of underground mining environment where the roof is higher and the pinch bar length is longer. Coal mining safety procedures are different to gold and platinum so the sounding and barring activities and equipment differs substantially from gold and platinum. Sounding and barring activities are perceived to be negligible when the roof conditions have been deemed good. Overall, there is less barring undertaken in the coal sector compared to gold and platinum. However, sounding activities are undertaken at the start of every shift.

Data was collected from two mines within this sector. Key informant interviews were conducted with the management and control officers at the mine as well as focus groups with the crews working underground who undertake barring practices daily. There were common themes identified when comparing the responses from workers at these mines and were analysed into key theme issues.

17.10.1 Mining House F

The main issues reported from interviews at the mine with the management groups were workers attitudes, training systems and incorrect barring procedures (refer to Figure 137 below). The trend of a significant frequency of responses on worker attitudes is once again presented as compared to the other main issues.

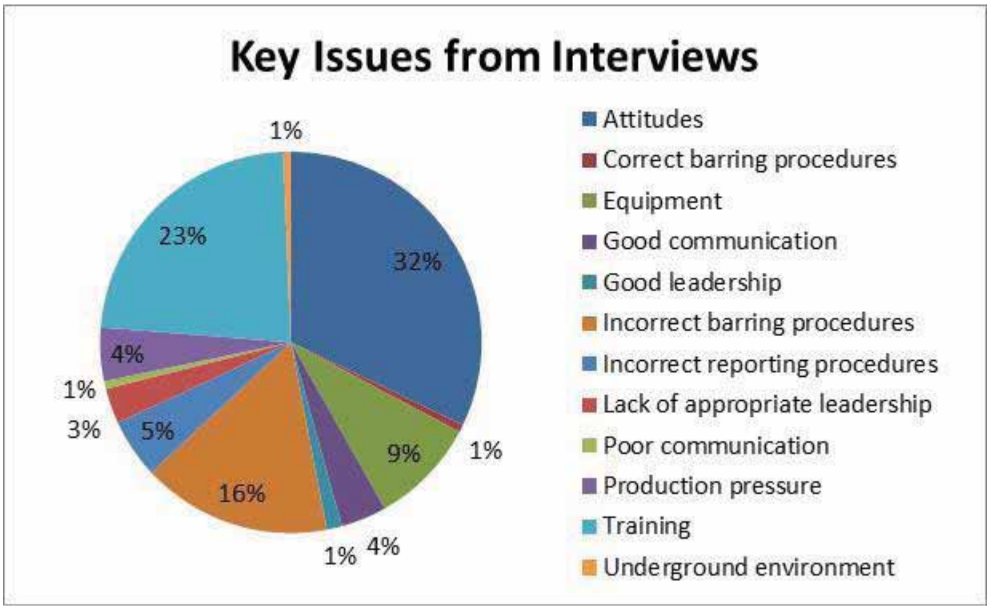

Figure 137: Key issues from interviews with management group

The main issues indicated from the focus groups of mine workers were equally worker attitudes and production pressure (refer to Figure 138 below). The other issues being lack of appropriate leadership and training systems.

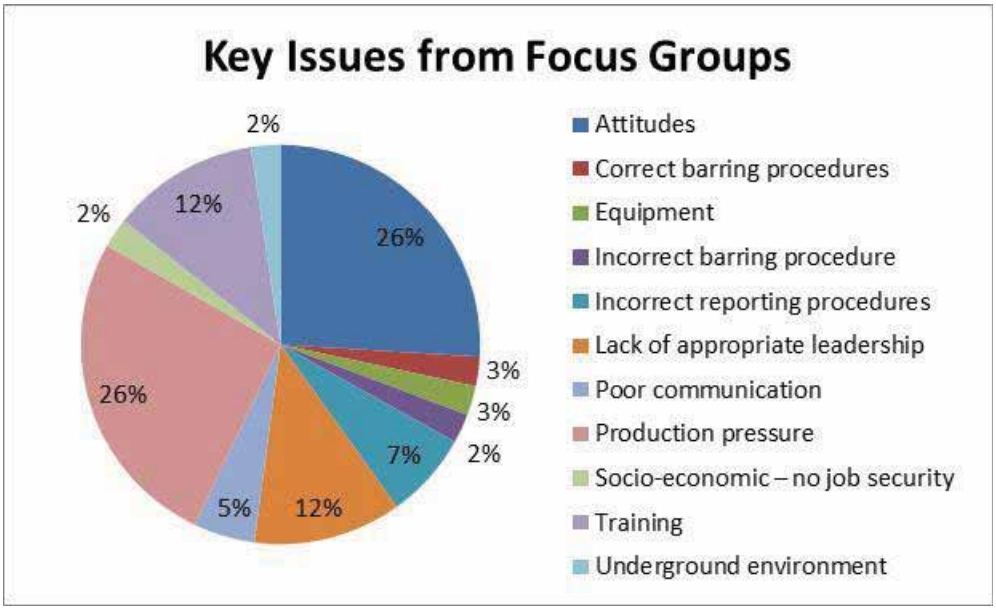

Figure 138: Key issues indicated from focus groups with mine workers

There were positive responses mentioned from both interviews and focus groups around good barring procedures being implemented as well as good leadership and communication. This was mainly reported through the interviews with management group. The frequency of these comments from the responses of mine workers was low but they were mentioned.

Worker Attitudes

The main worker attitudes highlighted through the interviews and focus group discussion responses are presented in Figure 139 below. Predominant responses on worker attitudes came from the interviews with the management group at the mine.

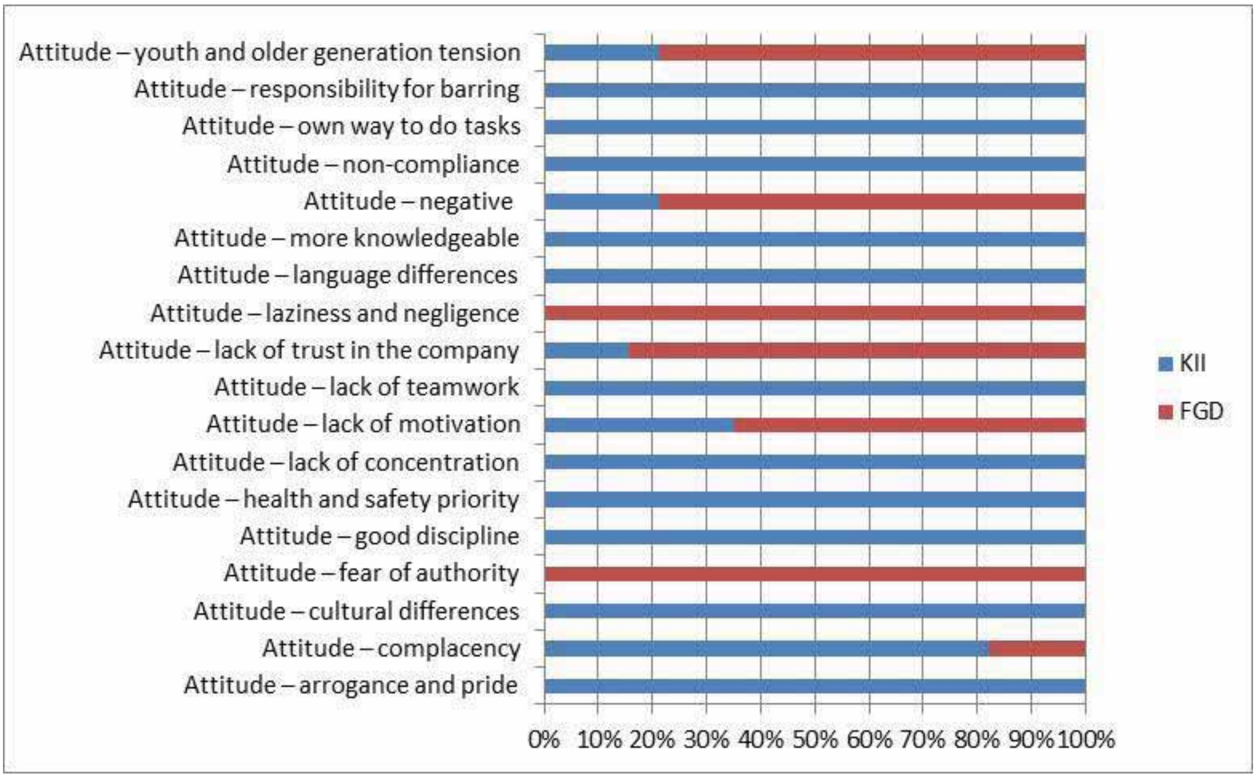

Figure 139: Distribution of worker attitudes

The most frequent responses from interviews indicated that complacency was high among the workers. The repetitive tasks and procedures combined with the lack of serious incidents and a relatively good roof condition lull workers into a sense of security and their vigilance while undertaking early entry examinations decreases. Responses from the manager group show that mine workers feel barring is not their responsibility but that of the team leaders and miners. They do their tasks in their own way which may or may not be the correct method. Workers are at times non-compliant to the correct procedures and this puts them at higher risk for injuries.

The perception from the interviews was that workers consider themselves more knowledgeable than their team leaders. This is evident among the youth as they are educated and it is perceived as arrogance by the older generation. This creates tension, lack of teamwork and poor communication within the crews. The language difference among some crews also creates poor communication and teamwork. It is the perception of management that workers show lack of concentration and negligence when working underground. Any lapse in concentration could lead to potential injuries as the underground environment is challenging to work in. It was also noted that workers have an attitude of arrogance and pride when interacting with each other and with leadership. The cultural differences between mine workers and the leadership of the mine as well as differences between individuals within crews were indicated as a factor which affects interaction among workers. Both these differences would further impact on teamwork, communication and leadership dynamics.

Some positive aspects mentioned by respondents from interviews indicated that workers have good discipline and are focused on health and safety as a priority. These positive aspects were not frequently reiterated through interviews but it was mentioned.

Based on responses from the focus groups, the main attitudes that were mentioned were a fear of authority or leadership at the mine and an attitude of negligence and laziness/complacency. The fear of authority and leadership is linked to the communication system and mentoring of workers by senior staff. Workers fear authority at the mine because leadership has the power to terminate employment, promote and increase salaries. They fear losing their jobs if they do not obey what leadership required them to do such as not reporting incidents correctly or misrepresenting the reasons incidents occur. Workers are perceived to be uncompromising when it comes to communication and responsibilities for job tasks. The perception surrounding workers attitude of negligence and laziness could also be derived from being fatigued and overworked from the conditions the workers experience underground.

As a backdrop to the negative attitudes and morale as mentioned in the focus groups is the current retrenchment of the coal mining sector workforces. This redundancy of labour increases the unemployment rates and creates the attitude that workers should be grateful to hold their current jobs at the mine.

Production Pressure

The main responses from interviews and focus groups were that pressure to meet production targets causes workers to take short cuts and rush through safety procedures. The attitude to rush through safety procedures indicates workers behaviour to practice non-compliance when undertaking barring activities. It also indicates the mine’s focus on production with minor emphasis on safety targets.

It was stated that during a shift, the workers focus on the production areas and maintaining roof conditions in these areas. However, the roofs in the passageways leading to the production areas are not maintained. Workers indicated that this type of maintenance was not done in order to save time and workers perceive that these areas are safe and barring isn’t necessary. This has led to a false sense of safety and security.

The rush to complete tasks also leads to incorrect reporting procedures. It was mentioned through the focus groups that forms were being completed without the relevant tasks being completed. Workers indicated that filling out paperwork wastes time which they could be using to work on production tasks. They are also pressured from management to misrepresent the reasons for incidents in order to maintain their good safety targets. It was reported that some workers just sign off on their safety declarations without undertaking the safety procedures.

Training Systems

The current training system is administered from a centralised training centre for all this mine's operational shafts and pits. The methods of training on the mine are a mixed system consisting of theoretical lectures, learning videos and practical barring sessions. The mine undertakes Planned Task Observations as a system for on-going barring evaluation and on the job coaching for underground workers. Workers indicated that they would like more detailed refresher training on barring and safety mechanisms.

Based on the responses on training presented in Figure 140 below, it was reported that there is a lack of practical training provided for barring activities. There should be more focus on practical and lecture style training systems to efficiently train the large number of illiterate workforce. It was mentioned that the older generation show a high level of illiteracy. It was also reported that there is a general lack of knowledge and experience in underground barring activities. The use of mentoring and coaching by leadership assists in shared knowledge and experience especially to the younger mine workers.

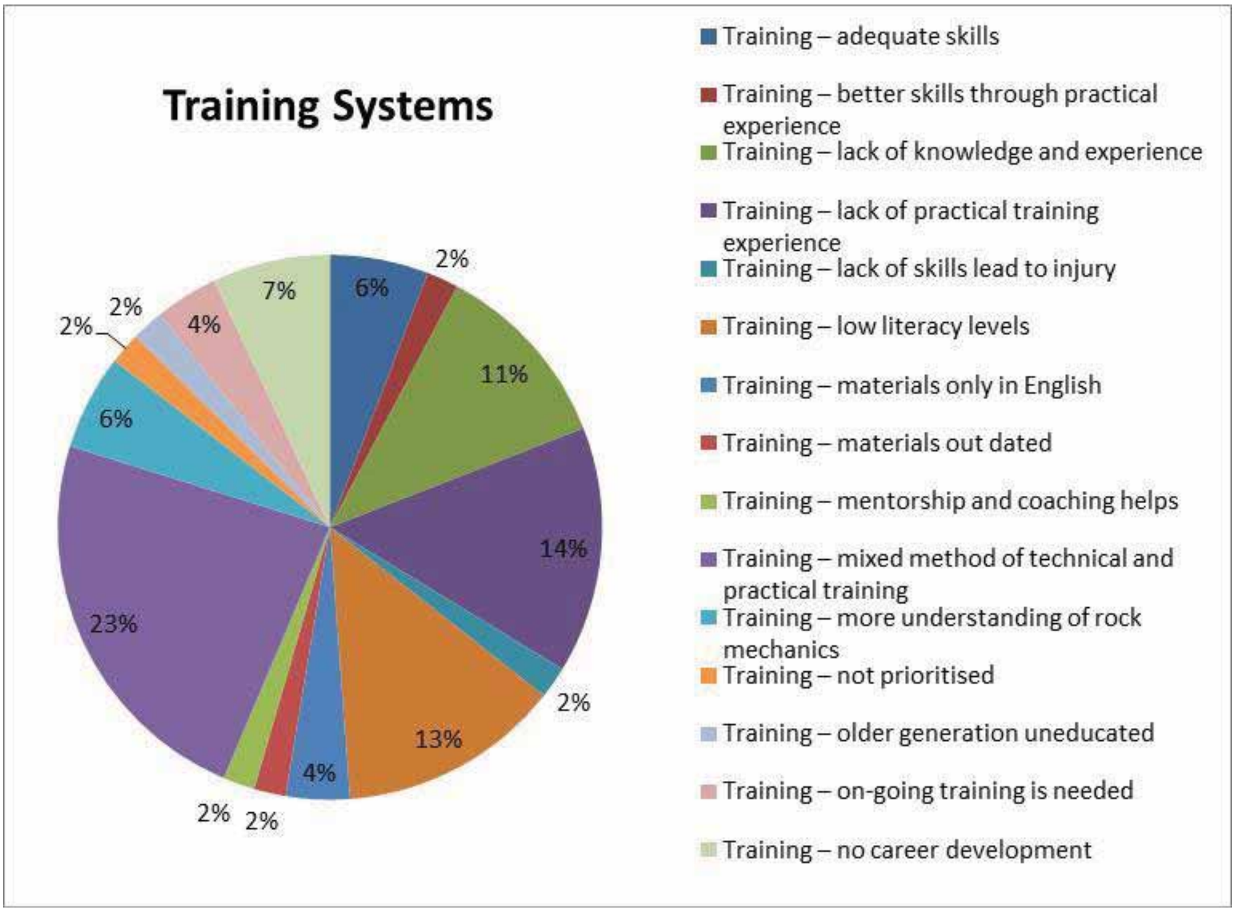

Figure 140: Responses on training systems at the mine

Responses regarding the training system mentioned that the training materials are out dated and are not available in other languages apart from English. Although the underground language at this mine is English, workers still prefer to learn in their first language (mother tongue). It was requested that more training on rock mechanics and identification of types of rock would be beneficial to underground workers. Some responses were that a lack of skills or barring knowledge leads to injury so more training in those areas is useful. Also an on-going training system is needed at the mine. As a contradicting response, there was a 6% positive response to say the mine has adequate training systems.

Incorrect Barring Procedures

Responses on the use of incorrect barring and reporting systems at the mine was a frequented issue and is presented in Figure 141 below. The failure to bar or failure to implement barring procedures causes incidents and is a correlation to the workers attitude of non-compliance to the correct safety procedures. Workers also do not undertake appropriate risk assessments when doing safety assessments. Miners will sign off the safety papers without doing the tasks.

Those being the main reported aspects of incorrect procedures, others include the incorrect practice of the barring steps.

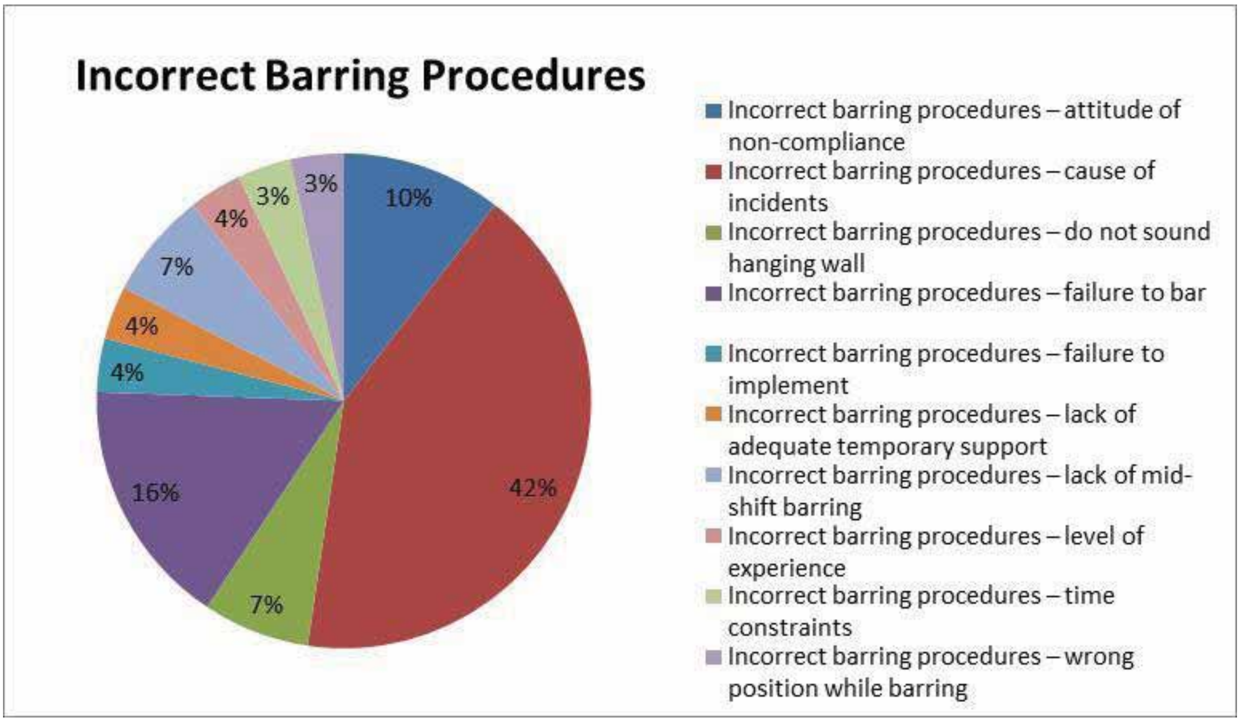

Figure 141: Responses on incorrect barring procedures

Not adhering to the proper procedures for barring also can lead to incidents. These procedures are described as follows:

- Do not sound the hanging wall.
- Lack of adequate temporary support.
- Lack of mid-shift (daily) barring.
- Wrong position with the pinch bar while barring.

It was also noted that the lack of experience of the workforce in barring related activities contributes to the incorrect procedures being followed and the incorrect use of pinch bars. Workers indicated that they face time constraints during their shifts where they are pushed to complete production targets and hence take shortcuts with the safety procedures. They rush through the safety or fail to do barring as often as is needed in order to finish their tasks within the shift.

Lack of Appropriate Leadership and Communication

It was reported in the focus groups that the leadership of the mine also encourages production priorities as opposed to safety procedures due to the frequency on non-compliance with barring procedures and workers attitude of non-compliance. But there has also been positive feedback on the leadership and communication structure stating that it is good and works appropriately. This good structure is when leaders are being consistent in their own safety procedures and supervise the crews through their presence underground during the shift.

Supervisors are complacent in their job tasks and turn a blind eye to sub-standard safety procedures. If an area is declared unsafe, that whole production section is put on hold and this has implications for the production targets. Even the workers, see it as an inconvenience as they lose out on work time and will be penalised for not meeting production and safety targets by losing out on their bonuses.

Other Issues to Consider:

Some of the other issues mentioned but not as frequently as the issues discussed above are:

- Equipment

The responses on equipment at the mine are presented in Figure 142 below and are contradictory. The worker groups were the main responses on equipment as they work with the underground equipment every day. Responses mainly regarding the length of pinch bars and use of the wrong tools for the required tasks were indicated. The quality of equipment was also reported as insufficient and the availability of the correct length pinch bars is not appropriate. It could be accrued to cost saving initiatives at the mine that the procurement of quality equipment is sub-standard. Pinch bars break, bend and are not strong enough. It was reported that the pinch bars aren’t maintained anymore as it is more feasible to replace old tools with new ones. Contradictory statements from workers also reported that there are sufficient tools available and that the correct length of pinch bars was available in the work areas.

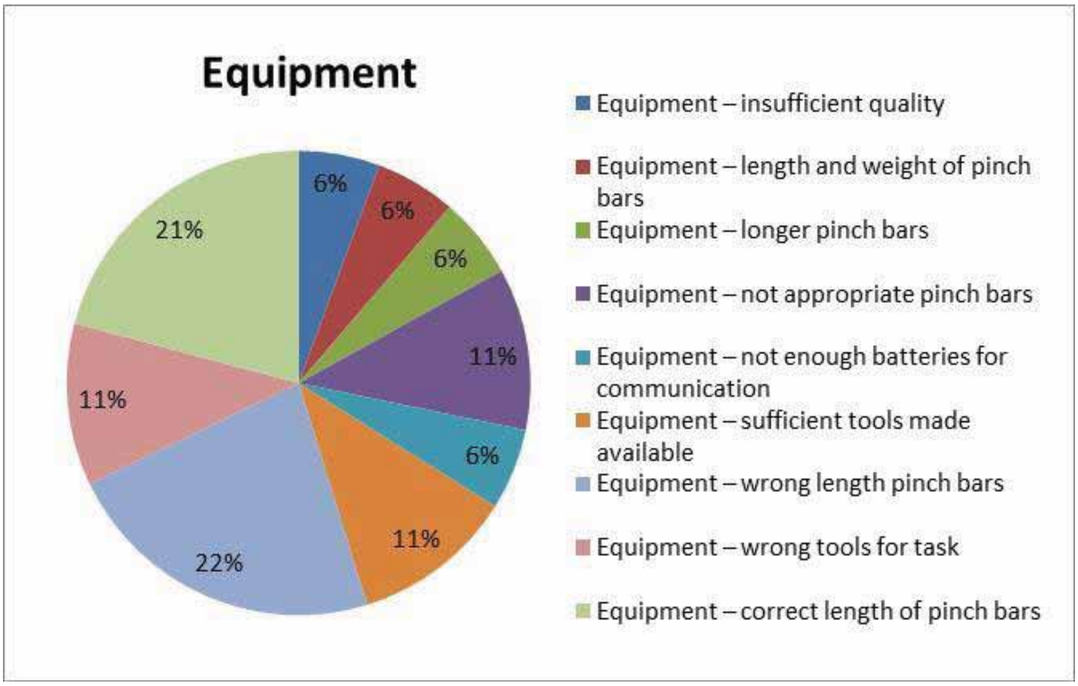

Figure 142: Responses on the equipment used to bar underground

- Underground environment

The underground environment is a challenge to work in and the coal mines have a higher ceiling or hanging wall than the other commodity mines. This means that the length of the pinch bar has to be longer and in most cases heavier. Hence barring becomes a labour intensive and physically exhausting exercise which leads to workers fatigue and lack in concentration.

17.10.2 Mining House G

The key issues mentioned in the interviews are presented in Figure 143 below. The main issues identified were worker attitudes, training systems and incorrect barring procedures. There were positive responses regarding good communication and teamwork from the interviews but the frequency was small (1%).

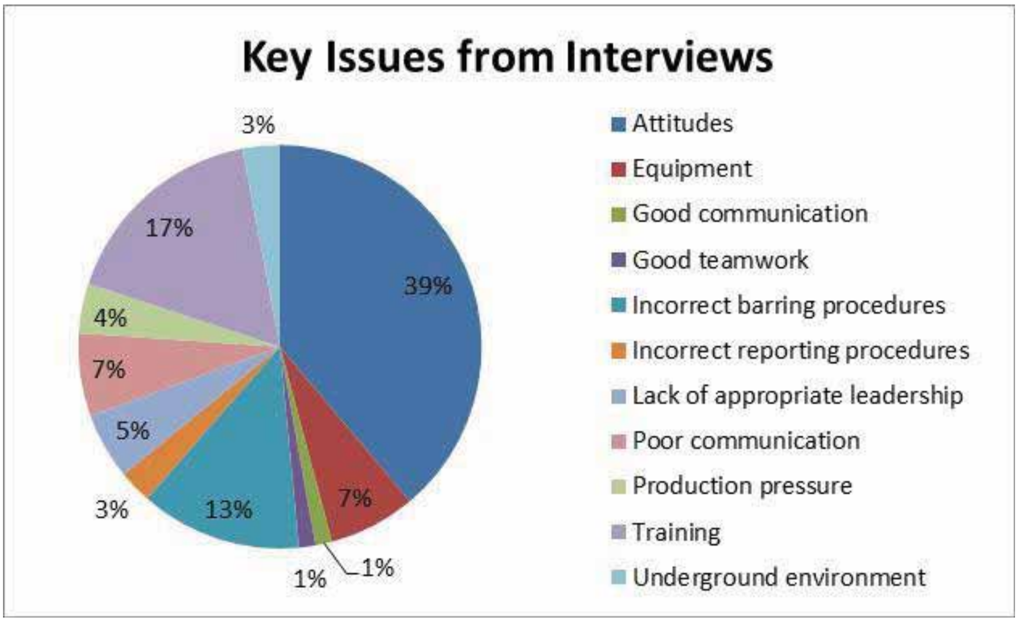

Figure 143: Key issues mentioned through interviews

The main issues mentioned in the focus groups with mine workers and presented in Figure 144 were worker attitudes, training systems, incorrect barring procedures and production pressure. There were some positive responses from workers which were also on good communication (5%), leadership (2%), good reporting procedures (2%) and good teamwork (6%).

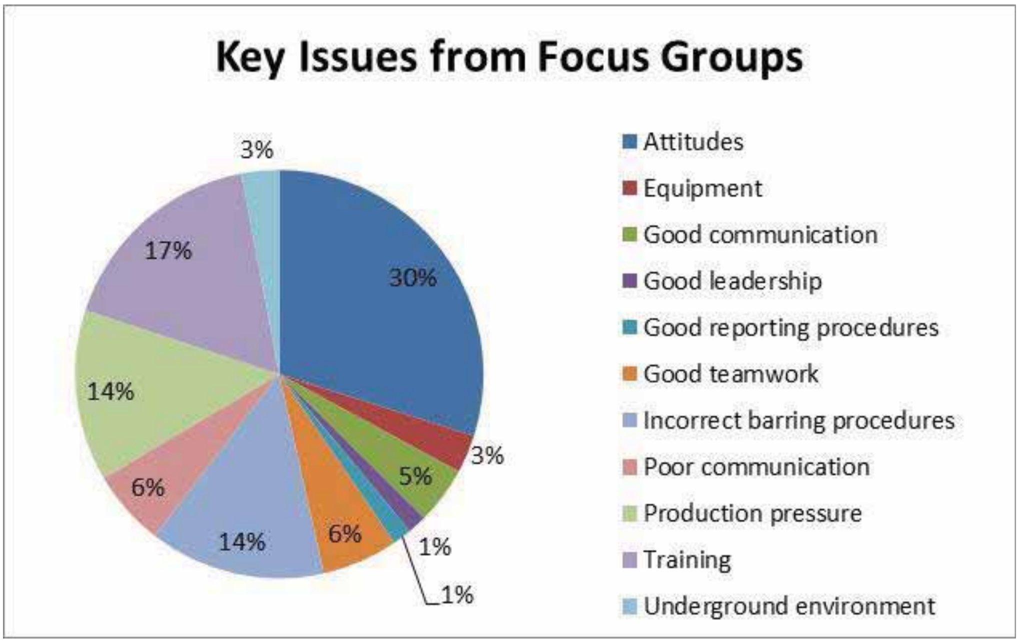

Figure 144: Key issues mentioned through focus groups

Worker Attitudes

The responses on worker attitudes described in both interviews and focus groups are presented in Figure 145 below. The distribution of responses was similar from both the management and mine workers group. The main attitude type mentioned from both the interviews with management and focus groups with workers were workers complacency while undertaking underground tasks. Workers grow accustomed to their working environment and the same tasks that are required from them during a shift. They develop a false sense of security which creates a lapse in concentration. The lack of concentration was also reported among the workers as a main type of attitude aspect.

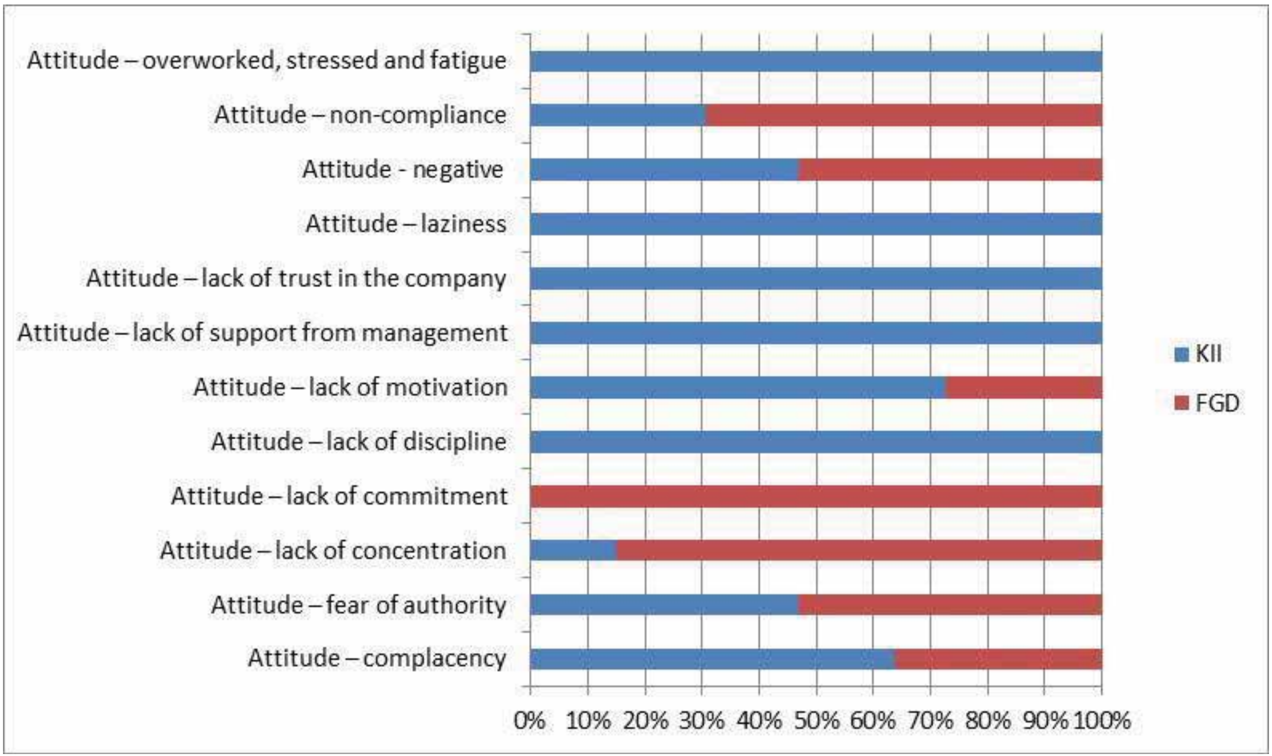

Figure 145: Distribution of types of worker attitudes

Interview respondents indicated that there is a lack of motivation among mine workers and the mine workers themselves indicated a lack of commitment to their work. The status of incentive bonuses and salary increases lends to these attitudes of lack of motivation and commitment to work. Interview respondents indicated that there is a lack of trust in the company and lack of support from management. The perception from the management group is that workers lack discipline and are lazy however this can be attributed to fatigue and complacency. Responses from the interviews stated workers are overworked, stressed and fatigued.

Other types of attitudes receiving mixed responses from both interviews and focus groups were the following:

- Non-compliance: Workers take risks when undertaking their tasks underground. They are nonchalant in taking shortcuts by missing important procedures and continually practice incorrect procedures.
- Negativity: The morale among the mine workers is low and generally negative toward leadership and the company. This negativity also decreases motivation and commitment from the workers.
- Fear of authority: The communication is poor between mine workers and managers so the perceived fear of authority stems from workers feeling they would lose their jobs if they don't obey the bosses.
- Reactive behaviour: Workers will only undertake correct actions and practices if they are being monitored or supervised.
- Lack of positive affirmations: Workers who do their jobs well do not receive any positive acknowledgement or praise from direct management. This contributes to lack of motivation and negativity. Workers also do not take pride in their day to day work as they do not receive any affirmations.

Training Systems

The current training systems at the mine are a mixed method of technical and practical training. These are done by lectures and videos in the surface training centre and practical training through mock-ups on the surface and barring work at the underground training centre. The mock-ups lack practical interaction among the workers as they do not get a chance to practice barring. The mine also utilises external training courses for mine workers but due to cost saving, training initiatives have been reduced or done away with. The mine also undertakes Planned Task Observations assessments for the underground workers.

The responses from interviews and focus groups on the training systems are presented in Figure 146 below. The main issue is that even with the training systems in place, there is still a lack of knowledge and experience displayed when undertaking underground activities. It was also reported that there is a lack of the practical aspects of barring training. For example a young inexperienced mine worker would be put in an area where it is known that there are favourable roof conditions and the more experienced mine workers are allocated to maintain the poor condition work area. This doesn't allow for the younger workers to gain experience and on the job coaching in poor condition roof areas.

As a contrary statement it was reported that the training does equip workers with adequate skills to undertake their daily tasks including the safety training and correct barring procedures. All miners hold a barring ticket which is issued during induction which equips them with the skills to undertake barring practices. Some respondents also indicated that the training system methods were good. However, even with sufficient training, incidents still occur.

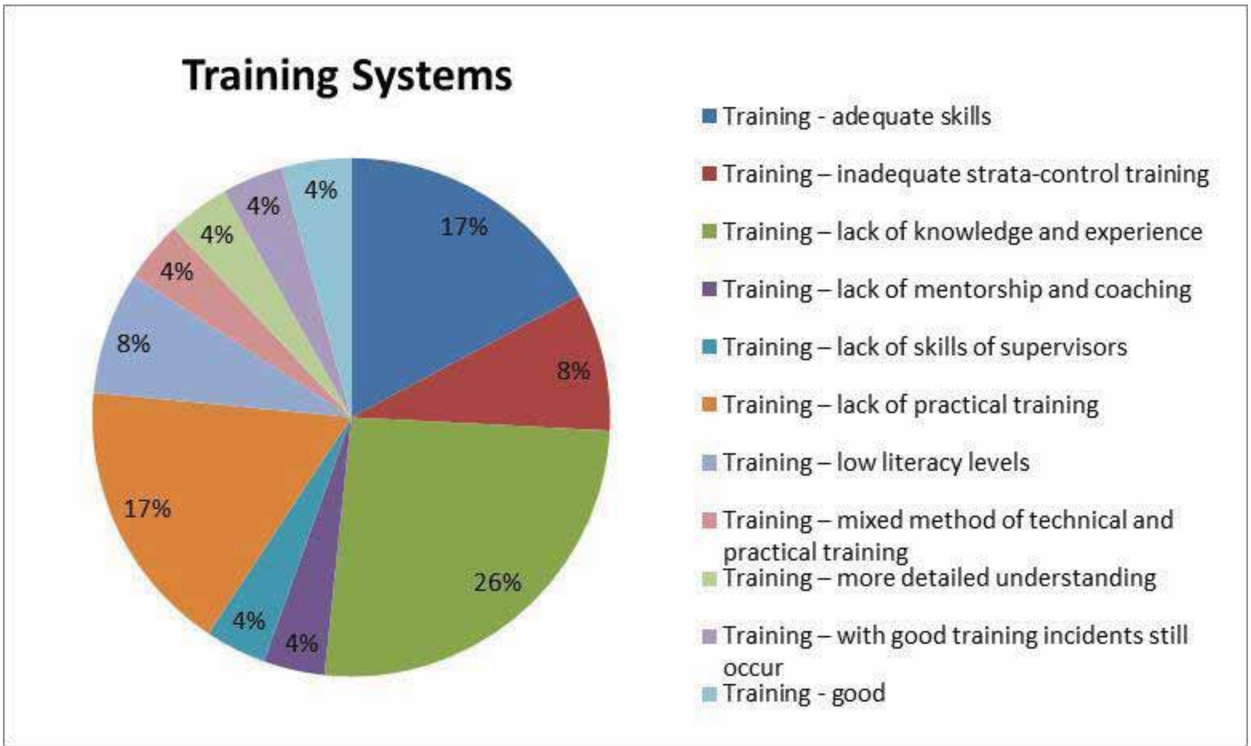

Figure 146: Responses on training systems at the mine

Other training issues which were mentioned in the interviews and focus groups were the low level of literacy among the workers which limits the training systems that could be effective for these workers. Once again the issue of lack of mentorship and coaching was reported and the system for on-going training is lacking among the workers. Lack of mentorship and coaching correlates with the lack of knowledge and experience mentioned above. Workers reported the supervisors lacked sufficient skills to support their crews through mentoring.

Incorrect Procedures

The mine has a reporting and barring procedure which gets communicated and taught to be applied practically by workers. Interviewees indicated that the workers know these procedures but they still practice barring incorrectly. Supervisors have to constantly monitor miners as they are unclear on what to do. The incorrect barring occurrences are presented in Figure 147 below. Most respondents are aware that incorrect barring procedures will lead to incidents or injuries yet there is still this culture of non-compliance. The risk behaviour of taking shortcuts by rushing through safety procedures to meet production targets is a common driver for incorrect procedures being followed. There is also a culture of not barring at all when doing the entrance examination or only barring when being supervised. The barring practice is underestimated by underground workers. Workers do not fully understand the reasons why barring is a critical safety exercise. All the correct procedures are followed when the supervisor or trainer (management level representative) is watching.

The reporting system is a formal procedure which requires paperwork and interviews with management. It has become generally acceptable to not report small incidents where there has been no serious injury which requires medical care. This behaviour is contrary to the priority on mine health and safety but it also maintains good safety targets. Barring is perceived as a paperwork exercise by miners and team leaders and forms are sometimes filled out incorrectly to maintain safety targets. Hence barring isn't actually undertaken every day.

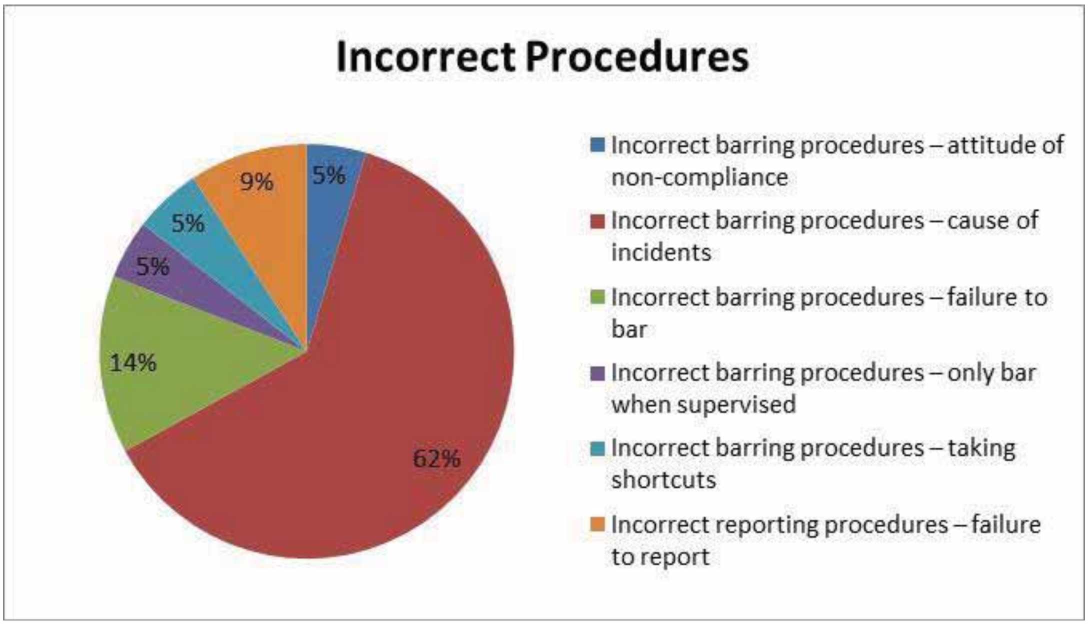

Figure 147: Responses on incorrect procedures practiced at the mine

Production Pressure

The main responses from interviews and focus groups were that pressure to meet production targets causes workers to take short cuts and rush through safety procedures. Once again the attitude of non-compliance to correct barring procedures is practiced in order to gain production bonuses. The mine leadership could also be prioritising production targets instead of safety where there should be a balance of reaching targets and undertaking safety procedure correctly.

When mine workers rush to complete their work tasks in a shift, there is less time to focus and concentrate on the correct barring procedures. Workers are feeling overworked, stressed and fatigued which leads to less concentration when undertaking work tasks and is a contributing factor to the occurrence of incidences and injuries. Workers indicated that the bonuses and work incentives are minimal for the labour intensive job that they undertake within the difficult underground working conditions. This perception adds to the negative attitudes and lack of motivation experienced by mine workers.

17.11 Summary of Findings

This section is a discussion on each of the commodity sectors analysed above to correlate similarities and differences in the findings at each of the mining houses.

The results from the previous study by SIMRAC indicate that the South African mining industry records more negative trends when compared to the safety culture in international mining industries. A significant proportion of employees believe it is necessary to cut corners (risk incentive) to achieve production goals. This indicates a high level of risk taking. Employees believing that it is appropriate or justified to take risks in the interests of production. Job satisfaction records a more negative trend, indicating that employees have a lower level of job satisfaction when compared to their international counterparts. The results for compliance to the rules highlight the difference between safety guidelines and the application of the safety systems and rules. This demonstrates that there is a high level of “non-compliance” of safety standards. The informal and practical aspect of safety appears to be significantly different to the formal programme. This result is related to the relatively negative trends recorded for risk taking for the management, specialist and supervisory groups (SIMRAC, 2005).

This research study indicates similar trends highlighting risk taking behaviours, behaviour of non-compliance, dissatisfaction and negative attitudes of the workforce. Incorrect barring procedures, training systems, lack of appropriate leadership and communication are also issues linked to these trends.

17.11.1 Platinum Sector

The key issues in the platinum sector are predominantly around worker attitudes, incorrect barring procedures and lack of appropriate leadership. The distributions of key issues raised in the platinum sector are presented in Figure 148 below. Once again the graph represents the predominant issues which were identified by respondents in this study and have significance in terms of worker’s perceptions.

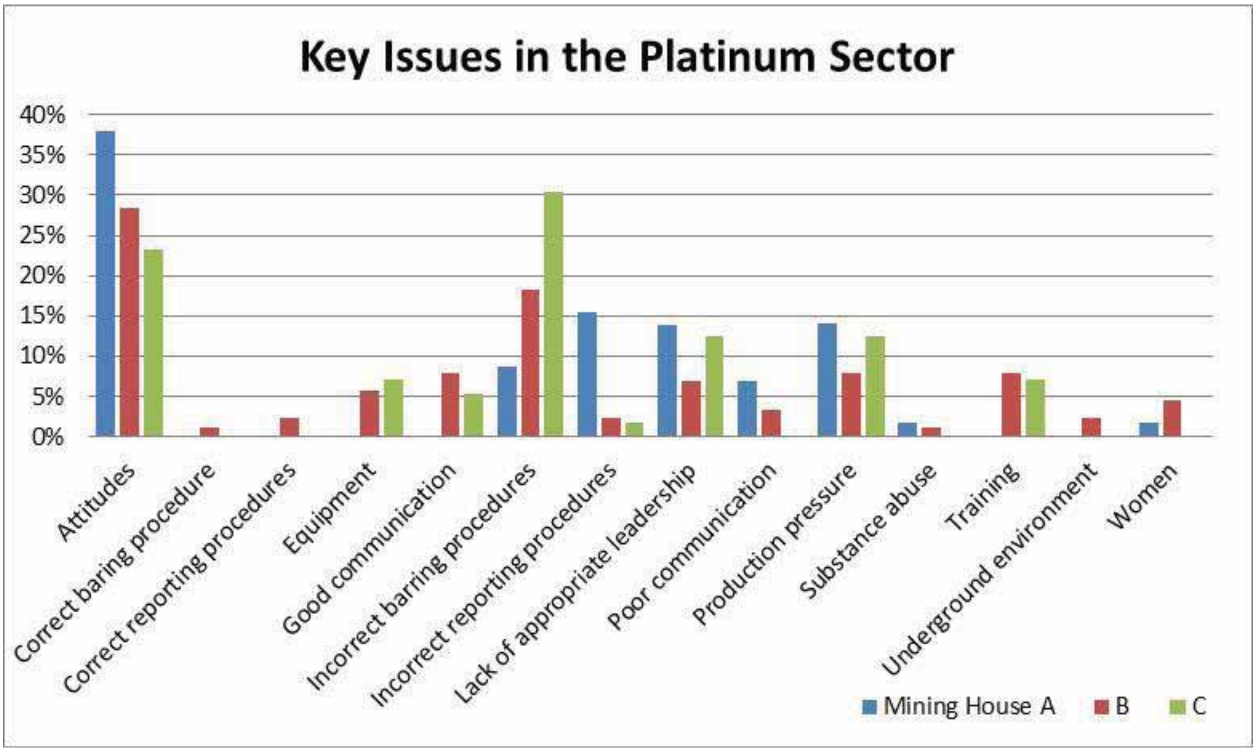

Figure 148: Distribution of key issues in the platinum sector

Worker Attitudes

The distribution of worker attitudes in the platinum sector is presented in Figure 149 below. The most frequently reported attitude for all the mines was complacency among the workers while undertaking their tasks. Mine workers have worked in the same sections for years without any occurrence of incidents which creates a sense of ease and workers tend to relax their safety practices. They take short cuts or fail to undertake the barring and safety procedures at all. There is a perception that the mine workers operate on autopilot in the tasks they undertake underground. It was reported that the main causes of incidents underground is due to workers complacency and lack of concentration when conducting their work.

Reports that workers choose to follow the incorrect procedures because of time constraints even though they are trained on the safety procedures and rules of the mines. The propensity for taking shortcuts is seen as a norm in order to deal with the time constraints and production pressure workers experience. It is an indication of non-compliance behaviour among the workforce. Workers indicated that barring was properly undertaken when there was adequate leadership and supervision.

Responsibility for undertaking barring activities is perceived to be the job task of a team leader and miner. Mine workers feel that the team leader makes the area safe during the entrance examination and the crew would then start on their production tasks. The team leaders receive no support from their crew for barring procedures. Team leaders also take on more responsibility for underground work during a shift. This additional responsibility on team leaders is due to a shortage of miners to manage the panels/working areas in the underground sections.

Workers are feeling overworked, stressed and fatigued because they undertake many tasks in the short timeframes of a shift. This is related to the labour shortages experienced within the platinum industry and according to Lawrence Williams on Mineweb, "*When I worked at Rustenburg there were some 24,000 employees on the operation whereas now the number appears to be more like 14,000 managing higher production levels. Even so, more needs to be done to bring workforce sizes down in order for the more marginal operations to survive in a higher labour cost environment barring big upwards movements in gold and platinum prices. However whether this is socially acceptable in a country with such high unemployment levels is perhaps another point which needs to be taken into account by the mine operators, their workforces, the unions and politicians alike.*" (http://www.mineweb.com/archive/south-african-platinum-and-gold-mine-mechanisation-no-simple-path/).

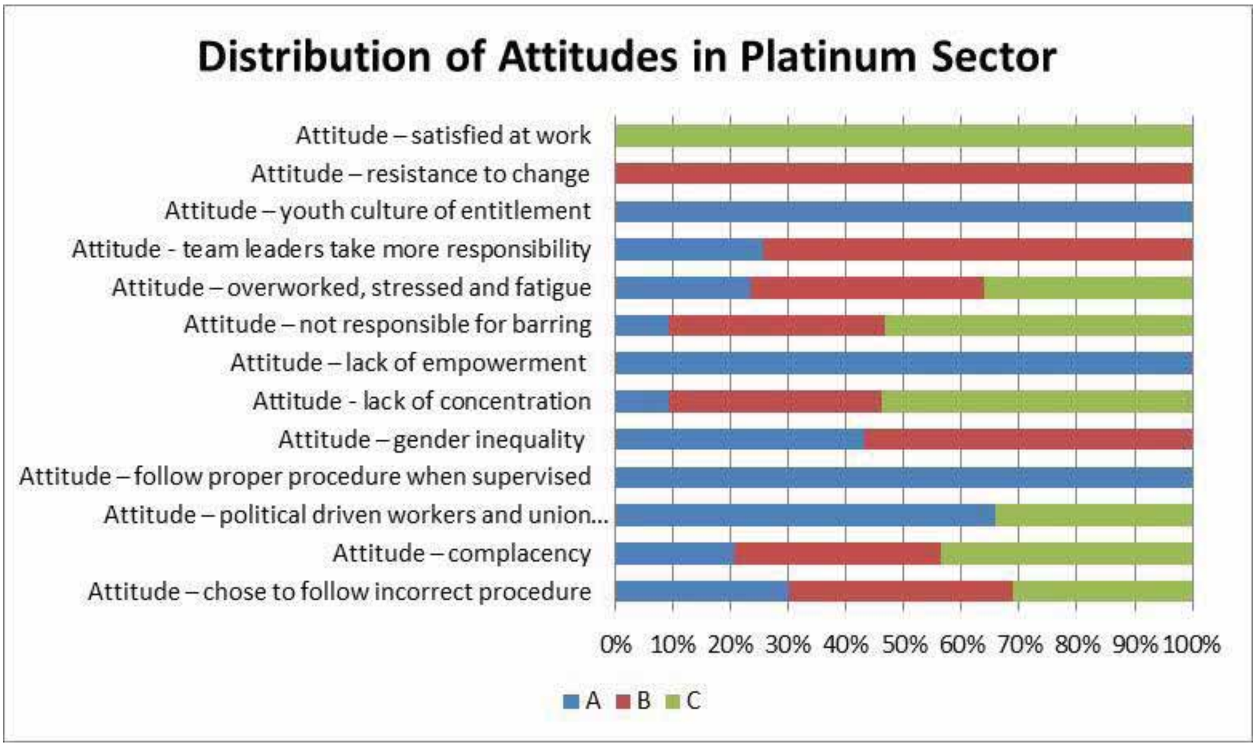

Figure 149: Distribution of worker attitudes in the platinum sector

Incorrect Barring Procedures

The non-compliance behaviour of workers is linked to the pressure on workers to take shortcuts in order to complete their tasks during the shift. Mine workers know the correct procedures and they have received training but they still choose to follow the incorrect procedures. This could be due to rushing through the tasks in a shift and choosing to prioritise the production targets rather than the safety procedures.

Workers are already overworked and fatigued and they view safety procedures as time consuming so they choose to follow incorrect procedures when it comes to barring activities. When workers are fatigued, they lack concentration when barring which can lead to incidents and facilitates lack of attention to instructions and undertaking the incorrect barring procedures. Lapse in concentration and vigilance when barring decreases the workers awareness of other workers and changes in the rock while barring.

Responses also indicated poor communication as a contributing factor to following the incorrect procedure. The communication of instructions from miners to the general workers was reported as poor although the team leaders' communication to their crews is good. Instructions may not be communicated adequately on the barring processes and lack of available supervision leads to incorrect barring procedures.

The pinch bar as a tool for barring is sometimes not held properly and does not have a gasket fitted to it for protection of the workers hands. The correct way to hold a pinch bar and position the body when barring are steps in the barring process and these get undertaken incorrectly due to lack of concentration, fatigue and complacency.

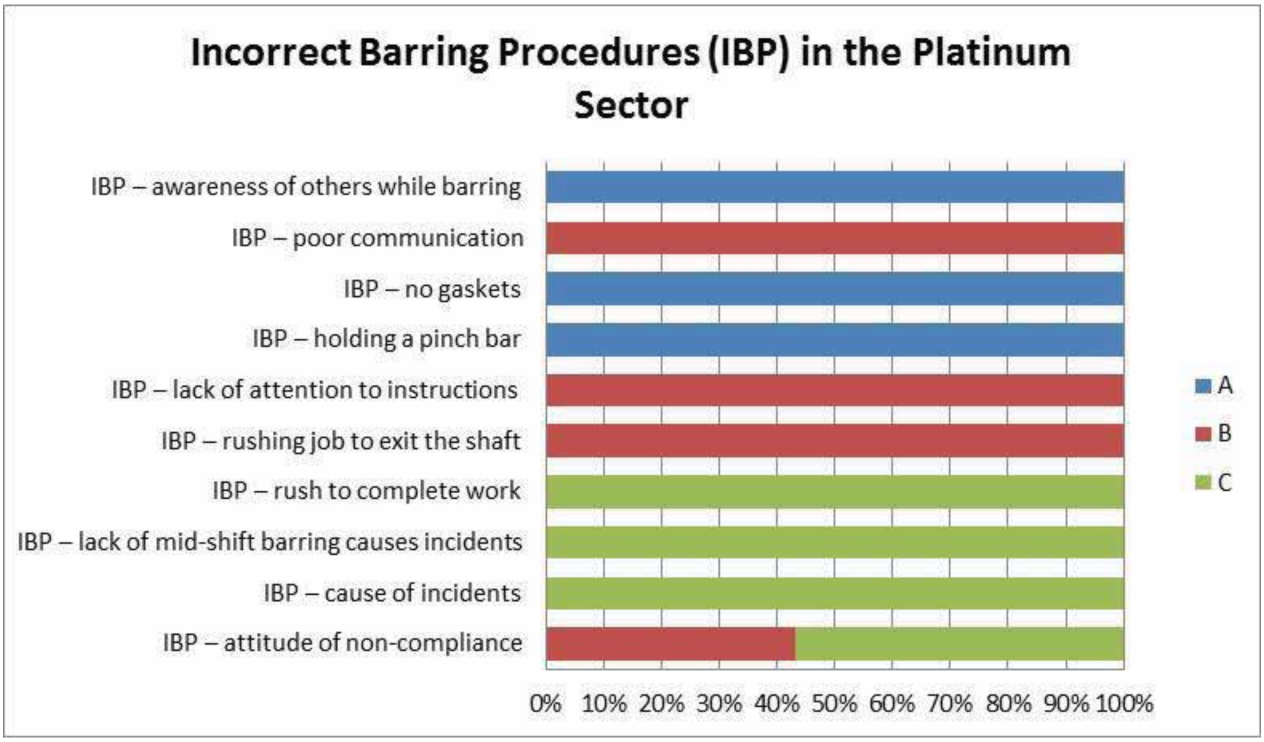

Figure 150: Incorrect barring procedures in the platinum sector

Lack of Appropriate Leadership

Tristan Casey (Casey, 2012), states that despite decades of attention across a raft of disciplines, the goal of zero harm continues to elude the grasp of most organisations in heavy industry. Quite simply, the costs of incidents (both personal and financial) continue to accumulate and represent significant road-blocks to safety performance and societal wellbeing. To overturn these costs and continue to realise performance gains in safety, organisations must look beyond engineering-based control, behavioural, and attitudinal solutions, and toward leadership. Significant inroads to our understanding of safety performance were made when organisations realised that traditional engineering and control-based approaches to safety management were insufficient. But the hierarchy of control can only take safety so far. The effects of technology, automation, job design, and formalised policies and procedures on safety performance ultimately plateau after a certain point. Without consideration of 'the person element', that inescapable and unpredictable energy experienced by all employers, organisations are destined for mediocre safety performance.

Leadership and communication have been reported together because the respondents indicated that one is closely related to the as both follow the same tiered level structure at the mines. The most frequent issue regarding leadership is the minimal presence of management underground during a shift. There are few miners to manage the panels underground and team leaders take on the miner's responsibility in their panels with no support from management. Team leaders may not have the sufficient qualifications or appropriate training for these tasks (for e.g. blasting) but due to the shortage of labour (reduction in the workforce within the platinum sector) they undertake more responsibilities underground. Due to the low number of miners per shift, there is also a lack of mentoring and training from that level of leadership underground. Some team leaders take on this role as well.

There is no communication between the team leaders and miners so there is no knowledge of what goes on in the panels, the miners and supervisors are not visible and actively managing. However, the communication between team leaders and their crews are good and they also demonstrate good teamwork. It was felt that the communication system is not adequate and more effective strategies need to be put in place to facilitate better transfer of task instructions and information.

The perceptions of mine workers toward authority figures are different for each mine. Some responses indicated that there is abuse of authority from the upper level of management as they favour certain employees based on nepotism even if they don't have the right training for those tasks. There are also links to the perception that union activities are creating a distrust and lack of respect to authority or leadership positions at the mines. Workers constantly question the leaders underground and sometimes there is no time to explain properly to them as the tasks have to be completed. The leaders need the workers to follow their instructions in order to work efficiently together as a team.

With stricter leadership and continuous supervision, there are better results with the workforce. It was also stated that with a stronger leadership system the correct barring procedures can be sufficiently enforced.

17.11.2 Gold Sector

The key issues in the gold sector are predominantly around worker attitudes, training systems, incorrect barring procedures and lack of appropriate leadership as presented in Figure 151 below.

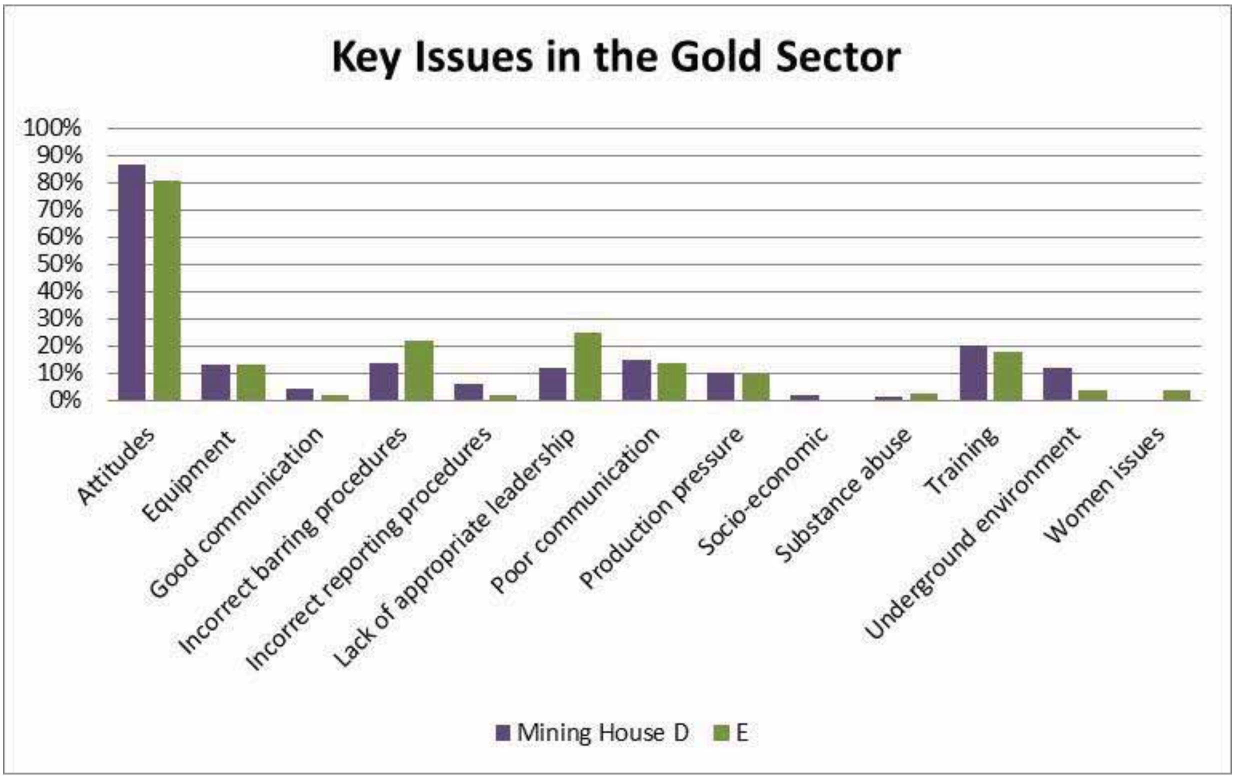

Figure 151: Key issues in the gold sector

Worker Attitudes

The distribution of worker attitudes in the gold sector is present in Table 26 below. The main attitudes in the sector are complacency and workers feeling overworked, stressed and fatigued. Other attitudes are lack of respect for authority, lack of responsibility, gender inequality, fear of authority and tensions between the youth and older generations within crews.

Table 26: Distribution of worker attitudes in the gold sector

Types of Worker Attitudes	Mining House D	Mining House E
Attitude – arrogance of crews	2%	0%
Attitude – bonuses and incentives	0%	2%
Attitude – chose to follow incorrect procedure	0%	5%
Attitude – complacency	12%	14%
Attitude – cultural differences	2%	2%
Attitude - favouritism	0%	1%
Attitude – fear of authority	6%	1%
Attitude – gender inequality	0%	7%
Attitude – hide incompetency when audited	1%	0%
Attitude – lack of concentration	3%	2%
Attitude – lack of motivation	5%	2%

Types of Worker Attitudes	Mining House D	Mining House E
Attitude – lack of responsibility	7%	5%
Attitude – lack of support	2%	0%
Attitude – lack of trust and faith in the company	2%	3%
Attitude – lack of respect for authority	5%	8%
Attitude – lack of discipline	0%	3%
Attitude – lack of empowerment	0%	2%
Attitude – lack of knowledge of consequences	0%	1%
Attitude – non-compliance	3%	0%
Attitude – overworked, stressed and fatigued	22%	15%
Attitude – personal issues	1%	0%
Attitude – political driven workers and union activities	3%	4%
Attitude – safety focus	1%	0%
Attitude – sense of togetherness among crew	1%	0%
Attitude – workers are not respected	1%	0%
Attitude – work for the money	0%	1%
Attitude – youth and older generation tension	7%	1%

Workers are overworked, stressed and fatigues within this sector. There is a high level of dissatisfaction and lack of motivation among the workforce. Workers work overtime but this is negatively impacting on workers family and personal lives. Being underpaid in correlation to the downturn on South Africa's economy provides additional stress on workers who are trying to meet the increasing cost of living and this was evident in responses from focus groups. These additional external stress factors impede worker concentration and create a high risk for potential incidents and accident occurring.

Complacency among the workforce is an issue which is also experienced in the platinum and gold sector. Workers gain a false sense of security when they work underground in areas they are familiar with and where there are safety nets. Vigilance decreases and lack of concentration pose higher risks for the occurrence of incidents and accidents.

Mine workers also mentioned the issue of gender inequality as the other main issue at the mine. It is physically exhausting and the pinch bars are heavy. Mine workers indicated that women bar for a shorter time than the men. Women are also favoured over men in terms of career progression to ensure that the Mining Charter targets are met.

There is a fear of the authority structure at the gold mines especially when it comes to reporting incidents. Middle management (supervisors) utilise threat tactics to ensure workers meet production targets and zero safety incident target. This has instilled a culture of fear toward supervisors.

There is reported tension between the youth and elderly generations working in the crews. The youth come from a mostly educated background and have demands on instant career development when they are employed at the mine. However, they lack on the job training and underground barring experience which the elderly have acquired through years of practical work experience. The elderly view these youth as wild and lacking discipline.

Mine workers take no responsibility for barring as they view it as the responsibility of the team leader or miner. It is everyone from the crew's responsibility to bar. There is a lack of trust toward the gold mining companies as well as lack of respect for people in authority positions. This was a perception from the management groups at the mines and was explained as a result of the growing union activities at the mine.

Training Systems

The need for improved worker safety training programmes, as a means to reduce accidents in South African mines, is being emphasised by all industry stakeholders and driven by legislation. Accident statistics highlight the need to address falls of ground as the primary safety hazard in underground (gold) mining operations. The high incidence of accidents and fatalities in the South African mining industry, in particular those associated with falls of ground in the gold and platinum mines, is often attributed to ineffective and/or inappropriate training methods and material.

The top two of these hazard categories being:

- Falls of ground (noted to be responsible for 62% of deaths and 31% of serious injuries in all gold mines in 1993); and
- Mining equipment and transport (noted to be responsible for 13% of deaths and 21% of serious injuries in all gold mines in 1993) (Squelch, 2011).

According to the data collected in the gold mining sector, the main challenge with the training is that the workers have a low literacy level so training has to be curtailed to suite these workers. Training materials should be more visual and auditory methods of training for the technical and practical modules. The training system should be reviewed to incorporate more focus on skills development through mentoring and coaching.

The youth demand training opportunities when they start work without allowing time spent gaining underground experience. The youth can be trained but they still lack the years of experience working in the underground environment and undertaking barring activities. The elderly workers may lack the formal education but they have the years of practical experience. They are also not receiving adequate mentoring and coaching from leaders (miners and supervisors) while undertaking their tasks during a shift.

The other main issue with the training systems reported was the poor career development opportunities for mine workers. It could be that the mine workers aren't aware of the potential training the mine offers or that there is more focus on production and less on the training and skills development of the workers.

Incorrect Barring Procedures

There are specific barring procedures within the gold sector which have to be followed in order to effectively and safely undertake barring activities underground in accordance with the Mine Health and Safety Act. However these procedures are not being followed or are being undertaken incorrectly by mine workers. The main factors for undertaking incorrect barring procedures is the general non-compliance attitude from the mine workers. The mine workers are risk takers and take short cuts in their tasks to finish their work within the shift. This incorrect barring leads to incidents or more serious accidents occurring underground.

Barring procedures refer to the step undertaken to make the area safe after blasting. How you hold a pinch bar, how you position your body to make the activity of barring safe and efficient. Some incorrect barring procedures which were mentioned relate to the following:

- Wrong positioning of the body in relation to the pinch bar when barring.
- The use of the wrong length pinch bars in the wrong size excavation area.
- Failure to wash the hanging wall to reveal any cracks was also reported due to the lack of water underground.
- Workers bar without a buddy which is against the safety rules.
- Insufficient training when it comes to barring practices.
- Lack of mid-shift barring is in contravention of the safety procedures which promotes continuous barring and hazard identification throughout a shift.

Lack of Appropriate Leadership

The leadership structure and the communication system are integrated as messages are passed along the tiered levels of the mines leadership structure. Both are interlinked in mine workers perceptions as well as the reporting structure which follows the same tired level of reporting. There is a lack of appropriate leadership which leads to a general lack of discipline among all levels of the workforce. This lack of leadership presence underground could advocate the perception that the workers are unsupervised and increase the risk for potential incidents.

Mine workers are receiving insufficient training which can be related to the lack of mentoring and coaching provided by leadership. Reasons for this perception are either that the superiors may not be sufficiently educated or experienced in the tasks they are managing or there are too few miners who are able to manage the various sections/panels in the underground areas. The team leaders end up being the highest level of authority in the section/panels during the shift if the miners aren't able to be present.

It was mainly reported that there is very poor communication between the team leaders and miners. It was also indicated that the generational gap between the youth and the older workers plays a part in the poor communication. Overall it is indicated that respondents had a lack of trust with the leadership structure at the mines.

Good communication has been reported with regards to the type of systems implemented at both mines. The use of notice boards in the waiting places underground where information is and the verbal communication once a week at the safety meetings and daily before commencing works in their section. This helps the illiterate workers to understand the communications and job instructions.

A strict leadership regime would be beneficial to balance the lack of available mentoring and coaching from the miners and supervisors. This would also address the lack of discipline experienced in some crews which are due to the felt absence of leadership and mentoring from management.

17.11.3 Coal Sector

The coal mining environment is very different from platinum and gold mining and due to the less dense rock structure and the depth of the coal seams, barring is not undertaken as often as in the gold or platinum sectors. Sounding and barring is undertaken in coal mines and prevalence is place on sounding activities.

The key issues mentioned in this sector are presented in Figure 152 below. The main issues which were reported more frequently among respondents are worker attitudes, training systems, production pressure and incorrect barring procedures.

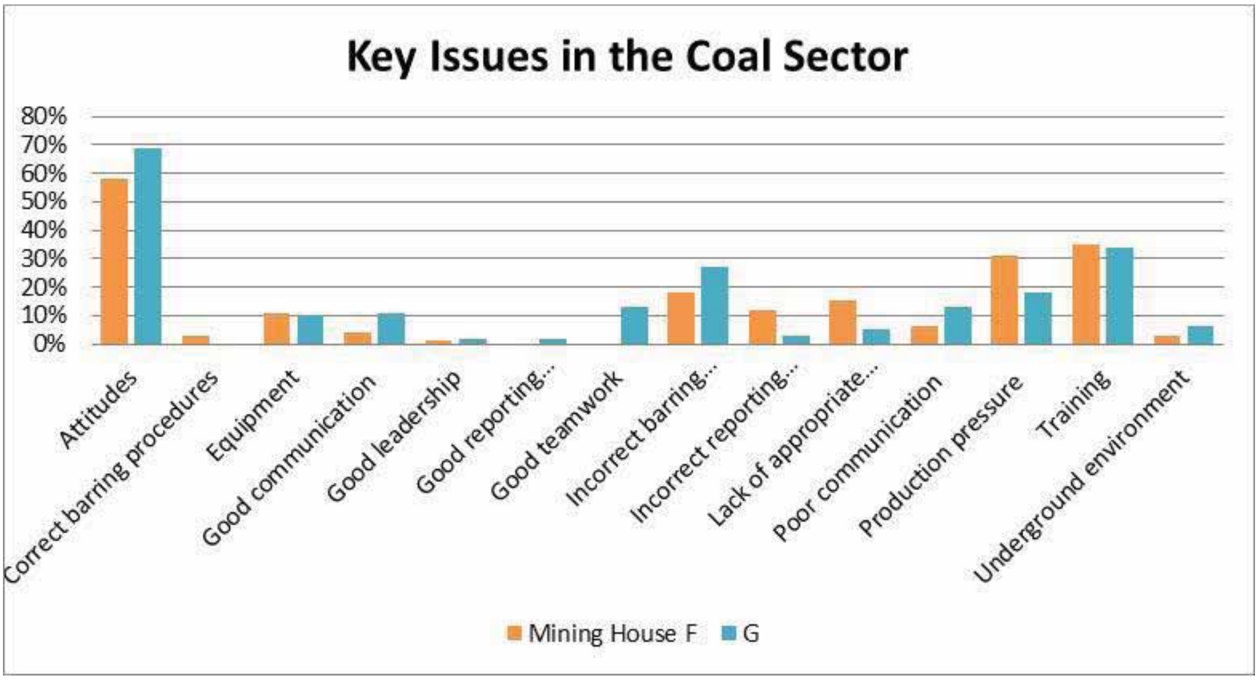

Figure 152: Key issues in the coal mining sector

Worker Attitudes

As with the other mining sectors, worker attitudes have been sub-grouped in similar themes. The distributions of these attitudes within the sector are presented in Figure 153 below. The most frequently reported attitude was complacency and lack of motivation.

Similar to the other sectors, complacency was high among the workers. The repetitive tasks and procedures combined with the lack of serious incidents and a relatively good condition roofs lull workers into a sense of security and their vigilance while undertaking early entry examinations decreases. Mine workers indicated a lack of motivation and a lack of commitment to their work. The status of incentive bonuses and salary increases lends to these attitudes of lack of motivation and commitment to work.

Responses also indicate that mine workers feel barring is not their responsibility but that of the team leaders and miners. They do their tasks in their own way which may or may not be the correct method. There is an attitude of non-compliance to the correct procedures which workers have and this puts them at higher risk for injuries. Non-compliance behaviour is prevalent in all sectors and has significant consequences when workers apply incorrect barring procedures.

Both mines in this sector mentioned that there is a lack of trust in the company and lack of support from management. The perception from management is that workers lack discipline and are lazy; however this can be construed as fatigue and complacency. In the coal sector, workers are also overworked, stressed and fatigued.

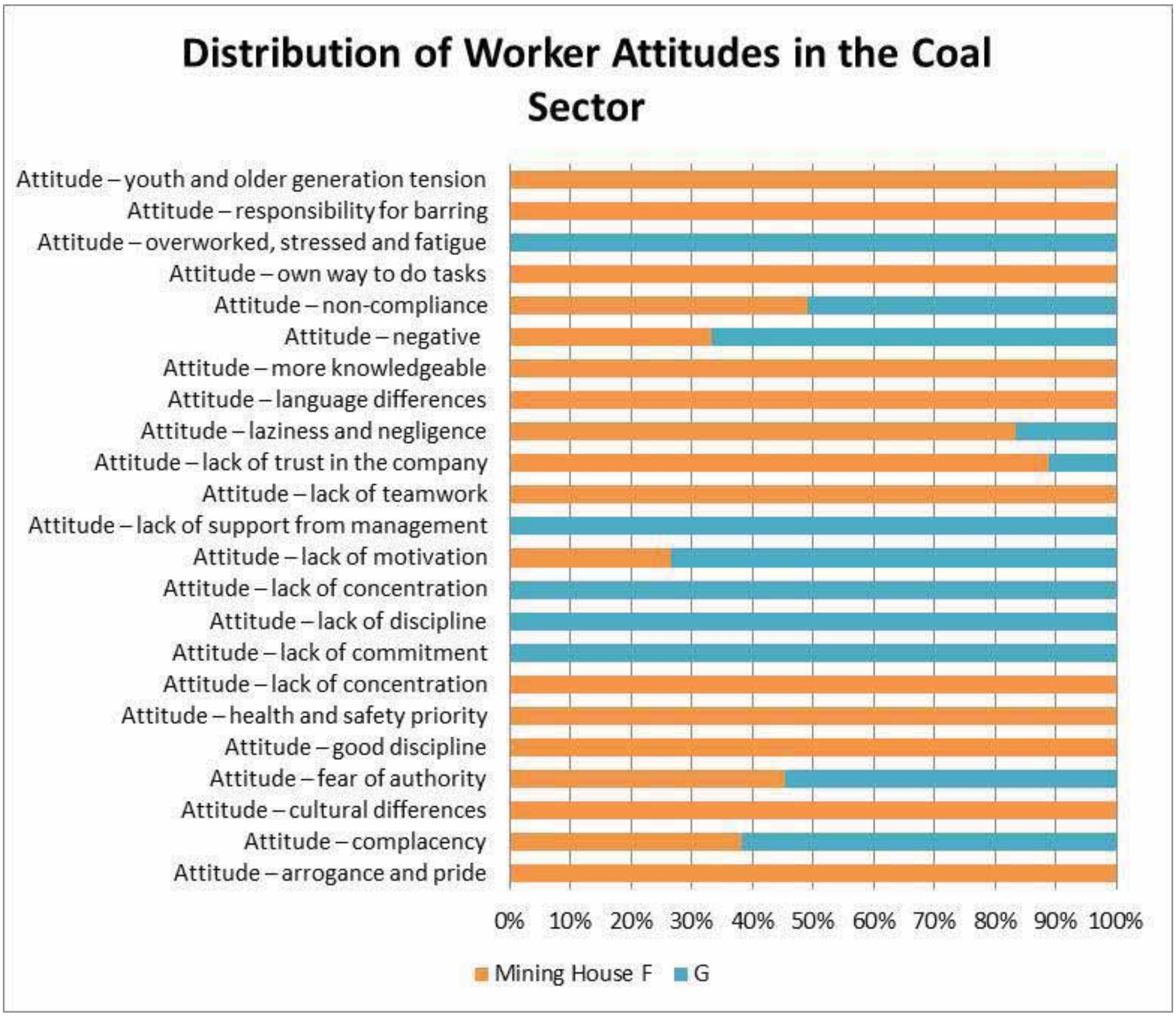

Figure 153: Distribution of worker attitudes in the coal sector

Training Systems

The coal sector has a mixture of theoretical lectures, learning videos and practical barring sessions as with the other mine sectors. However, the coal sector undertakes Planned Task Observations (PTO) as a system for on-going barring evaluation and on the job coaching for underground workers. Even with this system, it is reported that there is still a lack of knowledge and experience displayed when undertaking underground activities.

Figure 154 below presents the types of issues respondents had on the training systems at the mines. Workers indicated that they would like more detailed refresher training on barring and safety mechanisms. As well as training on rock mechanics and identification of types of rock would be beneficial to underground workers.

The low literacy levels are a challenge among the workforce and limit the training systems. There should be more focus on practical and lecture style training systems to efficiently train the large number of illiterate workforce. It is perceived that the older generation show a high level of illiteracy but many years of job experience whereas the younger mine workers are educated but lack the practical aspects of barring training.

The use of mentoring and coaching by leadership assists in shared knowledge and experience especially to the younger mine workers. However, a young inexperienced mine worker would be put in an area where it is known that there are favourable roof conditions and the more experienced mine workers are allocated to maintain the poor condition work area. This doesn’t allow for the younger workers to gain experience and on the job coaching in poor roof condition areas. There is a discrepancy on where the youngsters can get the adequate experience if they are only placed in work areas with good roof condition. This general lack of skills or barring knowledge can lead to incidents and injury. However, even with sufficient training, incidents still occur.

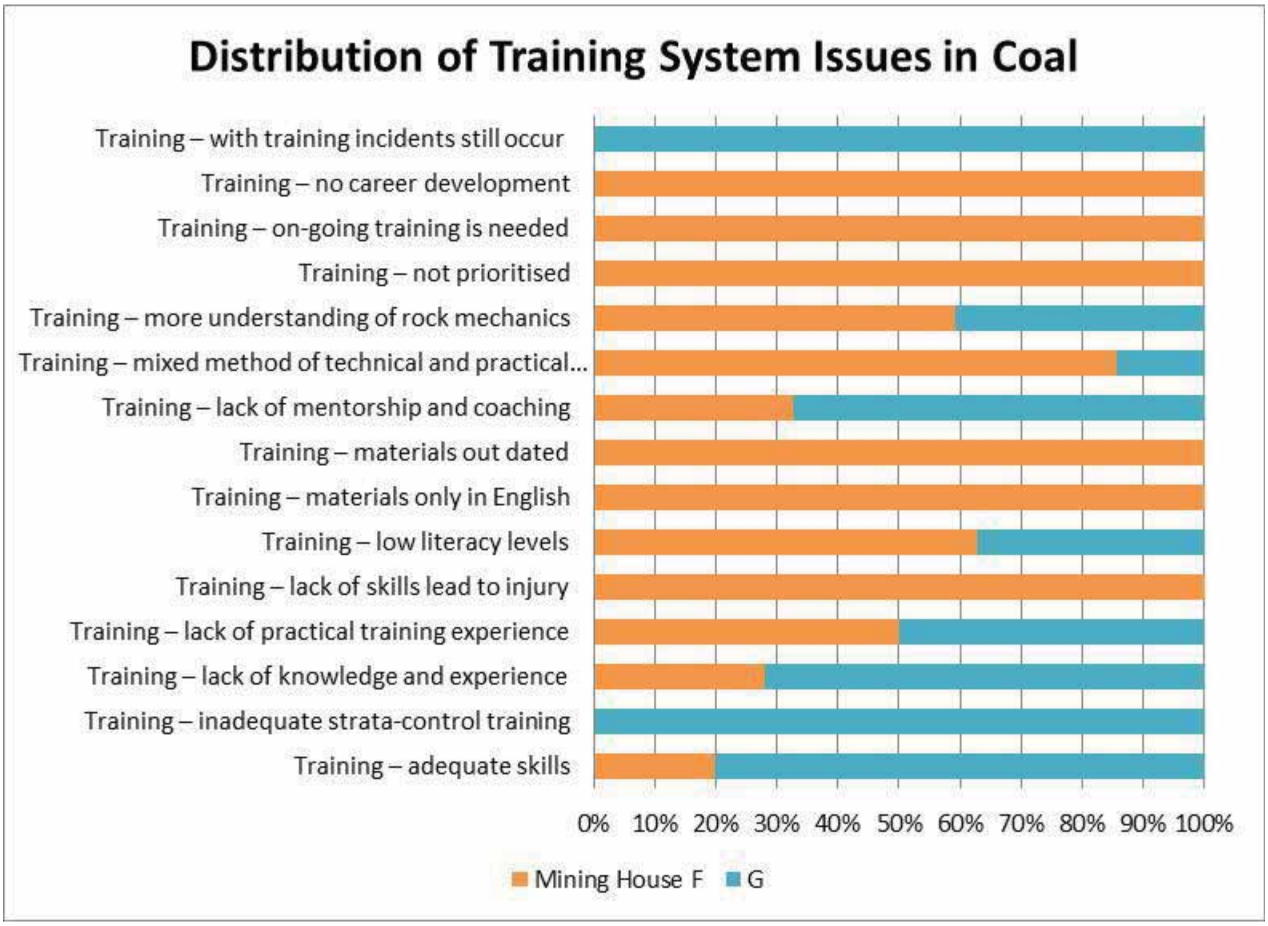

Figure 154: Distribution of issues on training systems in the coal sector

Production Pressure

Another issue experienced throughout the mining sector is production pressure. The pressure to meet production targets causes workers to take short cuts and rush through safety procedures. The attitude of rushing through safety procedures is indicative of workers non-compliance behaviour when undertaking barring activities. It also indicates the mines focus on production with minor emphasis on safety targets.

It was stated that during shifts, the workers focus on the production areas and maintaining roof conditions in these areas. However, the roofs in the passageways leading to the production areas are not maintained. Workers indicated that this type of maintenance was not done in order to save time and workers perceive that these areas are safe and barring isn't necessary. This has led to a false sense of safety and security and complacency in these areas.

The mine leadership could also be prioritising production targets instead of safety where there should be a balance of reaching targets and undertaking safety procedure correctly. Workers are also pressured from management to misrepresent the reasons for incidents in order to maintain their good safety targets. It was reported that some workers just sign off on their safety declarations without undertaking the safety procedures.

Incorrect Barring Procedures

Workers know the correct procedures but they still practice barring incorrectly once again displaying non-compliance behaviour. The risk behaviour of taking shortcuts by rushing through safety procedures to meet production targets is a common driver for incorrect procedures being followed. There is also a culture of not barring at all when doing the entrance exam or only barring when being supervised. The failure to bar leads to potential FOG incidents which causes injury and fatalities although the coal sector experiences fewer fatalities than gold and platinum sector.

Workers also do not undertake appropriate risk assessments when doing safety assessments. Miners will sign off the safety papers without doing the tasks. It has become generally acceptable to not report small incidents where there has been no serious injury which requires medical care. This behaviour is contrary to the priority on mine health and safety but it also maintains the good safety targets. Barring is perceived as a paperwork exercise by miners and team leaders and forms are sometimes filled out incorrectly to maintain safety targets. Hence barring isn't actually undertaken every day.

It was also noted that the lack of experience of the workforce in barring related activities contributes to the incorrect procedures being followed and the incorrect use of pinch bars. The barring practice is underestimated by underground workers. Workers do not fully understand the reasons why barring is a critical safety exercise. All the correct procedures are followed when the supervisor or trainer (management level representative) is watching.

17.12 Discussion of Findings

Understanding the human factors relating to underground barring activities is the key to further gains in safety performance. Consequently, psychology initiated the next evolutionary stage of occupational safety. Behavioural, and later, cognitive-based approaches contributed significantly to the effectiveness of safety management strategies across industries and work contexts. Knowledge of these collective social forces provided a neat extension to existing models of engineering workplace safety performance. Yet, despite this significant progress, occupational safety is an on-going and significant issue for many organisations (Casey, 2012).

It is indicated from other research that the role of the human factor, and therefore human behaviour, is pivotal to companies striving to accomplish goals such as competitiveness, customer delight, high quality, growing productivity as well as a safety-committed work force. The challenge of leadership is to change the worker's poor perception of safety to an excited, empowered, valued employee who is continuously committed to the achievement of high levels of health, safety and conformance - the challenge therefore is to transform from within. Any work force needs a set of behavioural rules which work for it - including safety rules which are accepted through involvement (Schutte, 1998).

Schutte (1998) conducted an empirical survey which proved that the South African mining industry has already gone a long way to maintain and improve health and safety performances, to seek best practices, to conform to safety legislation and to investigate continuous improvement interventions. However, we also learned from the empirical results that the South African mining industry has still a long way to go to meaningfully involve the work force, on-going in job and safety related matters and to respectfully accommodate work force ideas (Schutte, 1998).

In an effort to produce and recommend strategic guidelines (a success factor model) in order to enhance a harmonious and motivating workplace which is conducive to a safety-committed work force, it is verified, among others that:

- Acceptance is the most desirable attitude toward change, because it triggers enthusiasm and co-operation;
- Sound business runs through valued people;
- The human factor is pivotal to safety and safety related matters;
- Successful companies world-wide increasingly use:
- A culture of openness and involvement:
- Strategies of empowerment and people development, and
- Teamwork, to enhance their safety performance;
- Excellence in safety lies in the foundation of a healthy morale, positive attitudes, constructive behaviour and an involved work force; and
- In behaviour-based safety, effective and efficient safety management is a process which begins with human behaviour.

Fundamental to Schutte's models presented are the imperatives of high involvement leadership, vision and shared values accepted by the entire work force and a supportive and safety conscious culture. Safety must form an integral part of the pride of workmanship (Schutte, 1998).

In a recent article, Schutte also states that the essence of smartness in (risk) leadership/management (performance excellence in safety, quality, and productivity) lies in the pride of workmanship itself it is its own reward and must form an integral part of the overall significance of work. True emotional engagement at the work face (relationship credibility), which enhances mutual respect, a good morale, positive attitude and constructive behaviour, creates meaning of work-life (safety climate). This is imperative in growing a workforce's pride and dedicated commitment toward performance excellence in safety and productivity. Ultimate sustainable success in safety and productivity can only effectively be built on the employee's perceived experience of meaning/fulfillment/significance (safety culture) (Schutte, 2015).

Accountability, self-persuasiveness and a safe productive attitude toward work can never be forced onto or threatened into people. Every employee, while experiencing a specific leadership style, takes an inner-decision whether he/she is willing to grow a responsible, accountable and self-persuasive attitude and approach, or not. Every individual employee is the sole owner of his/her level/state of accountability, instigated by the leadership style. Everyday visible attention to Attitude Development at all levels of leadership will ensure and enhance sustainable business and safety improvement and success (safety mind-set) (Schutte, 2015).

So by improving leadership dynamics, increasing workers accountability and ownership of safety procedures, it is possible to decrease negative worker attitudes, non-compliance behaviour and incorrect barring procedures. Based on the results of the data collection, training systems and equipment can also be improved on certain mines to facilitate workers understanding of safety culture and to equip workers with adequate tools to undertake barring activities safely and efficiently. Through the data collection from this research study, respondents shared their own recommendations specific to their perceptions and experience at the mines where they are employed. Further details of these recommendations are discussed below.

17.13 Recommendations

Based on the data collected in this research, there are common themes around worker attitudes, incorrect barring systems and training systems. Issues raised from participants around the systems of the mines are specific to those mines and recommendations for mitigating those issues would be symptomatic recommendations. This section discusses the recommendations proposed for the findings of the study.

17.14 Core Recommendations

The key issues discussed in this study are linked to either system related issues or human construct issues such as worker attitudes and leadership. Through the linkages between themes, there are core recommendations which would assist in improving the health and safety culture at mines.

Leadership and Management

Lack of leadership has been consistently mentioned across all mines and is linked to lack of mentoring, coaching and on the job training as well as lack of enforcing the correct barring procedures. By improving the leadership at the mines, you could improve workers attitudes and compliance to barring procedures. Leadership models may be defined as guides that suggest specific leadership behaviours to use in a specific environment or situation. There are many leadership models and theories to draw from to improve leadership and management at the mines.

Upon review of available theories and models of leadership, it is proposed that the situational leadership theory would be favourable to manage worker attitudes as well as production and safety tasks. Situational theories of leadership were developed to find good ways of adapting leadership actions to meet the needs of different people, situations and circumstances.

One classic situational model of leadership developed by Paul Hersey and Ken Blanchard in 1977, is concerned with identifying the ability (or competence) and willingness (commitment or motivation) of those being led, and then determining the best style of leadership to follow. Leadership style in this case refers to the broad approach adopted by a leader. A leader's style of leadership is often based on a leader’s own beliefs, personality, experiences, working environment and the situation at the time. Some leaders work within one leadership style. Others are more flexible and can adapt their style of leadership to meet the needs of different situations (Harvey, 2009).

The situational leadership theory is based upon two continuums, namely, the required level of *supervision* and *arousal* required to coach workers in specific situations so that they develop into great performers:

- **Supervision** (directing) - The employee's skill and knowledge level determines the level of supervision (what the authors call *Directing*). On one end of the continuum is over-supervision, while the other end is under-supervision. The goal is to hit the sweet-spot. Under-supervision leads to miscommunication, lack of coordination, and the perception by subordinates that the leader does not care. Over-supervision stifles initiative, breeds resentment, and lowers morale. The goal is to provide the correct amount of supervision that is determined by the employee's skill and knowledge level.

- **Arousal** (supporting) - The employee's skill and knowledge level determines the amount of arousal or emotional support required (what the authors call *Supporting*). This emotional support raises or lowers the task holder's arousal level (the inner-drive within our self-system). A certain level of arousal motivates us toward change (learning). However, too much or too little will over or under stimulate our behaviour. In highly cognitive tasks a low arousal is required as over-simulation may occur (and vice-versa). For more information, see arousal.

Ken Blanchard (1985) later refined the model and changed the term *Situational Leadership Theory* to simply *Situational Leadership*. In his model, leadership is the act of providing the correct amount of supervision (Directing Behaviour) and arousal (Supportive Behaviour), which in turn, produces the best learning and developmental environment (Clark, 2015).

The style a leader uses under situational leadership is based upon combining levels of directive behaviour and supportive behaviour. You can think of directive behaviour as an order and supportive behaviour as providing support or guidance.

Hersey and Blanchard focused on four different leadership behaviours based on the levels of directive and supportive behaviour:

1. **Telling** is where the leader demonstrates high directive behaviour and low supportive behaviour
2. **Selling** is where the leader demonstrates high directive behaviour and high supportive behaviour
3. **Participating** is where the leader demonstrates low directive behaviour and high supportive behaviour

4. **Delegating** is where the leader demonstrates low directive behaviour and low supportive behaviour

A follower's overall maturity for the purposes of situational leadership theory is a function of two components. A follower's task maturity is the ability of a follower to perform the task. A follower's psychological maturity represents the follower's willingness to perform a task. The leaders function is to determine the level of a follower’s task and psychological maturity and then adjust their own behaviour in a way that most effectively manages the follower’s behaviours (Grimsley, 2003 - 2015).

Situational Leadership which stresses flexibility and simplicity in execution can equip leaders in the organisation with the tools necessary to skillfully navigate the demands of an increasingly diverse workforce and evolving global marketplace. Infinitely adaptable to any circumstance, the model prepares leaders to address the most pressing challenges pervasive in today’s work environment.

The process is so simple to both understand and apply that its creator, Dr. Paul Hersey, often described it as “organized common sense.” At its core, *Situational Leadership* provides leaders with an understanding of the relationship between an effective style of leadership and the level of readiness that followers exhibit for a specific task.

With application across organisational leaders, first-line managers, individual contributors and even teams, *Situational Leadership* utilises task specificity to serve as a mechanism through which leaders maximise their influence-related impact. We call these individuals “situational leaders” and would contend that they are critical to the success of any organisation.

More specifically, situational leaders:

- Maintain an acute awareness of their innate leadership-related strengths and areas for development – critical skill sets in working in high-performing organisations
- Conduct highly effective coaching conversations by understanding when a particular leadership style has a high probability of success and when it does not
- Skillfully influence up, down and across the organisation by knowing when to be “consistent” and when to be “flexible”

- Create more productive teams/organisations by accelerating the development of individuals that are new to their role and/or are learning a new task
- Develop engaged, committed employees by effectively recognising and proactively addressing the dynamics of performance regression
- Effectively drive behaviour change and business results by communicating through a common, practical language of leadership

While behaviour change is the ultimate goal of most adult-learning endeavours, it is not a realistic outcome for standalone, unsupported training events. Focused reinforcement needs to occur in order to ensure learning is retained and long-term behavioural transformation is realised (CLS, 2015).

Changing Employee Behaviour

This is a controversial recommendation as changing behaviour patterns are based on an individualistic concept. The discussion in this research highlighted the significance of workers attitudes as being a contributing influence to the mine safety culture and implementation of safe barring procedures. The research study is by no means a measure of the psychology behind worker's attitudes as this could only be determined through psychometric testing and as a more in-depth investigation. However, there is a need for a change in worker attitudes and behaviours.

There are clear differences between an employee's attitude and his/her behaviour. Attitude describes the way the employee feels inside. These are his/her feelings toward the manager, coworkers and his/her position within the company. Every employee has an attitude toward the environment, either good or bad. This attitude can also influence how he/she performs. Because attitude is an inward feeling, an employee's bad attitude might remain hidden. But if they are not careful, the bad attitude might show in their actions (Higuera, 2015).

Behaviour is the way the employee responds to his/her attitude. This response is either positive or negative, depending on how the employee views his/her position and the company. For example, an employee who disagrees with a manager might overstep boundaries or ignore office protocol. In addition, an employee who dislikes another coworker or has little respect for a coworker might display this attitude by speaking harshly to this individual, being biased or engaging in other inappropriate acts, such as sexual harassment (Higuera, 2015).

Several situations within the workplace affect attitude and behaviour. For an employee to consistently display good behaviour in the workplace, he/she must maintain a positive attitude toward his/her job. If employees develop a dislike for their job, they might lose interest in the assignments or lack motivation. These negative feelings influence behaviours and might trigger low productivity. In addition, an employee's negative attitude can become evident with other actions, such as poor performance, regularly staying away from work, poor business ethics and perhaps favouring one supervisor over another. To the contrary, employees who feel respected by management and other coworkers, and those who maintain a good attitude, typically respond differently and exhibit appropriate behaviour in the workplace (Higuera, 2015).

Employers can help their staff modify attitudes and behaviours. For example, hold training sessions or provide information regarding acceptable behaviour in the workplace. Sexual harassment and prejudicial behaviour are unacceptable actions that might occur in the workplace. These behaviours take many forms, and employees might unknowingly engage in these types of behaviours. Biased actions might include making comments about someone's sexual orientation, race, culture and displaying a biased attitude toward coworkers and management. Help employees recognise these negative behaviours and do not tolerate them in the workplace (Higuera, 2015).

By changing a person’s attitudes, their behaviour will subsequently change. Mine workers are currently dissatisfied with their work environment based on their level of being overworked, stressed and fatigued by the long hours they work with what they perceive as insufficient pay as well as bonuses and incentives. Workers have developed an attitude on non-compliance where they continually choose to follow incorrect procedures or rush to complete safety procedures. By making workers more aware that this non-compliance behaviour is unacceptable, the number of reported incidents and fatalities may improve. This in conjunction with improving the leadership structures and methods may show an improvement in worker attitudes.

17.15 Recommendations per Commodity

During the data collection process, participants of interviews and focus groups were asked to provide potential recommendations for the issues and challenges they are experiencing at the mines. Their responses provided solutions for the symptomatic problems experienced through the key issues mentioned at each mine. These recommendations are mainly addressing specific issues and challenges experienced by the participants in the study and are systematic in nature to deal with the day to day implementation of systems at the mines.

17.15.1 Platinum Sector Recommendations

The proposed recommendations from the mines in this sector have been consolidated into Table 27 below.

Table 27: Proposed recommendations for platinum sector

Key Issue	Recommendations
Leadership	Active supervision has the ability and the means to make a difference. There needs to be more supervision of workers underground. Reduce number of leaders in the supervision structure and make leaders more accountable. A need for increased supervision for underground workers to be more safety focused and driven.
Other (blasting)	The rock in platinum mines is dense and require more explosives which damages more of the geological structure than is needed. Blasting affects barring activities as uncontrolled blasting creates unnecessary instability in higher layers of strata which impacts on barring activities creating FOG incidents. More controlled blasting practices are needed because when you can control the impact you have in the strata layers, you prevent the potential for future FOG incidents. If you blast properly in the reef, you can create an environment which needs limited barring activity.
Training	Refresher training for barring activities to remind workers of the consequences when they don't bar Refresher training should be focused on scenarios or methods which have changed so workers aren't just taught how to bar but the understanding of the reason behind those changes of the method. Instructors should also undertake barring training underground to refresh their practical experience in order to train new employees. Using more interactive methods for barring training which shows workers what to bar, not just how to bar.
Environment	Putting in more ventilation for underground areas and adhering to the standards of the mine will make the working environment better.
Equipment	The new pneumatic pinch bar works with air pressure vibrations on the hanging wall. It is lighter and requires less effort so even if you are not physically strong, these can still be used underground. The disadvantages are that it opens up the fractures, and if you don't use it properly you can break the head or the sharp pointer of the pinch bar very easily.
Worker attitude and behaviour	Require better initiatives or more rewards to be given for safety focus behaviour.

17.15.2 Gold Sector Recommendations

The proposed recommendations from the mines in this sector have been consolidated into Table 28 below.

Table 28: Proposed recommendation for the gold sector

Key Issue	Recommendations
Equipment	Gaskets are too small and one way to be safer in the future is to design a larger gasket that covers a bigger surface area. Redesign the gasket to fit the pinch bar better. Longer pinch bars could be made lighter (3m steel bars are not good). A suggestion to make barring easier and safer is to introduce machines to bring down rocks to reduce the human element (mechanised barring activities).
Communication	The mines need to improve their communication systems. It was suggested that mines make use of SMS's to contact and update all mine employees on happening at the mine. It was also suggested that a PA system be used more effectively to communicate on a daily basis underground.
Training	Underground workers would prefer if training was more practical. There should be a good balance between theoretical training and practical training. Increase the knowledge of identification and awareness of hazards and about the advantages of barring. Crew members would like more training in understanding the geotechnical environment in which they work. Introduced a "Fit for Purpose Centre" which is a controlled underground training area. Expose workers to a controlled underground environment before introducing them into a production orientated environment.
Other (blasting)	Improve blasting practices to reduce the potential for FOG injuries. "No rock will fall uncontrolled" – Key informant interview quote.
Leadership	Implement a point system where demerits will be given for misdemeanours. There is a need to enforce rules at the mine. Management needs to recognise good work ethics and praise good behaviour.
Worker attitudes and behaviours	Encourage workers to take responsibility for the act of barring. Appoint a dedicated person for barring activity per crew as was previously implemented at the mine. Workers want better incentives to work in the underground environment conditions.
Communication	Underground incidents will reduce if there is an improvement in the communication from supervisors to crew members, with improved communication and relationships supervisors can get full buy in from workers and supervisors to take responsibility for their actions. A possible recommendation to improve communication underground is to introduce underground cell phones which can be kept by supervisors.

17.15.3 Coal Sector Recommendations

There were no specific recommendations mentioned from the data collected at both mines in this sector. The perception is that coal mining is much safer than gold because it is already highly mechanised. Also the underground environment is different to that of platinum and gold so sounding activities are undertaken more frequently.

General recommendations as already mentioned would be to improve leadership and enhance worker's perceptions and attitude to safety practices. By increasing workers accountability and ownership of safety procedures, the issues of incorrect barring and production pressure can be managed. Also improvements to training systems, skills development and mentoring/coaching/on the job training at the mines can assist in developing an improved safety culture.

17.16 Conclusion

This social research study investigated worker perceptions and attitudes to underground safety and barring related activities. Qualitative data was collected from seven champion mines in the platinum, gold and coal sectors through key informant interviews and focus group discussions. This data was analysed using thematic content analysis where responses were grouped into themes and the frequencies of these themes were presented in the results section of the report.

Results across all commodities highlighted worker attitudes, incorrect barring procedures, training systems and lack of appropriate leadership as key issues which were most frequently reported. Generally, worker attitudes reflect an unmotivated, unsupervised, non-compliant and dissatisfied workforce across all commodities. They lack appropriate knowledge and experience when undertaking barring activities and underground job tasks. The most frequent reported worker attitude is complacency on the job where workers grow accustomed to the environment and job tasks that they are not vigilant when working in potential risk areas. Workers have expressed that they are overworked, stressed and fatigued which leads to lack of concentration and incorrect barring which increase the risk of incidents and injuries.

Production pressure is also an important reason why workers continually choose to follow the incorrect procedures even though they are knowledgeable of the consequences. The behaviour to always take short cuts with safety procedures in order to meet production targets has been reported as a norm among the mining industry. Shortcuts are taken with the barring procedures but the practice of incorrect barring is not directly related to cause of incidents however, failure to bar retains the instability in the hanging wall which leads to FOG incidents that are the cause of injury and fatalities especially in the gold mines.

Based on the results of the data collection, training systems and equipment can also be improved on certain mines to facilitate workers understanding of safety culture and to equip workers with adequate tools to undertake barring activities safely and efficiently. Also by improving leadership dynamics, increasing workers accountability and ownership of safety procedures, it is possible to decrease negative worker attitudes, non-compliance behaviour and incorrect barring procedures.

Core recommendations are to improve the leadership model for the mines and to facilitate change in human behaviour. This can be achieved by choosing a leadership model such as *Situation Leadership* which identifies the ability (or competence) and willingness (commitment or motivation) of those being led, and then determining the best style of leadership to follow. Based on the research, mine workers are dissatisfied with their work environment. This is due to being overworked, stressed and fatigued by the long hours they work with what they perceive as insufficient pay as well as bonuses and incentives. Workers have also developed an attitude on non-compliance where they continually choose to follow incorrect procedures or rush to complete safety procedures. By changing a person's attitudes through training sessions on acceptable behaviour in the workplace, their behaviour will subsequently change. This in conjunction with improving the leadership structures and methods may show an improvement in worker attitudes.

18 Technological Advances to reduce the risks of falls of ground

As has been highlighted in the previous discussions of accident statistics, standard barring practices, training techniques, questionnaire surveys, etc., barring is a dangerous operation that needs to be carried out on a regular basis in all underground mines in order to reduce the risk of fall of ground accidents.

However much an operator is trained in the act of barring and made aware of the potential hazards in the hanging wall, the identification of potentially loose rock to bar down is mostly subjective. Any technological device that can assist in the identification of risk prior to barring can help to reduce fall of ground accidents.

A selection of these technological advances that have been developed within the past decade or so are discussed below, as possible ways of making the identification of loose rock in the hanging wall more objective. Most of the devices have been used in South African mining environments, so their practical application to the local barring environments has been assessed.

18.1 Illumination

The Simrac project GAP 202 (Piper, et. al., 2002) identified visibility as a major contributor to interfering with the ability to identify hazards in the hanging wall, and although it was concluded that the main problems were caused by saturated air, low air velocities and dust, rather than poor illumination, the latter has been the subject of investigation in collieries (COL 33A & COL 451).

The source of illumination in all production areas of South African underground mines is the cap lamp worn by the workers, which gives a 14° beam spread. There appears to be very little higher powered mobile illumination available to assist in identifying loose rock or dangerous conditions during entry examinations. GAP 804 recommended that good illumination is essential at static locations of a long term or fixed nature where mine personnel gather and congregate, on mobile machines to illuminate the workplace and make workers aware of the machine's presence, as well as dynamic locations such as development and production areas.

It is clear that there are fundamental problems associated with moving portable lights to production areas in order to illuminate sites where entry-examination is to be undertaken. When it is available, as was observed at Mining House B- Mine 5, these lights greatly enhance the ability to identify potentially dangerous ground conditions.

18.2 Pinch bar Development

The use of as pinch bar to make the roof safe during an entry examination into an underground workplace has probably been undertaken as long as mining has existed. The equipment used is archaic and has not been significantly modified over a significant period of time. The act of barring is difficult and arduous because the operator is holding a heavy pinch bar in an elevated position for significant periods of time, and fatigue occurs after several minutes of use.

A previous Simrac project (GEN 801) which investigated possible systems for "making safe" recommended that future developments should concentrate on developing a lightweight pinch bar, which could be manufactured out of composite materials, and in developing a hand held mechanical jaw which could use hydraulically activated jaws to pry rocks loose from the hanging wall.

The composite pinch bar has been available for a number of years, and was observed to be used at a number of the champion mines visited as part of this Simrac project. Simrac project SIM 020201 investigated the development and use of a composite pinch bar. They generally consist of a fibre glass or composite body which is bonded to hardened steel points and wedge ends. They perform like steel pinch bars, but are significantly lighter, so allow the operator to carry out the barring procedures for longer before fatigue is experienced. Because fibreglass or composite is less rigid than steel there tends to be more flexing of the composite pinch bar during barring, but it was found during the Simrac studies that the amount of deflection was less than for aluminium or steel square tubing. The load required to break the composite pinch bar was also greater than that for the aluminium or steel square tubing. The composite pinch bars were evaluated at a gold, platinum and coal mine. They were found to perform adequately, and it was found that the work rate was higher than when using normal steel pinch bars.

As part of the same SIM 020201 project, mechanical jaws attached to the end of a pinch bar were also investigated. The jaws of the Experimental Development Model (XDM) consist of two sharp jaw tips that can be inserted into a crack, and a hydraulic pump at the base of the apparatus which is operated to force the jaw tips to open and force the crack apart, causing the rock to become dislodged. A sliding hammer is placed behind the jaws to help hammer the jaws into the crack. Figure 155 illustrates the basic design of the XDM device, which was evaluated at a gold and coal mine. It was found that although the device could dislodge rocks in the hanging and side walls, the tips of the jaws are too wide and can only fit into cracks in excess of 10 mm wide. The jaws also needed to open wider in order to dislodge most loose rocks. Perhaps the major practical problem was that the main weight of the apparatus is at the “jaws” end, making the positioning of the device in a crack difficult and likely to cause fatigue in the operator.

It was reported by a miner at one of the champion mines i.e. Mining House B that a type of pneumatic pinch bar was being used during the barring operations in one section, but it was not seen in action in any of the production ends visited during the field work for this Simrac project. No knowledge of other mechanical barring tools (apart from scalers and the pneumatic pinch bar) was demonstrated by underground personnel across all champion mines.

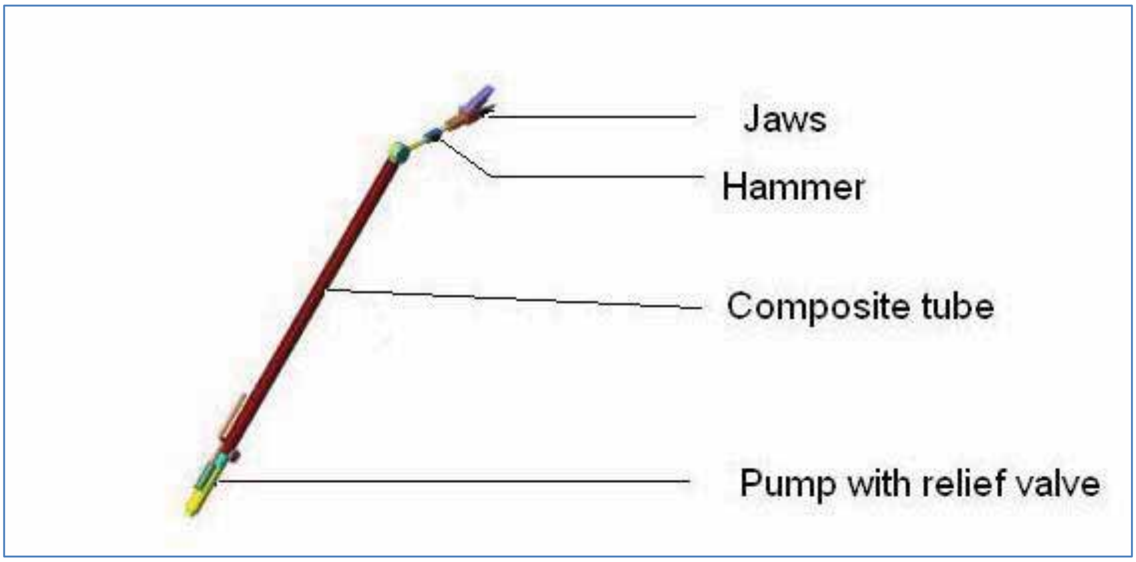

Figure 155: Illustration of the XDM mechanical jaws (SIM 020201)

18.3 Acoustic Techniques

As part of the daily entry examinations that occur in gold, platinum and coal mines throughout South Africa, the procedure involves visibly identifying possible poor or dangerous ground conditions, and using the pinch bar as a sounding device to help identify loose rocks that may be likely to fall. The visual assessment should be carried out with a basic knowledge of the rock mechanics to help identify the various discontinuities and bedding planes that may create a wedge or slab that has the potential to fall out the hanging wall or sidewall of the underground excavation.

The interpretation of the sound that is produced when the pinch bar is struck against the hanging wall rock is very subjective and difficult to teach during training. Essentially, a sharp ringing noise is produced if a strong, massive rock is struck, and a dull thud is heard if the rock is loose and has the potential to fall. The sound heard is dependent upon the ambient noise levels in the mining environment, the nature of the hanging wall rocks (quartzite, mudstone, lava), the type of pinch bar used, the quality of the operator's hearing and his ability to differentiate between the various sounds heard. The frequency of the sounds is estimated to lie in a range between 200 – 1500 Hz (GAP 202). The experience of the operator in a specific environment is essential for the correct interpretation of the sounds.

Because of these inherent difficulties, it has long been a research and practical goal of Simrac and other mining research organisations to produce a portable, rugged, intrinsically safe and reliable instrument that can be used in an underground environment to accurately determine if the sound made when striking the rock indicates a solid or loose rock.

The Acoustic Energy Meter (AEM) was originally developed by Rock Mechanics Technology (RMT) in the 1990's in order to locate voids behind concrete tunnel linings. It has since been developed and tested in a number of mining environments and has proven successful in identifying surface "looseness" in most of them.

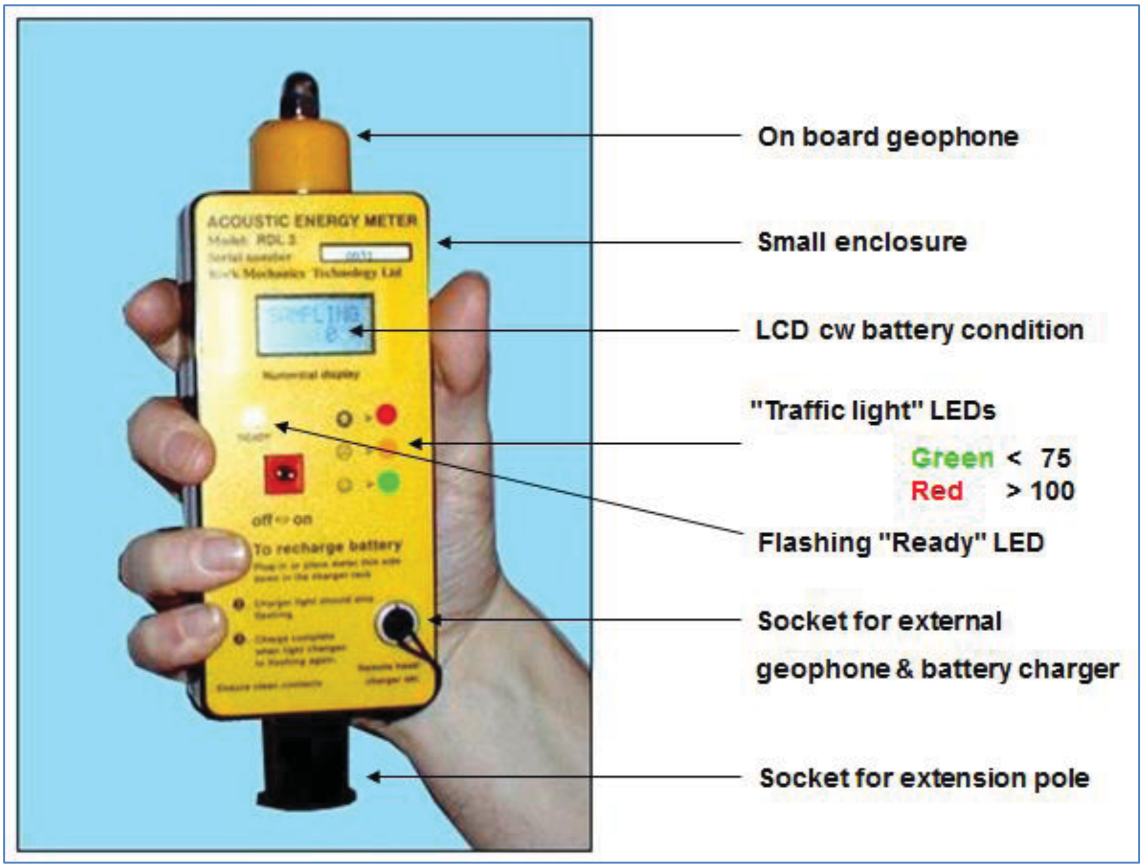

Figure 156: RMT Acoustic Energy Meter (Bigby, 2007)

The device uses a geophone which is placed on the surface under investigation to measure the transient vibrations caused by a hammer blow to the rock surface. The geophone signal is processed to derive a value which can be used to characterise the integrity of the surface. The signal is displayed on a LCD and a traffic light indication is also shown, with a green light indicating solid rock (Bigby, Bloor & Chester, 2004). Figure 156 provides an illustration of the Acoustic Energy Meter. It is recommended that when using the AEM device, the rock is struck with a single sharp blow from a small hammer approximately 25 cm from the instrument geophone contact point. Following the hammer impact the "hollowness" is measured by the rate of decay of the oscillation measured by the geophone, with low values indicating solid conditions, and higher values indicating potential looseness. Calibration of the device must be carried out for each site it is to be used at.

Laboratory and field investigations determined that the efficiency of the instrument was controlled to a certain extent by the type of hammer used to create the initial impact. A small ball pane hammer was found to give the best results, as shown in Figure 157.

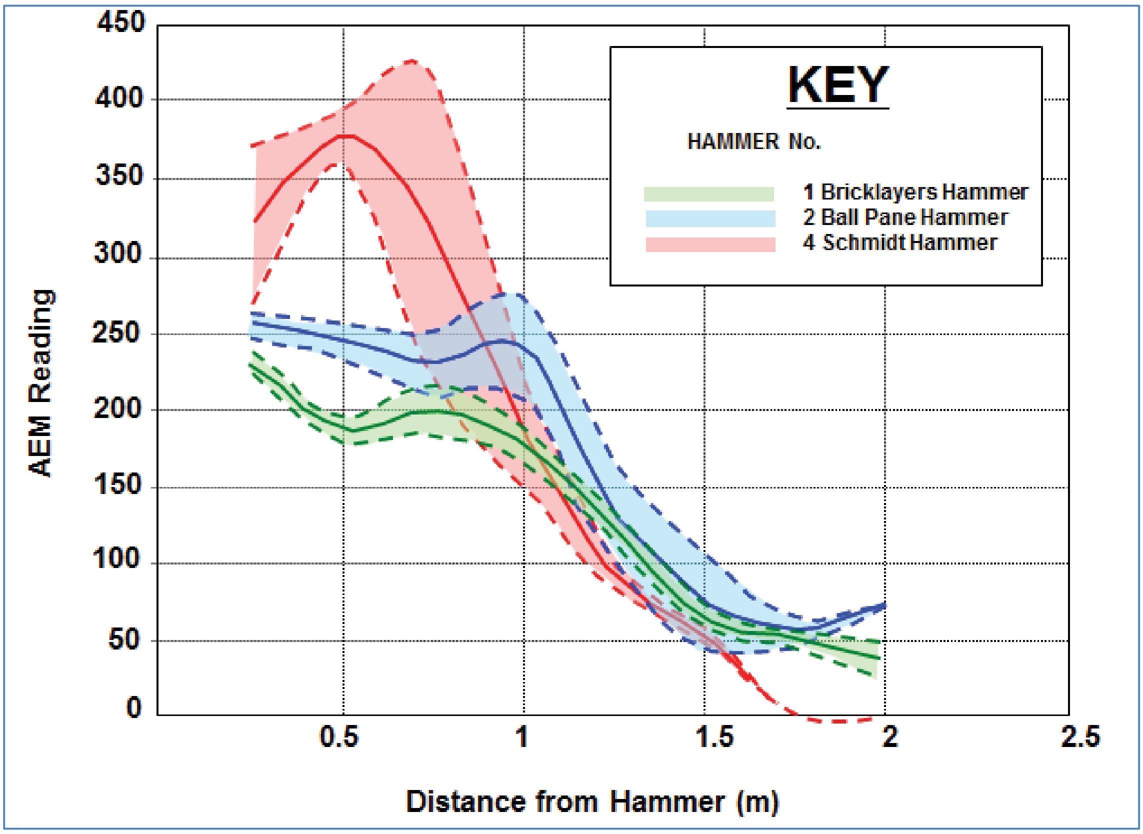

Figure 157: Effect of hammer type on AEM readings (Bigby, 2007)

Table 29: Potential AEM applications (Bigby, et. al., 2004)

Potential application	**Confidence level**
Detection of loose rock	High
Leading edge of dome structures	High
Indicate de-bonding of shotcrete support from rock surface	High
Monitor hanging wall deterioration over time	Medium to high
Determine opening on planes of weakness within 1st metre of rock surface	Medium to high
Indicate 'hot spots' within a stope panel	Medium to high
Indicate high damage geotechnical areas in seismically active areas	Medium to high (many readings)
Indicate effectiveness of pre-conditioning	Medium to low
Determine opening on planes of weakness beyond 1m into the rock surface	Very low

Table 29 shows some of the applications that the AEM instrument can be used in mining environments. It has been used for research studies in South African coal mines (COL 610) as well as gold and platinum mines (GAP 822).

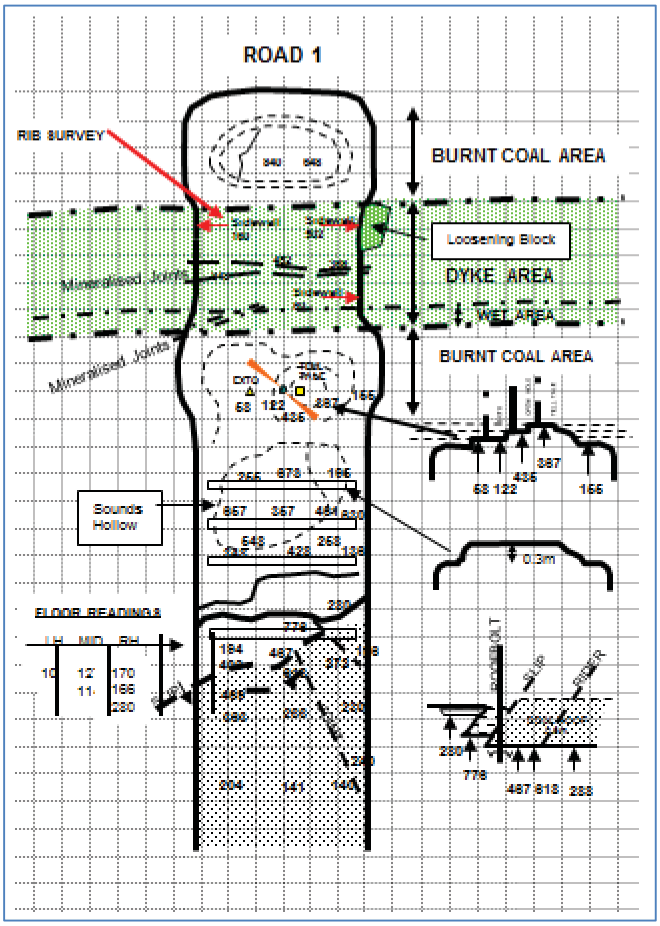

Figure 158: Results of using AEM near a dyke in a Colliery (Bigby, 2007)

The Simrac COL 610 project used the AEM device to characterize roof stability in eleven South African collieries, where slabbing in the roof had the potential to fail. The main conclusions from the study were:

- In visually good, intact roof conditions the AEM gave readings of less than 50;
- Where the immediate sandstone roof became thin and was prone to slabbing, the AEM readings were greater than 100;
- Geologically disturbed roof areas (such as dykes, faults and slips) gave AEM readings greater than 200;
- The weak side of slips could be identified;
- In stable competent areas, the AEM readings varied according to rock type (as low as 20 for sandstone and as high as 100 for coal). This was to be expected, but highlights the need for geological input and site-specific calibration;

- Old roadways gave AEM readings of 500 – 700, even though no visual evidence of roof deterioration was present. This may suggest a time-dependent effect on roof condition;
- Areas that were expected to be poor, because of geological conditions, but which had been remedially supported, gave low AEM readings, indicating that secondary support was effective;
- Taking AEM readings using a high density grid allows for the construction of a detailed picture of the roof conditions in areas of complex geology. Figure 158 shows the results of detailed mapping around a dyke in a colliery roadway.

Surface tests undertaken on unweathered andesite, carried out as part of the GAP 822 study, showed that the AEM could detect slightly open discontinuities up to 0.8 m inside the rockwall, but could not detect tight discontinuities beyond 0.3 m. Tests at Tau Lekoa gold mine indicated that the AEM detected slightly open discontinuities up to 0.5 m into the hanging wall. Similar tests at Mponeng and South Deep indicated hanging wall detection distances of 0.65 m and 0.7 m respectively. Results from platinum mines showed that open discontinuities up to 0.7 m depth could be detected at Bleskop and Eastern Platinum; 0.9 m depth at Frank shaft and 0.3 m depth at Waterval.

The AEM was also the subject of a demonstration and report to the Health and Safety Trust of New South Wales Coal Services Pty Ltd (Burke, 2004). Testing was carried out at nine underground coal mines in New South Wales, Queensland and Tasmania, and assessed according to the main lithologies tested.

The main conclusions were that the instrument was capable of identifying open partings and discontinuities within the lower 0.8 m of a coal mine roof, but that this could only be reliably done when laminated siltstones, sandstones or conglomerates were present in the roof. If the roof rocks consisted of coal or laminated/thinly bedded sediments, there was too much scatter in the readings to provide a reliable measure to recognise open partings. Since there were 14 fatalities reported in NSW between 1980 and 1994 involving roof falls from slabs of rock < 0.4 m thick emanating from the roof, the AEM was regarded as a fast and efficient instrument to detect open partings within this depth range, and thus could improve mine safety.

It is clear that this type of device is capable of detecting fractures in the hanging wall and helping to identify loose or potentially unsound rocks that would need to be barred down. However, for this to be done safely it would be necessary to develop a remote reading device that could impart energy to the rock and measure the resulting vibrations without direct rock contact, and without the need to stand under the hanging wall being tested. Such a device has been developed by CSIR and will be discussed separately, below.

18.4 Infrared Thermography

The main concept behind the infrared thermography method is the fact that due to the exposed hanging wall surface area, loose sections of rock in a ventilated environment should have a lower temperature than solid sections of rock in the same environment, because the former act like cooling fins. The temperature gradient between loose and solid rock depends on the thermal conductivity of the rock, the ventilation conditions, the looseness of the rock and, to a lesser extent, the type of rock and age of the mining. As illustrated in **Figure 159** the thermal gradient between the loose and solid rocks may vary from a tenth of a degree to a few degrees Centigrade (GAP 820, 2002).

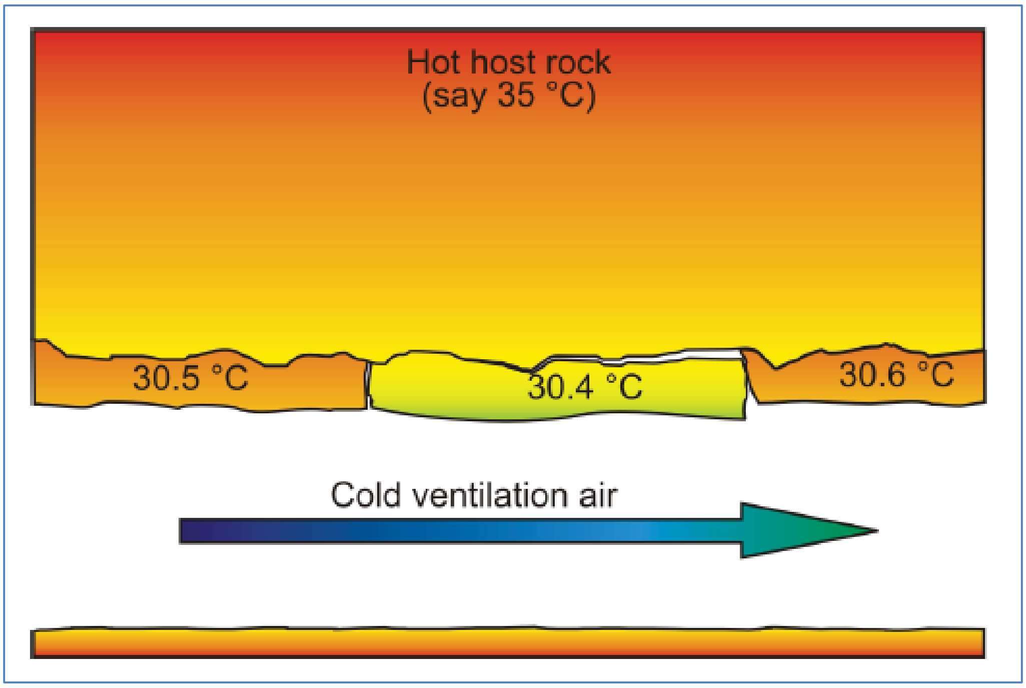

Figure 159: Principle of Infrared Thermography (Green, et. al., 2010)

It was found during the pre-feasibility study (GAP 706, 2001) that the type of measuring instrument used makes a significant impact on the results obtained. A commercially available IR thermometer (Raytek MX4) was modified to improve its stability in the hot and humid mining environment, and to make it rugged enough so it would survive regular use underground.

Underground tests were conducted at Townlands platinum mine and Driefontein 5 shaft gold mine, where the hanging walls to be studied were divided into 1 x 1 m cells. The temperature of at least five locations within each cell was measured, and each cell was measured at least three times during the duration of the project. It was found that in order to obtain a clear picture of the cracks and unevenness in the hanging wall it was necessary to use at least two light sources. Every thermogram was adjusted to produce the same colour coding, where dark blue represents the lowest temperature measured within a particular set of measurements and orange represents the highest temperature. However, the spot temperatures for the same colours across various thermograms may be different.

No good correlations between the fractures in the hanging wall and the temperature distributions were noted, but this may have been because one of the main ventilation fans in the haulage was changed during the period of the experiment. Similarly, problems with the Driefontein 5 shaft study, led to the conclusion that only two of the seventy hanging wall cells studied confirmed potential problems with the hanging wall stability in areas that were colder the general ambient temperature.

18.5 CSIR Electronic Sounding Device

The CSIR Centre for Mining Innovation has been at the forefront of research into the use of technology to help reduce the risk of fall of ground accidents for a number of years, and has developed a number of instruments that can assist with entry examinations and barring.

As has been discussed previously, the primary method of determining if the hanging wall is competent or loose is by striking it with a pinch bar and assessing the sound that is produced. Experienced miners know that a “safe” stable rock will give a relatively high frequency sound, whilst a potentially unstable rock will produce a relatively low frequency sound. In order to help overcome the subjective interpretation of these sounds, the Electronic Sounding Device (ESD) has been developed. It uses a 80 Hz – 10 kHz microphone to capture the sound produced by the pinch bar striking the rock and processes this through a neural network model, which is able to distinguish a safe region by analysing the envelope of the spectral distribution generated from the emitted sound.

The operation of the ESD is as follows (Vogt, et.al, 2010):

1 When the pinch bar taps the roof, the ESD captures the acoustic signal generated as part of the impact;
2 It then derives the frequency distribution of the captured signal;
3 The frequency distribution is processed by a neural network model trained to apply adaptive intelligence to assess the input signal;
4 The neural network outputs a signal that is indicative of the integrity of the rock mass;

5 If the rock is safe, the ESD beeps once, if unsafe it beeps twice.

Since one of the main design goals of the ESD is for it to be compact and portable, and not require any special preparations for the hanging wall, it is currently designed to be mounted on a miner’s hard hat (Figure 160), so that the operator can hear the audio signals from the unit directly. A visual confirmation of the audio signal is given by a green or red LED, which allows other people in the barring crew to monitor progress.

Figure 160: ESD Device mounted on miner's hard hat

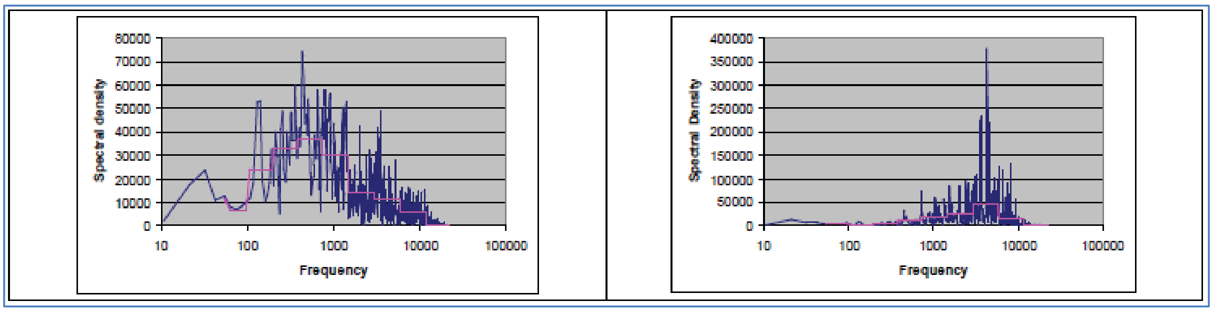

Figure 161: Spectral density of sounding responses (Vogt, et. al., 2010)

Before the ESD can be used practically in a barring situation, the internal neural network has to be trained. This is done with a special ESD training unit. A skilled barrer sounds the rock and declares whether, in his opinion, the rock is stable or unstable. The audio signals captured by the device, together with the stable/unstable assessments are run through a computer based neural network simulator to determine the neural coefficients for the operating units. The coefficients are then programmed into all the units that will be used under the same conditions as the training unit. Normally the ESD will need to be trained for specific mines and reefs.

Figure 161 shows typical frequency responses for an unstable rock on the left, and a stable one on the right. The purple lines superimposed on the graphs are the neural network bins that it uses to recognise the frequency responses.
The ESD has been subjected to a number of trials in operating mines, including sites at Driefontein gold mine with different reefs, groundwater conditions and rock mass classifications. Since there is no completely objective measure of rock stability, as far as fall of grounds are concerned, each ESD sounding was compared to the opinion of a skilled operator. Correlation between the machine and human judgement can be taken as a measure of success.

Table 30 summarises the performance of the ESD at Driefontein, in terms of correlation mismatch between the operator and the device, for different geotechnical domains. The errors can be divided into cases where the ESD was over cautious, when the ESD predicted an unsafe rock mass where the skilled operator judged it safe; and unsafe errors where the ESD predicted a safe rock mass where the operator judged the rock mass to be unsafe. From the table below, the higher percentage of unsafe errors appears to be related to intact rock masses. This could be overcome by training the units for stope environments in intact rock.

Table 30: ESD Performance Summary

Reef	Cautious errors	Unsafe errors	Ground conditions
Middelvlei Reef	7.80%	13.80%	Intact
Carbon Leader	16.46%	5.06%	Crushed, fractured
Carbon Leader	6.76%	4.05%	Crushed
VCR-Alberton Reef	16.21%	5.41%	Crushed, fractured
VCR-Westonaria Reef	11.77%	11.76%	Intact

The ESD device has gone into production, and although it is supposedly being used in a number of the champion mines (for various trials), it was not observed in use during any of the underground visits.

18.6 Thermal Imaging

In addition to the ESD device, CSIR has also been developing a portable thermal imaging device for identifying loose rock in an underground working environment. As discussed above, loose hanging wall rocks can be identified using thermal imagery because they are cooled more by ventilation than rocks that are firmly attached to the hot surrounding rock mass. Instead of using an infrared thermometer to record spot temperatures of the hanging wall, the CSIR device records a thermal image of the area under investigation.

Figure 162 shows the thermal image of a section of hanging wall in a Klerksdorp gold mine, with the temperature gradient graph on the right. The temperature difference of approximately 2.5° C between the hot rock mass and the cooler section in the image allows it to be readily identified as a potential loose slab that would need to be barred down. (The actual dimensions of the slab are 0.8 x 0.3 m, with a mass of approximately 65 kg.)

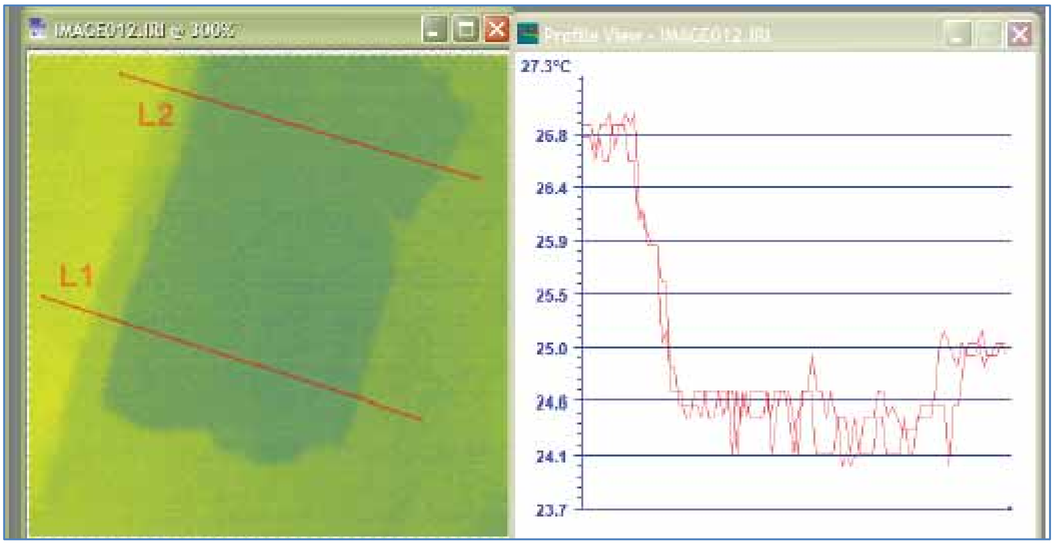

Figure 162: Thermal image of hanging wall (Vogt, et. al., 2010)

Current readily available infra-red cameras have an angle of view of approximately 55°. Whilst this allows useful images to be recorded in larger excavation such as tunnels, using such a camera in a narrow stope environment allows a target of only 0.5 m to be recorded. This limitation can be overcome by “stitching” a number of images together before analysing them, but wider angle infra-red cameras would help solve the problem.

18.7 Integrated Thermal Acoustic Device (ITA)

CSIR is currently working on a device that combines the electronic sounding and thermal imaging devices into one rugged and portable unit for underground use. The ESD would be able to identify rocks that sound unstable, and the thermal image, which would be visible on a cell phone-type screen, would indicate if the rock was cooler than its surroundings, thus providing two separate but overlapping ways of assessing the risk of the rock coming loose, and requiring the need for barring. Figure 163 shows images of a pre-production design for the ITA device.

Figure 163: Preliminary design of the ITA device (Stefan Brink)

Of all the devices that have been developed recently to assist in the identification of loose rock prior to barring, the CSIR ITA device appears to offer an exceptional opportunity for using two different technologies to provide objective ways to help assess the risk of hanging wall falls of ground.

This device is currently undergoing a trial testing phase at one of the platinum champion mines. The durability and portability of the device bodes well for a successful trial phase and the adoption of the use of this instrument is viewed as a future leading practice for barring and in the prevention of falls of ground as well.

18.8 Comment on usage of various barring instruments and aids

When a new device proves to be an effective way of identifying loose rock in the hanging wall, it still has to be accepted by the mine work force before it will be used widely in the underground environment. This will only be achieved if it is light in weight, rugged and waterproof, has long lasting batteries, can be used quickly and efficiently without adding too much extra time to the barring procedures, and can be demonstrated to reduce the risk to the barring crew.

Surprisingly, none of the instruments that are known to have been used on trial (and regularly) at the Champion mines, were observed to be used by any of the barring crews during the underground visits that comprised a large part of this study.

The reasons for technological advancements not being adopted could not be ascertained, but the practicality of using some of these devices is a highly plausible reason for lack of adoption. It is clear that when additional items need to be carried, it is seen to be a hindrance to easy mobility through the underground environment. Individuals may also initially resist the usage of the new devices as it is often perceived to add to the workload for the employee.

Ultimately, the successful adoption of new technology is dependent on keen and motivated individuals who are willing to drive its usage. One has to continually implement adoption campaigns and reinforce the benefits of usage until individuals see the advantages themselves and no longer need to be driven to comply.

19 Assessment of Training Material

The main objectives of the training assessment segment for this research project is to evaluate the training methodology and assessment efficacy, to identify beneficial training initiatives from the champion mines and to suggest broader training approaches that will contribute to the continual efforts made by the mining industry to cultivate a health and safety culture and improve the overall mine worker skills and competency.

In order to achieve the project objectives set out for this training assessment, it was necessary to subdivide them into various phases and tasks, namely:

a) Data collection phase which includes the following tasks;
   i) On site collection of available training material related to barring from the champion mines,
   ii) Visit to training centres to observe barring training methodologies, interviews with relevant training personnel as well as students and, where possible, completing the barring training,
   iii) Interviews with mine workers underground to assess level of barring competency and obtain their feedback on the current training practices,
b) Literature Review;
   i) Learning Theories,
   ii) Learning and Neuroscience,
   iii) Training Approaches,

    iv) SAQA Unit Standards,
- c) Efficacy of training and assessments methods;
    - i) Summary of Training Facilities and Training Practices,
    - ii) Summary of Findings from data collection,
    - iii) Questionnaire Data
        - (1) Interview Data
        - (2) UG Observation Data
    - iv) Evaluation of Training and Assessment Methods
    - v) Evaluation of Training Assessments
    - vi) Evaluation of Trainers/Assessors
- d) Beneficial training initiatives;
- e) Conclusions and Recommendations;

19.1 Literature Review

It is common knowledge that the learning principles form the basis of all educational and training activities. Training typically involves those activities that are designed to improve human performance on the jobs that employees are currently doing or are hired to do. The purpose of training within an organization is to facilitate learning of the employees to achieve the organisations goals and objectives.

During this study, it was apparent that not all personnel involved in training and development within the mining industry are familiar with these concepts of learning and/or the training approaches. A brief overview of the main learning theories is presented in an attempt to address the related training ineffectiveness.

19.2 Learning Theories

There are many widespread theories regarding learning, however, there are a few main ideas that support the various philosophical, psychological and behavioural concepts. These four main orientations to learning are namely, behaviourist, cognitivist, humanist, and social and situational. An overview of these orientations are summarised in Table 31 and the associated key principals identified in terms of learning is provided in
Table 32.

Table 31: Four orientations of learning (after Merriam and Caffarella, 1991)

	Behaviourist	Cognitivist	Humanist	Social and Situational

View of the learning process	Change in behaviour	Internal mental process (including insight, information processing, memory, perception	A personal act to fulfill potential	Interaction /observation in social settings. Movement from the periphery to the centre of a community of practice
Locus of learning	External environmental Stimulus	Internal cognitive structuring	Affective and cognitive needs	Learning is in relationships between people and the environment.
Purpose in education	Produce behavioural change in desired direction	Develop capacity and skills to learn better	Become self-actualized, autonomous	Full participation in communities of practice and utilization of resources
Educator's role	Arranges environment to produce required response	Structures content of learning activity	Facilitates development of the whole person	Works to establish communities of practice in which conversation and participation can occur.
Manifestations in adult learning	Behavioural objectives. Competency - based education	Cognitive development Intelligence, learning and memory as function of age	Andragogy Self-directed learning	Socialization, Social participation Associationalism, Conversation

Table 32: Learning Orientations - Prevalent Key Principals

Learning Orientation	Reference	Key Principals with brief description
Behaviourist	James Hartley (1998)	• *Activity is important* – Learn by doing, improved learning when student is active rather than passive • *Repetition, generalization and discrimination are essential* – regular practice in different settings is needed for learning to take place • *Reinforcement is the cardinal* motivator – Positive reinforces like rewards and successes are prefer to negatives such a punishments and failures • *Learning is supported when objectives are clear* – behaviourism teachings frame activities by behavioural objectives (e.g. Students will be able to… by the end of this activity)
Cognitive	James Hartley (1998)	• *Instructions should be well-organized* – Material that is well organised is easier to learn and remember • *Instructions should be clearly structured* – subject matter supposedly has inherent structure, logical relationships between key idea and concepts that link the parts together • *The perceptual features of the task are key* – learners pay attention to different aspects of the environment, hence the manner in which a problem is displayed is important if they are to understand it. • *Prior knowledge is significant* – learning will take place if it fits in with what is already known • *Differences between individuals are important as they will affect learning* – different cognitive styles or methods of learning of students will influence their learning

		• Cognitive feedback gives information to learners about their success or failure concerning the task at hand – reinforcement through the “gift of knowledge” reward
Humanistic	Carl Rodgers (1983)	• *It has a quality of personal involvement* – the person as a whole (feeling and cognitive aspects) being in the learning event • *It is self-initiated* – the sense of discovery, grasping and comprehending comes from within even when the stimulus is external • *It is pervasive* – it makes a difference in the attitudes, behaviour and possibly the personality of a learner • *It is evaluated by the learner* – the learner would determine if it (knowledge/skills/concepts etc.) meets his/her needs and if it addresses the ignorance he/she is experiencing • *Its essence is meaning* – when such learning occurs, the element of meaning to the leaner is built into the whole experience
Social/ Situational	Murphy (1999), Tenant (1997), Bandura, A. (1977)	• *Learning is in the relationships between people* - learning is the conditions that bring people together and organise a point of contact that allows for particular pieces of information to become relevant, in other words, without this point of contact and system of relevancies, there is no learning and there is little memory. • *Educators work so that people can become participants in communities of practice* – need for exploration of people in communities to maximise how all may participate • There is an intimate connection between knowledge and activity – learning is a part of daily living. Learning from experience and problem solving become central processes. Note that situational learning isn’t the same as “learn by doing”

All of these theoretical learning perspectives offer benefits to training designers however it must be considered in context depending on the situation, performance goal(s) and learners. The context in which learning can take place can be dynamic and multi-dimensional; therefore some combination of these learning theories, and perhaps others, should be considered and incorporated in the instructional design process in order to optimise learning. Training that incorporates these learning theories are more effective in changing the action, belief and knowledge components of a trainee simultaneously.

19.3 Learning and Neuroscience

The neuroscience of learning is related to the cognitive approach however it is necessary to include the biological perspective as well considering that neuroscience has produced some profound insights into the learning process. Neuroscientific research does not only present new ways to think about more effective and efficient learning activity design but also provides a scientific basis for evaluating different teaching approaches.

Learning is always occurring, be it consciously or unconsciously. Learning is "change", change that causes alterations in the physical structure of our brain which results in its organisation and re-organisation. Biologist and educator, Zull (2002) through neuroscientific research proposed a learning cycle that links to Kolb`s (1981) experiential learning model. According to Zull (2002), the completion of this cycle is a requirement for true change to behaviour and performance. An overview of this learning cycle is provided in Table 33.

Table 33: Learning Cycle Stages (After Zull, 2002)

Learning Stage	Region of the Brain	Brief Description
Gathering	*sensory cortices	Engages the sensory cortices by receiving input from the external environment in the form of vision, hearing, touch, position, smell and taste.
Reflection	*temporal lobe	Reflection allows for the brain to integrate the sensory information received. This process is inherently private and requires time and space for the learners to pause and digest the information received.
Creation	*prefrontal cortex	Learner shifts from receiving and absorbing the information to creating knowledge in the form of abstractions (e.g. Ideas, plans, concepts, symbols). It involves the manipulation of information in the working memory to create new relationships and new meaning. A process whereby learners create their own understanding.
Active Testing	*motor cortices	This process allows the brain to make the abstract concrete by converting the mental ideas into physical events (i.e. action). Any actions inspired by qualifying ideas are regarded as active testing.

*NB: This alignment with the regions of the brain is an oversimplification that serves only to assist in understanding the overall working of the brain with reference to learning.

Some of the dominant neuroscience concepts are as follows:

1) *Neuronal Networks – Neuroplasticity*;
    a) This is the probably the most important concept relating to learning and the brain. The brain is constantly changing and all that we do changes our brains however the changes can be short-lived or long lasting. Neuroplasticity refers to the brains extraordinary adaptability due to the process by which neurons connect when they are activated simultaneously ("Neurons that fire together, wire together"- Hebb, 1949). Focused attention and repetition assists neurons to fire together which creates new learning (Schwartz & Begley, 2003). Learning affects the brain by either altering existing connections or creating new connections. Learning begins with connecting with the learner's prior knowledge. Learning for experts and novices are different as the connections for experts are greater, stronger and better organised and hence it is easier for them to assimilate new knowledge and retrieve prior knowledge.

2) *The Social Brain*;

a) The brain requires and thrives/depends on interactions with other brains for its survival. The brain is an adaptable organ and develops its structures through interactions with others (Cozolino, 2006).
b) The brain interacts with social needs using the same brain networks as those used for physical survival according to Lieberman (2008).
c) A human mirror system in people that supposedly forms the basis for social behaviour, our ability to imitate, language acquisition, and display of empathy and understanding (Society for Neuroscience, 2007).

3) *Emotion and Learning*:
   a) Research indicates that almost all mental activities involve both emotion and cognition (LeDoux, 2000).
   b) The role of emotion is the learning process is both powerful and complex and could either enhance or inhibit the brains ability to learn.
   c) According to Zull, (2002), emotion is considered the fuel and foundation of learning as is required to engage the learning cycle as well as to move through it however the right balance is needed.
   d) Emotion and memory are also interdependent.
   e) Mirror neurons are involved reflexive transmission of emotions. They appear to allow people simulate both the actions and the intentions and emotions behind it.

4) *Attention and Memory*:
   a) Engaging attention is needed to begin the learning process of gathering information managing attention throughout the learning cycle to facilitate long term memory.
   b) Continuous partial attention is only useful in small doses and but could compromise ability to reflect, think creatively and make decisions.
   c) Novelty is a very effective way of harnessing attention as it has the potential for rewards in some way.

5) *Engaging the Senses*:
   a) Multisensory and multimodal media increase learning effectiveness.
   b) Visual are very powerful due to the brains extraordinary capacity to remember images.

Neuroscience research supports engaging multiple senses which is currently considered the best practice in learning design.

19.4 Training Approaches

There are numerous training methods which are continually being modified however these methods are generally based on three main training approaches, namely (Rama, Etling, & Bowen, 1993):

a) _Traditional approach_ – training personnel determine the objectives, contents, teaching techniques, assignments, lesson plans, motivation, tests, and evaluation. The focus is on intervention by trainers.
b) _Experiential approach_ – trainers incorporate experiences where the learner becomes active and influences the training process. This emphasises real or simulated situations in which the trainee will operate. The objectives and other components of this approach involve both the trainer and trainees. Trainers serve as facilitators or resource personnel.
c) _Performance-based approach_ - Goals are measured through attainment of a particular level of proficiency. Emphasis is given to acquiring specific observable skills for a task. Skill or task centred.

19.5 South African Quality Authority (SAQA) – Unit Standard

The purpose of unit standards is to inform learning program developers of the expected learning outcomes and advise assessors of what needs to be assessed and the quality of evidence required. In essence, the unit standards describe the results of learning not the learning process (Venter, 2000).

According to the unit standard for making a workplace safe by means of barring, a person is considered competent if they are able to explain the specified requirements related to barring down of loose rocks, carry out the necessary preparation for barring down, barring down loose rock and perform post-barring activities. These specific outcomes and assessment criteria as outlined in the unit standard can be summarised as follows:

1) Explanation of the significant risks and consequences associated with the workplace and work related hazards. Workplace hazards must include those related to support conditions, ground conditions, inadequate escape ways, obstructions in escape ways, persons in proximity of the area to be barred, fire, exposure to unsafe electrical connections, and working under unsafe roof or sidewalls. Work related hazards must include working in confined areas, steeply inclined excavations, and in proximity to moving machinery as well as handling heavy machinery and equipment. In addition, these explanations should

describe the actions to be taken when loose rocks cannot be barred down in terms of assistance and support and the effects to occupational health and safety if these are not adhered to.

2) Preparation for barring down. This involves assessment of personal protective equipment (PPE), tools, material and equipment; examination of area to be barred for workplace hazards; transportation positioning and storage of materials, tools, equipment according to the specified requirements; precautions to prevent accidental entry into area to be barred; and provide explanations for consequences to safety, occupational health and production, if these specified requirements are not adhered to.
3) Barring down of loose rocks. Specified requirements include warning and removal of persons, positioning and footing of person barring, identification of loose rocks, barring technique, use of escape ways, clearance to continue working and travelling in the area where loose rocks were barred down and precautions taken to prevent property damage. Assessments of proper use and inspection of tools and equipment, identification and addressing of work related hazards, positive interpersonal interaction which promotes effective teamwork and explanations of the consequences to safety, occupational health and production for non-adherence to these specified requirements.
4) Execution of post-barring activities. This involves preparation and storage of tools and equipment for subsequent use; dealing with those tools that are defective accordingly; explaining the consequences to safety, occupational health and production if non-adhered to; as well as completing and submitting of reports.

This unit standard was established to integrate knowledge on causes and effects and implications of: hazards not risks not addressed; sub-standard work practices, tools/equipment; barring and barring related procedures and techniques; regulations, legislation, agreements, policies, standards relating to safety, occupational health, and the environment; and, interpersonal interactions with team members.

In addition to specific outcomes, the SAQA has adopted a series of critical outcomes, CCFO`s (Critical Cross-field outcomes), that should be achieved in all qualifications and to an extent in any unit standard. According to the National Qualification Framework (NQF), these critical outcomes are:

1) Identify and solve problems in which responses demonstrate that responsible decisions using critical and creative thinking have been made.
2) Work effectively with others as a member of a team, group, organisation, community.
3) Organize and manage oneself and one's activities responsibly and effectively.

4) Collect, analyse, organise and critically evaluate information.
5) Communicate effectively using visual, mathematical and/or language skills in the modes of oral and/or written presentation.
6) Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.

With respect to the above mentioned CCFO`s, the following critical outcome details were provided by the SAQA unit standard for barring:

1) *CCFO Identifying* - Learners ability to identify sub-standard and hazardous conditions, assess and take appropriate action.
2) *CCFO Working* – Learners ability and willingness to accept and interpret work instructions correctly.
3) *CCFO Organizing* – Learners ability to indicate what methods, tools and personal protective equipment is required and communicate to fellow workers his/her intentions and assistance required.
4) *CCFO Collecting* - Learners ability to reconcile the information from visual and physical examinations and constantly evaluate the changing situation.
5) *CCFO Communicating* - Learners ability to effectively communicate, that is, to use appropriate communication with the relevant personnel with regard to the reporting of hazards and sub-standard conditions.
6) *CCFO Science* - Learner demonstrates an understanding of and ability to use advanced mining technology in terms of production, safety and communication.
7) *CCFO Demonstrating* - Learners ability to recognise unsafe ground conditions and to understand the consequences of not adhering to standards in terms of the safety of all persons working underground.

The specific and critical outcomes stated in this standard by the SAQA are aimed at promoting the general skills. Knowledge and understanding of persons responsible for making an underground working area safe by means of barring in the mining sector.

19.6 Efficacy of Training and Assessment Methods

A training method is a strategy that a trainer uses to deliver content to trainees to achieve the desired objectives. Selection of training methods appropriate for the content to involve trainees in the learning process is important to achieve the training objectives.

The researcher would consider training activities to be optimally effective based on the following:

- If the specific and critical outcomes set out by the SAQA have been achieved;
- If the training activities are aligned with the organisations visions, values and aid in attaining their goals;
- If the training activities promote learning of individuals that would improve skills, knowledge, understanding and overall competency;
- If training activities brings about a change in action and behaviour of trainees in accordance to the mine health and safety culture standard;

The training facilities, methods, assessments and data collected are summarised in the subsequent sections. The barring training practices at the various mining houses were evaluated with reference to the above mentioned outcomes and the level to which these outcomes were achieved.

19.6.1 Summary of Training Facilities and Methods

Table 34 provides a summary of the training facilities. Table 35, Table 36 and Table 37 summarise the training methods and assessments for the platinum, gold and coal industry respectively. It should be noted that the comments provided is based on observations made during the training centre visits and interviews with various mine personnel.

Table 34: Mining Houses Training Facilities and Barring Equipment

Training Facilities		**UG Training Centre**	**UG Mock-ups on Surface**	**Standard Classroom**	**Barring Equipment Comments**	**General Comments**
Platinum Industry	Mining House A	✓	✓	✓	Steel and aluminium pinch bars, various styles - rubber gaskets. Conditions of equipment varied with the shaft from poor to average.	Sections of the UG training centre still needs development.
	Mining House B	✓	✓	✓	Steel and aluminium pinch bars, steel/hard plastic, gasket type varied across the various mines. General pinch bar condition was average to good.	Generally, the training centre was well equipped and designed for training purposes.

	Mining House C	✓	✓	✓	Steel and aluminium pinch bars, various styles rubber gaskets. Gaskets sizes aren't compatible with compatible with the circumference of the pinch bar which results in the gasket moving around. General pinch bar condition was average.	UG training centre adequately equipped for training purposes
Gold Industry	Mining House D	✗	✓	✓	Steel and aluminium pinch bars, various styles rubber gaskets. General pinch bar condition was average.	The mock-ups used for some of the mines still needs to be developed others are adequate.
	Mining House E	✗	✗	✓	Steel and aluminium pinch bars, various styles rubber gaskets. General pinch bar condition was average.	-
Coal Industry	Mining House F	✗	✓	✓	Fibre glass or hollow-tube pinch bars, sounding sticks with copper end, fixed steel gasket. Pinch bar condition average to poor	Mine/Shaft 2 – No surface training facilities and no surface mock-ups. Mine/Shaft 3 - has inadequate training facilities.
	Mining House G	✓	✗	✓	Fibre glass or hollow-tube pinch bars, sounding sticks with copper end, combination stick/pinch bar, fixed steel/hard plastic gaskets.	Mine/Shaft 4 & 5 – No specific UG training centre. Mine/Shaft 7 – Dedicated training facility.
	Mining House H	✗	✗	✓	Fibre glass or hollow-tube pinch bars, sounding sticks with copper end, fixed steel gasket.	No specific UG training centre
	Mining House I	✓	✓	✓	Steel and aluminium pinch bars, various styles rubber gaskets. General pinch bar condition was average.	-

Table 35: Summary of Training Methods for the Platinum Industry

	Barring Training		**Assessments**	

Mining House	Theory	Practical	Barring Related Training (e.g. Hazard Identification)		General Comments
Mining House A	Barring a section of EE, Classroom based with Facilitator, Presentations	Mock-ups, UG Training Demonstration/ Coaching	Hazard Identification training – Classroom based with facilitator, Strata control Effective	Barring Rules, Hazard Identification in classrooms – theory. Practical Assessment UG training centre. Training duration varies 1 day and 3 days UG practical. Manual assessments	Refresher training yearly. No e-learning/ computer-based training or assessments.
Mining House B	Classroom based with Facilitator, Presentations, Hand-outs provided, Group Activities, Videos	Mock-ups Role Play, Coaching, Demonstrations. UG Training Centre, Group Activities	Hazard Identification e-learning system, Strata Control Comprehensive	Barring theory and practical application assessed in UG training centre. E-learning assessment	Refresher training occurs every 6 month or annually.
Mining House C	Classroom based with Facilitator, Presentations, e-learning	UG Training Centre, Group Activities, demonstrations	Hazard Identification System to be implemented. Strata Control e-learning based	e-learning assessments, UG training centre practical	Refresher training occurs every 6 month or annually.

Table 36: Summary of Training Methods for the Gold Industry

<table>
<tr><th rowspan="2">Mining House</th><th rowspan="2">Mine/ Shaft</th><th colspan="2">Barring Training</th><th rowspan="2">Barring Related Training (e.g. Hazard Identification)</th><th rowspan="2">Assessments</th><th rowspan="2">General Comments</th></tr>
<tr><th>Theory</th><th>Practical</th></tr>
<tr><td rowspan="2">Mining House D</td><td>Mine/ Shaft 1,2,3, 4,5,9 & 10</td><td rowspan="2">Classroom based with Facilitator, Presentations, Hand-outs provided, Videos Classroom based with Facilitator</td><td>UG Training, Mock-ups Demonstration</td><td>Strata Control Comprehensive</td><td rowspan="2">Barring Rules – Classrooms, On the job-PTO within the first month, if found competent certification granted. If not, coaching and re-training carried out until competent. Manual Assessment</td><td>No specific UG training centre. Refresher training occurs every 6 month or annually.</td></tr>
<tr><td>Mine/ Shaft 11, 12, 13 & 14</td><td>Mock-ups, UG Practical, UG on the job mentors</td><td>Strata Control Comprehensive</td><td>Mock ups – inadequate. Refresher training occurs every 6 month or annually.</td></tr>
</table>

		, Presentations, Videos				
Mining House E	Mine/ Shaft 15 & 16	Classroom based with Facilitator, Presentations,	Demonstration, UG on the job training	Hazard Identification, Strata Control	UG Practical Assessment – PTO	Mine/Shaft 16 – UG & Surface training No e-learning training

Table 37: Summary of Training Methods for the Coal Industry

Mining House	Mine/ Shaft	Barring Training		Barring Related Training (e.g. Hazard Identification System)	Assessments	General Comments
		Theory	**Practical**			
Mining House F	Mine Shaft 1 & 2	Outsourced Training Personnel	UG Training	Strata Control	UG competency Assessment	Mine/Shaft 1 – Contractor providing training for this mine, overall competency higher. High working standard and strong work ethic – long term employees.
	Mine Shaft 3	Videos Induction	On the job training	Strata Control		-
Mining House G	Mine/ Shaft 4 & 5	E-learning	UG Training Demonstrations, coaching	Hazard Identification system – e-learning	e-learning assessments, UG Assessment to obtain Barring license	People trained every 6 months, people issued with a barring license that expires after a year. Mine/Shaft 4 – poor attitudes towards barring, complacency due to generally good roof conditions.

	Mine/ Shaft 4 & 5	Classroom based with Facilitator, Presentations, E-learning	UG Training Centre	Hazard Identification system, e-learning	e-learning assessments, UG Assessment to obtain Barring license	Mine/Shaft 7 –Barring not been carried out regularly – poor attitudes.
Mining House H	Mine/ Shaft 8 & 9	Classroom based with Facilitator, Presentations, E-learning	UG Practical training	Strata Control	UG competency Assessment	Overall competency and understanding is good. Request by workers for more training. Mine/Shaft 9 – Competency higher
Mining House I	Mine/ Shaft 10	Classroom based with Facilitator, Presentations, E-learning	UG Practical training	Strata Control Comprehensive	UG competency Assessment	Training facilities seems good. Simulation work conditions etc. Generally training is comprehensive

19.6.2 Summary of Findings from Data Collected

The general findings from the questionnaire data collected, feedback from various interviews, and underground observation data are summarised below. It should be noted this section only presents the training related data. Statistics on other results are included in Appendix B.

19.6.2.1 Questionnaire Data

The questionnaire completed was comprised of a series of questions that were designed to test barring knowledge and understanding, gather generic social data and to receive feedback on the training practices at each mine.

19.6.2.1.1 General Information on Questionnaire Participants

1) Occupations and associated age category are shown in Figure 164 to Figure 166.
2) Rock drill operators/ machine operators between the ages of 31-40 years are the most common participants.
3) Nationality is shown in Figure 167.

4) First language is shown in Figure 168, Figure 169, and Figure 170. Tswana, Xhosa, Sotho and Zulu seem to be the most prominent languages.
5) Occupations and average number of years of mining experience are shown in Figure 171, Figure 172 and Figure 173.
6) Gender and age category shown in Figure 174. A total of 7% of the participants were female across the gold, platinum and coal industry.

<u>*Occupation with Age Category:*</u>

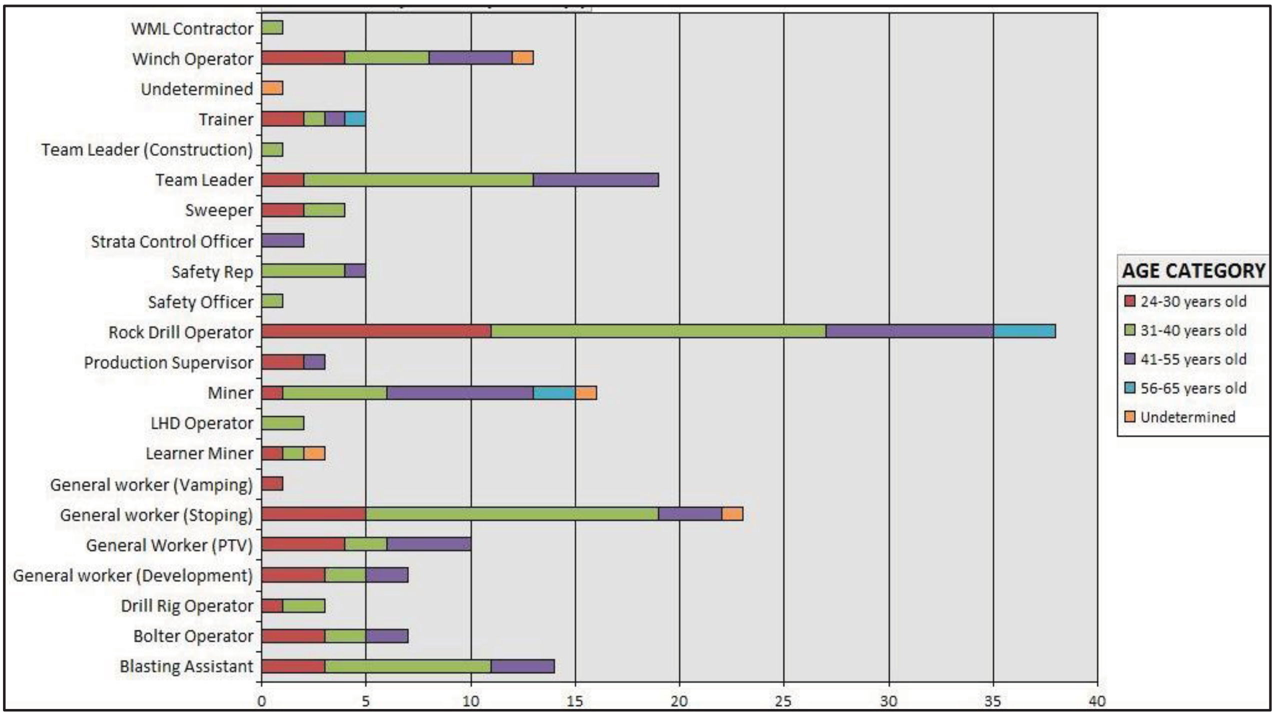

Figure 164: Bar graph showing frequency of participants' occupation and age category in the platinum industry

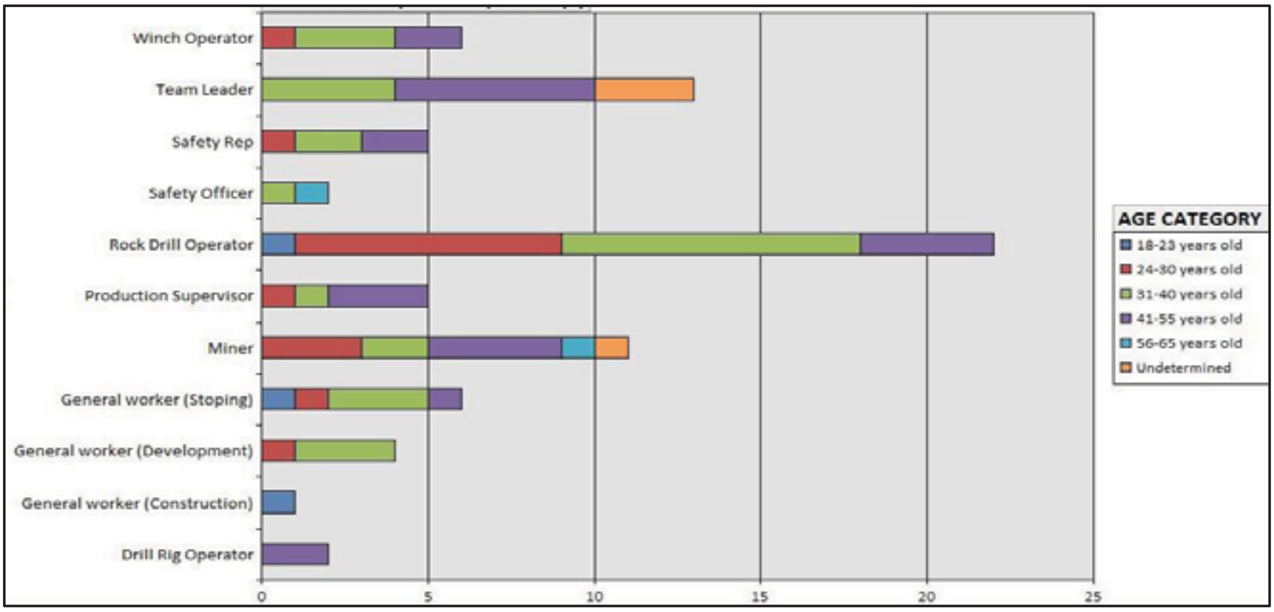

Figure 165: Bar graph showing frequency of participants' occupation and age category in the gold industry

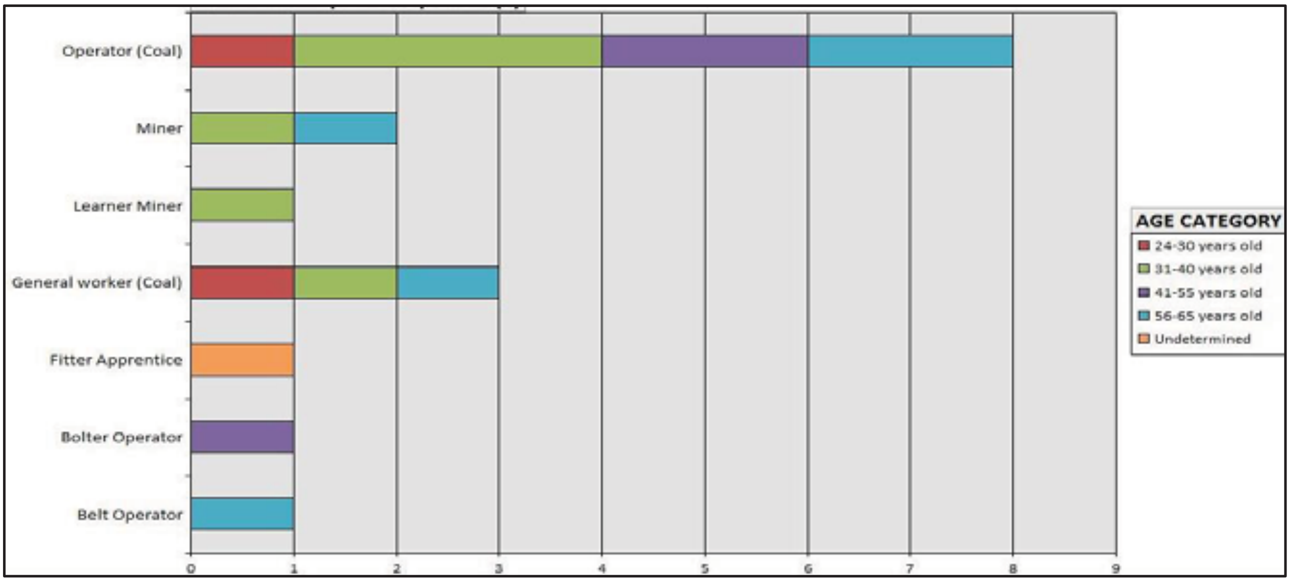

Figure 166: Bar graph showing frequency of participants' occupation and age category in the coal industry

Nationality:

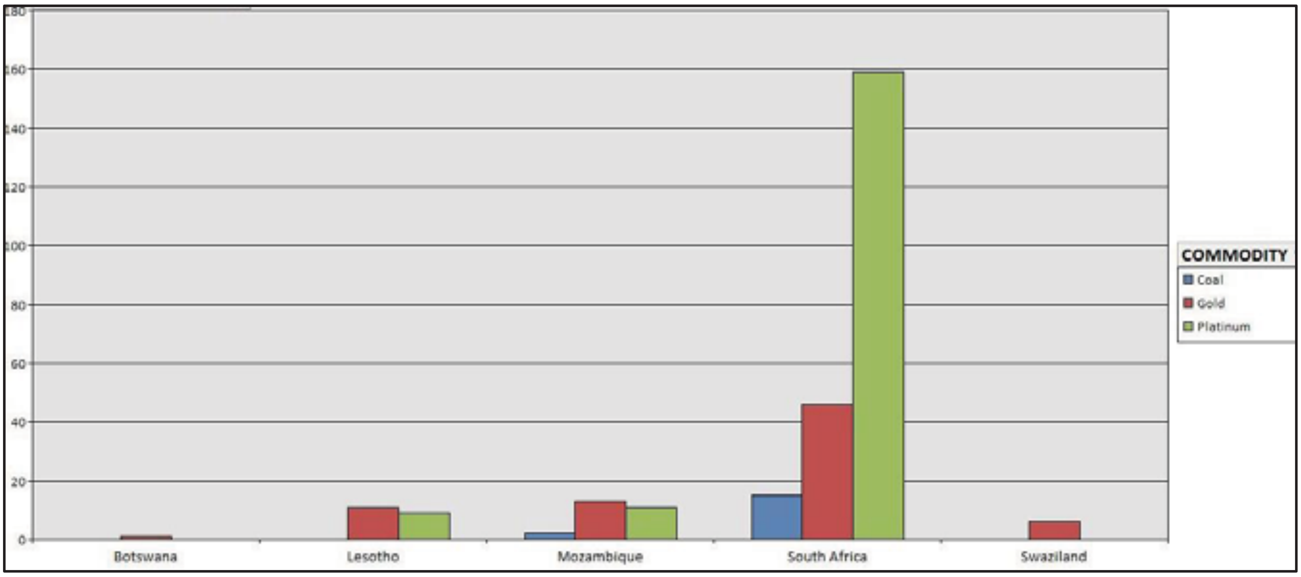

Figure 167: Histogram showing nationality of participants for platinum, gold and coal industry.

First Language:

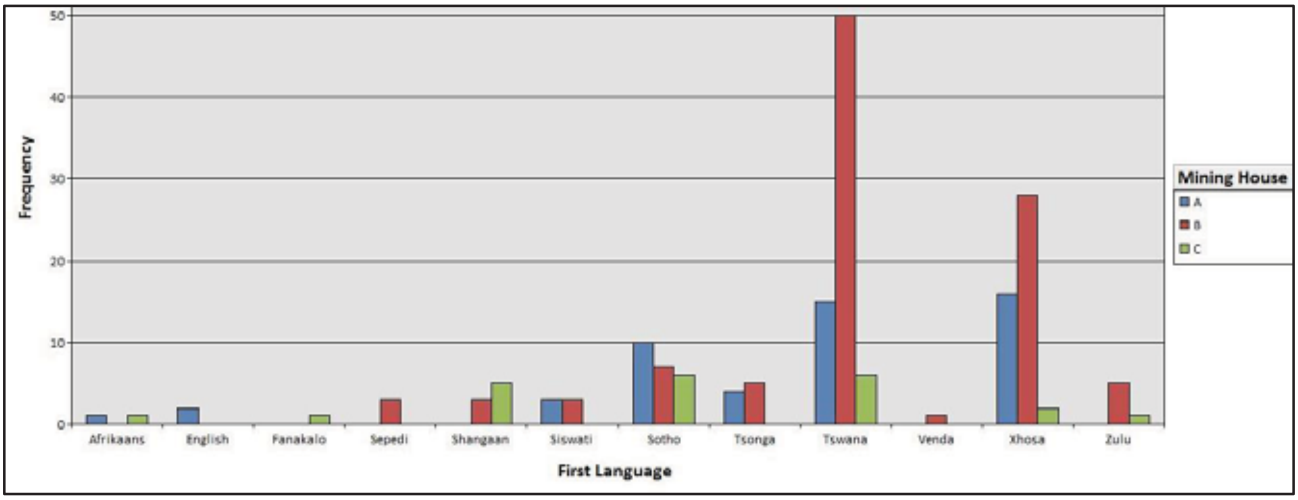

Figure 168: Histogram showing participants first language for the Platinum Industry

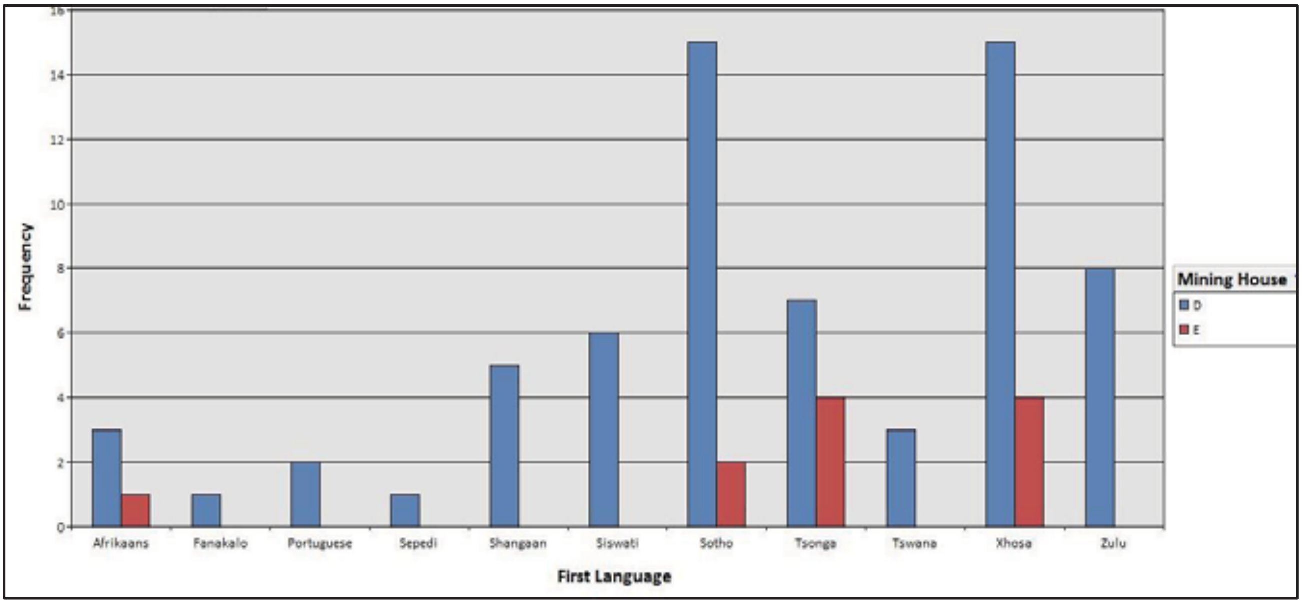

Figure 169: Histogram showing participants first language for the Gold Industry

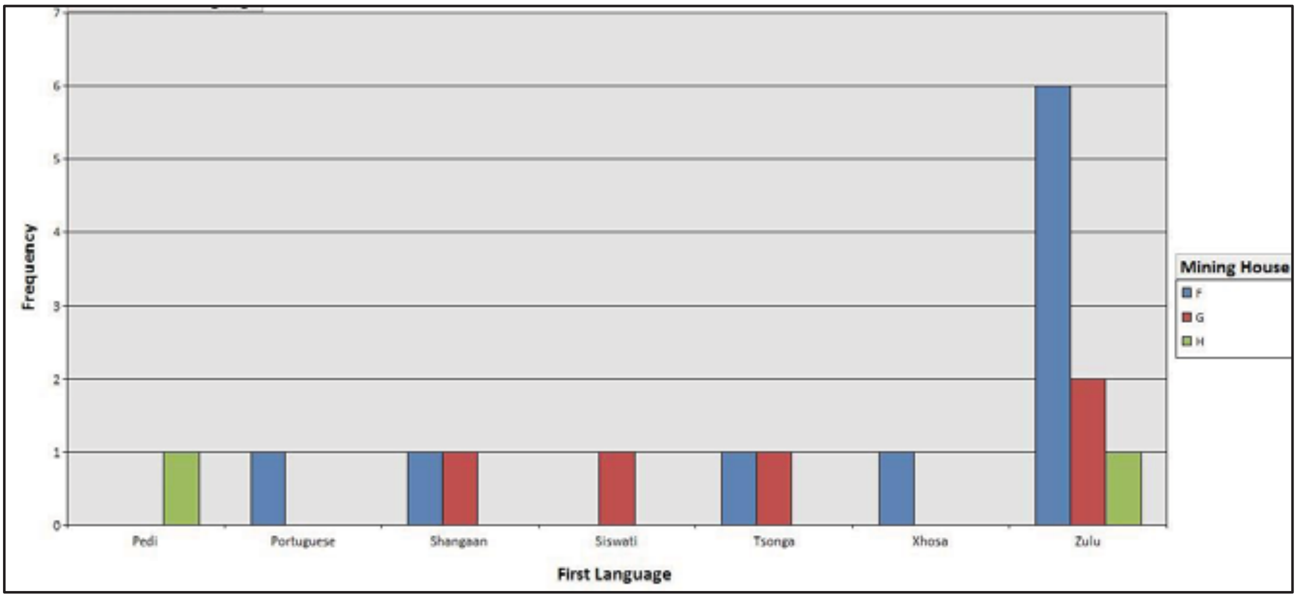

Figure 170: Histogram showing participants first language for the Coal Industry

Years of Mining Experience per Occupation:

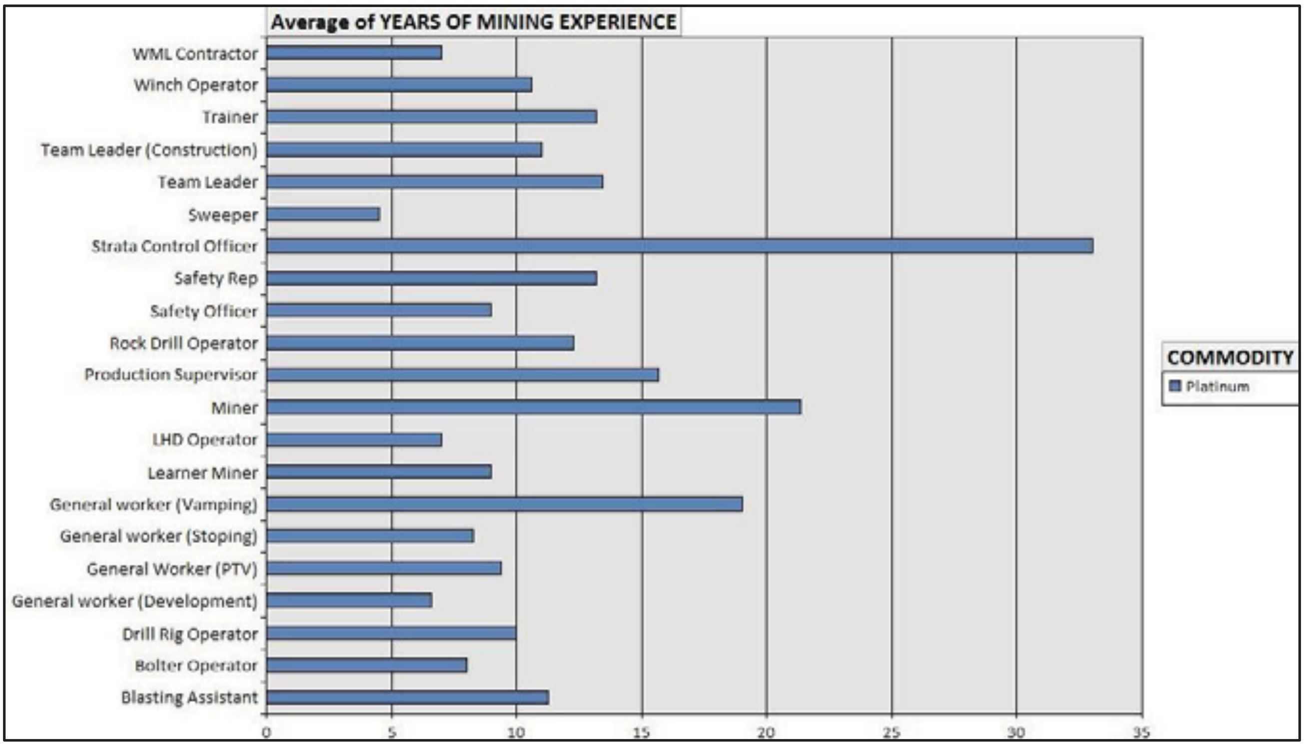

Figure 171: Bar graph showing average number of years of mining experience per occupation for the platinum mines

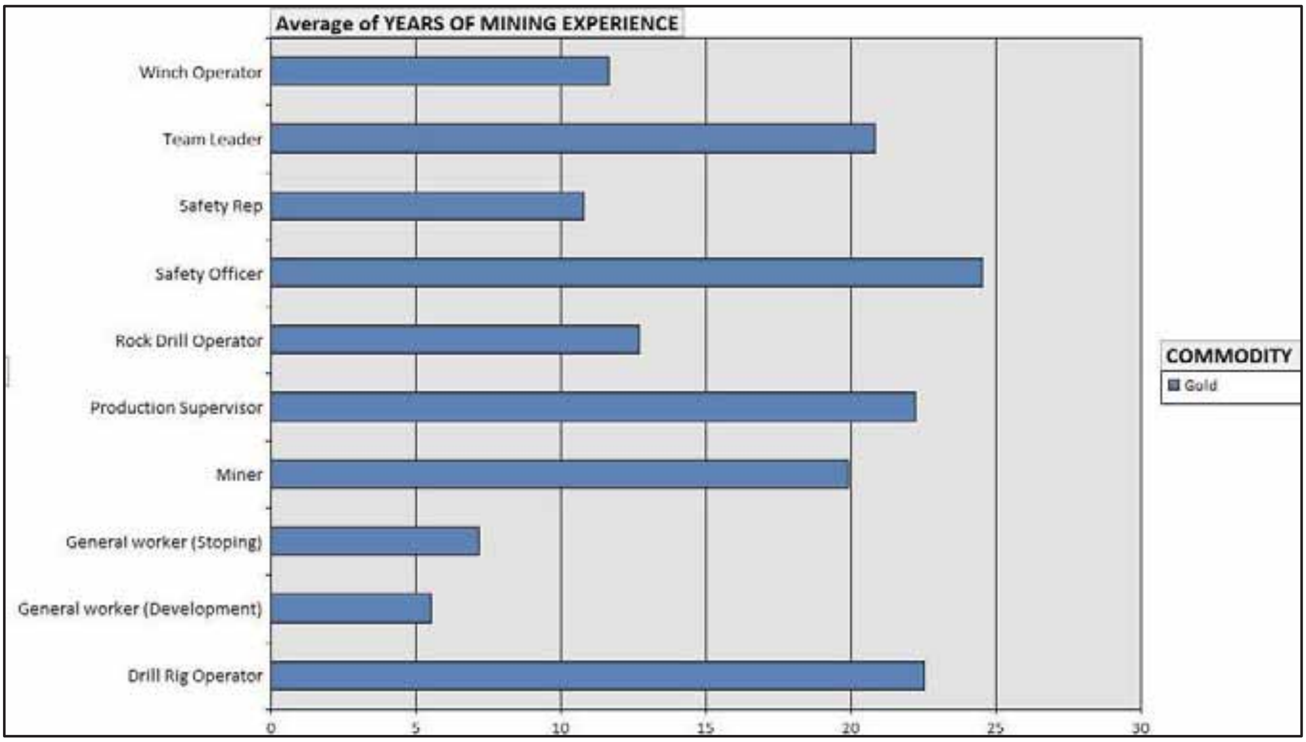

Figure 172: Bar graph showing average number of years of mining experience per occupation for the gold mines

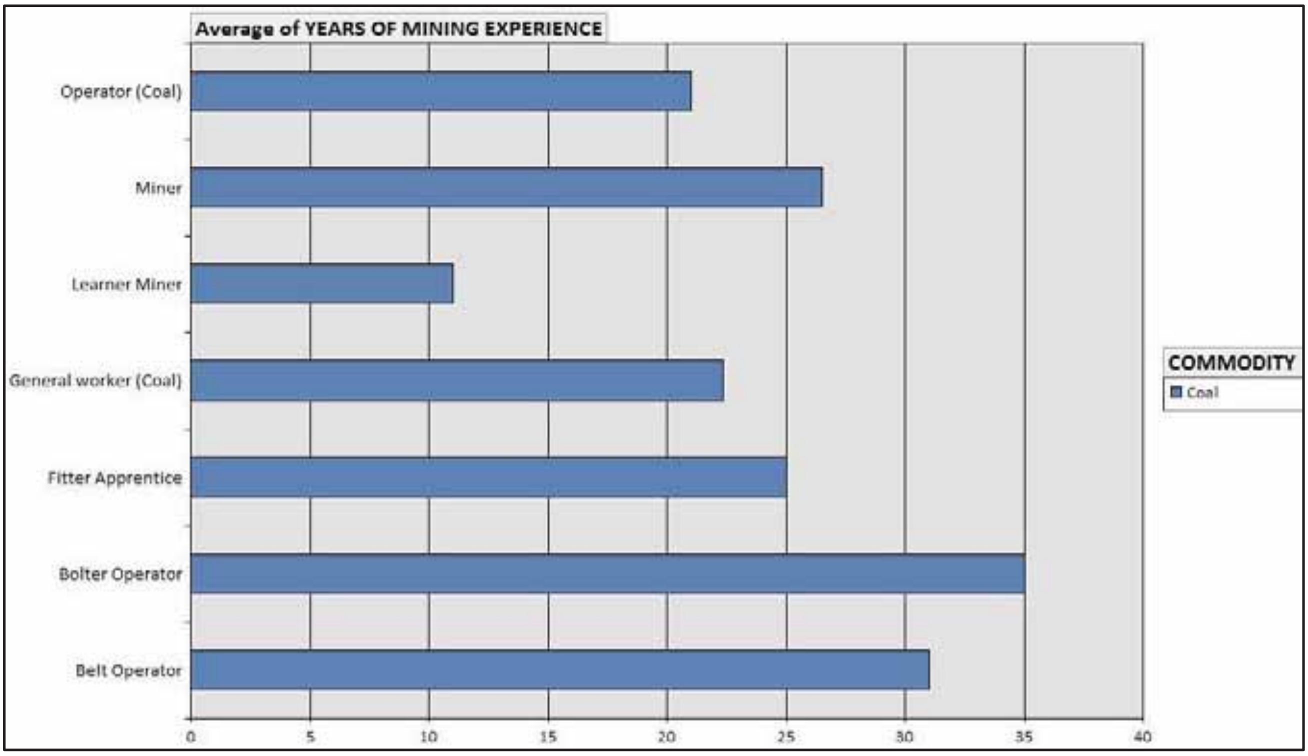

Figure 173: Bar graph showing average number of years of mining experience per occupation for the coal mines

Gender with Age Category:

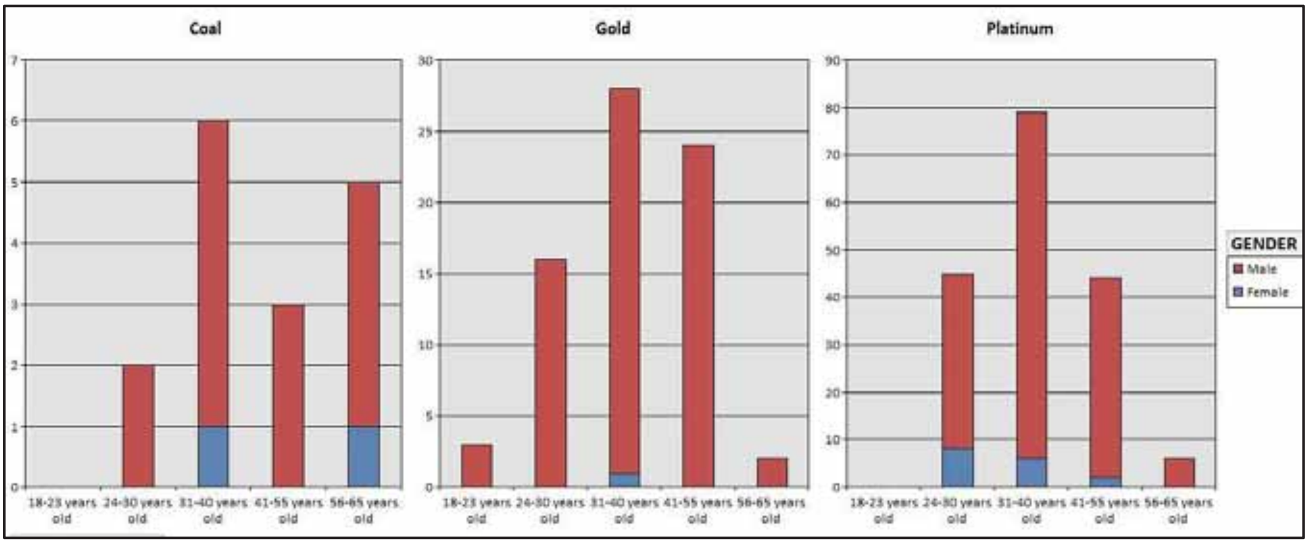

Figure 174: Histogram showing gender of participants and their age category for all commodities considered

19.6.2.1.2 Training Related Questions

General findings from the training related questionnaire data can be summarised as follows:

a. All persons have received training to carry out barring.

b. Most individuals have received training underground and in training facilities on surface.
c. The training duration for barring could not be determined as the responses from this question were not consistent. Barring training appears to be included mostly as sub-sections within other training modules (e.g. Early Entry Examination, Strata Control).
d. The method of training category for the various mining houses based on the questionnaire data is shown in Figure 175, Figure 176 and Figure 177 for the mining houses for the platinum, gold and coal industry respectively.
e. The training method preferred by most are shown in Figure 178, Figure 179 and Figure 180 with the various age categories of the participants.
f. The refresher training is generally carried out on an annual basis or every 6 months.
g. The languages the participants were trained are shown Figure 181, Figure 182 and Figure 183.
h. A total of 53% of the participants indicated that they do not have a choice with the language in which to be trained in and 47% indicated a choice of language.
i. The age of the participants don’t seem to be related to the method preferred.
j. The common languages include English, Tswana, Xhosa and Zulu. Fanakalo is also a dominant “language” used within the mining industry.

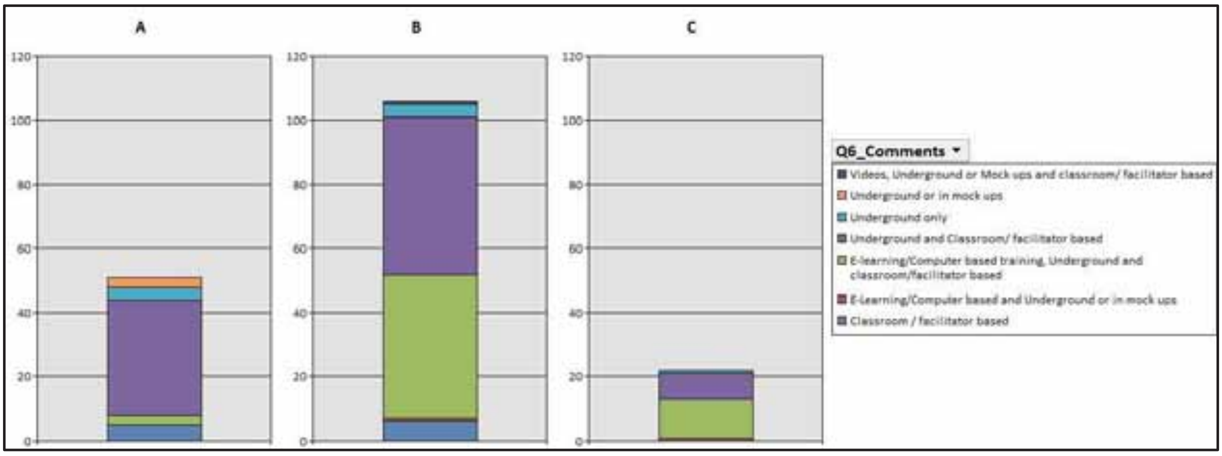

Figure 175: Responses for Question 6: "How was the training done?" for the platinum mines

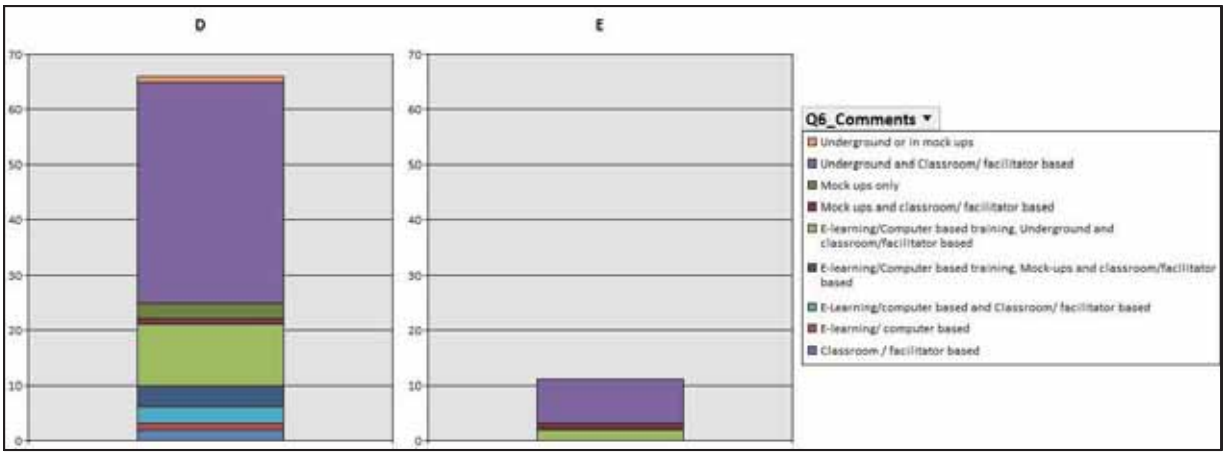

Figure 176: Responses for Question 6: "How was the training done?" for the gold mines

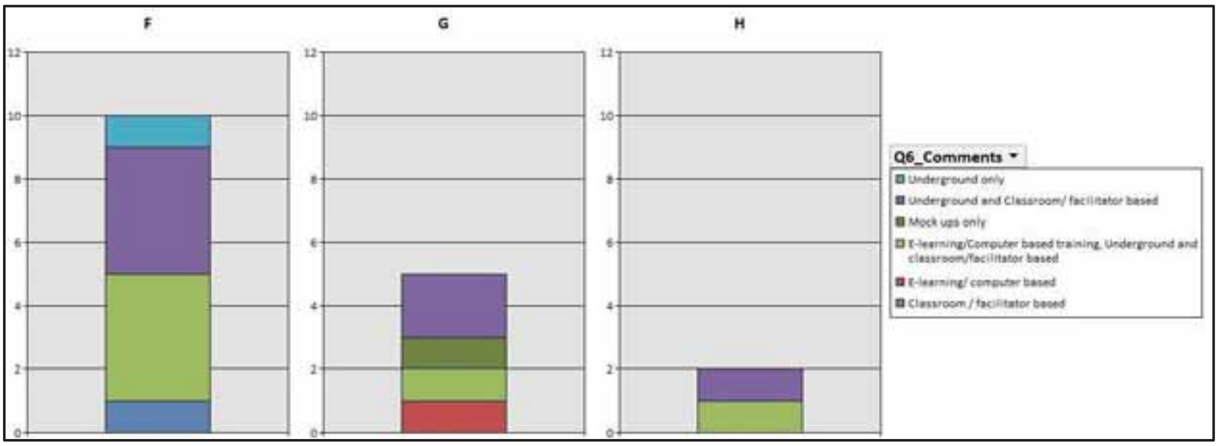

Figure 177: Responses for Question 6: "How was the training done?" for the coal mines

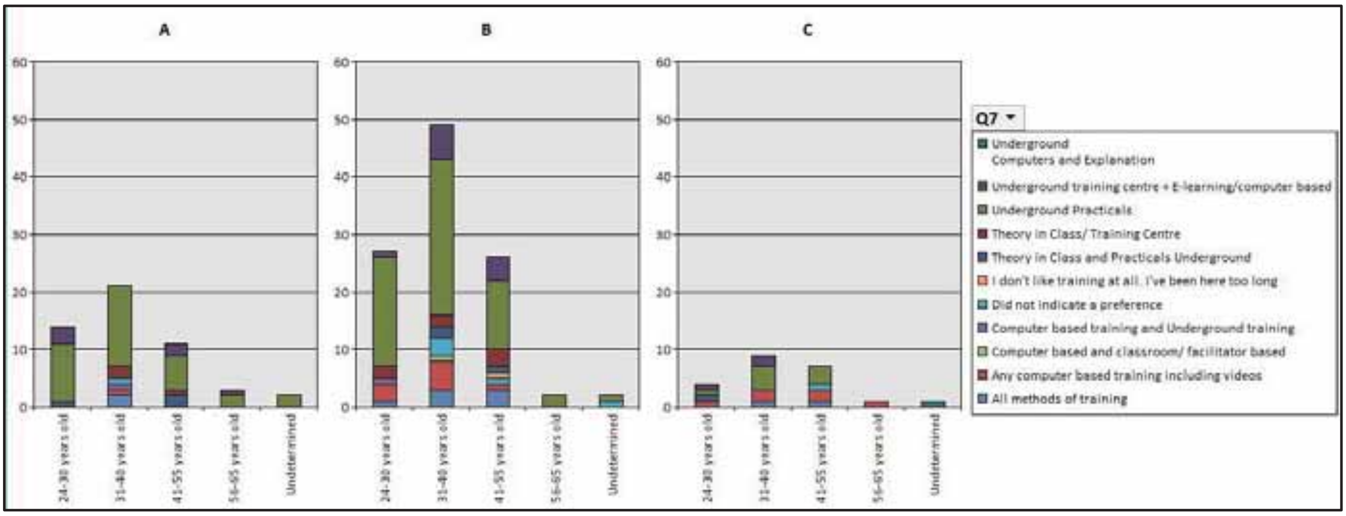

Figure 178: Responses for Question 7: "Which method did you think was best/learn the most from/find useful" for the platinum mines

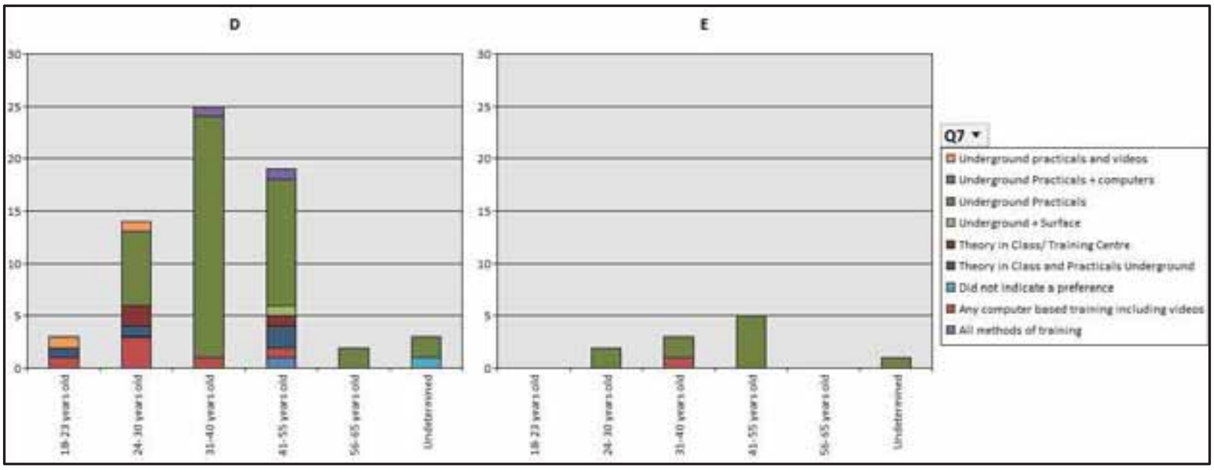

Figure 179: "Which method did you think was best/learn the most from/find useful" for the gold mines

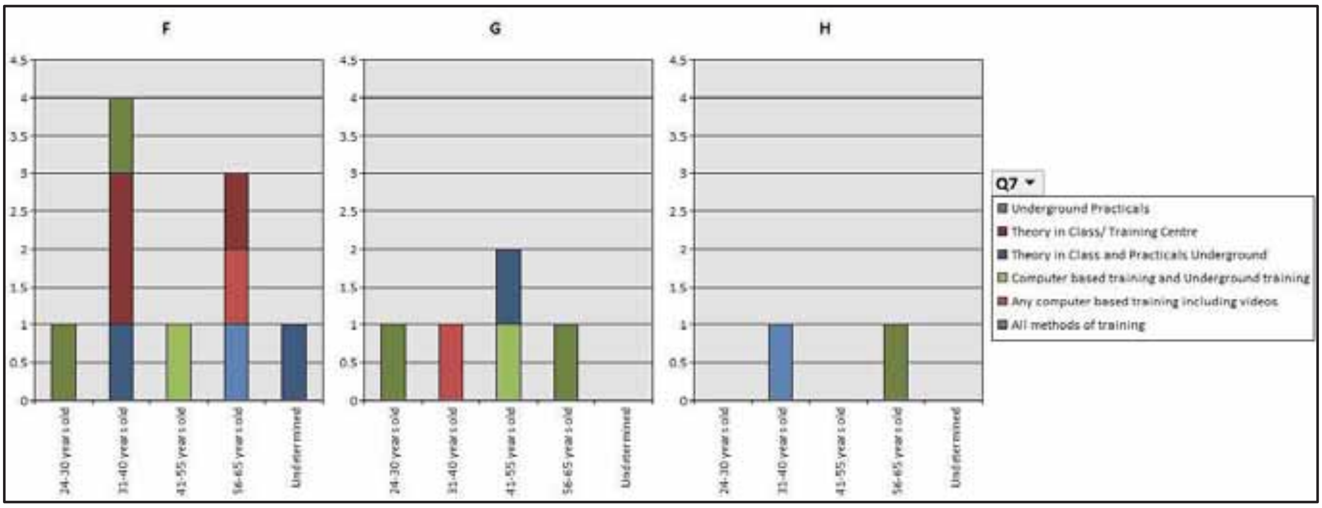

Figure 180: Responses for Question 7: "Which method did you think was best/learn the most from/find useful" for the coal mines

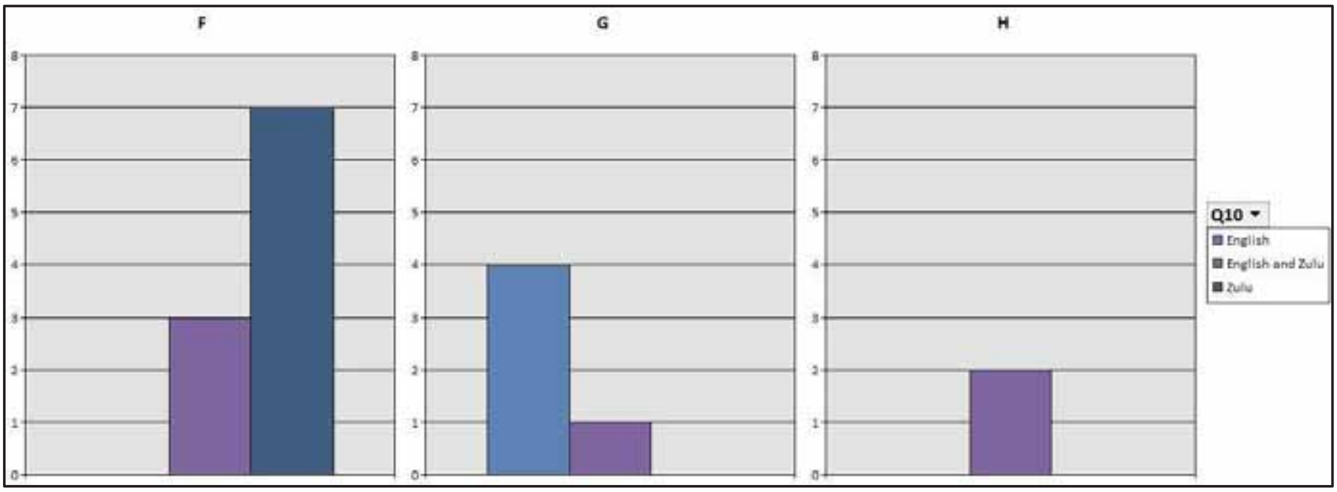

Figure 181: Responses for Question 10: "What language were you trained in?" for the coal mines

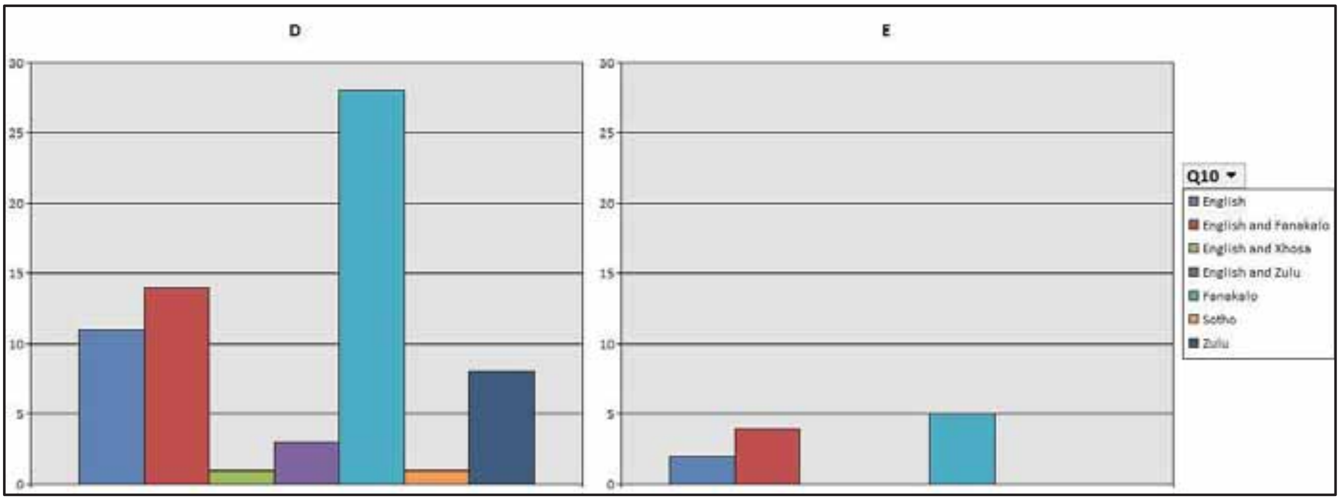

Figure 182: Responses for Question 10: "What language were you trained in?" for the gold mines

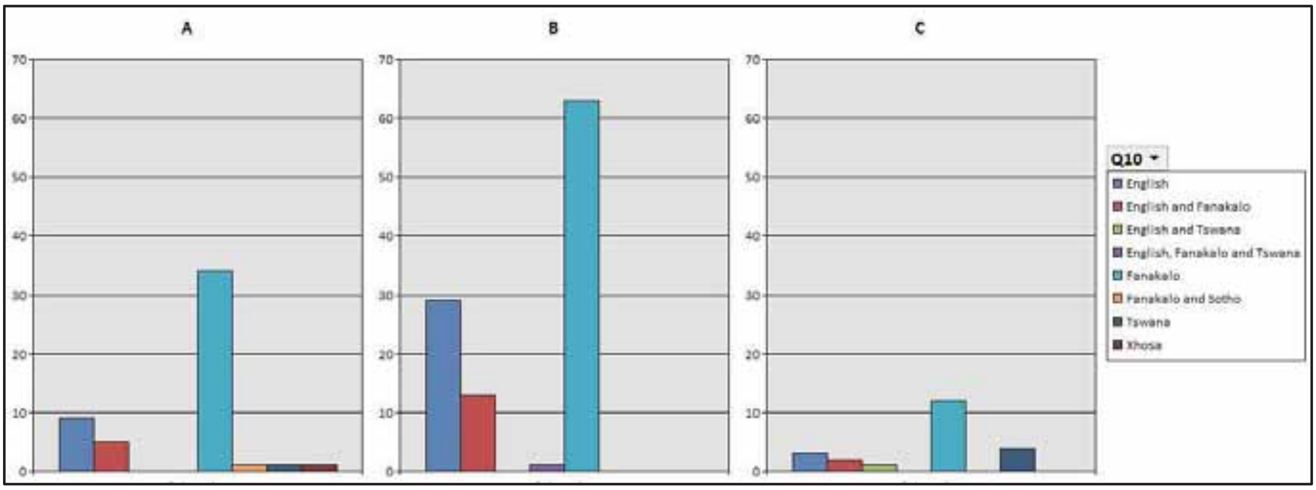

Figure 183: Responses for Question 10: "What language were you trained in?" for the platinum mines

19.6.2.1.3 Barring Competency

Based on the number of questions correctly answered and level of understanding demonstrated by the person being interviewed, a person was considered either "competent" or "not yet competent". In the event of the questionnaire not being completed for various reasons (time constraints, mine worker reluctance, language difficulties), the person's competency could not be assessed and was therefore categorized as "undetermined". The overall competency for the various mine houses are depicted in Figure 184, Figure 185 and Figure 186 for the platinum, gold and coal industry respectively.

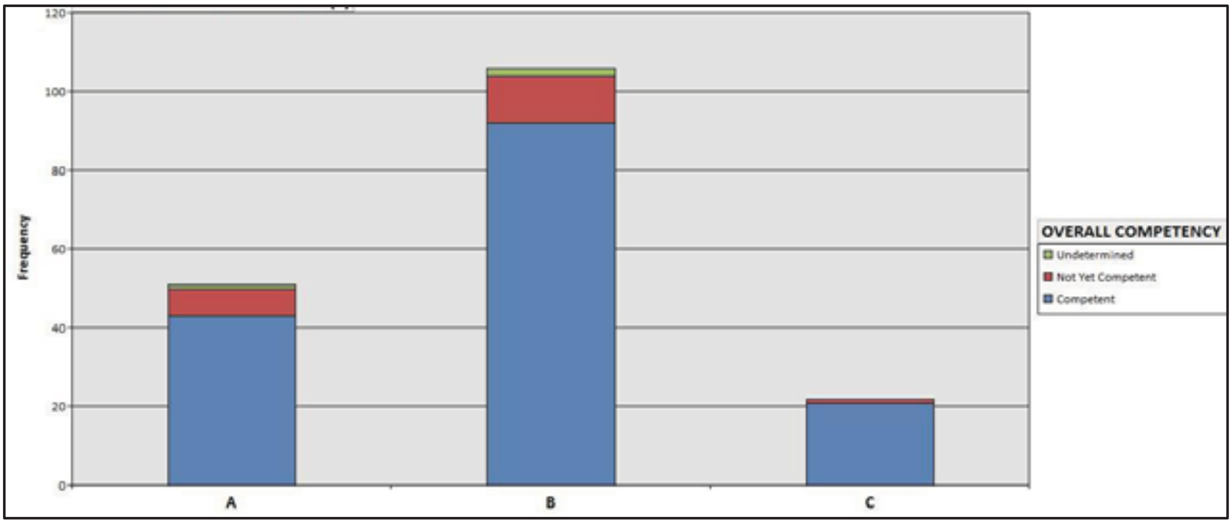

Figure 184: Overall Competency for the Platinum Industry based on questionnaire data.

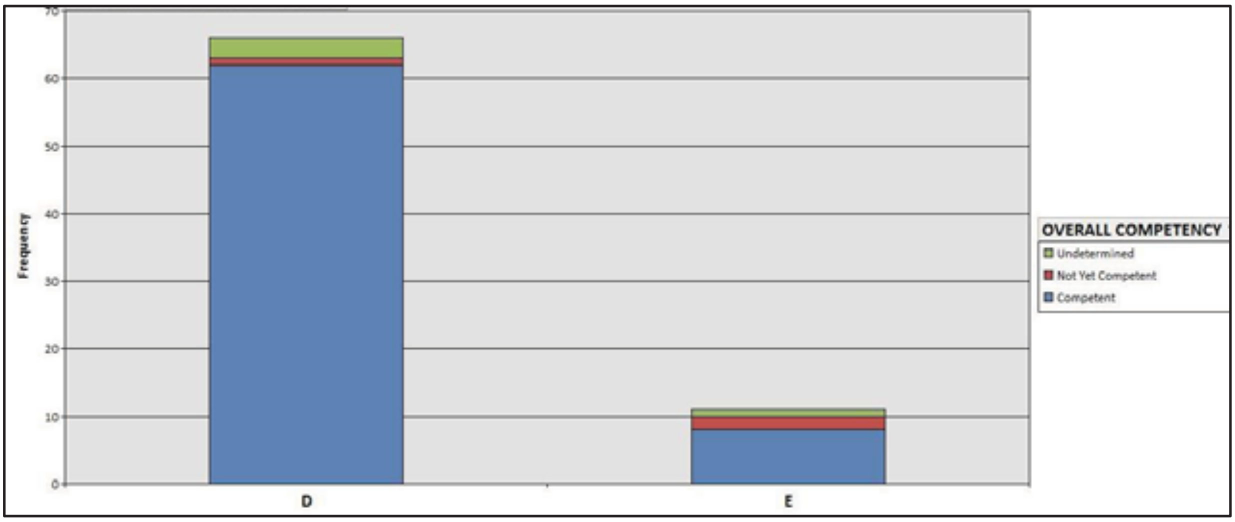

Figure 185: Overall Competency for the Gold Industry based on questionnaire data.

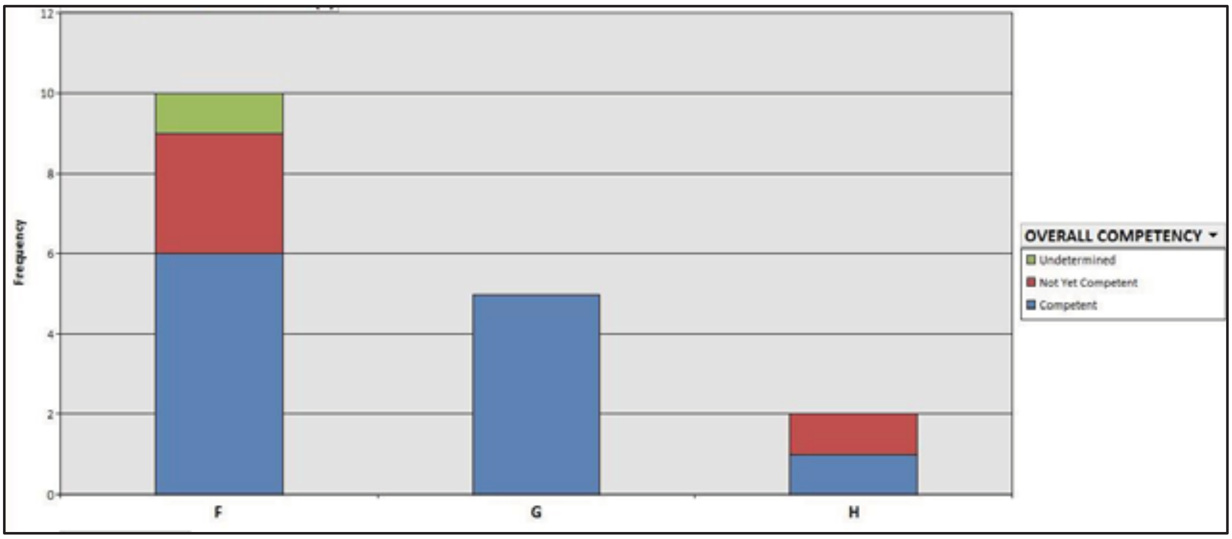

Figure 186: Overall Competency for the Coal Industry based on questionnaire data.

19.6.2.2 Interview Data

The interview data includes both formal and informal interviews held with mining personnel underground and on surface. Some of the feedback received regarding training is as follows:

d) E-learning and other computer based training is a good idea according to most however it can take too long. People tend to fall asleep and cannot concentrate.

e) Those that have not been exposed to any form of e-learning/computer based programs are interested in this training. "The videos help us a lot, it helps us know what`s happening underground".

f) Most people prefer underground practical training with a theoretical component in the classroom. It was found that that having various mnemonics for the rules and the use of visual aids help people remember the rules of barring.

g) People have a different mind-set underground. Complacency has been one of the main concerns for most.

h) Training is important but not everyone takes training seriously. Trainers don't use their allocated training time productively; instead they bombard people with lots of information with the promise of an early finish if allowed by the trainees.

i) Most training materials are not suitable for the training objectives. An example would be poor power point presentations.

j) Communication underground is mostly done in Fanakalo. The uses of other languages are not always promoted.

k) *"Even with training, complacency sets in. Documentary proof is achieved but knowledge cannot be ascertained. It is preferred that people go underground and get physically coached and tested".*

19.6.2.3 Underground Observations

A few of the key points related to barring observations that were made underground that are related to training include the following:

a) People remember the rules of barring when asked but do not always practice them in the sequence in which it should be. E.g. Warning people down-dip while barring as opposed to beforehand.

b) Sometimes the rules of barring are interpreted incorrectly and they are under the impression that this is the standard. E.g. A person entering the unsafe, unsupported area to water down. No sequential watering down from a safe place. Buddy barrers positioning is not always safe.

c) People tend to sometimes install nets rather than bar and on occasion bar through the net. This is a dangerous practice as the hanging wall is not clearly visible and the size of block cannot always be determined and the strength of the net may not always be adequate.
d) Many have amended the “rules” to ensure safer practice at their working places.

19.6.3 Evaluation of the Barring Training Methods and Assessment

A five category rating system was used to evaluate the overall efficacy of barring training at the champion mines. The rating is dependent on the level and number of outcomes training is believed to have achieved. It is based on the observation of barring practices and training practices and general feedback from trainees on the training practices. The five categories are:

O = Outstanding
M = More than Satisfactory
S = Satisfactory
I = Improvement Needed
U = Unsatisfactory

A summary of the evaluation for the overall barring training is provided in Table 38**.** The following general comments were made in respect to the training practices:

a) Barring is physical task and therefore requires a significant practical component. However knowing what, when, and why is key to making a workplace safe. The SAQA standard highlights the need for the person barring to be able to identify hazards and know the consequences however only a limited number of the barring training incorporated understanding of the theoretical components. The knowledge of the rules of barring without any knowledge for the reasoning behind the rules is not sufficient for being competent.
b) Barring rules should be unambiguous to prevent the misinterpretation by mine workers as this could lead to accidents.
c) More emphasis should be placed on the occupational health and safety hazards of the individual related to barring. E.g. Good posture.
d) Behaviour that is unsafe and safe should be included in the theoretical and practical components and re-iterated frequently. Essentially incorporated corrective behaviour techniques in barring training.

e) Transportation of the pinch bar and correct storage isn't always incorporated in the barring training.

f) The training methods employed do not satisfy all the critical cross field outcomes mentioned in the standard. Efforts need to be made to include them.

Table 38: Evaluation Summary for Overall Barring Training

	Mining House	Mine/ Shaft	Barring Practices	Training Approach	Learning Theories	Trainers/ Assessor	Overall Barring Competency	SAQA Specific Outcomes	SAQA Critical Outcomes
PLATINUM	A	1	M	S, I	S, I	S, I	M	S	S, I
		2	S	S, I	S, I	S, I	S	S,I	S, I
		3	S	S, I	S, I	S, I	S	S	S, I
		4	M	S, I	S, I	S, I	M	S	S, I
	B	5	S, I	S	S	S	S	S	S,I
		6	S	S	S	S	S	S	S,I
		7	S	S	S	S	S, I	S	S,I
		8	S,I	S	S	S	S	S	S,I
		9	S,	S	S	S	S	S	S
	C	10	S,I	S	S	S	S	S	S,I
		11	S,I	S	S	S	S	S	S,I
GOLD	D	1	M	S	S	M	S	S	S
		2	S,I	S,I	S	S, I	S	S,I	S,I
		3	S	S,I	S	S, I	S	S,I	S,I
		4	S	S,I	S	S, I	S	S,I	S,I
		5	S	S	S	S, I	S	S,I	S,I
		6	S	S	S	S, I	S	S,I	S,I
		7	S	S	S	S, I	S	S	S
		8	S	S,I	S	S, I	S	S,I	S,I
		9	S	S,I	S	S, I	S	S,I	S,I
		10	S	S,I	S	S, I	S	S,I	S,I
		11	S	S,I	S	S, I	S	S,I	S,I
		12	S	S,I	S	S, I	S	S,I	S,I
		13	S	S,I	S	S, I	S	S,I	S,I
		14	S	S,I	S	S, I	S	S,I	S,I
	E	1	S	S,I	S	S,I	S	S	S,I
		2	S	S,I	S	S,I	S	S	S,I
COAL	F	1	M	M	S	M	M	S	S
		2	M	M	S	M	M	S	S
		3	S	I	I	I	S	S,I	S,I
	G	4	S,I	S	S,I	S	S,I	S	S
		5	S	S	S	S	S	S	S,I
		6	S	S	S	S	S	S	S,I
		7	S,I	S	S,I	S	S,I	S	S,I
	H	8	M	S	M	S	M	S	S
		9	M	S	S	S	M	S	S
	I	10	S	S	S	S	S	S	S

19.6.4 Evaluation of Trainers/Assessor Training

The abilities of trainers to facilitate the learning process are fundamental to the success of training activities. The trainers need to be able to understand the learning process and be adaptable in their approach to training in order to achieve the desired outcomes. According to the feedback from the mine personnel and observations, a large percentage of the trainers appear to be meeting the requirements or achieving the desired outcome with the training. However there are a few trainers that are more effective than most and others that are not. A case study of a training activity with an effective trainer is presented below:

1) *Scenario* - Trainer uses a rock boulder to emphasise the impacts of rock falls by interacting with trainees. He used this activity to remind his students of the underground environments at the risks that they are exposed to daily. Learners were asked to put their hand under the boulder when it was dropped for a monetary reward and all learners refused. He reminded learners of the decision they have made in the classroom and questioned about the decisions people make underground. “Just like a scuba-diver that does not take off his oxygen mask because he knows he is surrounded by water and its potential to harmful him, similarly we should not forget our surrounding underground and how harmful it can to them”.
    a) *Learning Description* - He created a learning experience that incorporated humanistic, cognitive, social, and behavioural learning principles. The learners attention was engaged, they could draw from his/her prior knowledge of the underground environment and socially interacting.

Conversely, another case study whereby a criticism of a trainer`s competence was made. This resulted in the trainee being disengaged throughout the training practice as he believed the trainer was not able to demonstrate the necessary skills he required. He did not see value in the training exercise and as a result the training was ineffective.

These are case studies that explain the impact the trainer has on training practices. It is therefore necessary to ensure that all trainers are competent in the subject matter and that they are adequately trained to effectively train others.

19.6.5 Beneficial Training Initiatives

Beneficial training initiatives that are believed to improve learning and overall competency are described below:

1) *Learner Miner Shadowing:* This has been considered to be a beneficial training method as the learner miner is learning on the job in the environment in which he/she is to operate with the guidance and continual coaching from all team members resulting in knowledge and skills being acquired. This training method makes use of the behaviourist and social/situational learning theories.
2) *Buddy Barring:* The concept of buddy barring reinforces teamwork behaviour, prevents exhaustion of a single barrer, and improves efficiency if done correctly.
3) *Training the Trainer:* Formalised training of the trainer and assessments of assessors are necessary to ensure continuous effective training. Knowledge of the learning principles would allow the trainer to adapt and address the students' needs in order to achieve the outcomes and bring out behavioural changes.
4) *Underground Training Facilities:* Training facilities that incorporate learning with different media and approaches are essential to the learning of individuals. The facilities include, mechanisms that allow for simulations of underground hazardous events, models of machinery, tools etc. to familiarise learners with the job and equipment specifications. These facilities support the training methods that promote understanding, knowledge and skills to carry out specific jobs safely.
5) *E-Learning*: Enabling the trainee to visualise the hazards related to the underground work environments in the safe place has significant benefits. The success of such tools is dependent on the module developed. The interactive barring module is beneficial and it highlights the importance of sounding rocks in those geotechnical environments where visual aids are not adequate. It also allows the trainee to visual the hanging wall conditions and the interaction of the discontinuities that's observed.
6) *Barring Licenses*: This is a good idea as it emphasises the importance of making a workplace safe by barring and gives the learner a feeling of achievement.
7) *Corrective Behaviour Training*: Behavioural components are incorporated in the training if found to be the root cause of accidents.

19.6.6 Conclusions and Recommendations for Training

Training is an expensive undertaking and ineffective training practices are even more so hence the need for continual improvement of training practices. The beneficial training initiatives discussed previously are examples of the industries attempts to increase the efficacy of training.

In addition to these, the following recommendations will improve the training of barring: More emphasis should be placed on understanding the rules of barring so that people are able to apply this knowledge to those special geotechnical conditions where the rules may not apply e.g. safe positioning.

1) Barring training is generally included as a section in the early entry examination training for most mines. It is recommended that it be a stand-alone module as this would emphasise the need for barring skills in making a workplace safe underground and being fundamental to all production activities.
2) Soft skills training should be introduced to miners, team leaders and shift bosses. E.g. Leadership training.
3) It is apparent that not all training efforts used incorporate those learning principles necessary to prevent accidents whose root cause are behavioural based. The design of training methods that incorporate the neuroscience of learning with existing learning principles would be a feasible approach for the future to bring about change in human behaviour. Considering the diversity of people (race, gender, culture, attitudes, perceptions, habits, behaviour) within the mining industry, it is recommended that brain-based design principles be applied to the development of training methods. This is likely to be more effective in addressing behavioural concerns and will improve the safety culture.
4) Training the Trainer initiatives - Learning theories need to be included in the training the trainer's curriculum in order for the trainers to effectively adapt to the various individuals' personalities, learning styles, preferences and attitudes of people present in their classrooms. Learning theories have not been formally included in the training materials. Regular assessments of the trainers are also recommended.
5) Companies should strive to be proactive with their training approaches rather than reactive, so that incidents related to poor/inadequate/ineffective training practices can be omitted. Virtual Reality Training has unlimited potential. The vast technological resources available today will allow for these training methods to become more cost effective and efficient.
6) Optional Languages for training should be included considering the diversity of the mining environment.

The development of the training modules has attempted to incorporate these learning theories and address the barring shortcomings identified during this study. The “5P`s” approach to safe barring aims to improve the efficacy of barring training.

20 Identification of Leading Practices

Whilst a few of the following suggestions may already be included in the current FOG leading practice (LP) under the existing entry examination and making safe practice, they are listed below for a complete overview of actions that would lead to the improvement of the safety and health of individuals performing the barring act.

The best practices are classified as per the key identified areas specified for the study. These are risk assessment, skills, training, equipment selection, geotechnical environment, size of excavation > 2m high, size of excavation < 2m high, leadership, human behaviour and communication. Attempts were made to find leading practices that would enhance each key area. This approach led to some overlap between findings as leading practices by their nature; include the correct leadership behaviours and communication that enables the successful outcome of these practices.

Whilst the leading practices are broadly collated for the ten key identified areas specified for the act of barring, there are some exceptions to this approach which has resulted in the inclusion of sub-headings such as the act of barring and teamwork. These are deemed key to the safe act of barring.

20.1.1 The action of barring

The physical process of barring follows a standard procedure which has common steps and sequencing across all the champion mines. Some procedures are short and concise whilst others are lengthy and detailed with the shorter more concise steps being favoured. It is easier to recall five steps versus nine, ten, eleven or thirteen.

The barring act has been summarised by the 5P’s to safe barring. The 5P’s is suggested as a leading practice as it has the vital inclusions of key steps, is concise and has only five steps to remember. These steps are:

- Preparation of the employee by ensuring that the correct PPE is worn and the correct equipment is available for barring in your area.
- Preparing the area by watering down, if necessary and ensuring a clear escape route.

- Preparing others by ensuring they are standing in a safe position and by having buddies present to assist with barring.
- Positioning on the safe or up dip side and maintaining a firm footing.
- Proceeding to bar from a supported area to an unsupported area, sounding the hangingwall or roof and barring loose ground.

20.1.2 Risk Assessment

The introduction of the MOSH TARP leading practice has led to the creation of structured and customised processes at each of the champion mines. In attempts to personalise these systems, various names abound such as ALLeRT, ABS-P/ HITS and SLAM which all stem from the TARP leading practice. The outcome of usage of the various systems is the same, with hazard identification and treatment of these hazards being optimised by referring the action decision to a specific team designated to address the particular level of risk posed by the hazard in question. Barring is the first step in the elimination of FOG accidents, and thus the hazard identification and risk assessment process is the integral first step in properly making the area safe.

Currently in the MOSH EE leading practice process, teams discuss the hazards identified, decide on corrective actions and sign-off on the HIRA and declaration form which essentially serves as documentary proof that the working place was examined and found to be safe by the competent person. In the study group, Mine 6 of Mining House B (platinum) showed the strongest adherence to the practice of the MOSH EE process. This was consistently observed by three Golder engineers over the period of a week and by visiting various development ends and stoping panels across three shafts. Analysis of the social themes dominant at the mining house B may show mental models that appear non- conducive to the practice of the MOSH EE procedure. Note however that Mine/ Shaft 6 of the group has vastly different leadership practices to the dominant leadership practices at the rest of the shafts for this mining house. Only the dominant perceptions are given by the social study. There may be existing mental models of isolated sets of individuals and crews at this mine that would act as barriers to successful adoption but the case for Mine/ Shaft 6 of Mining House B being a source mine for the MOSH EE leading practice is strong.

i. Illumination of working environments to enable better hazard identification was identified as a leading practice. Mine 5 of Mining House B was the first source of the identification of the use of portable entry examination lights. These lighting units contained multiple LED bulbs and illuminated a wide arc of approximately 6m of the mining excavation (mechanised bord and pillar environment -Figure 187). Workers, including the visitors observing barring immediately identified loose blocks in the hanging wall by visual examination alone. Whilst this action is still achievable with the use of a cap lamp, the speed with which all hazards could be identified with the 'EE light - Figure 188 mean that the time taken to complete barring can be optimised.

Figure 187: Example of extent of illumination with the use of the EE light (No flash was used on portable camera)

Figure 188: EE LED light

Some logistical difficulties include the weight of the unit which whilst still portable, would be a challenge to shorter and physically weaker individuals. Charging of the units diligently would also ensure that units are always ready for usage. This was found to be a behaviour not practiced at one of the sites visited. Mental models at the mine would not be the ideal expert models to model the practice upon; as only two LED units were observed, one of which was utilised successfully and the other had been almost discarded due to lack of supervisor encouragement of its usage. These attitudes prevented widespread adoption of this practice at the mine itself.

Further, to emphasise the benefits of improved illumination, in-stope lighting was observed at Mining House B's underground training facility in central gullies and this again promoted visual examination during barring.

20.1.3 Skills

The development of higher levels of skills, knowledge and understanding at work is only completed if one engages with a substantive knowledge base either prior to starting work, while working, through career development activities away from work or through a combination of all three ways.

The barring skill takes into consideration the innate ability of an individual to perform the task and the time spent performing the task leading to the improved practice of the said task. Mine 5 of Mining House G (Coal) showed the promotion of the development of the skill by the issuing of a ‘barring license’ when an individual is found competent at the practice of the barring act in the underground environment. This license is renewed yearly and the time gap between refreshers can be as little as 6 months (if required). This novel way of declaring competency could be a leading practice related to training as well. Ultimately the skill displayed by individuals possessing the barring licenses (all competent B employees) was demonstrated during a week of underground visits to the four shafts visited at mining house G. Barring licenses may be described as a laminated card similar to the South African driver’s license. It displays an employee’s picture and basic company details as well as the period of validity for the barring license.

20.1.4 Training

The underground training facility utilised for mining house B is all-representative of the most ideal standards and practices required for safe mining in the underground environment. Crews at the training centre work as a unit to practice and complete the MOSH EE procedure. Ideal leadership behaviour is exhibited in this environment and trainees are exposed to the beneficial learning environment where they become active in the training process (experiential learning). The trainees bar in a real situation and retention of the correct procedure is promoted by repetition. It is suggested that two to four weeks at this underground facility would be sufficient time to entrench knowledge and understanding of the process.

Whilst not directly relevant for barring itself, the environment fosters team spirit when personnel test for gases whilst counting in unison out loud (Figure 189). This impacted researchers as well as it emphasised how much time should be spent on the activity.

Figure 189: Testing for gases whilst training

- The value of realistic mock mines on surface is incomparable for new employees who have never been underground before and this practice is suggested as a leading practice as viewed at Mining House B. Barring was practiced in this safe environment (Figure 190) with a trainer who immediately assessed the individual and highlighted when the barring standard was not being adhered to. This meant that the practice of the correct procedure was instilled in a positive manner allowing the correct behaviours to develop in the trainee.

Figure 190: Realistic stoping environment at a mock mine

- As mentioned previously, training the trainer initiatives would be a leading practice for barring. Whilst a champion mine could not be sourced for this practice, it is still a feasible practice worth exploring. Whilst there are trainers who succeed in impacting individuals in classrooms with their passionate approaches (training centre at Mining House A), there are many others who fail to transfer the required knowledge about the importance of barring to the workforce. For every passionate trainer and facilitator that the researchers encountered, they were easily outnumbered three to one by individuals exhibiting poor leadership behaviour and equally dismal communication skills (Mining House A). Personal prejudices and opinions were conveyed to trainees who were thus influenced. It is for these reasons that it is suggested that instilling soft skills in all training personnel would be beneficial to barring and strata control training, if not all training initiatives across the mines.

- Visual computer based training methods are already extensively utilised throughout the South African mining industry in various e-learning formats and computer based assessments for a multitude of topics, the most common being hazard identification, entry examination and operator training. As some degree of interaction with the end user is required, these systems may be termed ‘desktop virtual reality’. According to Van Wyk and Prinsloo (2015), desktop VR systems are the most popular type of VR system where users interact with the computer screen without being fully immersed in the computer generated environment. With the lower capital cost of hardware, software and peripherals, these systems are an attractive and realistic alternative for training for most mines. A product specific to barring has been developed as part of this project and this is a leading practice training initiative (5 P's). Barring training in this manner would lead to voluntary adoption of the user of specified subsets of leading practices for barring such as buddy barring and positive leadership behaviours. Whilst the nine champion mining houses will all receive the product, Mining House B (platinum) and Mining House F (coal) are suggested as initial pilots as they already utilise computer based training tools successfully. Mining House D (gold) is suggested for the pilot but they do not currently employ any computer based training methods. More traditional classroom environments with facilitators are preferred. As this mining house is currently a part of the Community of practice for adoption (COPA) of MOSH Entry examination, it follows that the barring training program must undergo adoption at this mining house.

- Virtual Reality (VR) immersive techniques are quickly gaining popularity as they have applicability in safety training, competency assessment and education by enabling immersive experiences for users. The use of immersive techniques is a less feasible leading practice for barring training for most mines due to the cost implications thereof. However, for those mines who would like to explore the advantages of these techniques, head-mounted displays could be purchased for use. These displays such as the Oculus Rift, Sony Morpheus and the Samsung Gear VR are all becoming more feasible for usage as costs of these units are decreasing as the technology advances. For example the Samsung Gear (Figure 191) utilises the user's Samsung smartphone as the display device which is mounted in the unit which costs approximately 99$. This unit is formulated with Oculus that is the trendsetter in the field. The Oculus Rift most popular original unit has a 100° field of view which Facebook has recently invested $2 billion into R&D. Any of the champion mines could be used as a source mine for the use of semi-immersive and immersive VR techniques if these units are feasible to purchase. Affordability of the headsets would be the greatest influencing factor to the adoption of these innovative training techniques.

Figure 191: Affordable Samsung Gear VR units

- Semi-immersive systems are when computer-generated images are displayed on large screens by a stereo projection system and are viewed by special stereo-eyewear (Van Wyk & Prinsloo, 2015). The newly established Kumba Virtual Reality Centre at the University of Pretoria provides this semi-immersive experience and is destined to change the face of education in mining. Facilities such as these can potentially provide training value for mine employees in a unique manner. Interactive barring exercises in the ‘cylinder’ are an interesting idea that would be easily achieved by early adopters of this future training method.

20.1.5 Equipment

- The best and most effective use of PPE was observed at the underground training facility at Mining House B. All employees display the correct attitudes and behaviours with regards to PPE usage. Whole body protection in the form of overalls, head protection in the form of hard hats, feet and shin protection in the form of gumboots, cap lamps, hearing protection devices, eye protection in the form of goggles and finger and hand protection in the form of gloves are continuously worn whilst underground. The use of eye protection and hand protection is frequently not observed in production situations where they should be required. It was encouraging to observe the eager adoption of the use of the full set of PPE at the training centre.

- The most effective equipment for manual barring is:
    a. Steel and Hollow/ Composite Steel Pinch bars – this is the traditional tool which has been used since barring was deemed necessary in mining excavations. The hollow steel tube pinch bars were developed to decrease the mass of the bar so it becomes easier to work with. The hollow tube bends easily at the ends, so there are advantages and disadvantages to its usage. The traditional solid steel pinch bar remains the sturdiest tool for the manual barring task but these are the heaviest work with over long periods of time. Pinch bars are also sometimes fashioned from old drill steels at mine sites and maintenance of the sharp ends is done on-site.
    b. Fibreglass Pinch bars – Longer 3m pinch bars are sometimes made of fibreglass. This is done in an attempt to make the bar lighter, but also sturdier than the aluminium versions. Fibreglass pinch bars longer than 3m in length have also been observed in use at some of the coal champion mines.
    c. Aluminium Pinch Bars – Longer 3m aluminium bars are commonly used in hard rock development environments. The aluminium assists in reducing the weight of the bar but these bars are known to also bend and deform easily.
    d. Wooden Sounding Sticks and Combination Fibreglass Pinch Bar and Sounding Sticks (Coal)
- The most effective equipment for mechanical barring:
    a. Pneumatic pinch bars
    b. Scalers (An example is shown by Figure 192 and the scaler point is shown Figure 193)

Figure 192: Fermel Scalers (Mining House I)

Figure 193: Mechanical Scaler Point

- Pinch bar exchange programmes were not observed at any of the champion mines visited. This is definitely an initiative that has been undertaken at certain mines previously. The benefit of having such campaigns include ensuring that more pinch bars that are in good condition are available at working places for use. By continually replenishing stores with equipment that is in good condition, the time spent barring may be reduced by having pinch bars that are in good condition. It is recalled that a particular mine even rewarded crews who were successful at exchanges. For example, the store attendant keeps track of numbers of old pinch bars returned on surface and a monthly or quarterly award could be given.

20.1.6 Leadership

What separates successful leaders from unsuccessful ones is their mental models or meaning structures, not their knowledge, information, training, or experience per se. Thus the development of leaders should focus on acquisition of new mental models, models that offer more valid and useful ways for effectively dealing with the complex challenges of leadership. With respect to leadership to improve the act of barring the following leading practices were observed:

- Leadership visibility is a leading practice identified at various champion mines (Shaft 3 at Mining House A and Mining House D. The specific directives include the requirement of production supervisors to complete early shifts during one day of the week which allows greater leadership presence to be felt by the workforce. This is often called Visible Felt Leadership (VFL) and promotes compliance to standards. Whilst the effects may be short term, continued interaction of underground employees with their leaders demonstrating positive leadership behaviours can lead to individuals emulating this behaviour in the long term.
- Management and leadership training where the development of soft skills is the focus would be a leading practice that contributes to the successful execution of all safety initiatives inclusive of barring. Specific failings include an inability to empathise with employees, a non-awareness of body language and tone when communicating and not being able to give constructive criticism. Other skills a successful manager or leader should display include:
    - Good communication skills
    - The ability to listen
    - Delegation ability
    - Being able to manage discipline and knowing how to deal with conflict, and
    - Being able to motivate fellow employees which are a critical component of running an accomplished team.

Eventually, focusing and improving leadership behaviours would lead to the improvement of attitudes and behaviours of the workforce as well. Currently, only some champion mines focus on training initiatives to improve the ‘soft’ skills of employees and this is often limited to personnel in senior roles. Underground employees especially miners and team leaders would benefit even more so from such courses if they are considered. A substantive knowledge base must be consulted i.e. training with experts to enable such skills to entrench themselves and influence leadership behaviour of the individual.

20.1.7 Human Behaviour

Leaders were commonly observed to be verbally communicating the mines health and safety procedures whilst demonstrating behaviour to the contrary, (i.e. the "Do as I say and not as I do" approach).

This ambiguous leadership behaviour (LB) has contributed to the increase in unsafe practices that compromises the health and safety of individuals. The identification of this poor leadership behaviour and subsequent implementation of "leading by example" initiatives will promote a culture change that is indicative of the mine's values and safety culture. Examples of such culture change initiatives include:

- Mind-set change at Mining House E (Gold): Promotes mind-set change with use of visual aids and verbal mottos amongst the underground mining workforce.
- Culture-change at Wessels Mine in Northern Cape (Cronje and Rajan, 2015): This involves coaching and modelling of expected leadership behaviours to all levels of leadership and a low tolerance for unsafe practices. "It was expected at all levels that leaders should intervene, engage and correct at risk behaviours and conditions on the spot, even if this meant interruption to production."

It is vital that leadership drives these initiatives and also drives the ownership of the barring activity to ensure that the FOG hazard is reduced. Ultimately, the entrenchment on a safety culture is reliant on focus being placed equally on people, environment and behaviour factors (Figure 194).

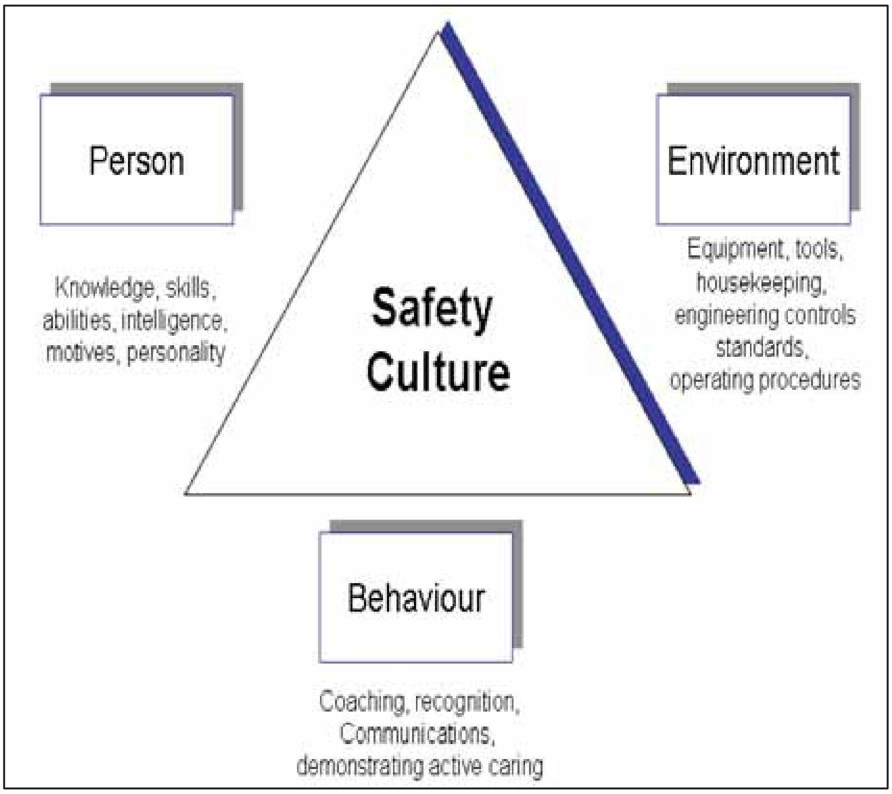

Figure 194: Elements required in establishing a safety culture (Geller, 2001)

- Behaviour based safety (BBS) programs are suggested as leading practices that will try to get people to act differently thus leading them to think differently. This program may be termed a systematic approach to reduce risky behaviours and prevent accidents. Behaviour is changed first in order to change attitude. BBS is currently used extensively in many companies and industries worldwide.

    - In the study group of champion mines, no single mine could be identified as a source for this training despite numerous attempts at Mining House D. Shaft 12 at the mining house invited researchers to observe their BBS training on the MOSH EE process. Poor execution was witnessed as the training did not adhere to key BBS principles (as specified by Geller, 2005):

    - Focus interventions on specific, observable behaviours.
    - Look for external factors to understand and improve behaviour.
    - Use signals to direct behaviours, and use consequences to motivate workers.
    - Focus on positive consequences (not punishment) to motivate behaviour.

- Use a science-based approach to test and improve BBS interventions.
- Don’t let scientific theory limit the possibilities for improving BBS initiatives.
- Design interventions while considering the feelings and attitudes of workers within the organization.

BBS training by Mining House D was carried out with crews re-enacting the sequence of the MOSH EE process at a surface mock mine. The mock-up was completely exposed to full sunlight and was unconfined so the lack of a hanging wall above trainees made the environment quite unrealistic. Behaviours were not individually assessed and the process was rushed through thereby not succeeding in changing behaviour of employees at all. For BBS training for barring to ensue as a leading practice, the correct behavioural communication and leadership behaviour must be identified for the expert mental model. At this stage, reference to the training suggestions indicate that the surface mock ups for Mining House B would be a source mine for BBS training on barring. Though not termed BBS itself, the trainers at this facility already adhere to the principles found in the successful application of BBS training initiatives.

- Mine/ Shaft 7 at Mining House D have a behaviour based correction system executed by individuals at their Safety department. The Safety department begins with a full investigation of accidents and where the root cause is behaviour related, and attempt is made to do corrective behavioural training. It covers a wide range of aspects such as counselling, positive reinforcement and training. Sometimes the cause of an individual’s poor behaviour may be personal issues and/ or their attitude and the safety department attempts to empathise, understand and help the person.

20.1.8 Teamwork and team communication

Buddy barring is a leading practice that typically involves planning the barring process with others, observing and stopping a buddy from barring if a hazard is seen. The buddy also assists with barring approximately every five minutes to minimise fatigue. This act fosters good communication, teamwork and empathy between peers and promotes camaraderie as mutual trust is developed. Mining House B and D had good examples of the expert mental models that would promote the adoption of this leading practice.

20.2 SUGGESTED FEASIBLE IMPLEMENTATION SOLUTIONS

The feasible implementation solutions are classified as per the key identified areas specified for the study. These are risk assessment, skills, training, equipment selection, geotechnical environment, size of excavation > 2m high, size of excavation < 2m high, leadership, human behaviour and communication.

These solutions are suggested following the findings of the various input studies for the research including social findings, underground observations and root cause analyses. It is tabulated for use as a quick reference guide. Notably, some leading practices and best practices have been excluded as they may not be feasible for all environments or due to general impracticality.

The feasible implementation solutions for the ten key identified areas are listed in the table below (Table 39):

Table 39: Feasible implementation solutions for the ten key identified areas

Risk Assessment	Skills	Training	Equipment Selection	Geotechnical Environment	Size of excavation > 2m high	Size of excavation < 2m high	Leadership	Human Behaviour	Communication
Adoption of the MOSH Entry Examination initiative	The introduction of barring licences	Underground training facilities	Combination pinch bars and Sounding sticks at collieries	Adoption of the MOSH Blasting initiative to minimise damage to the hangingwall in hard rock mines	Mechanical Barring equipment: Scalers	Telescopic pinch bars and shorter 1m long pinch bars	Increase in leadership visibility/ VFL underground/ Active supervision	Culture change initiatives	Practice of buddy barring to improve inter-crew communication
Adoption of the MOSH Trigger Action Response Plan initiative	Shorter time periods between refresher training	The use of realistic mock mines on surface	Optimisation of gasket design for hard rock environments i.e. better fitting or fixed gaskets	Geotechnical environment specific hazard identification training	Better Illumination	Better Illumination	Leadership training with soft skills development for all levels of supervision	Behaviour Based Safety training on barring	
Improved illumination e.g. use of 'EE lights'	Bi-monthly PTO's per person	"Training-the-trainer" initiatives	The correct usage of safety nets post barring		Longer pinch bars	Emphasis on the correct kneeling stances in the training process to enable quick escape		Mentoring/ Coaching in formalised processes for the workforce	
		Visual computer based training i.e. Desktop VR methods	Use of CSIR Integrated Acoustic Thermal device (currently in trial phases)		Sturdy platforms with safety harnesses in extremely high excavations i.e. >5m such and fridge plant and station areas.				
		Semi-immersive VR techniques i.e. use of cylinders as classrooms	Mechanical barring equipment: pneumatic pinch bars						
		Fully immersive VR techniques such as the use of the Oculus Rift.							
		Learner Miner Shadowing							

21 Development of Lesson Plans

21.1 Milestone Product Detail

Shown below is the detailed barring training product that is being developed by Simulated Training Systems (STS) and Golder Associates. This is the lesson that will be taught on the process of barring. This product addresses the process of underground barring practice.

The structure and approach of this module of the training product is based on:

- The process of barring in the underground workings, current mine standards and procedures and the MQA standard.
- The root cause analyses derived from Golder Associates' study. This analysis is considered with reference to interviews and observations of underground workers and the individual issues which workers deal with, that influence his/her attitude toward the job of barring.

To cover the syllabus, STS has designed a series of videos, consisting of 3 major sections, which are presented using a story telling approach.

The story will emulate the path of a South African miner, who is coached by an older, more experienced colleague about the correct barring practice and additionally the reason behind following the steps correctly.

The 3 sections presented, will be divided into 9 subsections as described below (Figure 195).

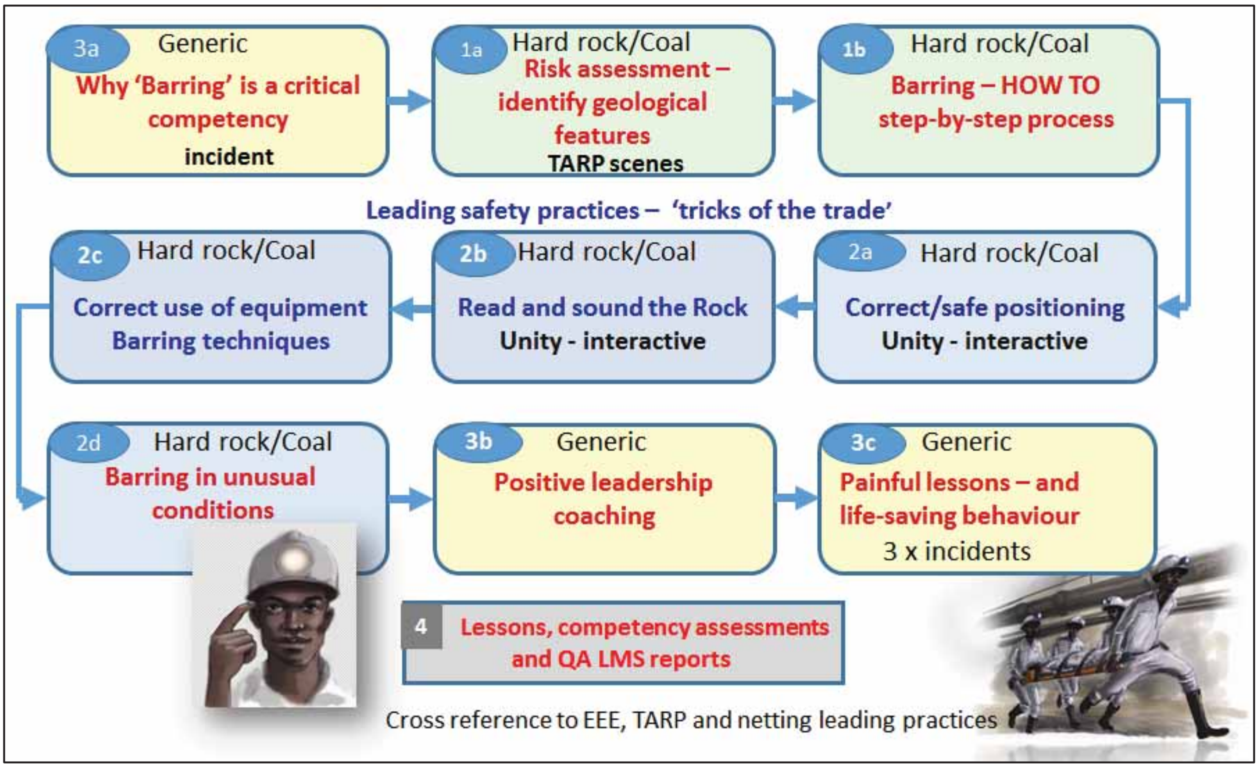

Figure 195: The complete Barring Training Product

Section 1: Technical and geotechnical aspects of barring

Section 2: Tricks of the trade

Section 3: Behaviour and culture related subsections

Subsection 3a: Why barring is an important skill

In this subsection, the "coach" character is visited by the younger underground worker. The underground worker will present his problems to the coach; problems that are relevant to the current mining workforce (based on the Golder study). Responding to the youth, the coach will justify and motivate the value of sticking to the rules and being assertive about his safety and the safety of his fellow workers.

Subsection 1a: Identify Geological features

This subsection will be a revision of geological features encountered in the underground workplace and how these can be identified. The aim of the section is not to discuss a comprehensive list of features, but rather to show that although there are many geological features underground, the process and rules for safe barring must be applied to all features.

Subsection 1b: The process of barring

Subsection 1b of the product will focus on a simple 5 step process to safe barring. The simplest approach to the process is called "The 5 P's of Safe Barring";

1) Prepare yourself
2) Prepare the area
3) Prepare others
4) Position yourself
5) Proceed with barring

Each of these steps has two key points to address and is presented in 3D simulated environments to show viewpoints that are otherwise inaccessible in real-world setups.

Subsection 2: Tricks of the trade

The following 3 subsections address essential technical skills related to the barring process; termed “Tricks of the Trade”.

Subsection 2a: Safe positioning

This subsection focuses on teaching the user how to take up the safest position before beginning to bar the hanging wall. The safest position ensures that there is a clear escape route if rocks dislodge, and that the user will not be hurt by rock which may fall and injure the worker.

Subsection 2b: Use the pinch bar correctly

This subsection describes how to hold the pinch bar correctly. This includes how to position your hands on the pinch bar relative to the firmly installed gasket. Positioning of the pinch bar from the users body, the angles of use and the transportation of the pinch bars will also be discussed.

Subsection 2c: Read and sound the rock

The “Reading and sounding the rock” subsection centres around examining the hanging wall after it has been watered down. Sounding the hanging wall, tells the user where rock is solid and where loose rock can be dislodged from the hanging wall. This is indicated by striking the pinch bar against the hanging wall systematically and listening to the tone of the sound.

Subsection 2d: Barring in unusual conditions

Unusual conditions for barring include areas where:

- It is impossible to bar from an up-dip position, a safe position or while standing under a supported area.
- It is impossible to see the feature that must be barred from a safe position or while standing under a supported area.

In this subsection, the coach suggests some way to bar in these conditions safely.

Subsection 3b: Positive leadership coaching

The coach character advises the youth about the future; when he will be a leader someday. This subsection is built to motivate the leaders of the workforce. It discusses leading in a positive manner and respecting the decisions of sub-ordinates should they choose not to work/ bar in hazardous environments.

We discuss peer pressure, and management pressure and how these issues can influence a worker to make mistakes or put him\herself into dangerous situations when barring.

Subsection3c: Painful lessons

As part of the study, Golder has extracted reports of barring related incidents that have occurred at the champion mines. These incidents vary from minor to major injuries.

For psychological impact, Subsection 3c will focus on some of these incidents re-created in 3D simulated environments. The particular information of each hazard will be omitted to maintain anonymity of the mines and the workers injured.

The incidents will be altered to fit with the current story. All injuries and violence will be implied rather than graphically shown.

Section 4: Competency assessments

- All features described above will be built into the STS Learner Management System (LMS).
- A question component will be added to the program that will test the user's retention of the information presented. The users' answers to these questions will be stored within the LMS database.
- For user results to be stored, user details must be captured by the facilitator of the training program.
- Individual results for each user can be extracted from the database, using the built-in reporting system.

21.2 The Process of Barring

Subsection 1b of the product has been conceptualized to limit the number of steps that must be remembered by the individual. For simplicity, five points were suggested i.e. the 5P's to safe barring.

The detailed script for the lesson reads as follows:

"Welcome to this lesson about barring. This lesson covers the 5 P's of safe barring.

In this lesson we explain the 'What', the 'How' and the 'Why' of each of these steps.

Learning how to bar correctly will help you, and everyone working with you, to work more safely.

Please pay close attention.

The 5 P's of barring are:

1) Prepare yourself
2) Prepare the area
3) Prepare others
4) Position yourself, and
5) Proceed

Each of the 5 P's has two simple key points to follow.

Let's take a closer look at each of the key points together.

#1: Prepare yourself

PPE

First, prepare yourself when you are about to bar. Remember, safety is always first. This is why you must make sure that you have all the correct PPE according to the standard required by your mine.

Pinch bar

After making sure that you have all the correct PPE, make sure that you are using the best tools for the job.

Have a look at your pinch bar. Is it long enough for the job? Remember, If your pinch bar is too short, you will end up reaching too far when barring. This may cause you to end up standing under the rocks which you will be barring.

If barring at the stope face, use a 1.2 metre pinch bar. When barring ASG's, use a 1.8 metre pinch bar. For development ends, use a 3 metre pinch bar.

When you have a pinch bar that is long enough, make sure that both the ends are sharp. Blunt ends will prevent you from wedging the pinch bar between rocks to loosen them. Make sure that the pinch bar it is fitted with a protective gasket. The gasket must be secure on the pinch bar to protect your hands from getting hurt should any small rocks fall towards you.

#2: Prepare the area

Next, make sure that the area you will be barring is safe for you to work in. To make sure the area is safe for barring, pay attention to the following two aspects; one, "Examine and water down", and two, "Clear an escape route".

Water down and examine the area

Use a water hose to water down the area which you will be barring. The water helps to move any dust and particles that make it difficult to see the rock.

After watering down, look closely at the rock. Look for fractures and jointing that can be barred down. It is important to understand the jointing and fracturing. This will help you to understand where the rocks will fall when barring them down.

Clear the escape route

Depending on which direction the joints and fractures run in the area, make sure that you have a clear escape route. Always make sure that you leave space behind you to move out of the way of falling rock.

Clear all rocks and tools that might be in your way. This will allow you to move to a place of safety if you need to.

#3: Prepare others

Preparing other workers in the area has two key points.

Warn people to stand +/- 5 metres on the safe or up-dip side

Make sure that people in the area are aware that you will be barring. Tell them to keep away. Make sure you withdraw all people from the down dip side of the area to be barred. Make sure that the area is secure

Use danger tape to border off the area. If you need to, place guards in the surrounding areas to warn other workers that the area is being barred. Place these guards according to your mine's standard.

Have buddies present

When barring, we aren't always aware of the dangers around us.

It's important to have a buddy in a safe position watching you bar. If a rock is difficult to bar down, make sure that you have a second buddy to help you bar down the rock with a second pinch bar.

#4: Position yourself

Stand on the safe, or up-dip, side

Select the safest side to bar from. The safer area will have less damage and fewer dangerous fractures. If the area is supported with timber, look at the timber support for signs of damage that could make the support weaker.

Never work under loose or suspect hanging walls and side walls – when in doubt STAY OUT! Always remember to bar from a safe position – usually from the up-dip downwards. This prevents barred rock from coming loose and falling onto you.

Have firm footing

Finally, make sure that you have firm footing so that you do not slip and fall while barring.

#5: Proceed

Bar from a supported area to an unsupported area

When barring, make sure that you always work under supported ground working your way toward unsupported ground. NEVER move into unsupported areas.

Sound the hanging wall

Sound the hanging wall by knocking the hanging wall with the flat end of the pinch bar. Start from at least 3 meters away from the actual area to be barred.

If you hear a hollow sound, it means that the rock is loose or has a gap and needs to be barred down.

Bar down lose ground with the pinch bar

When you find a hollow area, find a crack in the hanging wall where you can insert the sharp end of the pinch bar. Force the loose rock away from the hanging wall or sidewall. Always keep your eyes open while barring. Remember, immediately drop the pinch bar if any rock dislodges and falls towards you.

Remember, this procedure is in place to protect you and your co-workers.

Stick to the rules, stick to safety!

Let's review the steps one more time.

1) Prepare yourself by checking your PPE and your pinch bar
2) Prepare the area by watering down and looking for loose rock

3) Prepare others by warning people to stay +/-5 meters away and keep your buddies close
4) Position yourself on the up-dip or safest side with a firm footing,
5) Proceed with the job from a safely supported area by sounding and barring loose ground."

22 Development of Competency Assessments

22.1 Milestone Product Detail

Shown below is the detailed barring training product that is being developed by STS. The finalization of the script of Subsection 1b has been completed and this is the lesson that will be taught on the process of barring.

This product addresses the process and tricks of the trade of barring practices underground.

The structure and approach of the product is based on

- The process of barring in the underground workings.
- The Root Cause Analyses derived from Golder Associates' study. This analysis is drawn from interviews and observations of underground workers and the individual issues which workers deal with, that influence his/her attitude toward the job of barring.

To cover the syllabus, STS has designed a series of videos, consisting of 3 major sections, which are presented using a story telling approach.

The story will emulate the path of a South African miner, who is coached by an older, more experienced colleague about the correct barring practice and additionally the reason behind following the steps correctly.

Subsection 2d: Barring in unusual conditions

Unusual conditions for barring include areas where:

1) It is impossible to bar from an up-dip position, a safe position or while standing under a supported area.
2) It is impossible to see the feature that must be barred from a safe position or while standing under a supported area.

In this subsection, the coach suggests some way to bar in these conditions safely.

Subsection 3b: Positive leadership coaching

The coach character advises the youth about the future; when he will be a leader someday. This subsection is built to motivate the leaders of the workforce. It discusses leading in a positive manner and respecting the decisions of sub-ordinates should they choose not to work\bar in hazardous environments.

We discuss peer pressure, and management pressure and how these issues can influence a worker to make mistakes or put him\herself into dangerous situations when barring.

Subsection3c: Painful lessons

As part of the study, Golder Associates has extracted reports of barring related incidents that have occurred at the champion mines. These incidents vary from minor to major injuries.

For psychological impact, Subsection 3c will focus on some of these incidents re-created in 3D simulated environments. The particular information of each hazard will be omitted to maintain anonymity of the mines and the workers injured.

The incidents will be altered to fit with the current story. All injuries and violence will be implied rather than graphically shown.

Section 4: Competency assessments

- All features described above will be built into the STS Learner Management System (LMS).
- A question component will be added to the program that will test the user's retention of the information presented. The users' answers to these questions will be stored within the LMS database.
- For user results to be stored, user details must be captured by the facilitator of the training program.
- Individual results for each user can be extracted from the database, using the built-in reporting system.

22.1.1 Competency assessments

22.1.1.1 Summary

- During the production of these simulations, STS is developing the competency assessment sections of the product.
- The competency assessment sections of the product involve the design of prescribed questions inserted into the Learner Management System.
- Upon import of these questions, the user will watch the designed simulation and be posed with questions based on the content of the relative simulation.

22.1.1.2 Questions for the STS LMS

- The competency assessment is intended for 3 portions of the Barring Product:
- Module 1: Risk assessment and the 5P's to barring
- Module 2: Tricks of the Trade
- Module 3: Positive leadership and coaching

- Competency assessments are available for the Training Centre version of the product. A "video-only" version of the product will not have the Question component included.
- Questions for the competency assessments are in multiple choice form and all responses are stored in the LMS database. These responses can be extracted per user for reporting purposes.

Table 40. Questions for Module 1: Risk Assessment and the 5P's to barring

#	Question	Correct answer	Wrong answer 1	Wrong answer 2	Wrong answer 3
1	What is the first step to safe barring?	Prepare yourself	Prepare the area	Prepare others	Position yourself
2	The first step to safe barring is Prepare yourself; What is the second step?	Prepare the area	Prepare others	Position yourself	Proceed with barring
3	The second step to safe barring is Prepare the area; What is the third step?	Prepare others	Prepare yourself	Position yourself	Proceed with barring
4	The third step to safe barring is Prepare others; What is the fourth step?	Position yourself	Prepare the area	Prepare yourself	Proceed with barring
5	The fourth step to safe barring is Position yourself; What is the last step?	Proceed with barring	Prepare the area	Prepare others	Proceed with barring
6	True or false: Fellow workers are allowed to stand on the down dip side while you are barring.	False. Clear all workers from the down dip side.	True. Workers may stand down dip if they are far away.		
7	True or false: The longest pinch bar for the job is the best pinch bar	False. Use the correct pinch bar for the area that you are barring in.	True. The longest pinch bar will let you bar the most productively.		
8	True or false: Pinch bars without gaskets should not be used even if you have protective gloves.	True. Gloves will not give you enough protection while barring.	False. Protective gloves area not needed while barring.		
9	Why are buddy barrers important?	Buddy barrers help you bar down rock that	Buddy barrers are only needed when you need	Buddy barrers are not important.	Buddy barrers are there to make sure that the supervisor

#	Question	Correct answer	Wrong answer 1	Wrong answer 2	Wrong answer 3
		is difficult to bar alone.	somebody to talk to.		is not watching you bar.
10	Why do you need to water down the face wall?	It's important to water down the face wall to see dangerous fractures in the hanging wall more easily.			

Table 41. Questions for Module 2: Tricks of the Trade

#	Question	Correct answer 1	Correct answer 2	Wrong answer 1	Wrong answer 2
1	What is the best way to grip the pinch bar?	Grip the pinch bar with both hands	Grip the pinch bar behind the protective gasket		
2	What is the safest way to carry a pinch bar?	Carry the pinch bar below shoulder level		Carry the pinch bar over your shoulder.	Drag the pinch bar behind you so that it is out of the way
3	True or False: The best position when barring in narrow conditions is kneeling on both knees.	False. Kneel on one knee so that you can jump out of the way fast if large rocks fall down.		True. Kneeling on both knees will help you save energy so that you can bar for longer.	
4	Which is the safest position to bar from	Bar from an up-dip position		Bar from a down-dip position	Positioning does not matter.
5	How do you bar safely when you can only access loose rock while standing in a down-dip position?	Stand on the same level as the loose rock and bar so that the rocks fall in front of you and roll down-dip		Try to water down the hanging wall until the loose rocks wash loose.	In this case, it is okay to stand down-dip and bar.
6	When should you use the sharp end of the pinch bar?	When sounding against competent ground which has less blocky formations		When sounding against blocky formations	
7	When should you use the flat end of the pinch bar?	When sounding against blocky formations		When sounding against	

#	Question	Correct answer 1	Correct answer 2	Wrong answer 1	Wrong answer 2
				competent ground which has less blocky formations	
8	What does a high pitched sound in the hanging wall tell us?	A high pitched sound tells us that the hanging wall is solid	A high pitched sound tells us that the rock above us may be loose but is large.	A high pitched sound is sign of a water bearing feature.	A high pitched sound is sign of a good hanging wall.
9	What does a low pitched sound in the hanging wall tell us?	A low pitched sound tells us that there is loose rock in the hanging wall		A low pitched sound is sign of a good hanging wall.	
10	Why is buddy barring important?	They may see dangers which you may not see.	Buddies help you bar when large rocks are tough to bar alone.		

Table 42. Questions for Module 3: Positive Leadership and Coaching

#	Question	Correct answer	Correct answer 2	Wrong answer 1	Wrong answer 2
1	What is the first rule that you should stand by and apply when entering a work place?	Thorough barring of an area is the first step to making sure that the working place is safe to work in.		Always bring enough water into the working place.	Never allow more than one person to bar an area at a time. There is too much work to do.
2	How should you support your team with regards to safe barring?	As a manager you must become a champion coach.		Never let the team make any decisions.	Let the support team through past before barring starts. They have lots of work to do.
3	When is the right time to teach your team to bar?	Use every chance you can get to coach your teams on how to bar fast and effectively		While you are walking to the waiting place after the shift.	Once the shift is over and they need to go home.
4	Name two ways that you can encourage	Make sure that your team knows	Praise the team when	Let them know that they are	Make sure that the team is

#	Question	Correct answer	Correct answer 2	Wrong answer 1	Wrong answer 2
	good barring practices.	how to bar correctly	they bar an area well.	wasting time if they do not find problems in the hanging wall.	afraid of you so that they listen to everything you say.
5	What are the important steps to take when guiding your team when barring	Listen to the team and understand what they have to say.	Treat the team with respect and understand their problems without shouting at them	Don't ask them about their opinions. You are the leader of the team.	Keep the team busy with other work while the barer is making safe.

22.1.1.3 Questions for "Painful Lessons" simulations

- The "Painful Lessons" portion of the product may have questions relevant to the situations discussed in each simulated incident. Currently these simulations are still under discussion.
- Once the incident simulations have been designed, relevant questions will be added to the LMS platform to gauge the users' competence in identifying what went wrong with each case study.

23 Development of Quality Assurance Assessments for the Training

Quality Assurance in the training product is centralized to STS's Learner Management system (Figure 196). The Server computer collects the results for all tests using STS's LMS/QWIK software. The software records all data for each answer that every user submits while being tested. These results can be filtered and extracted according to test sessions, individual users, results and scores. Full reports can be displayed and printed.

Components may be added to the system to communicate results to existing SAP/MQA systems.

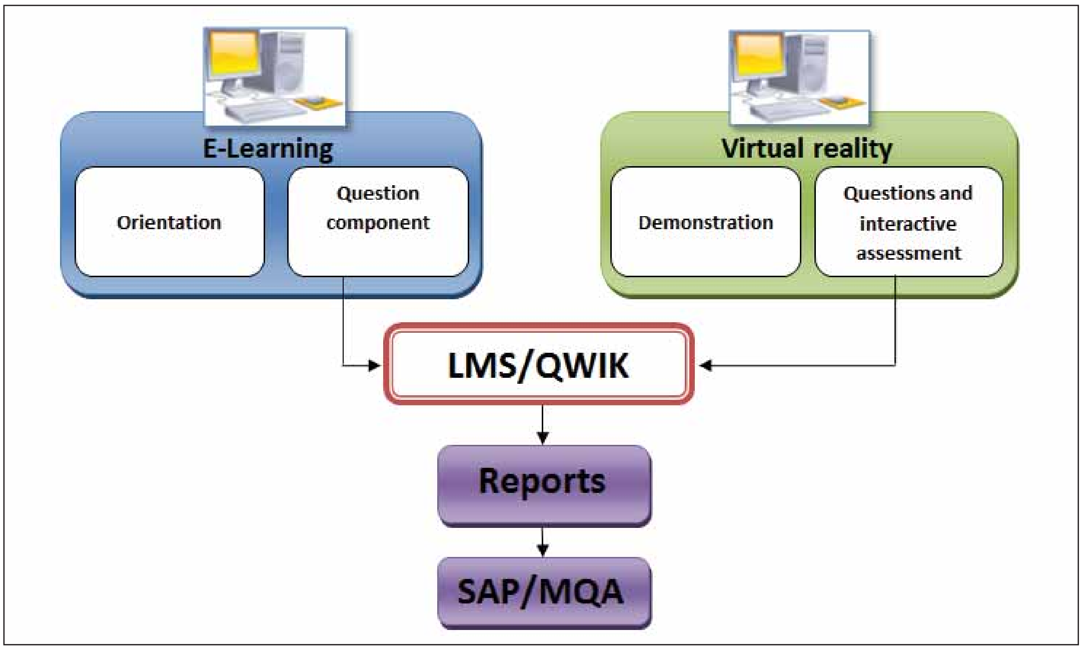

Figure 196: Product Development Overview

It was originally thought that lesson plans and competency assessments would be the main learning portion of the training product. However, the programme has now evolved to encompass nine virtual reality modules instead, which need to be quality assured in an all-inclusive manner.

24 Development of Virtual Reality Module 1

Milestone 11 is the development of Virtual Reality Module 1. The lesson plan shown in the accompanying video to this report depicts an environment created for use at platinum mines. It visually depicts the underground in-stope platinum mining environment with appropriate support systems. Visual rendering shows a typical UG2 looking reef with chromitite stringers at the face. Simple geological structures which are potentially hazardous are also shown in the hanging wall.

In addition to the 5 P’s to barring, a number of simple pictograms are employed to indicate actions that are not shown in detail in the video itself. The 5 P’s are represented by a right hand in the video to promote easy learning and retention of the steps (Figure 197). Each finger represents one of the barring 5 P’s i.e. Prepare yourself, Prepare the area, Prepare others, Position yourself, and Proceed with barring.

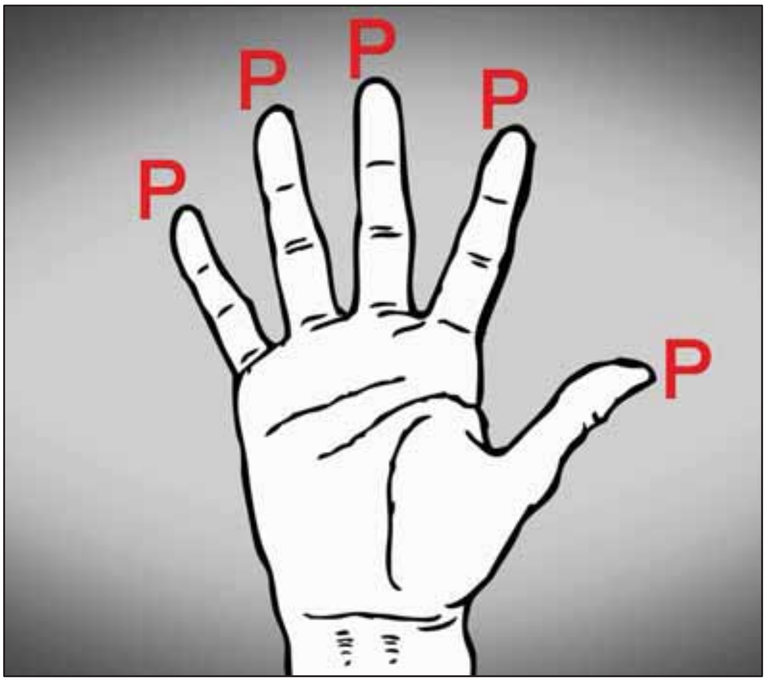

Figure 197: A hand representing the 5 P's of barring

It is based on the information collected during underground and site visits as well as the root causes discovered from analysis of the historical accident reports (Milestones 2, 3 and 6). The 5 P’s to Barring is the focus of this module.

Examples of pictograms used are shown below:

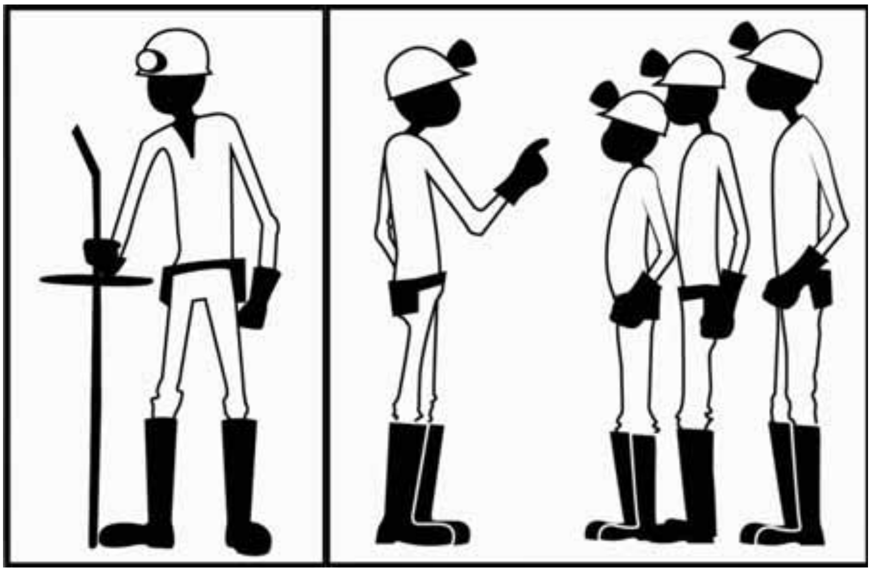

Figure 198: Pictograms of character preparing himself and others for the barring task

The 3D animation of the workers shows the use of generic PPE including hard hat, cap-lamp, safety goggles, ear plugs, arm guards, gloves, belt with self-rescuer and cap-lamp battery, knee guards and steel toed gumboots. It should be noted that the gold and platinum video presentations shows the use of arm/elbow guards. This could be changed, if required. The video narrator also indicates that the PPE must be used as per your mine standard.

Dangerous zones/ areas and ‘No-go’ zones are highlighted in red. Zones in-stope that are clearly supported and thus are safe, are shown in green. Packs that hinder visual representation and understanding are shown as translucent in order to shown detail and the correct barring procedure. Additionally, individuals in safe positions (including ‘buddies’ and ‘guards’) are temporarily highlighted in green and those individuals taking unsafe positions are highlighted in red (Figure 199).

Figure 199: Characters in the lesson plan shown in-stope

Sounding of the hanging wall and the sounds that can be heard in the video are actual recordings taken during underground visits. During the underground visits, a person’s posture in confined areas was also observed to find the best way to gain secure footing when kneeling. It was determined that one would gain more stability by placing one knee on the footwall rather than kneeling on both. This is shown in the lesson plan by all characters placed in-stope where the stoping width is limited. The video ends with a summary of the main points.

25 Development of Virtual Reality Module 2

25.1 Milestone Results

This module of the training product addresses the specific “tricks of the trade” used in when barring in the underground working place. The headings for each of these are intended to be some of the unwritten skills of barring that are meant to be used in parallel with the 5 P’s to safe barring discussed in Module 1. Whilst these points are briefly addressed by the 5 P’s, this module is meant to develop and instill the importance of these four skills even further. The ultimate purpose of this module is to transfer the "soft" skills which are used by workers to bar safer and smarter.

The four "tricks" were formulated following observations made during the number of underground visits completed in the hard rock mining environment. The same skills were found to be important in the coal mining environment as well. They are:

1. The use of the best equipment correctly
2. Choosing the best position
3. Reading and Sounding the rock, and
4. The use of buddy barrers

The root cause analyses of barring accidents in the various commodities showed that inadequate training and Inadequate Leadership were the basic cause of 35% of the accidents analysed (Figure 200). This is followed closely by the employee's habits or personal preference to deviate from the standard. This information was vital to the planning of the training material. Thus, in addition to the basic lesson plan for barring, four key skills were decided upon.

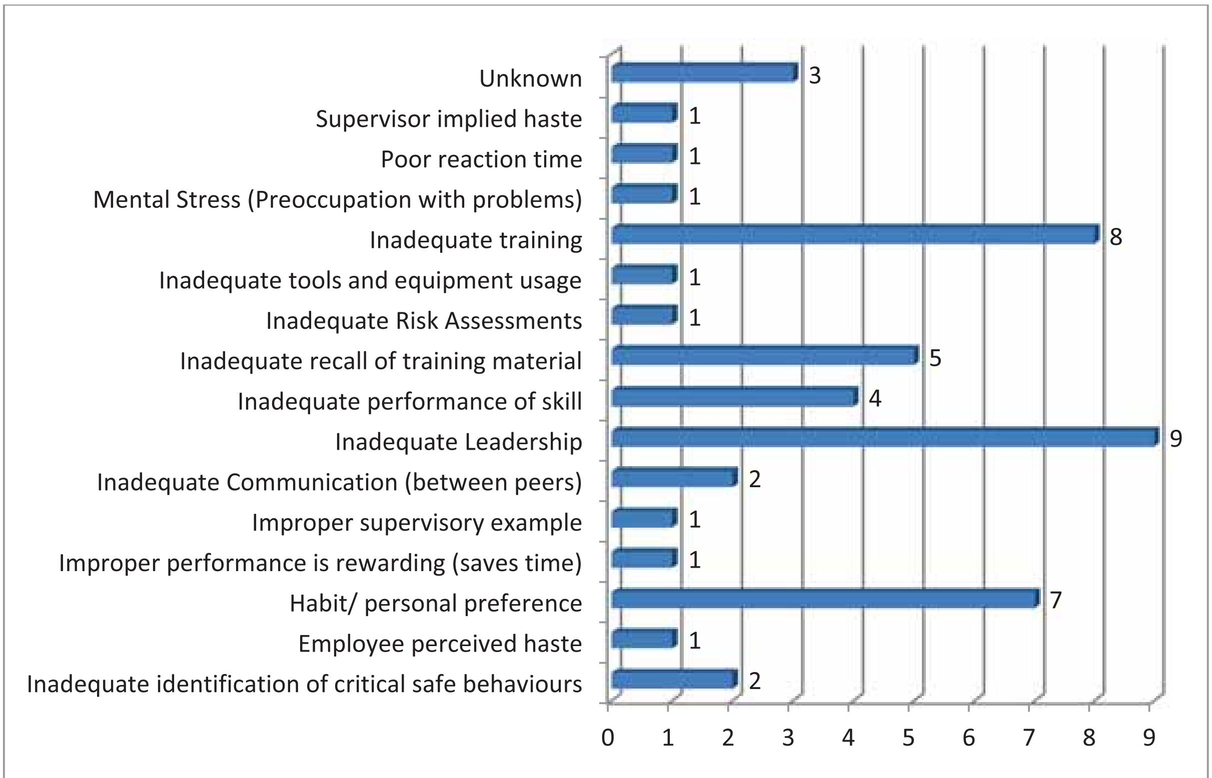

Figure 200. Summary of Root Causes for barring accidents from on-site reports (All commodities)

The dominant underground observations that influenced the choice of these skills were:

- During many visits, the improper use of equipment was observed. These factors ranged from not placing hands behind gaskets to incorrect pinch bar length to poor conditions of pinch bars.
- Incorrect positioning i.e. on the down dip side of the rock being barred was a common practice observed across all hard rock champion mines.
- Visual examination of the hanging wall could be improved as well as acknowledgment of the sound being made upon the sounding of the hangingwall or roof.
- Where crews performed the MOSH entry examination process together, this led to a better inspected hangingwall and thus therefore a safer working place. The obvious benefits of buddy barring needed to be included in the training module.

The topics discussed in this module consist of four headings or “tricks”. These are discussed in the following points and the narration is also included.

25.1.1 Use the best equipment correctly

This section of the module discusses the quality of the pinch bar, its transport and how to handle the pinch bar to get the best leverage out of the tool (Figure 201 and Figure 202).

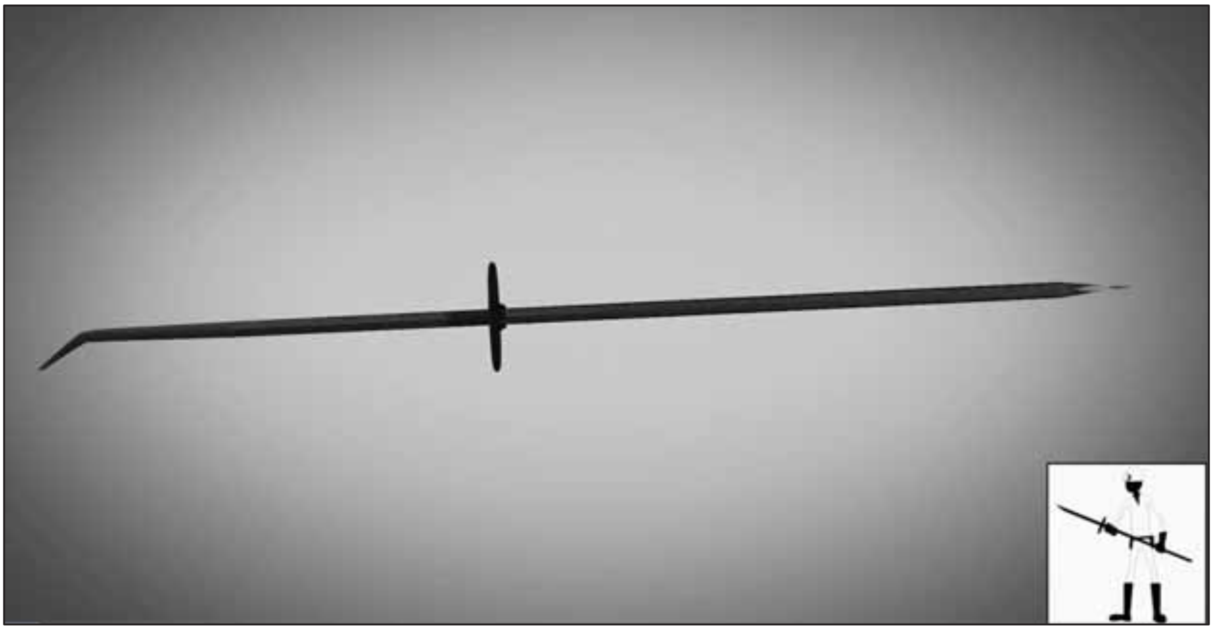

Figure 201. Visuals shown for the best equipment topic

Figure 202. Correct positioning of hands shown

25.1.1.1 Narration for this section is as follows:

“A workman is only as good as his tools. We say this, because you must have the best equipment to bar well. Your pinch bar is the key to successful barring. If you don’t have a good pinch bar which is the correct length with a protective gasket, you won’t be able to bar well.

Check that the pinch bar is sharp at both ends and has a tightly secured gasket.
When using the pinch bar, grip it firmly with both your hands behind the protective gasket. Push the pinch bar in an upwards and forward direction. Jab the end of the pinch bar properly into a fracture or crack in the rock before levering the rock away from the hanging wall.

Remember; hold the rear end of the pinch bar to the side of your body. If you hold the pinch bar directly in front of you, the rear end may injure you.
If you need to use the pinch bar for moving or lifting purposes, make sure to use strength from your legs and not your back. Using the power of your back is dangerous and can hurt you.

Take care to carry the pinch bar below your shoulder level so that you do not injure fellow workers or hit objects around you.

Lastly, make sure that your pinch bar not damaged after you have used it. If there is any damage to the pinch bar, make sure that it is replaced. These parts include damaged ends to pinch bars and torn or loose gaskets."

25.1.2 Choose the best position

This section discusses the best posture and revisits some rules regarding choosing a position to bar relative to the loose rock that you will be barring (Figure 203). Finally, barring in unusual conditions (Figure 204) when loose rock can't be accessed from an up-dip position is discussed.

Figure 203. Positioning up-dip of the rock being barred

Figure 204. Barring in a raise

25.1.2.1 Narration for this section is as follows:

“Use the correct posture

When barring in narrow stope conditions the best position is kneeling with one foot on the ground. This position will help you jump out of the way fast enough if large rocks dislodge from the hanging wall while you are barring.

When barring in a development end or high excavation, your legs should be slightly apart and firmly placed on the ground.

Bar from an up-dip position

When choosing a position to bar from, always make sure that the loose rock you will dislodge will fall AWAY from you. Even on a slight dip, a rock barred from the hanging wall will fall and move in the down dip direction. This is why we say that the ideal position for anybody who is barring is up-dip from the rock. NEVER stand down-dip of rock that you are sounding and barring.

Barring in unusual conditions

At times, you may find rock which is difficult to bar from an up-dip position such as in raises. You may find that the only way that you can see the fractures of loose rock is when you are standing in a down-dip position. The only way to work with conditions like this is to stand to the side on the same level as the loose rocks, then examine the hanging wall, and bar the hanging wall so that the rocks fall in front of you and roll down-dip. Even in this unusual condition make sure that you are standing at a slightly higher, stable position, so that the rocks fall and roll away from you. "

25.1.3 Read and sound the rock

This section discusses the skill of being able to understand discontinuities in the hanging wall before beginning to bar. Interpreting the angles of jointing and how the joints intersect to create wedges is shown.

Furthermore, the logic of sounding is discussed i.e. How a low pitched sound implies loose/hollow rock and how a high pitched sound implies solid rock (Figure 205).

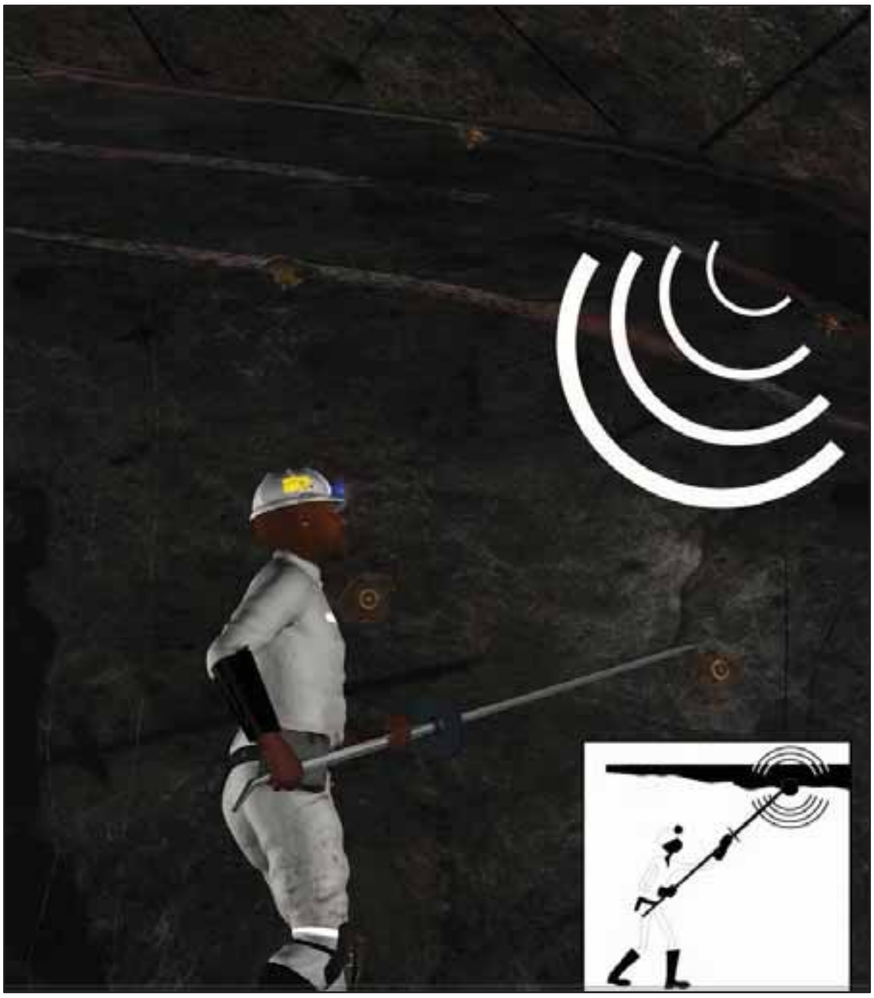

Figure 205. Sounding of the rock being shown

Two examples are included, one tackling rock that gives off a low pitched sound, and a second example where we encounter a brow with a high pitched sound, and how it is created by features such as bedding and a joint plane. It is at this point in the module where one is shown that one cannot successfully judge the state of the hanging wall by relying on the sound emitted by the pinch bar alone, but that we also need to look carefully at the jointing causing the formation of geological features (Figure 206). ("Do not be misled by the sound. This is why SEEING is just as important as SOUNDING.")

Figure 206. Intersection of jointing

25.1.3.1 Narration for this section is as follows:

"For this trick of the trade we need to understand how to interpret the orientation of discontinuities in the hanging wall. Discontinuities could be joints, bedding, stress or blast fractures.

It is important to understand how joints interact to form loose blocks of rock in the hanging wall.

For this, we will go into the hanging wall and show you how joints and other discontinuities can make the hanging wall unstable.

Let's look at the skills you need to find the rocks which you must bar down. To find these loose rocks while barring, we use a method called sounding.

Sounding involves striking the end of the pinch bar against the hanging wall or sidewalls and listening carefully to the sound.

Use the sharp end of the pinch bar when sounding against competent ground which has less blocky formations.

Use the flat end of the pinch bar when sounding against blocky formations. We use the flat end of the pinch bar in this case because using the sharp end of the pinch bar might loosen rock that is competent.

If you hear a solid sound when striking the rock, the hanging wall is more likely to be stable and may not pose a high risk.

If you hear a hollow sound, this is a sign that there is loose rock that you must do something about. You must either bar the rock down, or if the rock is too big, the area must be barricaded off and handled according to the procedures for your mine.

Example 1: Have a look at this section of hanging wall. Before sounding we can already see that these joints intersect.

Sounding indicates that there is a loose rock in the hanging wall.

Can you see that the edge has some fallout indicating a potential loose block? Also, notice the orientation of the jointing which creates these blocks in the hanging wall.

So, what we are looking at here is a wedge.

Sounding is a great way to find out whether a rock is in danger of falling, but it is only part of the skill which helps us find these rocks.

It is just as important to visually inspect the hanging wall for signs of rocks that are loose.

By looking at the hanging wall carefully one can pick up clues about the hidden structure of the hanging wall. Some of these clues are:

Fall out on jointing and the effect of joint infillings,

Brows

Faults or ‘slips’

Dykes and other intrusions and

Ground Water dampening the area,

Also be aware of those geological structures that are specific to your mining environment only.

Remember, just because the hanging wall sounds solid does not mean that it is safe. In fact, if the hanging wall sounds solid and the joint planes look like they intersect, the dangers may be far worse. Keep an eye on this area and judge when the key block can be barred down safely or supported. Do not bar if you doubt that it can be done safely.

Example 2: In this example we see a large brow.

When we sound the brow and hanging wall, it seems to be quite solid.

But let’s look carefully at the jointing. Do you notice the angle of the jointing? Notice how it dips at a high angle?

What we seem to be looking at here is a very large brow with created by a joint and bedding.

For features this size, the hanging wall may still sound solid.

Warning! It is important to understand that a solid sound with the pinch bar doesn't always mean that the hanging wall is safe.

Once you discover a geological feature, you need to look at it carefully to understand the jointing on dip and strike and how the joints extend deeper into the hanging wall; the places you cannot see.

If they intersect they may cause a deadly threat in the hanging or sidewalls.

Do not be misled by the sound.

This is why seeing is just as important as sounding."

25.1.4 Use buddies

Section 4 revisits the use of buddy barrers and why they are important (Figure 207).

Figure 207. A buddy pointing out a hazardous condition

25.1.4.1 Narration for this section is as follows:

"This trick of the trade shows the importance of having the help of other people when barring. Whenever you bar during entry examination, pre-task, mid-shift or continuous barring, the help of your crew members must assist you by visually examining the hanging wall for loose rocks. They may notice something that you could have missed. Remember, never bar alone!

Approach each task as if your family was watching you. Think of how you could do it safer!
Buddy barring is important because….
Buddies can point out hazardous conditions that you may not be able to see.
Your buddy should always stand in a safe position at some distance from you if you are barring and pay close attention to the orientation of joints in the hanging wall.
In this way he may see key blocks or loose rocks that you cannot see. And he can warn you of any potential danger. A buddy can also assist you, when barring a particularly large loose block in the hanging wall. A second pinch bar being used will provide additional leverage that may be required to dislodge the block.
You both should have firm footing and then proceed to lever the loose rock by pushing the pinch bars upwards at the same time. If you fail to bar the loose rock down safely, area must be barricaded off and handled according to the procedures for your mine.
Always remember that the warning from a buddy can save your life – Two pairs of eyes are always better than one."

25.1.5 Animation approach

The 3D model used to approach these headings is designed to resemble the working environment of a raise in the case of hard rock mining. The dimensions and support standards are based on the standards of various mine support standards without adhering to one particular commodity type. The raise is used in this module as stopes and development excavations are used in other portions of the product. These visuals could also explain how barring in such unusual circumstances should be carried out.
The coal version of the product however, will be simulated in a relevant coal working area.

25.1.6 Modeling

The simulated environment was modeled, textured and lit to include jointing and minor geological discontinuities that are discussed in the script.

25.1.7 Animation

Animation of each trick required approximately 2 – 4 days of animation time. This includes review sessions for alterations for timing synchronization. Included in the time for each step was:
Animation of virtual cameras (cinematography) for all 4 topics,
Animation for the main actor (who acts out the actions for each discussed step)

Ambient and secondary animation for each character not directly involved in the discussion

25.1.8 Rendering

As with the 5 P's to safe barring module, all portions of the 3D simulation are rendered using multiple passes to access vital parts of the simulation and highlight important portions of the environment. This includes:

Sectional views of the strata and geological features that existing in the hanging and side walls, highlighting of the characters, their activities, posture and position. Rendered out frames (and final composited output) are produced at full HD resolution (1920x1080).

25.1.9 Compositing

After rendering of the animation into individual frames, compositing draws animated frames, narration and special effects into a single product.

The compositing for the final product including recorded narration and special effects took ~ 5 days.

Final video is compiled using mp4 technology using the h.264 media standard compression algorithm.

25.1.10 Statistics for Module 2

The existing module for tricks of the trade equates to roughly 10 minutes of animation at 25 frames of animation per second.

Rendering basic animation for this feature consisted of between 3 - 4 passes calculated as:

(600 (*seconds*) x 25 (*frames per second*) x 4 (*passes*)

This leads to a figure of ~ 60,000 individually animated frames. The final layering into a final composite consists of ~15,000 frames of animation.

26 Development of Virtual Reality Module 3

This portion of the product, as opposed to the previous two modules ("The 5 P's of Safe barring" and "Tricks of the Trade"), is designed to engage the viewer on an **emotional** level. Its intention is to tell a story that is plausible to any worker in the underground workings who encounters the dangers of barring and sounding incorrectly or handling the process in a rushed manner.

This module of the training product is called 'Lessons Learnt – Shortcuts and Consequences' and has been designed to engage the viewer on an emotional level. Motivating factors for the inclusion of the lessons learnt module in the barring training programme stem from some of the research findings made to date. These include that 15% of barring accidents analysed showed that numerous employees have a settled or regular tendency to practice risky behaviour by not barring correctly, not barring at all or even taking up an unsafe position during the act. Additionally, underground visits consistently showed that entry examination and even the MOSH entry examination procedure is not diligently carried out by individuals who exhibit unfavourable behaviours. Consistently observed across the various champion mines were behaviours such as rushing to get out from underground, rushing to blast and taking shortcuts with the barring procedure/ standard.

Viewers are introduced to David who is a survivor of a fall of ground accident. David then proceeds with his account that is shown to be caused by his friend who was distracted and being careless. The story is told in the format of an interview setup and the tones are sombre and bleak. This is backed up even further by ambient sound effects, music, lighting and unique drawings created for the module. The consequences to David's self, his friends in the accident and even to his own family are dramatically conveyed and leave a lasting impression with the viewer. It is known that this module adequately conveys the message about the consequences of taking shortcuts.

26.1 Factors from Root Cause Analysis and on-site findings that contributed to module development

The following list shows the motivating factors for the inclusion of the lessons learnt module in the barring training programme:

- Barring accidents analysed showed that habit or personal preference was the third highest ranked root cause of barring accidents. It was often noted that some person's behaviour had caused them to perform improper critical activities.
- 15% of barring accidents analysed showed that numerous employees have a settled or regular tendency to practice risky behaviour by not barring correctly, not barring at all or even taking up an unsafe position during the act.
- Inadequate training and inadequate leadership are the main root causes and they have been addressed by the training programme either in in its entirety or as a targeted module.
- Field visits consistently showed at all champion mines that entry examination and even the MOSH entry examination procedure is not diligently carried out by individuals who exhibit unfavourable behaviours. Rushing to get out from underground, rushing to blast

and taking shortcuts with the barring procedure/ standard were the most common observations.

- Safety lessons need to be communicated as part of the training and by showing the consequences of risk taking behaviour, the repercussions to the self and the family unit, this module intends to stir emotions of the viewer and thereby be entrenched in his/ her memory.
- Understanding that leadership behaviour should model low tolerance for risk taking behaviour, this module is then followed with a story in a similar style to painful lessons module title "Positive Leadership".

26.2 The script

The story is meant to be emotional charged, and relevant to the underground workings.

It is told from the view point of a survivor of a fall of ground, David. Within David's recollection, the fall of ground is shown to be caused by his friend who was distracted and being careless. We developed the story in this way to indicate that the sub-standard actions of **other members in your crew** may lead to horrible consequences for **you**. This is meant to combat the idea that people who are in the area of someone barring incorrectly are at risk as much as the people doing the sounding and barring.

The story, told by the main character, is in the format of an interview setup, with David recalling a story to someone off camera. The tones and the setting of the script are sombre and bleak. This is backed up by relevant ambient sound effects, foley and accompanying music.

The character from the beginning of the script identifies himself as a worker that has been working underground for 15 years. This statement alone introduces the character as a peer; a worker with a lot of experience - a fellow worker that the viewer can relate to.

David tells the story of an incident which unravels slowly and dramatically leading to the death of his friend. Most of the [virtual] camera work is designed to frame David in close-up frames so that the viewer can't tell that he is disabled. We reveal this at the end when he describes his woes in the phrase:

"A man is supposed to care and protect his family. I used to be a breadwinner. Now, I'm just a burden."

Furthermore, the closing lines of the script end with him saying: "My name is David… I am 35 years old." Leading the viewer to:

1) Remind the audience that David is a person (and could be them) and

2) Realise how young he is and how much potential he may have had.

Overall, the emotion tapped into for the story is a fear, not brought on by **dying** as a result of poor barring and sounding practices, but something far worse; a fear of **surviving** the ordeal as a disabled person and not being able to adequately provide for your family; a far more devastating repercussion.

26.2.1 David's script

It was over in a flash. One moment life was going well. A normal working day with my team… then…. Everything changed.

I'd been working underground for 15 years.

We started the shift as normal that morning…., praying for good health.

My friend - Siphiwe – it was his birthday. He was excited – you could see that. He was up and about, chatting. He invited my family to a braai at his place that weekend.

He couldn't stop smiling. His first born was coming home…. Joseph…. from the city. "Family was everything to him."

I worked with Siphiwe and his brother Thulani for 9 years. They were good men. Thulani – hey! He was a soccer star. We used to call him Ingulule - the cheetah. Fast with his feet - a top goal scorer.

Siphiwe – he was Mr. Stable… never missed a production target. Never gave anybody trouble. A real champion in the crew… someone to rely on.

But on that day, he was playful.

He was just moving too fast, taking short cuts when we did the entry examination. I should have stopped him …. Told him to make safe properly…. But… I didn't want to change his mood.

While barring Siphiwe was in a hurry – didn't sound properly when loosening a brow in the hanging wall… Thulani was just behind him, shouting.

And then … a hell of a noise… rocks falling… dust all over. The sound… it shook the earth under us… A rock hit Siphiwe's head… and I, I froze… for *a moment I couldn't move. I tried to jump – too late. The last thing I felt was something hitting my back and then… nothing.*

I woke up on a stretcher. People shouting, calling for the emergency vehicles…

A loose rock hit the bottom of my back, the doctor said. Broke my rib cage…. Shattered my spine….

And Thulani? His football days are over – no more goals for him. He lost a leg. But he's alive, and back at the mine… doing office work. But his spirit is gone…….

We buried Siphiwe a week later.

And me? They say I'm lucky... I could have been killed…. But I'm not sure about being lucky. I used to be a bread winner - now I'm a burden.

And I still have three children in school……

To think that it only took one mistake, one short cut to cut me in half……

My name is David. I am 35 years old.

26.3 Writing and development approach

As opposed to previous modules which can be described as informational, the voice acting for the part of David was intentionally characterised as a worker telling the story as a broken man, for whom the recollection of the story is intensely painful. His emotion, tone and hesitance are synonymous with a survivor accurately suffering from PTSD (Post Traumatic Stress Disorder). To supplement the “interview styled” setup, the composition features digitally coloured drawings, illustrating the story that David tells.

26.3.1 Animation

Animation of the feature consisted of approximately 6000 animated frames of the David character, including voice sync and body language queues.

Rendered out frames (and final composited output) are produced at full HD resolution (1920x1080)

26.3.2 Drawings

To illustrate memories or fragments of the ordeal, the feature includes dramatic art made to supplement David’s story. Ten unique pieces were made taking an average of 2.5 working days per piece from story board through to line work, scan, final inking and shading. Examples of these pieces are shown below (Figure 208 to Figure 210).

Figure 208: Example of drawing used in the module

Figure 209: Drawing depicting situation prior to the accident

Figure 210: Drawing of accident during entry examination

26.3.3 Compositing

After rendering of the animation into individual frames, compositing draws animated frames, narration and special effects into a single product.

The animation for the final product including recorded voice and special effects took ~15 working days.

Final video is compiled using mp4 technology using the h.264 media standard compression algorithm.

Samples of the imagery and renders are featured below (Figure 211).

Figure 211: Sample imagery from the lessons learnt module

- Many changes to the actual module and scripting have taken place to get to the emotionally charged effect that is currently delivered by this section of the training program.
- This module is a precursor to the summary module on positive leadership that concludes the training programme.
- The lessons learnt module will undergo no changes for the coal product as the module has been designed in a generic manner for both hard rock and coal mining environments.

It is felt that many incident reconstructions and stories or videos would be overwhelming and even boring for the viewer, thus leading to less of an impact. The emotion tapped into for this story is adequate and the message is clear of devastating repercussions if one has a high tolerance for risky behaviour.

27 Workshops in Commodity Areas

This chapter of the research will reflect feedback from the various champion mines and representatives following workshop sessions in each commodity area. These workshops will be aimed at presenting the findings of the research as well as introducing the Barring Training Programme that has been developed.

28 Further Recommendations

Detailed recommendations are given at the end of each chapter and key points are summarised by the table indicating feasible implementation solutions (Section 20.2).

- Golder could undertake further investigations into the mine's leadership model and suggest improvements specific to the mine. In addition we could also run training sessions for acceptable workplace behaviour and tolerance for different cultures.
- Possibilities of more extensive barring VR training products exist and champion mines as well as the Mine Health and Safety Council are encouraged to invest further into semi-immersive and fully immersive training products in the future.

29 Conclusion

Often history can explain why some ideas take hold and spread, while others do not. Ideas take root only when they become important to people at a particular time, when they hitch on to something that those people care about. Similarly, barring has always been a simple task that did not require innovation until the recent past due to the increase in the number of people that were being injured during the act of barring.

Even more concerning was the rise in fall of ground accidents due to the lack of barring. The more focus that gets placed on barring, the more the industry will grow to care about its correct implementation. Eventually, the focus on barring will lead to a decrease in the occurrence of FOG incidents, accidents and fatalities.

The research project has identified system deficiencies from historical barring accidents and the innovative training material that is developed addresses in various manners the top three causes for these barring accidents being inadequate leadership skills, inadequate training initiatives and the habits and behaviour of the workforce. The extensive field data collection phase identified the existence and practice of leading actions that support the safe act of barring. The have been discussed extensively with source mines being identified for some of the leading practices. Barring and Entry examination are a subset of the MOSH FOG leading practice and there are many ways to aid in the practice of successful barring that were identified by this research.

The feasible implementation solutions for the key identified areas are numerous and mining personnel will need to peruse and decide even within this list what would be best for their own working environments. There is much work being done for barring in the industry in isolation of one another and this study has successfully attempted to collate and identify the best solutions to the age old problem. Whilst it may be perceived that innovative training material is the only new outcome, the social study gives detailed information on the perceptions of the mine workers at the various mining houses and the common themes give insight to the South African mining workforce .

Because this study is comprised of sixteen separate milestones, some of the interim reports may not appear to draw any new conclusions related to barring, but overall the study has combined together raw accident data from the DMR SAMRASS database and the relevant accident reports to carry out root cause analysis of barring related accidents. This information has been combined together with the research on the social aspects and mining employee beliefs and understanding of the barring process, to provide a thorough and comprehensive study of the subject. The number of champion mines visited as part of this project is large, as is the number of shifts spent underground, so it is felt that this research is representative of the whole of the South African mining industry.

This final report is considered as a definitive study on barring and associated perceptions at the champion mines. The behavioural factors relating to barring accidents have been discussed from a social standpoint however the psychology behind these behaviours and attitudes require further investigation by means of psychometric testing.

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