A Study of the Risky Positioning Behaviour of Operators of Remote Control Mining Equipment

By CJ Pitzer

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Abstract

This study investigates the risky positioning behaviour of underground coal mine employees, specifically the behaviour of drivers of remote controlled continuous miners. The patterns of behaviour of these employees are of particular interest, not only because of a series of fatal accidents in New South Wales coal mines with such equipment, but also because of the lack of scientific enquiry of risk-taking behaviours of coal miners in Australia in general.

The study was done at eight underground coal mines, where the standard operating procedures of those mines were used to assess the degree of compliance with the procedures on each mine. Possible causal factors for such risky positioning are also identified and analysed in this report. Generally, for some routine tasks, the level of compliance was found to be quite high, while for other non-routine tasks, compliance was found to be extremely low in some cases.

Importantly, it was found that knowledge of, and employees inclination to, comply with procedures played only a limited role in employees decisions on where to stand, and the effectiveness of such procedures is doubtful. Risk-taking played a significant role in the behaviour of employees, with safety considerations only a tertiary consideration for their positioning decisions. The study outlines areas of future research, proposed as phases 2 and 3 of the research project.

1. Introduction

One of the biggest dangers for underground coal miners occurs near the coalface where cutting operations take place. The roof and rib (sidewalls) of these areas are often unstable, and the nature of their work puts underground operators in close proximity to these risky conditions. Staying within supported and safe areas is crucial for operators' safety.
The use of large equipment, such as continuous miners and shuttle cars, add a significant degree of risk, as underground miners constantly have to position themselves close to moving equipment in confined spaces in circumstances of very poor visibility and poor environmental conditions. Add to this contributing factor such as fatigue, lack of awareness and work pressures, and the compounded effect can create conditions that are extremely prone to accidents. All of these conditions may exist for any length of time without any accident occurring, even at extremely acute levels - but some coincidence may trigger an accident at any time. Of particular significance is the fact that miners spend many hours underground, observing these conditions, without any accident occurring. They may, for example, never see an unplanned movement of a continuous miner and then logically conclude that such an event is "practically impossible".

This study investigates the positioning behaviour of drivers of remotely controlled continuous miners. The past two decades have seen a continuing emphasis on the remote operation of mining equipment. The benefits are obvious, namely that operators, who used to sit in a protected canopy on the miner, are now able to position themselves in supported roof areas all the time and at the same time achieve better observation of the task at hand. This has led to significant improvements in productivity and ease of performing the tasks. The remote position of the driver also reduces the fatigue and discomfort associated with the manual operation of the equipment, where severe vibrations, movement, shocks and dust used to contribute to extreme discomfort of the driver.

Over a period of time, several fatal or serious accidents occurred in New South Wales with the operation of remote mining equipment, and concerns are evolving as to whether the remote equipment is in fact safer to operate, and how fatal accidents with these types of machines can be eliminated.

The positions that operators take up vary constantly, depending on the type of operation, type of machinery and stage of the task, and are determined by a variety of factors - such as visibility, perception of the danger, ventilation and even the habits of the particular operator.

2. Significance

The study offers significant opportunities for broadening our knowledge of risky positioning behaviour and of the causal factors. It will assist in deriving practical guidelines and protocols for future procedures and the training of operators. It is especially of significance, given that the environment in which this behaviour occurs is extremely dangerous and such behaviour could be potentially fatal.

Overall, this study can make a significant contribution towards the theoretical concept of risk-taking behaviour - a phenomenon about which relatively little is known in the context of mining. The operators are often well informed of the fact that their behaviours are risky, even life threatening in some observed cases, and they still compromise their personal safety to make gains. These "gains" are not necessarily production performance (although most of it is), but could be simply gains of comfort, for example to limit movement during periods of tiredness. This study will attempt to put observed behaviours in the broader context of risk-taking behaviours.

3. Design of Research Project

The study is divided into two phases, with a possibility of extending into a third phase.
Phase 1 focuses on the measurement and mapping of risky positioning behaviour, and the identification of possible causal factors at 8 underground coal mines in New South Wales.

Phase 2 is an assessment of the positioning behaviour at a further 20 mines, to asses all possible variants of such behaviour, and to conduct a comprehensive assessment and analysis of the causal factors identified in phase 1.

Phase 3 provides an opportunity to extrapolate the findings of this study into a broader theoretical model of risk-taking behaviour and to consider an industry wide survey of that phenomenon.
This report is on Phase 1 of the study only.

4. Aims of the Study

The aim of the study is twofold:

(a) To measure the extent to which mining operators and personnel enter so-called "no standing zones" at underground coal mines in New South Wales.

The measurement of this risky positioning behaviour (RPB) was done by assessing the relevant guidelines (MDG 5002), in-company procedures, policies and guidelines, and, through work sampling ,observation and mapping, determining the percentage of time that people enter or adhere to no standing zones. These observations were done for the duration of shifts and for different activities.

(b) To assess and analyse possible causal factors why operators and personnel enter those "no standing zones".

The assessment determined the range of possible reasons why this risky positioning would occur. A number of possibilities were explored through targeted interviews, with the aim of finding out whether risky positioning is related to one, some or all of the following "causal factors":

Information processing needs (to complete tasks, the positioning behaviour might be influenced by a variety of information needs of the operator, or on their assessment that the no standing zones are
inappropriate)

Motivational issues, such as incentives for risky positioning

Risk awareness deficiencies, where operators may be unaware of the risk associated with the positioning behaviour

Risk tolerance/ignorance, where operators may at some stage have been aware of the risks, but because of their personal experience of "no consequences" over a period of time, have started to ignore the risks

Risk assessment skills, where operators may underestimate the likelihood and/or potential consequences of the risks

5. Similar Research

A similar study in the U.S.A., conducted by A.C. Love and R.E. Randolph of the US Bureau of Mines (USBM) preceded this study in 1992. This study should not be considered a duplication of the USBM study, for several reasons:

- The USBM study only focused on the quantification of risky positioning behaviour
- The specific procedures governing these activities were not compared
- The USBM study was conducted at 35 mines, while the NSW study could only be done at 8 mines
- The NSW study is considered to be an initial assessment, with the aim of extending the study to other coal mines in NSW, in order to conduct a comprehensive study of the phenomenon of risk-taking behaviour.

6. Definitions of "No Standing Zones"

A demarcation of so-called "standing" and "no standing zones" is made to define areas where the operators of these machines may stand and not stand while operating the equipment. These definitions are based on the guidelines of the Department of Mineral Resources, as described by MDG 5002. The guidelines state:

"A control zone is specifically related to continuous miner operations and is a designated area where people can pass or work when the continuous miner is operational or energised."

"A no standing zone is specifically related to continuous miner operations and is an area where people can not pass or work unless appropriate isolation procedures for the continuous miner have been carried out"

The MDG 5002 guidelines also state that an Operator should give consideration to the factors listed below when selecting a position (MDG 5002, page 26).

The list is not exhaustive and other issues may need identifying, depending on the particular work environment control zones, the operator needs to consider the following when selecting a position from which to remotely operate a continuous miner:

- Location of the last row of roof bolt support - operators are to remain under supported roof at all times.
- Location of the ventilation ducting or brattice - operators are to remain clear of airborne dust generated by production operations.
- Cutting sequence (breakaway, straight drivage) - operators are to position themselves safely to maximise vision of the operation and to ensure they are clear of shuttle cars during loading and clear of miner pinch points. The miner operator must at all times communicate to shuttle car drivers when changing operating positions.
- The best operator view of all other personnel and equipment during flitting.
- When holing into a heading or cut through, 'No Road' signs are to be installed

7. Sampling and Management of the Study

A total of 10 coal mines in New South Wales were visited between December 1999 and January 2000, two mines for an initial assessment and 8 mines for the study. These mines were selected to represent the four areas of coal mining in New South Wales, namely:

- The Western Coalfields
- The Hunter Coalfields
- The Southern Coalfields
- The Newcastle Coalfields

The author arranged visits to each of the mines, and accompanied mining crews for the duration of their shifts. The crews were asked to operate the equipment in the ways that they would normally do it, and with the exception of one operator, all were expressly eager to demonstrate the "practical" ways of operation as against the "unpractical" or "letter of-the-law" ways of operation.

The crews were specifically told that the author wished to investigate the extent to which "no standing zones" could be practically implemented. The author believes that the operators and mine managements did little to "dress up" the operations to appear more compliant. (Several mine managers were eager to obtain feedback on this investigation.)

It was often found that operators have such limited knowledge of the exact definitions of "no standing zones" that they would find it difficult to act compliant simply for the benefit of the study.

8. Limitations of the Study

The main factors that can influence the validity of the findings of this study are:

The "observation effect" of employees who are clearly aware that an observer is present - who will be watching their every move during the shift. Most of the crews had some idea of the scope and intention of the study. This effect was largely overcome by the approach followed at each mine, namely to indicate to workers that the author was there to "observe the general practicality" of positioning procedures and not to assess compliance. Most employees were then eager to demonstrate the "normal ways of work when no one is around".

Only eight mines were part of the study and generalisations about trends in the underground coal-mining sector can clearly not be made. It should be remembered throughout that the study at this stage represents findings on the participating mines *only,* and should therefore be interpreted carefully. It is however felt that sufficient information was gathered to support a broader study and to make some conclusions about potentially risky circumstances at mines.

9. Method

A total of 40 employees were observed during the study, including some deputies, while 14 drivers of continuous miners were observed and interviewed, sharing a variety of tasks as listed below. Of the 40 employees, thirty-six were also interviewed.

The drivers' (and other personnel) positions were plotted on a chart. Observations were done throughout the whole shift, and notes were taken intermittently. The completion of at least 7 observation periods of 5 minutes each in every hour was attempted. The rest of the time was utilised to conduct interviews of operators, as they became available during slow times. The observations were recorded on sheets of paper, roughly one sheet for every hour, including a description of the main activities undertaken during that period. During each part of the task, it was observed how long an operator would be positioned in a no standing zone, and at the end of each hour, the proportion of that hour in which operators worked/positioned themselves in a no standing zone was calculated.

The stages of the mining cycle were also closely monitored, namely cutting, tramming and loading of the shuttle car.

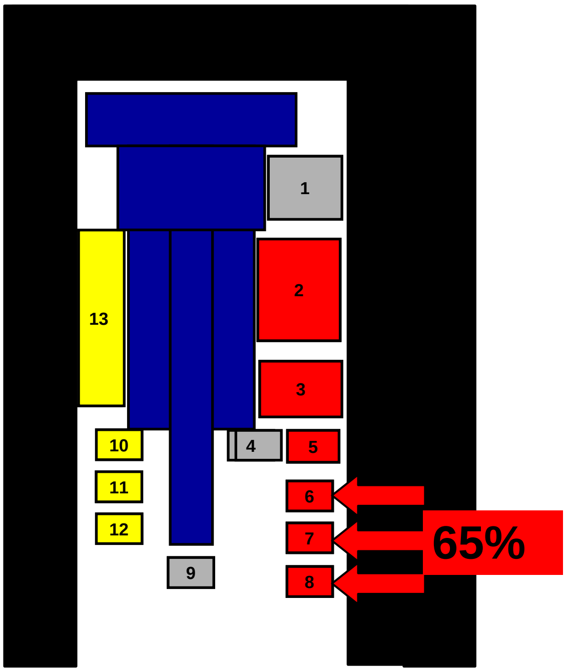
Each mine was asked to provide their Standard Operating Procedures that govern the positioning zones of personnel around Continuous Miners. It was found that these procedures were fairly consistent between the various mines, for the same type of equipment. The procedures would obviously differ substantially for, say, a Joy 12 Continuous Miner 11 narrow head cutter and an ABM 20 machine. The mines' own SOP's were used to do the assessments of operators' positioning behaviour on the mine concerned.

The following tasks were observed:

- Non routine maintenance work, such as repairs to the mechanical equipment of the Continuous Miner, such as fitting a repaired gearbox and repairs to the hydraulic lines of the roof bolter rigs)

The task that was most consistently observed was the one of Cutting Straight ahead with a miner - a total of six observations.
The various positions taken up by drivers are shown on the diagram below:

Figure 1: Standing positions of miners



Cutting straight ahead with a narrow head Continuous Miner – three observations (double pass cycles)

- Cutting straight ahead with a wide head Continuous Miner - three observations (of which one was a double pass cycle)
- Cutting a Breakaway left – one observation
- Cutting right during lifting operations - one observation

Loading of shuttle cars as part of the Straight Ahead Cutting with Wide Head Continuous Miner

Notes:

During the first pass, positions 1, 9 -13 would in most mines' SOP's be indicated as a no standing zone. During the second pass, at some mines positions 1 - 8 and 9 would become a no standing zone, while at others only positions 1 - 4 become a no standing zone.

Most drivers indicated position 2 as the best position from an operational and a safety perspective, because it places them closer to the cutter for better visibility and "feel" and in a safe zone should the Continuous Miner swivel. However, drivers tended to abandon this position when ventilation in that area was poor, and compromise both line of sight and safety considerations.

Most drivers and other employees indicated position 3 to be the most dangerous of all because this represented a pinch point should the Continuous Miner swivel. Despite that, it was still a position taken up fairly regularly, especially if this represented the best-ventilated area. Less consideration was given to the danger associated with this position with wide head Continuous Miners, as there would be more space between the Continuous Miner and the rib and drivers took the position up more frequently in those circumstances.
While most mines SOP's indicate position 4 to be a no standing zone, most employees, including most deputies, interviewed indicated this position to be relatively safe. The reason for this is obvious, namely that the clearance between the boom (conveyor) and the rib is larger. However, this position was seldom taken up, because the driver's line of sight would be compromised and drivers are wary of the risk of being by the shuttle car in that position, especially when the shuttle car driver is on the Continuous Miner driver's off side.

Position 5 was especially preferred during the loading cycle, because it gives the driver a good line of sight on the quantity of coal that enters the shuttle car and how to distribute the coal around. Most experienced shuttle car drivers move the shuttle car around, which makes it easier for the driver.

A minority of the drivers observed, seemingly the more skilful and experienced drivers, took up positions 7 and 8 frequently.

Position 9 would be defined as a no standing zone at most mines, but is still a position that drivers sometimes takes up to align the Continuous Miner according to the laser marks on the coal face. This activity is required fairly regularly and would be a main reason why drivers enter no standing zones.

During the first pass, positions 10 - 13 are on most mines a no standing zone. During the second pass, most mines define those positions as standing zones, while positions 1 - 8 then becomes no standing zones. Some mines retain position 5 as standing zone during the second pass.

10. Findings on Positioning Behaviour

Observation and Findings of Cutting Straight Ahead task

Drivers would place themselves on the side where ventilation ducts and the cables are set up. For the purposes of this report, the right hand side set-up was selected as the norm, and where a mine had the set-up on the left hand side, the results are "mirrored" to the right hand side, to make comparisons possible.

Positions 2, 3 and 5 were the most popular positions for drivers to take up. Most drivers had a preferred position and tended to remain in that position. The overall percentages of time that drivers were in these positions were:

- Position 2: 20%
- Position 3: 25%
- Position 5: 20%

Some drivers would leave their positions more frequently than others to attend to a variety of tasks, for example, when tramming the Continuous Miner, or during loading operation, when some miners would take up positions 6 or 7. In those circumstances the position of the driver and of the cable hands varied significantly, and could be considered the most risky part of the mining cycle. Drivers showed definite awareness of the movement of the Continuous Miner, but would be willing to position themselves much closer to the Continuous Miner, and in the pinch point position (at the rear corner of the miner)

The situation changed significantly when the second pass was taken and at most mines these positions, as well as 6,7 and 8 became no standing zones. It was found that most drivers would continue to position themselves on the same side, and more frequently take up positions 6, 7 or 8, and therefore be standing in a no standing zone for most part of that operation. These are also the positions more frequently taken up when the Continuous Miner is beyond the last row of roof bolts.

Some drivers were able to effectively operate the Continuous Miner from positions 6, 7 and 8 for the duration of the tasks and only change their positions infrequently. The author's opinion is that these positions are much better than operating on the side of the machine, as the drivers are only at risk during loading cycles, and the risk is then confined to, primarily, falling rocks from the shuttle car or the shuttle car itself. However, the exposure (time of being exposed to the risk) is significantly lower than the exposure in positions 2 or 3, as well as the possible consequences of the risk (although the author is not able to speculate on the likelihood of the risks).

The above situation differed significantly for wide head miners doing a single pass. The observations were however too small to make generalisations about the positioning behaviour of drivers. Drivers of the larger ABM Miners, where all operators stand on top of the Continuous Miner on platforms, are most of the time in a standing zone, except when getting on and off the Continuous Miner. In some cases, the SOP for these larger Miners state that only the platforms are standing zones and that ascending or descending the Continuous Miner must be done only when the Continuous Miner is not operational (energised). This happened very seldom and it was estimated that operators would go through the no standing zone, for whatever reason, some 10% of the time. During cutting operations, drivers were positioned in standing zones for 82% of the time when doing the first pass. The 18% of time they positioned themselves in no standing zones were mostly during tramming of the Continuous Miner, or when the driver stands behind the conveyor to align the direction of the Continuous Miner. On the mines where the SOP indicate that the "first pass" positions become no standing zones during the second pass, this percentage of time in the standing zone reduced significantly to approximately 35%.

Observation and Findings of "Other Tasks"

Flitting operations

At all the mines visited, the areas between the sides of the Miners and rib are declared no standing zones for flitting in drives, and the areas in front of and to the rear of the Continuous Miner (varying between 2m and 5m, depending on the direction of travel, and whether flitting is done an open or closed drive) are no standing zones.

Operational practices differ quite significantly between the mines. For example, tying the cables in loops to the booms as the Continuous Miner is flitted backwards, and progressively untying the cable when the Continuous Miner is flitted forward, is permitted on some mines, and on others the practice is prohibited (and winders or shuttle cars are used to move the cables.) Where the practice is allowed, operators may then only approach the Continuous Miner while it is not operational. This would require the Continuous Miner to be fully isolated each time it stops and cables to be loaded on the platform, or tied to the boom.

Precise quantification of the positioning behaviour of the drivers for this task is not possible, because of the small number of observations and the varying practices. However, strong indications are that this task exposes operators to considerable risk. Drivers positioned themselves on average approximately 55% of the time in a no standing zone -either on the side of the Continuous Miner or within the 2-meter distance from the rear or front of the Continuous Miner.

However in one case the positioning of the driver in a no standing zone was as low as 25% of the time, but in another, approximately 75% of the time. Similarly, the operators handling cables were in one case more than 80% of the time in a no standing zone because of the practice of loading cables onto the Continuous

Miner while it is being flitted in the drive, and in another, the practice of tying cables to the boom (with the Continuous Miner fully energised) resulted in the operators positioned in a no standing zone for about 15% of the time. (During one of the observed cases, the Continuous Miner swivelled dangerously and hit the rib violently. The driver had been positioned right at that pinch point only seconds before. The driver did not show any visible reaction to this and continued to position himself around the moving Continuous Miner in the same positions as he did before the impact.)

It is suspected that the flitting operation at most mines often puts workers routinely in a risky position and that this operation should be considered as extremely accident-prone.

Routine maintenance of the Continuous Miner

Routine maintenance of the Continuous Miner requires mostly that the machine is isolated by switching off the remote transmitter and the main isolator is switched off and tagged out (procedures vary somewhat). This is to allow access to the Continuous Miner and enables entry into no standing zones.

In all three observed cases of power filling the machine with hydraulic oil (and in most other cases on other mines where the "practical procedure" was described to the author), the correct procedure was not followed. In most cases, the machine is not correctly isolated and in one case, the filling was done with the machine fully energised and operational, <u>during</u> roofbolting operations. In another, the Continuous Miner was fully operational and operated with the transmitter, while one operator was on top of the machine, on the conveyor and while the Continuous Miner was trammed (even though only for a few meters).

Cutting breakaways or lifting off operations

Other tasks observed such as cutting breakaways or during lifting off created many more variable situations because of the continuous changes of the Continuous Miners angles and positions, which require more changes in the position of the driver. It was then observed that drivers would position themselves closer to the Continuous Miner itself, in the confined spaces between the rib and the machine, significantly increasing the extent to which they stand in no standing zones. Because of a heightened exposure to unsupported roof, the drivers seemed less concerned with the risk presented by the Continuous Miner itself, and focused more on the roof conditions. During one observation of lifting off operation, indications are that drivers walk "frequently" under unsupported roof during the final stages of the operation, and are significantly exposed to roof falls.

Other risky behaviours observed, related to no standing zones

Among the most dangerous actions observed were:

An operator was using the cutter head as a work platform. He was standing between the picks on the drum to reach roof bolts to which water cables were tied. The Continuous Miner was operational at the time and the transmitter placed on the machine itself, while the driver was attending to other tasks. Falling from that position would have had very serious consequences, while a coincidental start-up of the head could have been fatal.

An engineer entered the work area and proceeded to make adjustments to a part of the Continuous Miner, while the driver was busy tramming the Continuous Miner forwards and backwards and proceeded with the next pass.

An operator walked on the conveyor to lift the drums of oil onto the Continuous Miner, while the machine was operational and moments prior to being trammed. The driver trammed the machine with the operator sitting on top of the conveyor waiting for the drums to be brought in by another operator.

A fitter carried out repair work on a roof bolting rig and was positioned between the shovel and the roof bolt rigs, carrying out mechanical repairs. The remote transmitter was used periodically to align mechanical pieces up for the fitter.

Changing picks on the Continuous Miner head was observed on three occasions. Only once was the Continuous Miner correctly isolated while the task was performed (and the deputy and a helper used their body weights to turn the head over). In other cases, flicking the head was done with the transmitter, while the operators were positioned within one meter of the head. It is suspected that this task is typically performed by only one person, and that behaviours generally would be close to what was observed during this study.

11. Conclusions and Discussion on Positioning Behaviour

The positioning of operators during straight ahead cutting operations seem fairly consistently compliant to the requirements. Indications are that this is significantly less so for cutting breakaways and lifting off operations

Drivers of Continuous Miners tend to select their positions primarily for line of sight, then comfort, then out of habit and only then in terms of their perception of the danger. Rarely did drivers report that the position was selected because it was indicated as the "correct" (standing zone) position. (See discussion in Section 12)

The flitting operations showed significant deviations from mines' procedures dealing with the no standing zones. It is potentially also one of the operations where accidents are most likely and it is recommended that special emphasis be placed on this aspect during the second phase of the study and when guidelines for this type of task are considered in the future.

During tramming of the Continuous Miner, the drivers would continuously vary their own positions to maintain an optimal line of sight to manoeuvre the Continuous Miner, and would be considerably less concerned with their own safety. Under these circumstances, most drivers would significantly increase the rate with which they check the roof and their position relative to the last row of roof bolts. It seemed however a "classic" case of risk homeostasis, where the introduction of one risk (the potential of roof fall) reduces a person's awareness of another risk (being struck by the Continuous Miner) - as if the persons are not "able" to be effectively aware of two or more risks simultaneously.

There seem to be adequate control of positioning during "normal" mining activities, such as described above for cutting tasks. It became apparent during the visits to the mines that risk-taking during non-routine activities may sharply increase. This was noted during several instances of breakdowns, trip outs and production delays. For example, behaviours such as failure to perform correct isolation and start-up procedures of machinery seemed to occur readily and employees take action more hastily to ensure that delays are minimised.

12. Findings on Possible Causal Factors

Possible causal factors cannot be quantified in any way as a result of this study, as it only set out to identify possible causal factors for further research in Phase 2 of the project.

The following issues are discussed for purposes of clarification.

Drivers' reasons for position selection

All observed drivers were questioned on the reasons they selected the standing positions they did. Most found the question very difficult to answer at first. The following rank order was obtained, by collating all the responses:

Reason	Percent
Optimal line of sight	100
Comfort	78
Used to do it	57
Least dangerous position	42
Because it is a standing zone	7

It is disturbing that only one person referred to the requirements of being positioned in a standing zone, and even this response is suspected to have been made because of the person's eagerness to appear compliant.

Only six persons mentioned the actual risk as a consideration when selecting a position, while a surprisingly high number selected positions out of "habit". For example, drivers were observed to constantly take up different positions, but then cite the reasons as above. This was especially noticeable when drivers changed turns on operating the Continuous Miner, when the second driver would regularly take up a different position from the driver before, but then state the same reasons for his positioning as the previous driver.

Also, it was evident on several occasions that drivers would compromise their better position for visibility (position 2) for a position where the ventilation is better (position 3, 5 or 6) even though they ranked these two considerations differently when asked about it, as shown above.

Drivers' perception of risk

Drivers were questioned on a rank order of risk in their work. Other operators and deputies were also questioned, and a remarkable degree of congruence was found.

The following rank order was arrived at after collating all the individual rank orders provided by the drivers and operators.

Risk	Rank
Rib spall	1
Roof fall	2
Hit by the shuttle car	3
Struck by Miner	4
Hit by loose rock	5

In all cases observed, the standing zones placed the driver against the rib, rather than against the Continuous Miner. In most cases, operators could not resolve the "discrepancy" of standing continuously closer to what they themselves perceive as the bigger danger, namely rib spall.

It also raised the question of whether strict adherences to no standing zones are in fact the "least risky". For example, at some mines, workers interpreted (incorrectly) that the standing zone is towards the rear end of the miner, but indicated a strong preference for the standing position to be near the middle of the miner (again to be outside the pinch points of the machine). The mine's SOP permitted any position from the rear end to the front end behind the head, creating an impression of equal risk, which it clearly isn't.

A second question being raised is, accordingly, whether some standing zones could have a significantly higher risk (to be positioned in) than no standing zones. The definition of no standing zones may be a result of some fatal accidents in the industry, while on a particular mine the actual risk of a potential fatal accident as a result of, say rib spall, or a shuttle car slipping sideways because of poor floor conditions, could be higher in real terms.

Operators develop a highly individual perception of risk, and very little of this is in any way realistic in probability terms. Each person's concept of what is risky may differ significantly from the next person; based on the "amount of information" the person has about the likelihood of an accident. For example, many operators questioned had only heard of "unplanned movements" of the Continuous Miner once or twice over the last 10 years, had seen only a few serious roof falls over the same period, yet continuously observe rib spall several times a week large enough to seriously injure someone. They will naturally tend to position themselves closer to the Continuous Miner itself rather than to perceived poor or suspect rib. Additionally, drivers believe this to be less risky because they are "in control of the Continuous Miner, but not in control of the rib". No standing zone procedures may not adequately into account take the risk of rib spall.

13. Conclusions and Discussion on Possible Causal factors

Conscious Risk-Taking of mining, employees seem aware of the tendency to take risks, even potentially fatal ones. The majority of employees questioned indicated that they routinely enter dangerous work areas, such as under unsupported roof. Some gave accounts of performing maintenance work on equipment after breakdowns occurred on the Continuous Miner under unsupported roof areas, without creating temporary support, and with the knowledge of supervisors. An operator described an action that he would routinely take, namely to sit on the Continuous Miner, near the light tower, while operating the machine, even though this position is for long periods of time under unsupported roof. He does this in areas where the rib conditions are particularly poor and continuously cave in. His assessment was that "if the roof is good and the rib is bad, the choice is simple".

Knowledge of "No standing zones"

The majority of drivers and operators had only a limited idea of the definitions of no standing zones, as they pertain to the equipment they operated. Without exception drivers were in one way or another deficient in their knowledge, and in a disturbingly high number of cases, their knowledge was seriously limited.

However, all were quite aware of the "most risky positions" around the Continuous Miner, namely at the pinch points (the rear corners of the Continuous Miner) and were seemingly somewhat aware of those positions during normal cutting operations (the situation was quite different during flitting operations). Interestingly, only one of the mines' procedures showed the corner of the Continuous Miner as a specific pinch point, by, for example, extending the no standing zone in an "arch" around that point, as illustrated by the MDG 5002 guidelines. Even though this arched no standing zone was originally done because this mine's Continuous Miner was fitted with a hydraulic arm for the purposes of managing the cables, the idea of an arched no standing zone around that pinch point nevertheless seems a good one.

Awareness of rib spall

Almost without exception, operators were very aware of rib conditions, and seemed to take some precautions in relation to it when they positioned themselves. Several "tests" were conducted by the author, mainly to identify an area of poor rib (and roof) conditions and to question workers about "where in this area are the physical (rib/roof) conditions potentially dangerous". In a high number of cases, workers would be able to point these conditions out with ease and accuracy.

Physical Fitness

The issue of operators' general fitness may be one that is seriously underestimated in the whole complexity of risk-taking behaviour. It was observed during the shifts that workers body movements appeared to be slightly slower and appearing visibly more tired towards the latter half of the 8 hour shift. This resulted in a considerable degree of "economic activity" where workers would (subconsciously) minimise the physical demands of tasks - resulting possibly in a higher inclination to take risks. This was observed during rib bolting operations, where workers would readily stand under unsupported roof, to stretch wire mesh out past the last row of roof bolts where, during earlier parts of the shift, they were inclined to stand under supported roof and "lean" out and forward - putting the body under more strain.

Motivation to take risks

As mentioned, operators seemed well aware of most risks in their environment, yet would often take those risks intentionally. The motivation for doing so could only be investigated to a limited extent, because workers tended to become defensive when questioned about it.

It was however clear that pressure to get the job done, even though not overtly demanded or stated by the company, plays a significant role in operators' willingness to take risks. The "pressures to get jobs done" are built into the very fabric of the organisation (in any organisation) and the behaviours of managers and deputies. Employees produce the behaviours to make the production calls possible. It is a "best fit" model of behaviours in the organisation where organisational demands are traded off with productive behaviours of workers. The productive behaviours may or may not be very safe ones, and it is suspected that managers and deputies are often aware of the extent of the risky behaviours, but have limited choices as to what they can do about it.

A second strong motivation to take risks, and often not easily distinguished from taking risks to satisfy production demands, is an inclination with workers to expend the "least amount of energy". For example, the risky behaviours during flitting operations are adopted both to complete the task as soon as possible, and to limit the effort of pulling cables manually or having to isolate the Continuous Miner every few meters to be able to gain access to the no standing zone. The reality is that the task simply won't be done in the "correct way", no matter how strict the supervision of that task is. A clever alternative will have to be developed to reduce the risks associated with this task.

Risk ignorance/tolerance

The complex issue of risk ignorance or risk tolerance clearly plays a role in the overall risky behaviours of operators. This topic cannot be adequately addressed in this paper, but must form part of any follow-up to this study and of efforts by industry stakeholders to improve the safety of coal mines.

One of the most significant examples of this issue is operators' perception of the risk of roof fall. Most drivers questioned indicated that they have personally experienced roof falls, or were present when a roof fall caused serious injury and in some cases death of fellow workers. The majority of operators admitted to the author that they enter into unsupported roof areas, for a variety of reasons -mostly to perform short tasks on the Continuous Miner after breakdowns or trip outs. Yet most operators ranked roof fall has the biggest danger in their work environments.

Furthermore, most operators were quite aware of the condition of the roof and very skilled at identifying potential roof falls. However almost every operator interviewed remarked: "It is the good roof that gets you!" and then stated that before they did enter an unsupported roof area, they would first make sure that the roof is "good enough" to do so - apparently oblivious of the paradox of the action. (One deputy expressed the view that roof bolting is largely "cosmetic", because if the roof falls, it will do so despite the roof bolts.)

This is related to the complex issue of "exposure" of the individual, and the influence on his/her risk perception, as against the quantification of that risk in probability terms. A single person can work in a particular environment for extremely long periods e.g. 20 years underground and his individual exposure is only a fraction of the "required exposure" (in statistical terms) necessary for him to make a valid judgement of the actual risk. Naturally someone would conclude that the risk is low or even negligible.

For example, a person driving from home to work over 30 years, say a distance of 100 km a day, would spend approximately 5000 hours on that road. Statistically, it is required to observe that condition for 1 million hours to make judgments on the actual risk with a confidence level of 95%.

This suggests that even the most experienced mine worker never achieves a level of "statistically sufficient exposure" to risks, to make an accurate judgement of those risks. Yet the "accident experience" of each person largely influences his "personal data base" about his own risk exposure.

It was the author's assessment that the operators are seldom *not* aware of the risks, but would often underestimate or tolerate them.
This phenomenon often occurs in high-risk environments, where a belief develops over time that risks are under control, because of an over-confident reliance on procedures, controls and back-up safety systems. It is for the same reason that mine disasters often happen in organisations where good safety management apparently exists

Risk-takers' behavioural profile - External sources of risky behaviours

It is often speculated that the risk-taking personality of some employees plays a significant role in the occurrence of accidents. This "hypothesis" has however received very little support in scientific literature and it is a notion generally discarded in behavioural science circles. The reason for this primarily is that the studies almost exclusively attempt to correlate "risk-taking personalities" with the accident rates and therein lies the flaw: Accident data (rates or actual numbers) are statistically too weak to be able to make this kind of analysis. (In simpler terms, so-called "risk-takers" may take many risks and not be involved in accidents, while risk-avoiders may only take one risk once, and be involved in an accident, simply because the "risk-taker" is skilled in taking risk and the risk-avoider is not.

Risk-takers may therefore be totally under-represented - and probably are -in accident rates and risk-avoiders over-represented. The true variable here is risk-taking behaviour and not accident rates, which are unfortunately very difficult, if not impossible, to measure. Another flaw with most of these studies lies in the generally poor reliability and validity of psychometric tests used to measure the "risk-taking personality".

However, during the study the author observed events that suggest there may be some substance to the whole notion of the risk-taking personality being more involved in risk-taking behaviour, which may warrant further research. It was, for instance, observed that certain workers who more regularly breach general rules of safety in the underground work environment are the same workers who more readily described risky behaviours in themselves and others, and generally tend to be the ones who stated that they would "routinely" go under unsupported roof. These workers were also noticeably less compliant about wearing required personal protective equipment.

Poor placement of trip/isolation switches can contribute to drivers being "forced" into an unsupported roof area, such as was identified on some Continuous Miners, where a trip switch was hit by a piece of coal and tripped the machine out. A worker would quickly enter the area to energise the Continuous Miner again. (Poor placement of isolation switches can also contribute to workers general unwillingness to mechanically isolate the machine, simply because of the inconvenience of doing so.) A particular machine was pointed out where the task of isolation could certainly be regarded as cumbersome. When faced with a choice of a certainty of an uncomfortable task and a remote possibility of a danger, workers are inclined not to be too concerned by the latter.

Breakdowns on the Continuous Miner during the cutting operation often lead to operators entering no standing zones. Several operators expressed the opinion (and recollected their own actions) that workers would "routinely" go past the last row of roof bolts. The reasons are mostly operational. At one mine, the Continuous Miner tripped out three times, twice while under an unsupported roof, and each time the driver quickly stepped forward to flick the mechanical switch to energise the machine. The position of the mechanical trip switch on the Continuous Miner itself may be reconsidered or a trip switch with an automatic reset function could be used, because if this situation occurs routinely, workers will continue to act in a way to save time and expend the least amount of energy - and enter the dangerous area.

Behaviour of cable hands and maintenance staff

The behaviour of drivers of Continuous Miners, as indicated above are fairly compliant during cutting operations and, as mentioned earlier, drivers are well skilled in identifying risks in their environment when asked to. The same could not be said of other operators such as cable hands and especially maintenance staff.

It was observed that maintenance workers would more readily enter no standing zones, perform tasks in the close proximity of the Continuous Miner while operational and perform other maintenance work without proper isolation. The author observed such actions as energising a Continuous Miner and operating it without removing any of the fitted danger tags, starting servicing tasks on the Continuous Miner while it was still being operated by the driver, wandering into no standing zones routinely, walking under unsupported roof areas to try and locate an unusual sound from the cutter head during the cutting process, etc.

It is the author's opinion that the unusual, non-routine periods of operations around the Continuous Miner create the higher level of risks and potential for serious accidents. These include the flitting task, maintenance work and during breakdowns. It is suspected that the lack of clear guidelines/procedures and especially training in the risks of these activities result in operators underestimating or even overlooking the dangers.

More guidelines and/or procedures may not be very effective in dealing with this issue. It was noted for instance that there was little observable difference in risky behaviours between operators of mines where an abundance of procedures are issued and mines where procedures are hardly available or known to the operators.

The behaviour of drivers and helpers when the machine was not operating (but still energised) seem to be quite risky, such as walking underneath a raised boom. When questioned, most expressed the view that an accident in these circumstances is "extremely remote or practically impossible". The general awareness of risks associated with booms are quite low, even though most operators agreed that movement of the boom and striking a person is at least as possible as the other risks of which they are more aware of the likelihood and consequences of possible accidents.

Operator behaviour near the shuttle cars shows a high bevel of risk acceptance/tolerance. It is clear that operators are aware of the risk (and ranked that risk as higher than being injured by the Continuous Miner), but they seem to position themselves fairly close to the shuttle cars' line of operation. Workers described the risks of shuttle cars as:

- Large coal pieces falling from the loaded shuttle car, and striking a worker.
- Being hit by a shuttle cars' sudden sideways movement when pulling away and sliding off a gradient on the floor.
- Being hit by a shuttle car in the event of a mechanical failure, such as a steering rod (in one case, this possibility was dramatically demonstrated when a broken steering rod caused a shuttle car tocrash into the side wall).

Perceptions of rules and procedures

Most employees interviewed were asked about their perceptions of safety procedures, managers' rules and standard operating procedures. Most employees (above 90% of all those interviewed) expressed misgivings, doubt and outright criticism of the value of these procedures. A very popular expression is that any mine "that operates 100% within the rules will not produce a single tonne of coal." Employees make a clear distinction between operating within the rules and operating "as normal" - a term which clearly refers to doing task in the quickest possible way(s) and with minimum compliance. Several of the procedures that were demonstrated to the author were, if followed meticulously, downright impractical and extremely cumbersome -although the safety benefits are tangible and obvious, even to the operators themselves. The issue is not whether the rules are practical or not, or whether the rules should simply be followed or not. A more serious issue is that possibly the large majority of employees (including deputies/supervisors) operate dangerous machinery every day in underground (and other?) mines with a basic disposition that safety rules are "irrelevant, superfluous, non-essential or excessive." If this is the case, an important resource for limiting the risky behaviours of employees is critically deficient.

Routine risk-taking

Miners, and employees in general, develop certain fixed patterns of task execution, based on a "best fit" compromise between required task sequences and practical circumstances. These patterns, if they include risk-taking and other deviations from the ideal sequences, become the basis for behaviours, and importantly, employees perform these tasks often with little conscious thought about steps or possible consequences of the task. These routine behaviours are often what are referred to as the "culture or climate" in the organisation, although those two terms often imply a level of decision-making and "attitude", which it may not have. This was reflected in the finding that drivers more often gave "habit" as a reason for their positioning behaviour, rather than safety considerations.

14. <u>Proposed Conceptual Model of Risk-taking Behaviour</u>

The following model is proposed for a basis for Phases 2 and 3 of the project.

The model is only at a conceptual level at this stage, developed from the observations and findings of this study. It is currently being developed further as a survey of mining employees, to ascertain the propensity for risk-taking at a particular mine. It will aim at the operator level, with similar surveys posing questions for the supervisory and managerial levels of the organisations, to test the safety climate. These will be based on the SAFEmap survey, which already measures those aspects.

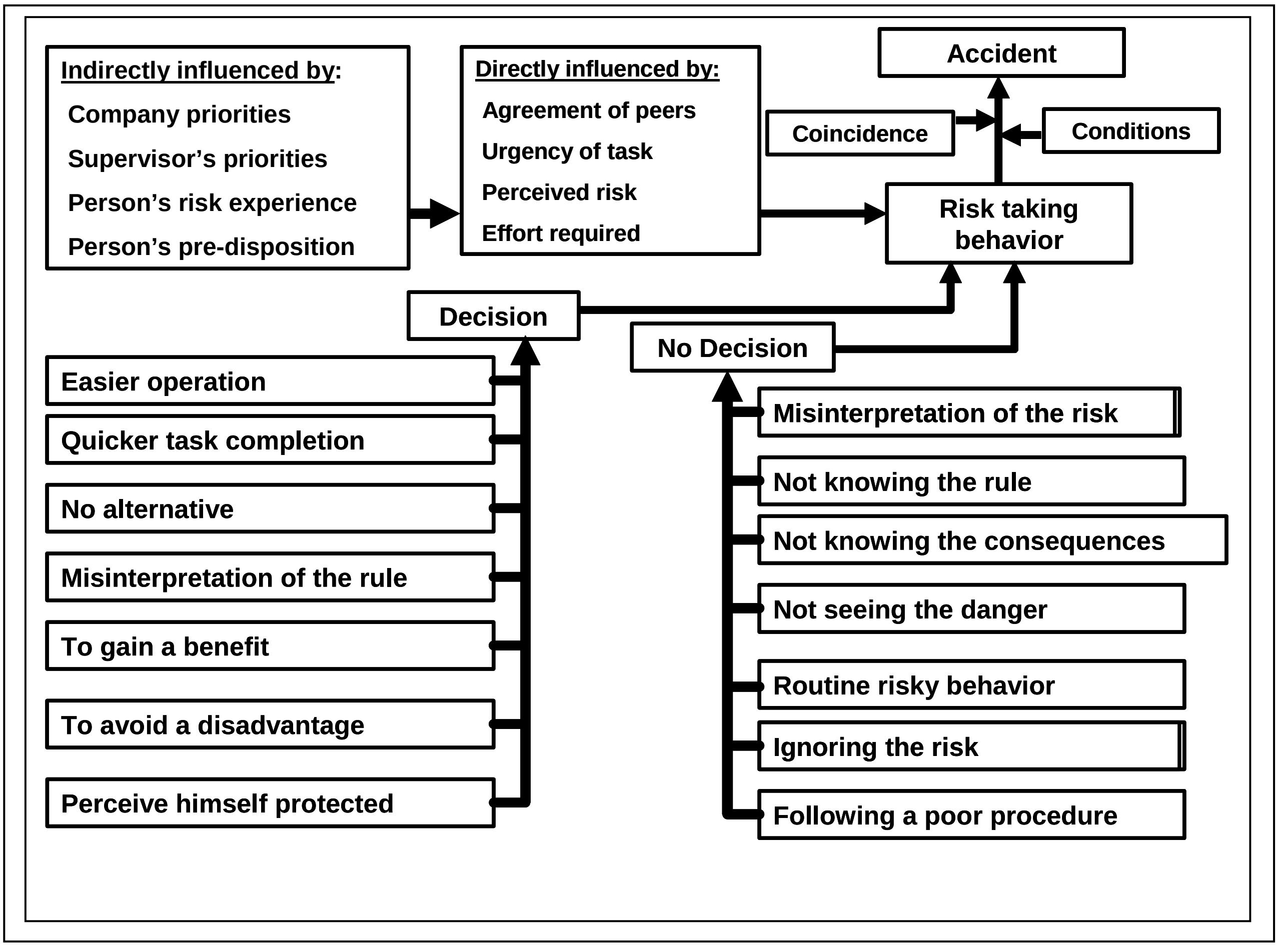
The model (shown below) proposes that risk-taking behaviour is:

a. Preceded by a decision to take the risk, in which case a number of factors are identified as influencing that decision
b. Not preceded by a decision, but by a "state of mind" in which the "decision to take the risk" is done automatically by the individual.

The actual risk-taking behaviour is "influenced" directly and indirectly by a variety of factors, again in the mind of the person. One can argue that these factors should be seen as influencing the "decision" to take a risk, although it is shown here separately as factors influencing "perception", which impacts on the behaviour of the individual. There is some argument for this as conceptually "neater" and more practical to build a survey instrument around.

An aspect of possible debate in this model is the statement of "coincidence" as an influencing factor in the occurrence of accidents. A discussion of this aspect is beyond the scope of this study, but it is certainly an issue than needs to be considered in any research about accidents. It is also a powerful influence on the perceptions of risk underground workers. The majority of workers indicated that they "rely on luck", when asked why they think they haven't had a serious accident.

Figure 2: A model for Risk-Taking Behaviour



15. Conclusions and Discussion

The different causal factors identified for standing in no standing zones around Continuous Miners are probably the same as the reasons why people generally take risks underground and possibly why people take risks in everyday life as well. However, the underground situation is different in a number of ways, in particular:

- Risk-taking in the underground environment is done more routinely;
- Risks are "numbed" ("normalised") by the operators due to the above routine nature of risk-taking

These factors may have a profound and different effect on the way risks are perceived in the underground situation.

The positioning behaviour of drivers are quite compliant to their mines' Standard Operating Procedures for some tasks (cutting straight ahead), but indications are that the compliance level reduces dramatically for other tasks, such as during flitting, maintenance and other "peripheral" activities - with a resultant significant increase in the actual potential for accidents.

Disturbingly, the positioning behaviour of underground workers is generally not influenced by the procedures on no standing zones and one would certainly have to question the effectiveness of regulating these behaviours in this way. Drivers use a variety of other, often individualistic heuristics (decision rules) to position themselves, which seriously inhibits management's and the regulator's ability to affect that behaviour. Perception of risk, and the acceptance of risk by underground workers, seems to be the area that needs to be focused on.

This also raises the question of the effectiveness of procedures and management rules for other work practices, where similar deficiencies may exist if employees tend not to be influenced by the rules themselves, but by their own perceptions of risk and habits of behaviour. Given the enormous amount of time, effort and money spent on the generation and enforcement of procedures, it is possibly doubtful that the last hurdle -gaining intentional compliance - is cleared. It is especially of concern in light of the negative perceptions that most employees have of safety rules in general, as identified in this study.

Working underground and in confined, potentially explosive, situations is obviously risky, but it is suspected that not enough is known about the psychology of people who are exposed so intensely and so continuously to severe risks. Most workers in other types of environments would only be exposed for short durations to risky circumstances and would be able to remove themselves from that situation and "recover". Underground coal miners are exposed for 6 to 8 eight hours and can only occasionally remove themselves from that exposure to a situation which most other people would still consider extremely dangerous. (At one mine, the rib conditions were the worst in the crib room.) Yet, these risks have become "normal" for these individuals, and no amount of procedures, shock tactics or enforcement will change that.

Immediately before the person takes a risk, he (or she) either makes a decision to take a risk, or doesn't make a decision to do it, but simply performs the risky act subconsciously. Some people would only occasionally do something risky, while others may do it habitually. In the underground environment, the terms "occasionally" and "routinely" take on vastly different meanings, given the serious possible consequences of accidents.

Identifying the reasons for risky behaviour and quantifying that would be an invaluable source of knowledge about a phenomenon about which relatively little is known: the thinking process of people who work in extremely risky conditions.

It is considered important to better utilise the inputs of drivers and operators into the design of standard operating procedures, particularly in this case, but also in general. Only three of the mines designed their procedures with worker inputs, and in all other cases, the procedures were the work of the safety practitioner and/or of the mine manager. The use of a structured risk assessment approach to procedure design seems imperative.

There is very little doubt that much more can be done to improve the design of equipment and improve the scope and practicability of underground work procedures, but the significant gains are in understanding the behaviour of people who work there and to introduce effective behaviour monitoring and behaviour change systems. There is little doubt that workers' behaviour will strongly be driven by a motivation to expend as little unnecessary energy as possible - to get the job done, to avoid discomfort, to avoid negative consequences, to achieve positive consequences and to not get injured. Unfortunately, it is apparently that sequence that people use before acting - safety being the last consideration.

Causal factors for the risk-taking behaviour of employees are difficult to identify and to quantify, and influence people's behaviour in a complex, interactive way. The result is that people's behaviour is difficult to predict, to monitor or to change. Nevertheless, stating basic workplace rules can have a significant effect on the safe behaviour of employees, but only if the rules and procedures are seen as relevant and practical.

Employees' perception of risk can be regarded as one of the most powerful influences on behaviours, and without a concerted effort focusing on this, no amount of procedures will affect risk-taking at the coal face. Secondly, the increased introduction of rigid procedures, or inflexibility of work practices will generally not be effective in the long term. The large variety of risky situations that employees encounter in the workplace makes it impossible to design and implement procedures to govern every possibility. It is crucial that regulators and the management of mines achieve a realistic and "intelligent" balance in the scope and level of intended control of such procedures - otherwise employees will continue to find ingenious ways to perform tasks effectively, but not necessarily safely.

Results from this study should obviously not be seen as representative of the underground coal mining industry of New South Wales. The number of mines that participated was only 8 and it was not possible to observe the same type of mining tasks at each mine, due to practical circumstances at each mine at the time. However, there are certainly strong indications of potentially very dangerous circumstances and tasks on mines that warrant further consideration and research.

16. Recommendations

It is not considered appropriate to make any specific recommendations about the issue of risky positioning behaviour of underground workers, or of the adequacy or otherwise of the procedures in place, simply because the study lacks scientific rigour at this stage.

There are however indications of trends that could assist mine managements and the regulators in their efforts to improve underground safety - especially about an aspect of mine safety that is at the "cutting edge" of the problem, namely the behaviour of employees in high risk environments. A normal reaction is often to focus on more and better procedures, or to ensure closer supervision and/or enforcement of procedures. However, it was demonstrated above that the effectiveness of this approach may be limited, and it is therefore recommended that the emphasis be placed more on the actual behaviour of employees to:

- increase the perceived benefits of safe or cautious behaviour
- decrease the cost of safe/cautious behaviour
- increase the perceived cost of risky behaviour
- decrease the perceived benefit of risky behaviour

The issue of risk perception and risk tolerance clearly needs to be focused on. It is recommended that the issue of "training in risk perception" of Miner drivers, cable hands and shuttle car drivers be pursued.

The second and third phases of this study is seen as very important steps in the achievement of a better understanding of the phenomenon of risk-taking behaviour that could contribute significantly to the elimination of fatal accidents in the mining industry.

It is recommended that more mines -possibly all of the underground coal mines in New South Wales - be encouraged to participate in the study, in order to make significant progress towards improved underground safety in the state.

It may also be considered how the process of this study can be duplicated for other types of mines, where the risks may be different and relatively smaller, but where their workers behaviours in risky situations are still the main reasons why accidents occur. It will be a mistake to fix all attention on the underground environment only.

It is imperative that mines do not perceive the study process in a negative way, such as a perception that the "exposure of risk-taking on their mines" through this study will confirm criticism of the mining industry. If this happens, all potential gains from a study like this will be lost permanently. It is therefore strongly recommended that the content and communication of the report are treated with great circumspection by the Department of Minerals and Energy and that distribution of the report is limited until constructive ways of communicating the findings can be found.

It is strongly recommended that more mines actively participate in the next phases of the study, if they are to be implemented.

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