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IMPROVING MINE SAFETY BY USING A SAFE WORK BEHAVIOUR MODEL

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Abstract - A survey of approximately 500 miners in Queensland and New South Wales mines took place at the end of 2001 and beginning of 2002. A variety of underground and open cut, coal and metalliferous mines were targeted. The survey aimed to determine the attitudes and perceptions of the workforce towards:

- Knowledge and understanding of mine rules and regulations in general
- Communication in the workplace
- Compliance with rules and regulations
- Risk taking and error making

Awareness of specific rules governing remote controlled continuous miners[1], remote controlled boggers[2], heavy earthmoving equipment[3], and haul trucks[3]. (1 = underground coal, 2 = underground metal, 3 = surface coal, metal or quarries). The results were used to derive a safe work behavioural model. The model was developed using criteria established during the survey and each mine was allocated a safe behavioural score. The results were correlated against safety performance data from each mine. Although at the prototype stage, a definite link between the safe behavioural score and safety performance was established.

INTRODUCTION

This paper presents the results of research and investigations, which aim to improve safety performance in the Australian mining industry. It will focus on the human aspects of mine safety rather than the traditional emphasis on safer equipment or safer systems. The extent of the contribution of unsafe behaviours to accidents and incidents on mine sites in Australia is illustrated by Table 1. Here it can be seen that many of these accidents were caused, at least in part, by:

- Lack of awareness of procedures or rules
- Not complying with or ignoring rules
- Lack of clear instructions
- Poor communication generally
- Production taking precedence over safety
- Failing to wear protective equipment

- Overriding or bridging out safety barriers
- Inadequate training
- Lack of familiarity with equipment
- Fatigue

Table 1 - Extracts from Significant Incident Reports 1998 to March, 2002 – Queensland, NSW and WA (from Departmental web sites)

INCIDENT	BEHAVIOURAL CONTRIBUTION TO CAUSE OF INCIDENT
QUEENSLAND MINES	
HIGHWAY TRUCKS COLLIDE	Local road rules not clearly understood and followed.
FOOT TRAPPED IN DRAGLINE ROTATION RACK	If workers are given tasks to perform where they are in remote locations, on back shifts or likely to perform the task with infrequent supervision and a safe written procedure has not been developed, there is a likelihood that a convenient but unsafe procedure will be developed.
LIGHT VEHICLE DRIVES OFF HIGH WALL	Operators should ensure that they are provided with clear work instructions particularly where they are working in an area of the mine with which they are not familiar.
CATASTROPHIC FAILURE OF A DRAGLINE BOOM	Unconfirmed reports indicate that draglines are now being loaded above their RSL (rated suspended load), in a drive for greater productivity.
DUMP TRUCK WITH UNBALANCED LOAD BECOMES UNSTABLE	A standing instruction that large rocks are not to be loaded but re-blasted was ignored by the shovel operator
DRILLER REPORTS FOR WORK IN AN INTOXICATED STATE	The driller's offsider was disciplined and given a mine site reinduction where the statutory requirement of not reporting for duty in an intoxicated state was stressed. His workmate was also given the same mine site reinduction. The manager of the drilling contractor was reminded of his safety and welfare obligations to his employees at all time.
METHANE MONITORS WERE BRIDGED OUT OF CIRCUIT IN TWO MINES WHILE PRODUCING COAL.	On each occasion the tail gate methane sensor was bridged out of circuit during calibration checks and not recommissioned once these routine checks were completed.
DUMPING OVERBURDEN NEAR COAL CREW OPERATIONS	A dump truck operator dumped overburden outside of the allotted dump area without knowledge or consideration of the potential consequences.
AN OPERATOR HAD TWO FINGERS PINNED AND A THIRD SEVERELY LACERATED WHEN A BOLTING RIG AUTO RETRACTED.	Operator was attempting to do multiple tasks consecutively and pinch points were not guarded or identified.

INCIDENT	BEHAVIOURAL CONTRIBUTION TO CAUSE OF INCIDENT
COLLAPSE OF BRIDGED MATERIAL IN PUGMILL FEED BIN	The plant operator walked along the edge of the top of the feed bin with no safety belt/harness attached.
RIGGER STRUCK ON HEAD BY 500KG ASSEMBLY	The crews dismantling the crusher did not understand the function of the component parts or were unaware of the condition of the component parts.
DOZER RUNS OVER LIGHT VEHICLE	The mine site procedure for entry into a work area was not followed.
TRUCK FALLS BACKWARDS OVER TIPPING EDGE	Ignorance of safe work practices. The truck driver was not familiar with a safe procedure for tipping over the edge of a stockpile
ROLLOVER OF REAR DUMP TRUCK	The height and size of the rill was inadequate and not identified as a risk by the operators. Lack of handover between shifts led to hazards in the workplace not being communicated. The dozer operator on the previous shift had not worked to the mine's standard for a dump area by allowing the dump face to become misaligned.
NEW SOUTH WALES MINES	
TWO LARGE TRUCKS OUT OF CONTROL	Maintenance, testing and inspection of the braking systems were inadequate. Drivers had not been given training in emergency response procedures
DANGER FROM A MISFIRE	Communications were not clear between the day shift and the night shift about the result of the refiring.
UNSTABLE STRUCTURE CRUSHES WORKMAN	For some time before the accident, both the injured person and his supervisor had worked more than eleven hours a day.
QUARRY WORKER KILLED BY FRONT END LOADER	Management should have safe work procedures in place for people who need to approach mobile equipment. Everyone at a mine, including contractors and visitors, should be trained in the procedures.
OPERATOR CRUSHED BY OVERTURNED FORKLIFT	No standard operating procedures were available. No formal training, refresher or emergency training had been given. The vehicle appears to have been travelling too fast for the conditions; The driver was not restrained by a seat belt.
ELECTRIC SHOCK FROM DAMAGED CIRCUIT BREAKER	It was found that the Electrical Maintenance Engineer and the electrical staff generally were not aware of this hazard, even though it was reported in previous safety alerts.
CONTINUOUS MINER DRILL RIG FATALLY CRUSHES TRADESMAN	Managers should also address basic hazard recognition and control skills training as a priority.
VEHICLE BRAKE FAILURE WHILE TRAVELLING IN A DECLINE	The driver was unfamiliar with the radio. If the truck were driven in 3rd gear in the decline, it would have eliminated the need to use the brakes.
THE 415 VOLT CONDUCTORS SHORTED OUT AND THE POWER TRIPPED OFF ON SHORT CIRCUIT.	The electrical contractor was not aware of the site Electrical Management Handbook.

INCIDENT	BEHAVIOURAL CONTRIBUTION TO CAUSE OF INCIDENT
WESTERN AUSTRALIAN MINES	
FATALITY ON HEAVY-HAUL MINE RAILWAY	The operator of the ballast regulator saw the grader approach the rail crossing but was unable to stop when it became apparent that the grader was not going to stop at the STOP sign governing right of way on the level crossing.
FATALITY IN REMOTE CONTROLLED BOGGING OPERATION	Initial reports contain unconfirmed indications from an eyewitness that the deceased may have inadvertently operated the wrong control and unintentionally precipitated the incident which resulted in his death.
LOADER OPERATOR CRUSHED BY ROCK FALL IN STOPE	The remote control unit for the LHD was found placed in a cuddy next to the drawpoint with its controls locked in the manual position. It was subsequently established that (for reasons presently unknown) the operator was on the LHD inside the stope.
MINER STRUCK BY FACE BLAST	The induction procedure adopted appears to suffer from two deficiencies:The volume of written information made available was too great to enable the inductee to gain an adequate understanding of the material before commencing work. It is clear that the income of some underground workers is linked to production and that pressure has been applied to increase production.
MINER STRUCK BY ROCK FALL	We also recommend that a system be developed which formalises the procedure for assessment, both practical and theoretical, of an employee's understanding of working practices, bearing in mind the dynamic nature of those safe working practices and the need to continually monitor and/or update them.
MINER STRUCK BY ROCK FALL	An induction process should include a mechanism to evaluate the inductee's understanding of the material covered. The process should include provision for regular re-assessment of employees' knowledge of induction material.
A TOYOTA PERSONNEL CARRIER REVERSED INTO AN ORE DRIVE IN AN UNDERGROUND MINE, GOING OVER THE BENCH EDGE OF AN OPEN STOPE.	The driver was unaware of the position of the bench edge in the drive.
OPERATOR TRAPPED BY SUCTION HOSE	The hose operator had not been formally trained in the task.
PRESSURE VESSEL ENTRY - SCALDING INJURY	The absence of a written procedure to perform this task. The failure by the operators to get authorisation from supervisors to open the vessel. The absence of more experienced supervisors to approve and oversee the work. The lack of adequate competency tested training in the performance of this task.
LOADER OPERATOR CRUSHED BY ROCK FALL IN STOPE	The safe working procedure for loading by the use of remote control equipment stipulated that operators were not to go beyond the stope brow. The operator was not complying with the procedure at the time of the accident.
CRUSHED IN ARTICULATION POINT OF LHD	The operator had omitted to engage the manual lock prior to exiting the cab. He accidentally hit the joystick which activated the steering control and articulated the loader to the left, crushing the operator

The research used an attitudinal survey to seek the opinions of the mining workforce on safety rules and regulations generally and as they apply to their specific jobs on a mine site. In particular, it sought to investigate in depth:

- The level of awareness and understanding of mine rules and procedures such as manager's rules and safe work procedures
- The level of awareness and understanding of mine regulations and legislation
- The extent of communication of and commitment to rules and regulations
- The extent of compliance with rules and regulations
- Attitudes regarding errors, risk-taking and accidents and their interaction with rules and regulations
- The level of awareness of mine rules and regulations in specific competencies such as the operation and maintenance of continuous miners in underground coal mines, boggers and haul trucks in underground metal mines, and heavy earthmoving and haulage equipment in surface coal and metal mines

From the survey, comparisons of the attitudes towards safety could be made between both employee groups and industry sectors, such as coal and metalliferous and underground and open cut. The survey also enabled a safe working behavioural model to be developed.

WORKFORCE SURVEY

A total of 65 questions (68 in the underground coal version) were asked of which:

- 8 were designed to gain personal (yet confidential) information about the respondent
- 12 were open questions designed to elicit more in depth responses from the participant
- 45 required the respondent to signify his/her agreement or disagreement with a short statement by placing a cross (X) in a box.

The survey was designed to ensure maximum response from the mining workforce and thus:

- It was designed to be completed within a typical break for crib (lunch) or a safety meeting (toolbox talk)
- Plain language was used
- Loaded or biased or emotive phrases were avoided
- Closed questions were preferred although enough open questions were included for the workforce to adequately "have their say" if necessary.

DISTRIBUTION OF SURVEYS

The surveys were mostly emailed to mine managers who had been contacted in the first instance by telephone to inform them of the survey and enlist their support. The advantages of email compared with posting or faxing include low cost, effectiveness, speed of distribution and an ability to reach an international target easily. It needs to be stressed that this pilot project was not industry-funded. The problems encountered with email distribution included:

- It is an impersonal means of communication
- The message can be swamped by either higher priority or junk email
- It is easy for managers to avoid acting on the message.

Surveys were completed by 33 mines, and 478 respondents from Queensland and NSW. Two Swedish mines and a Canadian mine also participated in the survey.

SUMMARY OF SURVEY RESPONSES

Management and Operators

A comparison between management and operators indicated strong differences in the following areas:

- Reasons for working at the mine
- Knowledge and awareness of rules and regulations
- Why they have problems with rules and regulations
- The importance of common sense in a rule
- Perception of efficacy of communication
- Deviation from rules although supervisors were similar to operators
- Reasons people take risks
- Fatalism regarding accidents and injuries

Contractors and Employees

There was evidence of a significantly different culture between contractors and company employees. This was demonstrated in the;

- Age,
- Reasons for working at the mine,
- Ability of training to improve awareness and understanding of rules and regulations,
- Necessity for breaking rules to get the job done, checking if rules are breached,
- Influence of management and work pressure to get the job done, fatalism regarding occurrence of accidents and injuries and
- Significance of the working environment contributing to an accident.

Coal and Metal

The major differences between the responses of the coal and metal workforce was in the areas of:

- Age and experience
- Knowledge and understanding of the rules
- The reasons that there are problems with rules
- Deviations from rules, although somewhat inconsistent results were noted
- Fatalism

Open cut and Underground

The safety culture at open cut mines appears to be superior to that existing at underground mines. The major differences between the responses of the surface and underground workforces were in the areas of:

- Experience and length of service at their current mine
- Reasons for working at the mine
- Knowledge and understanding of the rules
- The rule and regulation-making process
- The reasons that there are problems with rules
- Deviations from rules
- Fatalism

These results can be combined in a matrix as shown in Table 1. A cross (‘x’) signifies a negative attitude or behaviour. It can be seen that the underground sector, the coal sector, the employee sector and the operator sector in general, displayed a number of negative attitudes regarding safe work behaviours. This contrasts with management, the surface sector in general and contractors.

Table 2 - Summary of Attitudes and Behaviours Across Various Industry and Workforce Sectors

	Experience	Reasons for working	Knowledge & understanding	Deviations	Fatalism
Management					
Operators	X	X	X	X	X
Employees		X	X	X	X
Contractors	X				
Coal		X	X	X	X
Metalliferous	X			X	
Open cut	X				
Underground		X	X	X	X

THE ADULT LEARNING MODEL AND ITS APPLICATION TO SAFE BEHAVIOURS

It is instructive at this point to focus on how adults learn. Even the most mundane tasks such as eating and drinking were “learned” at some stage. Initially those tasks required a great deal of effort and conscious attention. As the skills are “learnt”, the whole activity gradually shifts from conscious attention to unconscious control. Driving a vehicle is an excellent example of a complex task and it requires, in its early learning stages, complete and conscious focus on the task. Eventually, driving becomes “automatic” with little conscious attention and safe habits are ingrained (Senge, 1990). Geller (1996) and other researchers describe this process in an adult learning model where humans proceed from an unconscious incompetence or a lack of knowledge to an unconscious competence or safe work habits. The learning model is illustrated in Table 3.

Another way of describing this model is moving from the situation where a person is directed to do something and does it without thinking. This is also known as “Information” or “Directed” stage where a person is provided with knowledge to carry out a job safely. The second stage is a “Systems” model, which is the post Piper Alpha approach involving auditing, worker participation, risk assessment and safety cases. The third stage is a “Communications” model where effective communication is a feature of the organisation and is interactive. The final stage of learning is the “Automatic” or “Emergency Preparedness” stage where an employee has thought through the various scenarios and will know how to unconsciously act safely but also to react to a crisis situation.

The model can be used to explain why safety performance in the Australian mining industry is still at an unsatisfactory level. In a similar manner in which motor vehicle drivers move along a continuum of learning the rules to finally adopting unconscious safe driving habits, so should the mining workforce. The origin of the learning model is not clear with at least one researcher asserting that Maslow conceived of it during the 1940s. Regardless of its age, the model is a very useful tool to be applied to the mining industry. Table 3 describes the characteristics of the model in detail.

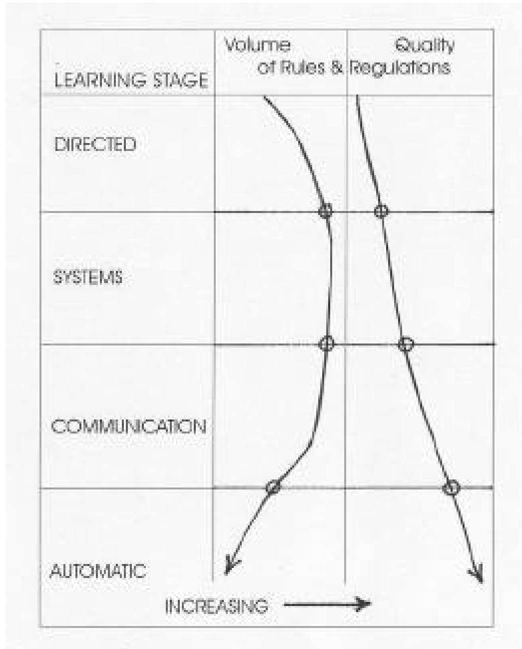
Table 3 - Workforce Behaviour and the Learning Model

STAGE OF LEARNING (traditional nomenclature)	STAGE OF LEARNING (revised nomenclature)	DESCRIPTIONS OF WORKFORCE BEHAVIOUR
Unconscious Incompetence	DIRECTION	Lack of knowledge (what rules?); still learning what can go wrong; directly flouting or breaking rules; person directed and does task without thinking; don't know you don't know;
Conscious Incompetence	SYSTEMS	Provided with and learning the rules; putting hazards into a risk management system; safety management systems, planned risk management; know you don't know;
Conscious Competence	COMMUNICATION	Following the rules; communication is interactive, effective and two way; know you know;
Unconscious Competence	AUTOMATIC	Safe work habits, advanced emergency preparedness; automatically act to avert danger; risks managed through to constant wariness; responsive and disciplined workforce taking responsibility for their own safety and the safety of others; internal control; autopilot, do it without thinking;

It is also useful to consider, in the context of the learning model, the issue of volume and quality of rules at each stage of the learning model. Figure 1 illustrates that the volume of rules, regulations and legislation reaches a peak in the systems stage of the model, decreasing to a minimal amount in the automatic stage. The quality and effectiveness of the rules however continue to increase throughout each stage and reaches its peak in the automatic phase. The automatic stage is thus the nirvana where there are minimal rules and regulations but their quality is high. At this stage, a miner:

- has developed safe working habits,
- is able to detect hazardous situations and identify warning signs
- does not take risks
- cares for his fellow workers
- reacts automatically and appropriately in crisis or emergency situations
- is not lumbered with onerous, complex rules and regulations to impede his safe work behaviours or conflict with internalised safe habits

Figure 1 - The Volume and Quality of Rules at Each Stage of the Learning Model



AN EMPIRICAL MODEL OF SAFE WORK BEHAVIOUR

The rules and regulations survey provided a wealth of data on the attitudes and perceptions of almost 500 mine workers in Australia and overseas. It is possible to extract from the data, a set of criteria to enable a relatively objective analysis of each employee group at each mine to be carried out. Each criterion has been allocated a weighting reflecting its contribution to safe work behaviour.

It is acknowledged that the choice of criterion and its weighting have a degree of subjectivity. However, it is expected that once the model is disseminated throughout the industry, more mines will be analysed. As the database increases, the model will necessarily be fine tuned and improved.

Having established the safe behaviour criteria, it is now possible to relate the total points scored to one of the four stages on the learning model continuum of Directed, Systems, Communication and Automatic. This allocation is labelled the Safe Behaviour Score (SBS). It is also possible to relate the Safe Behaviour Score to safety performance as shown in Table 4.

Table 4 - Relationship between Safe Work Behaviour, Safe Behaviour Score and Safety Performance

STAGE OF LEARNING	ALLOCATED POINTS (SAFE BEHAVIOUR SCORE)	SAFETY PERFORMANCE
DIRECTED	0-25	Very high LTIs; high potential for fatalities and disasters;
SYSTEMS	26-50	Moderate LTIs; high potential for fatalities and disasters;
COMMUNICATION	51-75	Low LTIs; medium potential for fatalities and disasters;
AUTOMATIC	76-100	Nil or very low LTIs; low potential for fatalities and disasters;

APPLYING THE SAFE WORK BEHAVIOUR MODEL TO AUSTRALIAN MINES

Each employee group of each mine was analyzed according to the criteria established in Table 4 and the results shown in Table 5.

Table 5 - Analysis of Mining Workforce and the Safe Behaviour Model

STAGE OF LEARNING	U/G COAL	U/G METAL	O/C COAL	O/C METAL	QUARRIES	SWEDEN & CANADA
DIRECTED	UC1O, UC8O, UC6D,	UM1O, UM2C,	OC5M,	OM1O,		
SYSTEMS	UC3O, UC1D, UC2D, UC4O,	UM3O, UM5C, UM4C, UM60,	OC4C, OC3,C OC1C	OM2O, OM3O, OM4O	Q1O, Q2O	
COMMUNICATION	UC9M		OC2C			SW2O, SW10
AUTOMATIC			OC1M			SW1M, CA1M

It can be seen from Table 5 that the bulk of the workforce of many mines is still at the unconscious incompetence or “directed” stage of learning safe behaviours. This category is dominated by underground coal and metalliferous mines and open cut metal mines.

Contractors overall seem to be at a more advanced stage of learning than company employees. This seems to contradict earlier studies, which showed that safety attitudes and systems of contractors were a major “problem” in the industry. Contractors and their management “scored” highly at two open cut coal mines with both judged to be at the conscious competent or “communication” stage. This may be a reflection of the amount of work being done by contractors to reverse their former, relatively poor safety image.

Quarries, somewhat unexpectedly, were placed in the systems stage. Many quarries now have safety management systems and the Institute of Quarrying has published its own Safety Management Handbook. The result does not confirm that the operators know and understand the rules, risk assessments and the content of their safety management plans.

Very few mines, based on the surveys, reached the unconscious competence or “automatic” stage. The only groups that could be allocated to this category were the management representatives from three mines – one each from Australia, Canada and Sweden. It is disconcerting to note that even though 30 Australian mines participated in the survey only one mine, and only one employee group from that mine, could reach this stage. The management of this mine:

- Mainly worked at the mine because they enjoyed the work
- Employed a specialist consultant to assist with the awareness of the new regulatory framework
- Understood the rule and regulation making process
- Demonstrated knowledge and understanding of rules and regulations and their difference
- Demonstrated understanding and awareness of risk management techniques and safety management systems and the importance of a safety culture on site
- Demonstrated advances in communication and consultation
- Demonstrated commitment to complying with rules and regulations
- Appear to have genuinely thought through the issues

With the result that these leadership actions have had a positive effect on the workforce as demonstrated by the workforce's response.

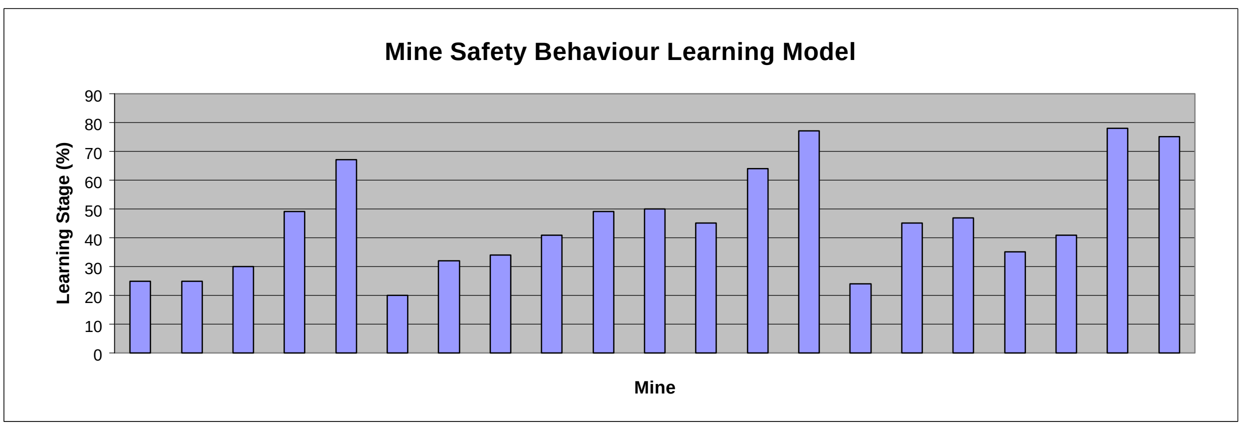
The newer metalliferous mines such as UM4C and UM6O did not rate as highly on the learning scale as expected, despite the publicity given to their safety strategies. The Swedish and Canadian managerial responses were very positive which resulted in their classification in the highest category. In the case of SW1M, the genuine emphasis on communication, consultation and cooperation is apparent from its response. The Canadian responses all show a very high knowledge of rules and regulations and a commitment to high levels of communication.

THE SIGNIFICANCE OF THE MINE SAFE WORK BEHAVIOUR MODEL

The significance of this model is that, through a relatively straightforward survey process, it is possible to analyse the attitudes and perceptions of an employee group at a mine. Form this analysis, it is possible to classify and measure their behaviours according to relatively objective criteria. A graph of safe work behaviours, expressed as a percentage, for each of the participating mines is shown in Figure 2.

The model demonstrates that a good knowledge and understanding of both general and specific rules and regulations is fundamental to progressing along that continuum. Most mines that participated in this research cannot demonstrate that knowledge and awareness and are thus still at the directed learning stage. It follows from this that the rules and regulations applying to those mines are ineffective. Furthermore, their compliance is substandard. Therefore, initial efforts to improve safety behaviour must focus on making rules and regulations more effective, accompanied by an education program to reinforce them.

Figure 2 - Graph of Safe Work Behaviours



Once effective rules and regulations are in place, the knowledge and understanding and the compliance of the workforce will improve, and the focus of management should be on moving the workforce to the next, systems stage. Here, the workforce follows the rules and become aware of and involved in risk assessments and safety management systems. Once these systems are in place and working effectively, the next stage can be addressed, where the focus is on ensuring the three Cs, communication, consultation and cooperation are at a high level. Finally, a stage will be reached where the workforce are taking responsibility for their own safety and looking out for the safety of their colleagues, they are constantly wary and alert for the possibility of incidents or accidents, and they automatically adopt safe working habits. It will be at this point that, provided the equipment, processes and systems are operating safely and effectively, that a truly safe mine will be achieved. The high frequency and lower consequence events will be at or close to zero and the opportunities for low frequency and high consequence events or disasters, will be averted.

The last three stages of the model however will not be achieved unless the workforce successfully passes the first, directed, stage. This in turn will not happen unless the workforce is provided with an effective rule and regulation regime to:

- facilitate knowledge and understanding
- reduce violations and improve compliance
- reduce the need and opportunity for risk taking
- reduce the opportunity for errors
- recognise warning signs
- improve the resilience of the organisation in order that errors do not result in accidents.

As shown in Figure 1, at this stage the volume of rules and regulations will be at a minimum but their quality will be superior.

COMPARISON OF SAFETY PERFORMANCE DATA

It was concluded above that it is possible to now analyse any mine according to a predetermined set of criteria and derive a quantitative estimate, known as the Safe Behaviour Score for that mine. The Safe Behaviour Score is a measure of the learning stage of the employee group at the mine. In order to assess the usefulness of the score in predicting the safety performance of a mine it is necessary to correlate the model against known safety performance data.

The only data that is relatively freely available to be able to assess the safety performance of a mine is the Lost Time Injury Frequency Rate or LTIFR. This index is not perfect as it is a lagging indicator of historical data and is open to manipulation. Table 4 compares the LTIFR with the Safe Behaviour Score for all the mines that participated in the survey. It was decided to use operators for this analysis because they are the target group in this research and because there is sufficient numbers in the sample data to be confident about trends.

Table 6 - Comparison of Safe Behaviour Scores and Safety Performance Data

MINE	SAFE BEHAVIOUR SCORE (operators only)	LOST TIME INJURY FREQUENCY RATE 1999/2000	LOST TIME INJURY FREQUENCY RATE 2000/2001	LOST TIME INJURY FREQUENCY RATE 2001/2002 (ytd 180302)
OC1	49	5	18	2
OC2	64	18	0	0
OC4	45			0
UC9	67	11	20	9
UM2	32	11	14	10
UM6	50	7	5	1
UM3	34	20	11	16
OM1	24	9	13	3
OM4	45	14	5	3
OM2	40	13	24	10
OC6		3	15	
OC5		7	26	
OC3		19	26	
UC1	25	41	18	
UC2 (dep)	49	40	40	

UC3	24	53	46	
UC4	30	67	50	
UC5	39	12	9	
UC6	20	105	91	
UC7	22	30	59	
UC8	25	57	36	
UM1	20		33.7	
UM4	51		17	3.3
UM5	41		16.3	
OM3	50		7.1	1.4
UM7[1]	20		N/a	N/a
Q1	35		N/a	N/a
Q2	41		N/a	N/a

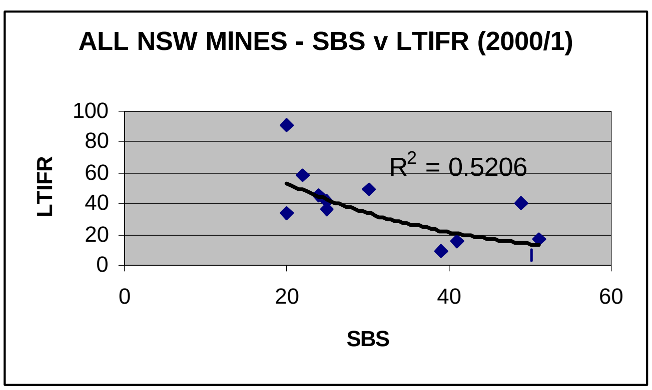
Note: 1 – No LTI data available – this mine experienced over 40 recordable injuries between 1998 and 2001 including three fatal incidents. The low SBS equates to a poor safety performance.

It is now possible to correlate these data sets to determine if there is a relationship and by calculating a correlation coefficient, the magnitude of that relationship. According to Pitzer (1999), a correlation coefficient in analyses of this type of 0.70 or higher, is considered very high, 0.50 is moderate to high and 0.00 as "no relationship". In the 1999 minerals industry safety culture survey, in some analyses a correlation coefficient of 0.50 is considered as extremely high.

New South Wales Mines

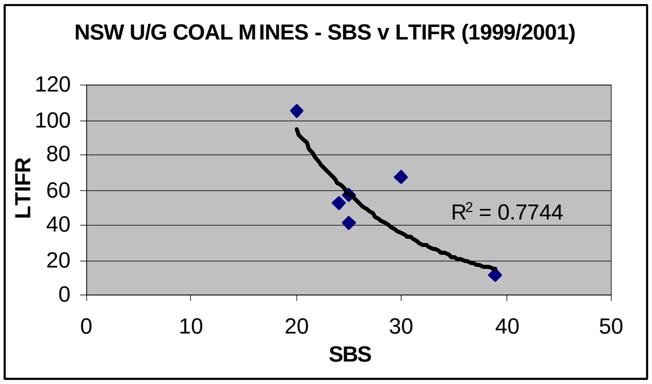
The Safe Behaviour Scores for NSW mines were correlated with Lost Time Injury Frequency data in a similar manner to the Queensland data. The results for all NSW mines are shown in Figure 3.

Figure 3 - Graph of LTIFR v SBS – 2000/2001 – New South Wales Mines



It can be seen that the trend line shows an exponential function with a correlation of 0.52 that as the Safe Behaviour Score increases, the Lost Time Injury Frequency Rate decreases. This has significant implications for mine management. It shows that as the SBS increases from the area of directed behaviour to systems and communication behaviours a large decrease in accidents can be expected to occur. The graph shows that the improvement will plateau. This trend is confirmed by Figure 4, which shows the correlation for NSW underground coalmines. It should be noted that the LTIFR plateau modelled replicates the real-life mining industry situation.

Figure 4 - Graph of LTIFR v SBS – 2000/2001 – New South Wales Underground Coal Mines

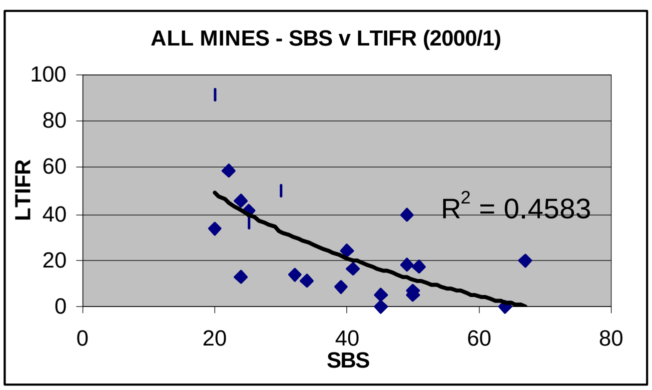


The correlation coefficient for underground coal is very high at 0.77. This makes sense as the graph represents a comparison of "like with like." Again, the trend line shows that a significant improvement in safety performance should occur as mines move from a low or directed safe behaviour to the systems or communication stages. The trend of the data indicates that achieving safe behaviour in the automatic range may not achieve zero accidents. However, it may achieve zero fatalities or zero disasters as well as this desirably low accident or incident rate. This is because the automatic or emergency preparedness stage of learning is the stage where every employee, including managers and other key personnel, are equipped for the possibility of recognising those warning signs leading to a disaster.

All Australian Mines

When the Queensland and NSW data is combined, an exponential function with a correlation of 0.46 can be drawn, showing again that as the SBS improves, the LTIFR should decrease, but without necessarily reaching zero. This is shown in Figure 5.

Figure 5 Graph of LTIFR v SBS – 2000/2001 – All Australian Mines



CONCLUSIONS

This paper discussed the development of an empirical model to enable safe work behaviours to be classified. The criteria for the model were developed from the rules and regulations survey. It verifies the importance of the safe behaviour model in being able to predict the safety performance of a mine and its workforce. It also confirms that, if a workforce can improve its safe learning behaviour, so too will safety performance improve. Most mines are still at the directed and system stages although one open cut coalmine has advanced to higher stages. Swedish and Canadian mines seem to be further advanced than the Australian mines. The model reinforces the importance of improving the effectiveness of rules and regulations. The model provides management with a tool to objectively measure the existing safety behaviour on a mine site and thus map out a strategy for improvement.

The relationship of the model with "hard" safety performance data has shown a very high correlation in the case of NSW underground coal mines, a high correlation with all mines and all NSW mines and a low correlation with the Queensland mines participating in the survey.

FURTHER WORK

The research work described in this paper demonstrated that with no industry funding, 33 mines could be surveyed and a prototype model developed. It is proposed that, subject to industry support, a Stage II investigation is undertaken, involving as many mines as possible. Clearly, the more mines that participate in Stage II of the project, the more valid the resultant Safe Work Behaviour model will become.

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