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SYSTEM SAFETY IN AUSTRALIAN COAL MINING

AVUSTURALYA KÖMÜR MADENCİLİĐİNDE SİSTEM GÜVENLİĐİ

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ABSTRACT

In the past ten years, there has been an evolution in the assessment and control of mining risks in the Australian coal mining industry. This change has involved the development and use of structured, systematic, team-based risk assessment exercises to identify, assess and control unacceptable risks to people, equipment and production. The principles behind this approach come from System Safety technology. The outcomes have improved mine management systems. This paper discusses the evolution of the risk assessment approach in equipment design and mine operations, as well as the specific risk assessment methodology. The paper also presents the reactive side of risk management. System Safety Accident Investigation (SSAI). SSAI has been adapted by regulatory authorities and mining companies to investigate major losses.

ÖZET

Geçtiđimiz on yıl içinde, Avustralyan kömür madenciliginde, madencilikteki risklerin teşhis ve kontrolü alanında bir evrim yaratıldı. Bu yenilik çalıřanlara, ekipmana ve üretime gelebilecek risklerin tanımlanması, deđerlendirilmesi ve kontrolü için sistematik bir şekilde belli bir gruptan tarafından yürütölen risk teşhis egzersizlerinin geliřtirilip düzenlenmesini gerektirdi. Bu yayın risk teşhis alanında yapılan büyük geliřmelerin ekipman dizaynını ve maden operasyonları üzerindeki etkilerini, ve belli bir risk teşhis metodunu anlatmaktadır. Ayrıca risk yönetiminde kullanılan ve büyük kayıplara sebep

olan incelemelerde kullanılmak üzere kanuni otoriteler ve madencilik şirketleri tarafından adapte edilen Sistem Emniyet Kaza Araştırması tanıtılmaktadır.

1 INTRODUCTION

" The revolutionary idea that defines the boundary between modern times and the past is the mastery of risk the notion that the future is more than a whim of the gods and that men and women are not passive before nature " (Bernstein, 1998).

Laws regulating the health and safety of workers in many different parts of the world are visibly integrating a requirement for risk assessment. In the European Economic Community and in Australia, codes of practice have been developed to include risk assessment as part of the methodology to address areas such as plant safety, and the storage of hazardous chemicals

Ten years ago, the Australian coal mining industry started to investigate the use of systematic safety engineering to reduce the highly unacceptable injury rates occurring in the industry The initial interest occurred simultaneously within the regulatory agencies and the coal mining industry with the regulators presenting information on safety and risk management while the industry established a funded project to investigate and trial the approaches Recently, regulations have changed to require this approach

Since those early initiatives, Risk Assessment and Management, using System Safety Approaches, (SSA) has become an integral part of safe mining in Australia Many of these efforts have helped reduce the underground coal sector's Loss Time Injury Frequency Rate (LTIFR) in one state from pre 1988 levels far exceeding a 200 LTIFR to current levels less than 50 and, in some cases closer to 10 These average rates are still considered as high, but the trend is very positive, leading many mining companies to believe that single figure LTIFR's are achievable (Minerals Council of Australia, 1997-98)

Currently, the New South Wales (NSW), Queensland and Western Australia Mines Inspectorates require risk assessment for development of certain mining system changes and the introduction of new equipment This is supplementary to the traditional approval process that after concentrates on well defined mechanical and electrical standards Government departments also investigate serious incidents and accidents using this technology (Joy, 1994)

A spin-off of the risk analysis technology has been the application of System Safety Accident Investigation (SSAI) techniques (US Department of Energy, 1996) These applications have undoubtedly helped collieries to see how well they manage critical systems in events such as mine fires and fatalities

Although the full impact of all these techniques has not yet been objectively measured, comments from all levels of the mining industry are positive It is clear that the approach has a valuable role in assisting the mine to plan and manage operations, as well as helping equipment manufacturers to supply functional and easily maintained machines This will have longer term safety and productivity implications to the entire mining industry

This paper discusses how System Safety Risk Analysis and Accident Investigation, is being applied in Australian coal mines as part of the drive to reduce injuries, equipment damage and production losses

2. RISK ASSESSMENT BACKGROUND

Increasingly, the control of risks is necessary to secure compliance with the requirements of Occupational Health and Safety Acts, State Mines Regulation Acts, Environmental Protection Acts and protection against litigation following major accidents or fatalities (New South Wales Department of Mineral Resources, 1997)

The role of risk assessment in management activities is well accepted in many industries. The approach is characterised by the four stage process of risk management

Risk Management Steps:

- 1 **Hazard identification** - identifying the situations which have the potential cause harm or losses
- 2 **Risk assessment** - assessing the risk which may arise from the hazards
- 3 **Risk control** - deciding on suitable measures to reduce or control risk
- 4 **Implementing & maintaining control measures** - implementing standards and ensuring they are effective (Stephensen, 1991)

This four stage process forms the basis on which hazards are identified and evaluated in terms of the risk to people, production, the environment, suppliers, customers and shareholders

Hazard identification is the essential first step in risk management. The identification of hazards should involve a critical appraisal of all the potential hazards to employees, others affected by the organisation's activities (the public and contractors for example), and those using the organisation's products and services. Understanding of the nature and the magnitude of the hazard is also critical.

Assessing risks is necessary in order to identify their relative importance and to obtain information. It is important to acknowledge that these aspects (identification and assessment) produce reasons for conducting a risk analysis

- firstly, to decide where to place the major effort in prevention and control of risks, and
- secondly, to decide on the adequacy of control measures (existing and planned)

Determining the relative importance of each risk involves deciding on the *consequences* of the hazard, and the *likelihood or probability of its occurrence* (sometimes described as the risk equation where Risk equals Probability and Consequences)

The two components of the equation are simple definitions of how risk is manifested, an incident causes damage or interruption with some frequency and some infrequently. The available information of these two measures determines the type of risk assessment possible.

- when the severity of the loss can be measured exactly, in terms of something measurable, and when the incidence or frequency of the event can be traced from historical data, a quantitative risk assessment can be conducted
- when the severity and likelihood cannot be specified exactly but are the result of judgements or opinion, a qualitative risk assessment can be conducted

In the vast majority of cases, the Australian mining industry necessarily conducts qualitative risk assessments. This is because

- there is a lack of accurate, valid "hard" data in terms of the events, and the frequency, and
- there is a wealth of industry experience at the management, supervisory and operational levels to realistically judge severity and incident potential according to the subjective experience

There are no general formulae for rating risks, but a number of techniques have been developed to assist in decision making. Emphasis should be given to risks which present the greatest severity. Risks which would create catastrophic consequences, albeit infrequently, are given greater priority than those risks which create only small losses. The likelihood of occurrence (or probability) cannot be ignored in forming the overall qualitative assessment.

Risk control occurs after risks have been identified and assessed. All final decisions about risk control measures must take into account the relevant legal requirements which establish minimum levels of risk prevention or control. Basically, risk control activities fall into the following categories (Joy, 1994)

- elimination of risks by substituting hazardous substances or practices for others
- designing machinery and work activities to minimise the release of energy, or to suppress energy releases
- isolation from the risk by remote operation or guarding or enclosures
- protecting people with protective equipment and clothing
- defining work methods and procedures
- establishing emergency recovery systems to reduce the impact of losses

Implementing and maintaining risk control measures is usually a function of carefully designed safety management systems together with thorough auditing and upkeep.

Control measures should be recorded as a means of ensuring consistent implementation, and conformance with the principles of total quality management such as those defined by the international standard ISO 9000

3. MINING RISK ASSESSMENT

There are many methods available for risk assessment, however the basic approach usually comprises (Joy, 1994)

- identifying the hazards, sometimes called unwanted energy releases
- defining the magnitude of the hazard, the consequences if the event occurs
- estimating the probability of the event, either by historical data or by best available expert opinion
- combining the consequence and probability estimates to determine the risk for each event or loss scenario
- identifying the methods to reduce or eliminate the identified hazard risk

Methods of gathering information on hazards include observation, interviews, documentation review and, in some cases, group exercises. The latter method allows for quick and effective data gathering, especially if the group is made up of people who clearly understand the current or potential situation being reviewed. It is also a good alternative if documented information and historical data is limited, as is the case in virtually all Australian industry.

In group exercises or the participative approach, hazard analysis is done by a team of mine personnel from a colliery, for example facilitating them through the exercise in a step-by-step manner over several days.

The group may comprise representatives from Corporate Management, Colliery Management, Machine Operators / Fitters / Electricians, Union Representatives, and Equipment Suppliers / Government Representatives.

The group is led by a skilled facilitator through a step-by-step method for completing the risk assessment. At certain points in the process the group defines criteria for identifying or analysing the information. When this is done the facilitator's role is to ensure consistency throughout the exercise.

Specifically, the group exercise operates as follows:

- 1 Participants are given a purpose of the risk assessment and the expected outcomes.
- 2 The team is provided with direction on the risk areas that needed to be examined (based on historical data or expert opinion) from which a list of the major types of risk concerns (e.g. rock falls, electrical faults, manual handling, control operation error, pinch points, etc.) is prepared.

- 3 A process model is developed for the equipment or product by using a team to identify each step in its operation. A flow chart style of model is often used to create a clear operational process image (Buys and Clark, 1978)
- 4 Any reasonable deviations (planned or unplanned) from the process model are identified that might be likely to occur
- 5 A review of the model is done, step by step, identifying the "what if potential accidents (loss scenarios) that might occur, using the list from Step 2 to stimulate thinking
- 6 A risk score is created for each loss scenario by defining risk as the combination of CONSEQUENCES and PROBABILITIES where the former may involve people, equipment or production losses. Qualitative scoring methods are used, similar to those presented in U S Department of Labour information on System Safety Engineering (Rankin, 1978)

An example of the qualitative risk approach is as follows (Joy, 1994)

Table 1. PROBABILITIES:

A	common or frequent occurrence
B	is known to occur or "it has happened"
C	could occur or "I've heard of it happening"
D	not likely to occur
E	practically impossible

Table 2. CONSEQUENCES:

People	Equipment	Production
1 - fatal or permanent disability	1 - more than \$500K damage	1 - more than 1 day mine production delay
2 - serious lost time injury/illness	2 - \$100K to \$500K	2 - 1 shift to 1 day delay
3 - moderate lost time injury/illness	3 - \$50K to \$100K	3 - 4 hours to 1 shift delay
4 - minor lost time injury/illness	4 - \$5K to \$50K	4 - 1 hour to 4 hours delay
5 - no lost time	5 - under \$5K	5 - less than 1 hour

The three consequence ratings are often all considered, with the highest risk rank in any category (1 is the highest rank) selected as the level of consequence

The method of deriving a risk score is illustrated in Table 3

Table 3. Risk Scoring

		PROBABILITY				
		A	B	C	D	E
CONSEQUENCES	1	1	2	4	7	11
	2		5	8	12	16
	3	6	9	13	17	20
	4	10	14	18	21	23
	5	15	19	22	24	25

- 7 Scores are used to rank all the loss scenarios in order to devise methods to reduce the risks. The discussions occur for all the "unacceptable" risk ranking scenarios (rank 1 to 15)
- 8 Finally the group identifies planned and potential additional control methods for reducing the probability and consequences for each risk starting with the highest risk rank (1 is highest). At this point there is an opportunity to introduce improved safety engineering or other loss control procedures
- 9 The exercise is closed after documentation of potential controls for the priority risks and the results documented for review by the mine. The results from Step 8 should include alternative design or operational ideas that may require additional discussion and, perhaps, cost-benefit analysis before the final action

This type of exercise has been carried out by over two hundred groups in the NSW coal mining industry. The results have been used to pursue government approval for mine initiatives related to the introduction of new equipment and operations both in underground and open cut mines.

4. SYSTEM SAFETY ACCIDENT INVESTIGATION

Other analytical techniques that can be applied to reduce mining risks include Logic Tree Analysis, Job Safety Analysis, Management System Change Analysis, Energy / Barrier Analysis and Human Error Analysis. These techniques provide through different analytical frameworks, suited to different operational or design concerns, the same principles of participative, priority based risk management outlined above.

Since June 1991 the Australian coal mining industry has used System Safety Accident Investigation techniques to investigate serious losses.

The original SSAI concepts were developed by E G & G Co of Idaho Falls, U S A in conjunction with U S Department of Energy for use in the nuclear power industry in the 1970's. Since then these techniques have been modified and used in many high risk industries where fatalities or other catastrophes occur (U.S Department of Energy, 1996)

Initially, the approach was adopted by a state Department of Mineral Resources to investigate fatalities or other serious problems in open cut and underground coal mines. Subsequently, several mining companies have used the techniques for fatality investigations, major production problems and other significant events. There have also been metal mining applications.

The technique offers a systematic method of identifying clearly "what happened" and "why it happened". The event is examined with specific focus on the work management system in order to identify behavioural issues as well as engineering and management decisions that may have contributed to the event.

A unique set of concepts drive the investigation process, leading to more effective outcomes. One concept involves the recognition that there is an inherent risk in every activity which is increased whenever a change occurs. When the change is deliberate (i.e., revised procedures, new personnel, improved equipment, etc.) the risk can be returned to its previously accepted level by implementing an effective counterchange. However, many changes are unintentional (i.e., behavioural change, component failure, human error) and often are unnoticed or unexpected. Failure to adjust to a change leads to either planning errors, operational errors or both.

Once an error has occurred, an unsafe situation occurs that could result in an accident if three conditions exist:

- (a) lack of adequate barriers
- (b) an unwanted energy flow
- (c) a target (such as a person or equipment) in the energy flow

The SSAI concept considers an incident or accident to be an unwanted energy release where the existing barrier was not adequate.

When serious incidents occur they are symptomatic of deficiencies in the safety management system (Stephensen, 1991). This system controls the energy sources in use at the mine through the provision of appropriate barriers, appropriate work methods and competent personnel for the activities undertaken.

When the incident is used as a window through which to view the existing management system, the deficiencies are revealed and benefits are derived which go far beyond correction of the immediate causes of the accident. This is the major difference between the SSAI concept and other accident investigation methods.

Analysis follows a methodical and logical link between the fact finding process and the development of conclusions. The analysis process is beneficial to the investigation as it:

- Method gives credibility to the investigators
- Goes beyond "what happened" into "why it happened".
- Imposes an overall discipline on the investigation process itself

There are several analytical techniques used in the System Safety investigation process, usually applied in a specific order (U S Department of Energy, 1996)

- 1 Events and Conditions Charting as a means of graphically displaying the events in the accident sequence and the preconditions which affect these events uncovered in the fact finding process (Buys and Clark, 1978)
- 2 A Failure Mode Tree Analysis for depicting the possible scenarios for any event in the accident sequence where there were no witnesses
- 3 The Energy/Barrier Analysis to illustrate the unwanted energy flows and barrier inadequacies which contributed to the accident
- 4 Human Error Analysis for systematic examination of the deviations from expected human performance that often occur in serious accidents.
- 5 Change Analysis provides some insight into why the accident occurred by comparing the accident free situation to the accident situation. It is a powerful tool for examining the ideal management system versus actual event situations
- 6 An Analysis of Applicable Codes, Standards and Regulations (CSR's) and mine standards, policies, rules and schemes to indicate areas of non-compliance. This technique commonly exposes deficiencies in the existing CSR's as well as communication breakdowns

Not all of the above techniques are necessarily applied to any particular accident investigation. They are merely "tools" to be used where an accident investigator deems fit. Also, it is important to note that there is an intentional overlap in the techniques themselves, and in combinations of the techniques with respect to the findings revealed.

Each technique usually manages to turn up several unique findings. At the very least, it should provide a new perspective or substantiate findings uncovered by another technique.

Not all accidents or incidents require a full SSAI analysis. Indeed, the cost of doing so may be prohibitive. Typically, accidents resulting in or having the potential for loss of life, massive equipment damage, or prolonged system failure, are those that receive a full and extensive investigation. Investigations for accidents / incidents of lesser severity are typically less intensive.

There have been many applications of the SSAI method in Australia since 1991. Many have been done by government as a result of a serious accident involving one or more fatalities. Some applications have also been done by mining companies and have led to significant changes in mine management systems directly related to spontaneous combustion, large vehicle operations in open cut mines and high pressure hydraulics applications.

5. CONCLUSION - RISK ANALYSIS TO RISK MANAGEMENT - THE FUTURE

Risk assessment and SSAI techniques are firmly entrenched in many Australian mining, despite some initial scepticism over mandated use in certain circumstances. The initial target and benefits were clearly safety based, but other issues are now attracting as much, if not more, attention. Ultimately risk management is seen as good for business. It not only helps management focus clearly on the critical issues, but may be the sole means of satisfactory compliance with duty of care based legislation.

Most mines are now in the process of revising policies and procedures to integrate these techniques into day-to-day operations.

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