IN-DEPTH REVIEW

Occupational safety risk management in Australian mining

J. Joy

Abstract
In the past 15 years, there has been a major safety improvement in the Australian mining industry. Part of this change can be attributed to the development and application of risk assessment methods. These systematic, team-based techniques identify, assess and control unacceptable risks to people, assets, the environment and production. The outcomes have improved mine management systems. This paper discusses the risk assessment approach applied to equipment design and mining operations, as well as the specific risk assessment methodology. The paper also discusses the reactive side of risk management, incident and accident investigation. Systematic analytical methods have also been adopted by regulatory authorities and mining companies to investigate major losses.

Key words
Australia; mining, occupational safety; risk management.

Introduction
Across the globe, laws regulating the health and safety of workers are increasingly including requirements for risk assessment and risk management. 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 [1].

Fifteen years ago, the Australian coal mining industry started to investigate the use of more systematic safety engineering to reduce the highly unacceptable injury and fatality rates occurring in the industry. This 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 research project to investigate and trial the approaches.

Since those early initiatives, risk assessment and management, often using system safety principles, has become an integral part of coal mining in eastern Australia. Some of the related initiatives have helped reduce the loss time injury frequency rate (LTIFR) in Australian coal mining from pre-1988 site levels sometimes exceeding a 200 LTIFR to current levels of <20 and, in some cases closer to 5. The trend is very positive, leading all mining companies to believe that single figure LTIFR’s are achievable [2].

Reduction of the industry fatality rate has also been heartening. This apparent trend has occurred despite major reductions in the industry workforce and changes in mining technology, often involving major hazards.

Although the full impacts of risk assessment on the industry have not yet been objectively measured, comments from all levels of the mining industry are generally positive. It is clear that the approach has a valuable role in assisting with planning and managing operations, as well as helping equipment manufacturers to supply safer machines. This should have even greater future safety and productivity implications for the entire mining industry.

Currently, most Australian state mining regulators require risk assessment for development of management systems and other applications. However, many mining companies have gone beyond regulatory expectations, developing procedures and resources in the area that clearly indicate a ‘good-business’ belief behind the effort.

Minerals Industry Safety and Health Centre (MISHC), University of Queensland, Queensland, Australia. e-mail: j.joy@mishc.uq.edu.au

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Risk assessment background

Increasingly, the control of risks is necessary to secure compliance with the requirements of Occupational Health and Safety Acts, State Coal Mines Regulation Acts, Environmental Protection Acts and protection against litigation from accidents.

The role of risk assessment in management activities is well accepted in many industries. The approach is characterized by the four-stage process of risk management. These risk management steps are as follows.

1. Risk identification—identifying the hazards and the situations that have the potential to cause harm or losses (sometimes called ‘unwanted events’).
2. Risk analysis—analysing the magnitude of risk that may arise from the unwanted events.
3. Risk control—deciding on suitable measures to reduce or control unacceptable risk.
4. Implementing and maintaining control measures—implementing the controls and ensuring they are effective.

This four-stage process forms the basis on which hazards are identified and evaluated in terms of the risk to people, as well as production, the environment, the community and other potential consequence areas.

‘Risk identification’ is the essential first step in risk management. The identification of unwanted events should involve a critical appraisal of all the potential hazards to employees and others affected by the organization’s activities such as the public and contractors.

Hazards must be recognized and understood so that potential unwanted events related to the hazards can be credibly defined. Looking for hazards proactively can be a challenge. Often people find it difficult to see beyond their experience base. One commonly used method to prompt creative thinking involves the energy concept.

Damage cannot occur without the unwanted release of energy. There are only a few general types of energies within which virtually all specific hazards can be listed. The following list is a typical prompt basis:

- gravity;
- electrical;
- mechanical;
- chemical;
- pressure;
- thermal;
- radiation;
- biomechanics;
- biological.

Methods of gathering information on hazards include observation, interviews, documentation review and team exercises. The latter method allows for quick and effective data gathering, especially if the team includes people that clearly understand the current or potential situation being reviewed.

There are many different risk assessment techniques. Each has its own specific purpose and outcome [3]. The most common risk assessment techniques in Australian mining are listed below.

- Informal risk assessment (RA)—general identification and communication of hazards and risks in a task by applying a way of thinking, often with no documentation.
- Job safety/hazard analysis (JSA/JHA)—general identification of hazards and controls in a specific task, usually for determining the basis of a standard work practice (SOP).
- Preliminary hazard analysis/hazard analysis/workplace risk assessment and control (PHA/HAZAN/WRAC)—general identification of priority risk issues/events, often to determine the need for further detailed study.
- Hazard and operability study (HAZOP)—systematic identification of hazards in a process plant design.
- Fault tree analysis (FTA)—detailed analysis of contributors to major unwanted events, potentially using quantitative risk analysis methods.
- Event tree analysis (ETA)—detailed analysis of the development of major unwanted events, potentially using quantitative methods.
- Failure modes, effects and criticality analysis (FMECA)—general to detailed analysis of hardware component reliability risks.

The risk assessment team membership varies with the exercise objective and the technique. A team might comprise representatives from any, some or all of the following:

- corporate management;
- mine/site management;
- machine operators/fitters/electricians;
- union representatives;
- equipment suppliers/government representatives.

The team is lead by an appropriately skilled facilitator through a step-by-step method for completing the risk assessment. The facilitator’s role is to ensure that the specific risk assessment method is applied effectively and consistently throughout the exercise.

Analysing risks is necessary in order to identify the relative importance or priority of an unwanted event. It also requires that the events be discussed to obtain information about their extent and nature [4].

Determining the relative priority of each risk involves deciding on the consequences of the unwanted event and the likelihood of its occurrence (sometimes described as the risk equation, where risk = probability × consequences) (see Table 1).
The availability of accurate information for the two variables determines the type of risk analysis possible:

- when the severity of the loss can be measured objectively and the likelihood of the event can be identified from relevant historical data, a quantitative risk assessment can be conducted;
- when the severity and likelihood cannot be specified exactly but can be estimated based on judgements or opinion, a qualitative or semi-quantitative risk assessment can be conducted.

In the vast majority of cases, the Australian mining industry conduct qualitative risk assessments [5]. This is because:

- there is a lack of accurate, valid ‘hard’ data about event likelihood;
- there is a wealth of industry experience at the management, supervisory and operational levels that can suggest subjective consequence and event likelihood;
- most of the time the objective of the risk assessment is to manage priority risks, an objective that does not require a quantitative approach for an effective outcome.

There is no single method for subjectively rating risks, but a number of techniques have been developed to assist in establishing priority. Emphasis should be given to risks that present the greatest potential consequence. Risks that could lead to catastrophic consequences, albeit infrequently, are given greater priority than those risks that can result in only small losses. The likelihood of occurrence (or probability), though sometimes very subjective should also be considered when establishing the overall qualitative risk.

A qualitative risk value can be created for each unwanted event by using pre-established tables to assist in identifying the likelihood and consequences, usually the maximum reasonable (Table 2). Qualitative risk scoring methods have existed for many years and remain similar to those presented in US Department of Labour information on system safety engineering [7].

Following is an example of a basic qualitative risk ranking approach.

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 rank is illustrated in Table 3.

The numbers are used to rank the unwanted events in order to devise methods to reduce the risks; methods commonly called controls. The discussions occur for all the ‘unacceptable’ risk ranking scenarios (possibly rank 1–4).

The group identifies planned and potential additional control methods for reducing the probability and consequences for each risk starting with the highest risk rank.

Risk control discussions occur after unwanted events have been identified but sometimes before and sometimes after event risk is analysed. All final decisions about risk control measures must take into account the relevant legal requirements that establish minimum levels of accident prevention. Basically, risk control activities fall into the following categories:

- elimination of hazards by removal, reduction or substitution;
- designing machinery and work activities to minimize the release of energy, or to suppress energy releases;
- isolation from the risk by remote operation or guarding or enclosures;
- defining work methods or procedures;
- protecting people with protective equipment and clothing;
- 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 effective monitoring and auditing. Priority controls should be documented as a means of ensuring effective auditing and conformity with the principles of total quality management such as those defined by the international standard ISO 9000.

Many Australian mines frequently apply some form of

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<th>Table 2. Maximum reasonable consequences (should the event occur)</th>
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<td>1. Fatality or permanent disability</td>
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<td>2. Serious lost time injury/illness</td>
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<td>3. Moderate lost time injury/illness</td>
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<td>4. Minor lost time injury/illness</td>
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<td>5. No lost time</td>
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formal risk assessment method for a change or post incident review.

Systematic accident investigation

Systematic incident and accident investigation is a spin-off of the risk assessment application. These techniques, similar to risk assessment methods, have undoubtedly helped mines critically examine how well they have managed critical risks after events such as mine fires and fatalities.

Since the early 1990s, the coal mining industry has used various formal techniques to investigate serious losses.

The system safety accident investigation (SSAI) techniques constitute one example, developed by E.G. & G. Co. of Idaho Falls, USA in conjunction with US Department of Energy for use in the nuclear power industry in the 1970s. The techniques have been subsequently modified and used in many high risk industries where fatalities or other catastrophes occur.

The techniques offer 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 that 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 counter change. 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 can lead to either planning errors or operational errors, or both.

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

1. lack of adequate barriers;
2. an unwanted energy flow;
3. a target (such as a person or equipment) in the energy flow.

This concept considers an incident or accident to be an unwanted energy release where the existing barriers were not adequate.

When serious incidents occur they are symptomatic of deficiencies in the safety management system. 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.

Systematic accident analysis provides a methodical and logical process for fact finding process and the development of conclusions. It is beneficial to the investigation as it:

- 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 SSAI investigation process, usually applied in a specific order, as follows.

‘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 [6].

‘Fault tree analysis’ for depicting the possible scenarios for any event in the accident sequence where there were no witnesses.

‘Energy/barrier analysis’ to illustrate the unwanted energy flows and barrier inadequacies that contributed to the accident.

‘Human error analysis’ for systematic examination of the deviations from expected human performance that often occurs in serious accidents.

‘Gap 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.

Not all of the above techniques are necessarily applied to an accident investigation. They are merely ‘tools’ to be used by an accident investigation facilitator. Typically, accidents resulting in or having the potential for loss of life, massive equipment damage, or prolonged system failure, receive a full and extensive investigation. Investigations for accidents/incidents of lesser severity are typically less intensive.

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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.

### Conclusion—the future

Risk assessment and systematic accident investigation techniques are firmly entrenched in most Australian mines. The initial target and benefits were clearly safety based, but other issues such as the environment and production delays 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 also may be the sole means of satisfactory compliance with duty of care based legislation.

### References