REPORT

Fatal accidents in the Western Australian mining industry 2000-2012

What lessons can we learn?

Government of **Western Australia**
Department of **Mines and Petroleum**
Investigation Services and Resources Safety

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Reference

Department of Mines and Petroleum, 2014, Fatal accidents in the Western Australian mining industry 2000-12: what lessons can we learn? – report: Investigation Services and Resources Safety Division, Department of Mines and Petroleum, Western Australia, 17 pp.

ISBN 978 1 922149 20 6

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1 Introduction

This report examines the 52 fatal mining accidents that occurred in Western Australia over the 13-year period from 2000 to 2012, inclusive.

Most of the information came from completed investigation reports in the Department of Mines and Petroleum's archives. However, a number of investigations, some dating back to 2008, were continuing through legal proceedings when the information was compiled. If the findings of a magistrate or coroner during any future prosecution or inquest differ from the investigation findings, the results reported here may require minor amendment, but such a scenario is considered unlikely.

The information was analysed to identify common hazards, causation factors and critical activities. Twenty-four causation factors were identified and used to provide a framework for analysis. A person might conduct 50 to 100 tasks during a shift, of which just one or two could lead to a situation with the potential for serious injury or death. So knowledge of the critical tasks is important when addressing risks.

The sample size is too small (fortunately) for statistical comparison and therefore the reviewers looked for trends and clusters to determine what might have contributed to the fatalities. The reviewers also sought to recommend areas for industry to address that may result in improved safety performance by raising awareness and reducing the exposure of workers to the hazards implicated in the fatalities. This improvement should be achieved through a more rigorous application of the hierarchy of control, and better targeting of preventative action programs and activities.

Note: To ensure confidentiality, this report does not identify deceased employees, mines or mining companies.

2 General safety theory and practice

The development of safety theory has been a progressive process since the 1950s. The earliest safety legislation was developed in the mid-1800s in the United Kingdom as the industrial revolution gained pace. Many thousands of people were leaving the land to seek employment in mines and factories, which unfortunately led to many accidents, with people being killed and maimed.

Social concerns about these deaths and injuries resulted in the development of safety legislation based on a regulatory model. In mines, regulations were promulgated to cover situations that could cause accidents. The method worked well for many years in addressing common standards, practices and machines.

This model continued until the late 1960s, by which time it was apparent that safety performance had reached a plateau. The United Kingdom parliament commissioned a review of industrial safety to investigate this problem. The review was conducted by a committee under the chairmanship of Lord Alfred Robens. The review proposed a model of enabling legislation to replace the regulation-based system, and it was introduced in the United Kingdom in the 1970s. Australia followed this legislative trend.

The enabling model allows employers and employees to develop safe systems of work without the need for government to develop ever more complex regulations. The legislation places duties on all industry stakeholders, with the emphasis on employers to provide a safe working environment.

The Robens' model promotes employee involvement by way of safety committees and safety representatives. Employees are also required to report hazards and incidents that might cause injuries.

Many of the concepts of enabling legislation were put into practice in the British coal mining industry by the mid-1970s, and contributed to it being the safest mining industry in the world at the time.

The Du Pont organisation in the United States of America also made great progress, over more than a century, in safety associated with the production of explosives and hazardous chemicals. Safety committees are an integral component of the Du Pont system. This resulted in Du Pont being regarded as a world leader in safety system development.

Also in the 1970s, another important development was the structured safety system approach pioneered by Frank Bird. He was a safety professional from America who worked in a number of industries, including steel and insurance. Bird developed the International Safety Rating System (ISRS), which was adopted by the Chamber of Mines in South Africa and later purchased by Det Norske Veritas for use in the North Sea oil and gas industry. The element-based safety system model has been applied around the world, and to Australian/New Zealand Standards AS/NZS 4801 and 4360 for safety systems and risk management, respectively.

The ISRS system incorporates a risk management approach, including a formal method to identify critical tasks that pose the risk of injury to employees. The method also emphasises the importance of investigating incidents and near misses as well as accidents that cause injuries.

Professor James Reason's work on accidents within an industrial system is a more recent development. He worked with a range of industries, including nuclear, medical, railways and mining, and compares hazards in a system to pathogens in a medical environment. Just as infections and cancers can develop in the human body, so can accidents develop in an industrial system. The way people interact with industrial systems can lead to errors and accidents.

Professor Reason also introduces the concept of latent and active failures. There can be combinations of factors that accumulate to cause an active failure. It is important to understand the underlying issues, as well as the final event, to understand how accidents develop.

These developments in safety theory have led to a greater understanding of accidents in the work place, and it is now recognised that accidents are not simple events caused by the neglect of employees. They are due to combinations of factors, such as safe systems of work, culture of organisations, knowledge of employees, effectiveness of supervision, extent of training, and involvement of employees.

Accident investigation techniques typically adopt the multiple cause theory — causal events align to cause a failure. In Australia, this concept is commonly applied using approaches such as:

- incident cause analysis method (ICAM)
- TapRooT® root cause analysis methodology
- event and causal factors analysis.

These methods recognise that accidents generally result from a specific sequence of events initiated by immediate and underlying causes. An investigation should strive to identify all the causes and analyse the circumstances surrounding an accident. It is only by completing this process that effective improvements can be implemented.

The following definition of safety comes from Frank Bird's work and is considered to be most useful as a background to this report:

Safety is an attitude of mind by which people are constantly aware of the hazards around them and take action to prevent themselves or others being injured.

The attitudes of mind in a workplace can be heavily influenced by the culture of the organisation, and the motivations and beliefs of employees.

There are always hazards in industrial systems and these hazards involve the risk of injury to people. For workers to be aware of the hazards around them, the hazards must first be identified. Instruction and training must then be provided to inform workers about those hazards.

To prevent the risk of injury to employees, it is essential that safe systems of work are developed and implemented. Workers should be involved in the development process — involved and engaged employees are more likely to take action to prevent themselves and others being injured.

Western Australia's *Mines Safety and Inspection Act 1994*, which is based on the Robens' model of enabling legislation, allows for the use of safety systems, risk management and employee participation.

3 Workforce and fatality statistics

Table 1 shows the number of employees increasing from about 40,000 in 2000 to almost 100,000 in 2012. The number of workers involved in exploration, and underground and surface mining all increased over that time.

There were 50 mining and two exploration fatal accidents over the 13-year period. This gives an average of four fatal accidents each year.

Of the 52 fatal accidents, 17 were underground and 35 were on surface. Over the period of the review, there were about ten times as many people employed in surface mines as underground mines, giving a fatal incidence rate about five times greater for underground work as compared to surface work.

There have been a number of step changes in fatal accident performance over the past 50 years. In the 1940s-50s, the accident rate was around two fatal accidents per thousand employees per annum. This would equate to 200 fatal accidents a year at 2013 employment levels.

In the 1960s-70s, the rate halved to one fatality per 1,000 workers, which would correspond to about 100 deaths each year at 2013 employment levels.

In the 1980s-90s, there were typically eight to ten fatalities each year for a workforce of around 30,000.

Figure 1 shows that the workforce grew rapidly over the period of the review, apart from a decline between 2008 and 2009 at the time of the global financial crisis.

The highest number of fatal accidents was in 2000.

There was a significant reduction in the number of fatal accidents in 2002, with only two fatalities from 42,000 employees, which clearly represents a major change in performance over time. This improvement may be attributed to a range of factors. The enabling safety legislation and in particularly industry's increased application of safety systems and risk management techniques probably had a significant influence on performance.

Unfortunately, there was an increase in the number of fatal accidents after 2002 as the workforce increased. A second peak of six deaths occurred in 2009. This cluster of fatalities resulted in the Minister of Mines undertaking a review of the safety matters affecting the industry. Commissioner Kenner was appointed to conduct the review. The resourcing and structure of the mines inspectorate were key issues identified.

In late 2009, the Department implemented the Reform and Development at Resources Safety (RADARS) strategy, funded by the Mines Safety and Inspection Levy. This strategy was developed in response to the Kenner and other independent reviews and inquiries following mining incidents and fatalities.

Table 1 Employee statistics for the Western Australian mining industry from 2000 to 2012

Exploration			**Mining**					
Year	Number of exploration employees	Total exploration fatalities	Number of mning employees (underground)	Number of mining fatalities (underground)	Number of mining employees (surface)	Number of mining fatalities (surface)	Total number of mining employees	Total mining fatalities
2000	769	**0**	3,517	**5**	35,465	**2**	38,982	**7**
2001	640	**0**	3,361	**0**	37,863	**6**	41,224	**6**
2002	618	**0**	4,057	**1**	37,324	**1**	41,381	**2**
2003	535	**0**	4,197	**1**	40,007	**4**	44,204	**5**
2004	643	**0**	4,551	**1**	43,434	**3**	47,985	**4**
2005	817	**0**	5,061	**2**	49,333	**2**	54,394	**4**
2006	988	**0**	5,630	**2**	52,572	**1**	58,202	**3**
2007	1,469	**1**	7,026	**2**	56,981	**1**	64,007	**3**
2008	2,296	**0**	7,585	**0**	62,837	**4**	70,422	**4**
2009	2,353	**0**	6,901	**1**	60,579	**5**	67,480	**6**
2010	3,231	**1**	7,841	**2**	66,907	**1**	74,748	**3**
2011	4,059	**0**	9,447	**0**	78,074	**3**	87,521	**3**
2012	3,211	**0**	10,500	**0**	85,190	**0**	95,690	**0**
TOTAL		**2**		**17**		**33**		**50**

Both government and industry had realised that an improved approach was needed. Other recommendations of the Kenner review relate to the use of the safety system and risk management approach. The application of principal hazard management plans was endorsed in line with the National Mines Safety Framework.

There were no fatal accidents in the Western Australian mining industry in 2012, the first time this has been achieved in over a century of recorded history.

Since the end of the review period until March 2014, there have been four fatal accidents, three in 2013 and one in 2014. These tragic incidents reinforce the need for everyone involved with the industry to remain vigilant at all times.

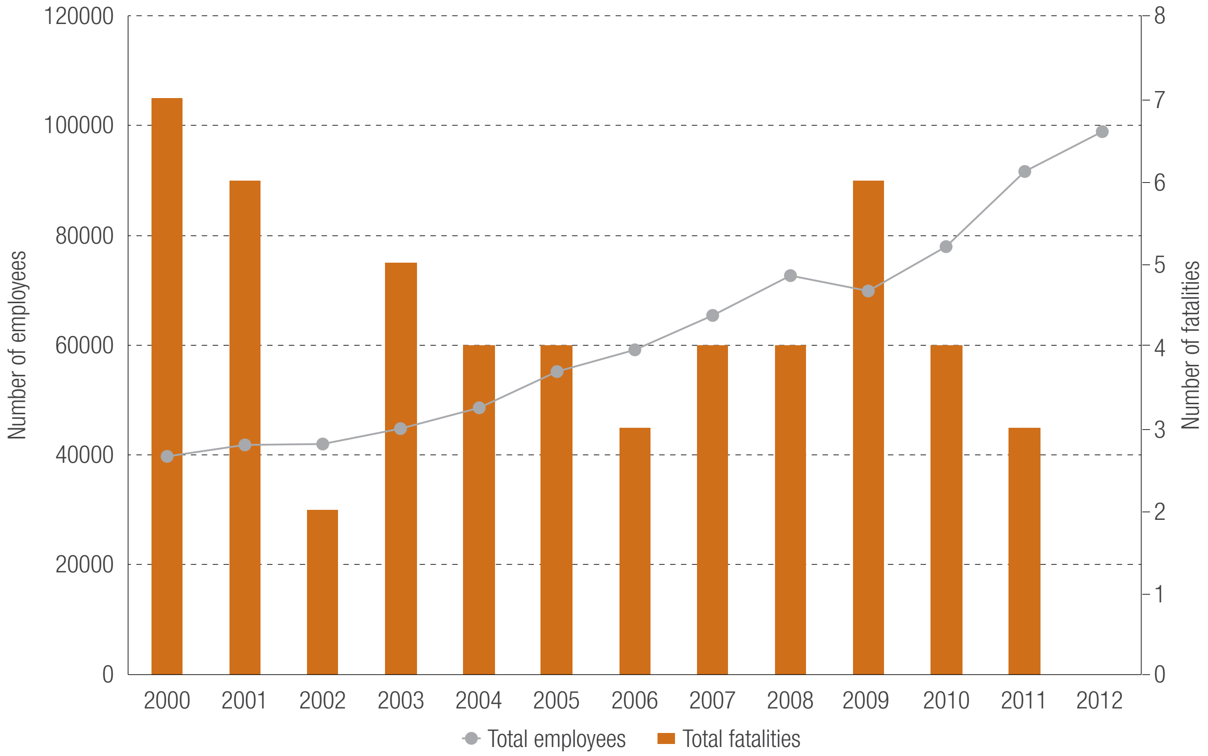

Figure 1 Annual workforce and fatality figures for the Western Australian mining industry from 2000 to 2012

4 Causation factors

4.1 Factors considered

The following causation factors were gleaned from archived information. Some factors were evident from the commencement of the project, while others became apparent as the investigation reports were reviewed.

- Day of the week
- Age of deceased person
- Occupation of deceased person
- Commodity group
- Activity area (e.g. maintenance, production, operations)
- Mine site
- Principal employer
- Location (e.g. surface, underground)
- Written procedure or rule for the task
- Compliance with written procedure or rule
- Changes to standard provided by original equipment manufacturer (OEM)
- Trigger event (e.g. unsafe act or workplace)
- Roster cycle
- Time of accident
- Shift (i.e. day, night)
- Hours into shift
- Days into roster
- Duration in the role – deceased person
- Duration at the mine – deceased person
- Employment type (e.g. contractor, employed by Principal Employer)
- 457 Visa (e.g. temporary or permanent resident)
- Language (e.g. spoken English proficiency)
- Age of supervisor
- Duration in the role – supervisor.

Factors for which trends or clusters can be identified are discussed below, broadly ordered according to apparent influence. Given the significance of trigger events to individual fatalities, critical activities are described in more detail in Chapter 5.

No patterns of influence are apparent for the remaining factors, such as day of the week, employment status and visa type. Fatalities were evenly distributed between maintenance, production and operations. The lack of discernible influence may be because there is no causation effect, or further analysis was not possible due to insufficient information or the requirement for normalisation to aid interpretation.

Note: The sample size for some graphs is less than 52 where the relevant information could not be determined from the investigation report.

4.2 Occupation of deceased person

The occupation groups of tradesmen and operators contributed 36 fatal accidents, which is about 70 per cent of the total.

There were 19 fatalities across the trades:

- 9 fitters
- 3 electricians
- 4 technicians
- 3 maintenance personnel.

Equipment operators contributed 17 fatal accidents in the following categories:

- 5 haul truck drivers
- 4 service vehicle drivers
- 4 jumbo operators
- 3 LHD (bogger) operators
- 1 bulldozer driver.

These occupations require personnel to work with or near sources of high energy. Application of the hierarchy of control, particularly elimination, substitution and engineering solutions, is important to limit the potential effect of energy exchange mechanisms.

4.3 Duration in the role – deceased person

As illustrated in Figure 2, almost one-third of fatalities occurred in the person's first year in a role, with 48 per cent of fatalities being workers who had been in their role for two years or less. This indicates the importance of effective induction, training and supervision of new workers in the first months of employment or contract.

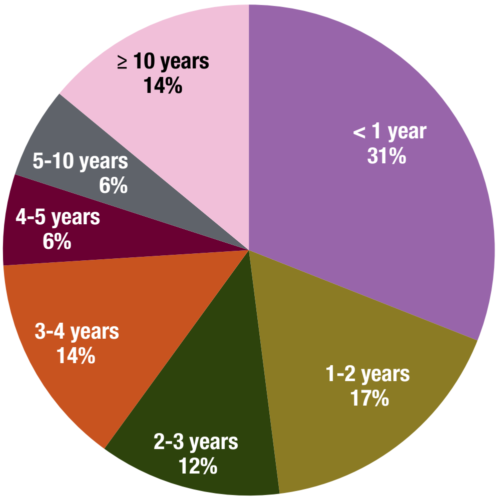

Figure 2 Duration of deceased person in role as a percentage of total fatalities [sample size = 49]

4.4 Duration at the mine site – deceased person

Figure 3 shows that the first year working at a mine site is an important period, regardless of experience elsewhere or years in an occupation, and accounted for 49 per cent of fatalities. The graph shows 6 per cent of fatalities were workers in their first week at a mine, 6 per cent in the remainder of the first month, and 37 per cent from the second month to the end of the first year.

As for duration in the role, this indicates that the induction, training and supervision of workers in the first months of employment at a new site are very important. Training procedures and verification of competency should ensure personnel are familiar with the site and its hazards, as well as the hazards within the task and site's method to complete the task.

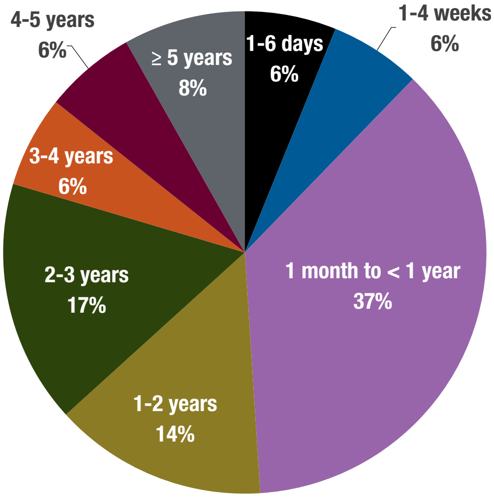

Figure 3 Duration of deceased person at the mine as a percentage of total fatalities [sample size = 49]

4.5 Duration in the role – supervisor

The length of time the supervisor had been in the role also features when reviewing the fatality data. Figure 4 shows that 44 per cent of fatal accidents occur under the supervision of a person in their first year in the role, with 6 per cent in the first month.

Almost a quarter of fatalities involved a supervisor in their second and third year in the role. Overall, 68 per cent of fatalities occurred during the supervisor's first three years in the role.

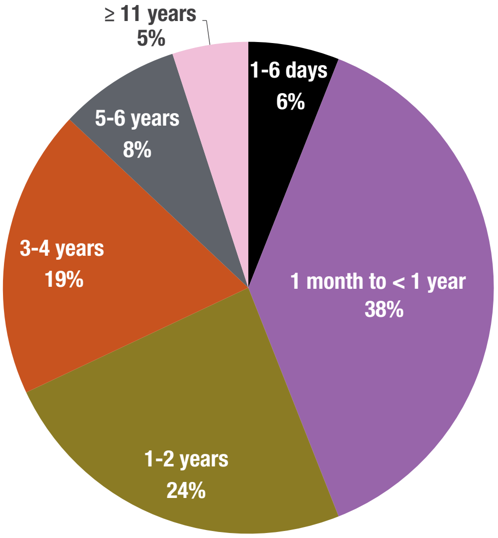

Figure 4 Duration of person undertaking supervisor's role as a percentage of total fatalities [sample size = 37]

4.6 Compliance with procedures

The review considered whether or not there was a written procedure or rule for the task being carried out at the time of the accident and, if so, whether it was being followed.

As shown in Figure 5, it is clear that the hazards associated with the work were known in most cases, with a procedure available to guide people in the task in 73 per cent of fatal accidents. However, in 89 per cent of fatal accidents, there was either no procedure in place or the procedures or rules were not complied with.

It appears that the long-standing adage that there are "very few new accidents, just repeats of old accidents" is confirmed by these observations and illustrates the importance of a safety approach that is hazard and precaution based. This concept recognises that many accidents are repeat events where both the hazard and the precaution or controls that will prevent injuries are known.

It also raises questions about why workers are not complying with the procedures for known hazards, or why there was no procedure in place for tasks that accounted for over a quarter of the fatalities. It could be inferred that there are problems with hazard recognition and the implementation of effective controls. These will need to be addressed through effective supervision, training, instruction and the provision of information. The results also emphasise the importance of risk assessments for new tasks, systems of work and plant.

The legislation requires safe work practices to be developed for all tasks that could cause a worker to be exposed to a hazard which could result in an injury. Workers should be involved in the development of safe work practices because engaged workers are likely to be more motivated to comply with job requirements that they have developed.

Employers must then provide adequate information, instruction, training and supervision to ensure that work standards are complied with. Planned inspections and task observations are recognised methods to monitor compliance with work standards.

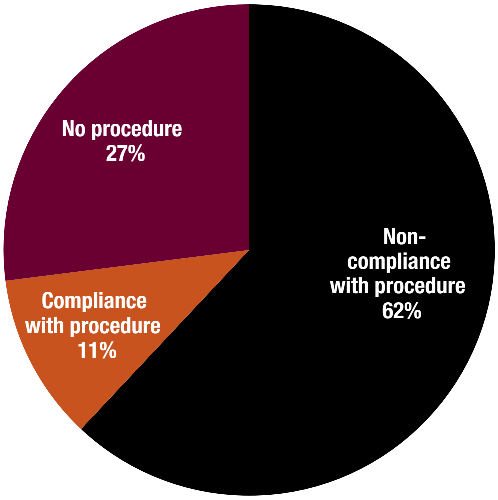

Figure 5 Availability of procedure and procedural compliance as a percentage of total fatalities [sample size = 52]

Improved supervision and strict discipline regarding procedural compliance can lead to rapid improvements in this area. Indeed, this could partly explain the marked improvement in accident outcomes at the end of the review period.

4.7 Trigger events

In most accidents, a number of factors influence the outcome and they commonly occur as a sequence of events. As the sequence progresses, opportunities for prevention are missed until the final barrier is overcome. The term "accident trigger" is used to represent the last event that contributed to the accident — it was the last chance to stop the sequence of events leading to the accident.

For analysis purposes, the information derived for trigger events was divided into unsafe acts (Figure 6) and unsafe workplaces (Figure 7), with no blame assigned or implied to individuals for outcomes. Under Professor Reason's model, the final outcome can be regarded as the product of the pathogens in the system. If the final barrier had not been breached, the accident would not have occurred.

A significant number of the fatalities had common triggers, and these were placed in groups that correspond to the top ten fatal accident scenarios or critical activities. Chapter 5 contains brief descriptions of the accident trigger for each fatality assigned to a critical activity group.

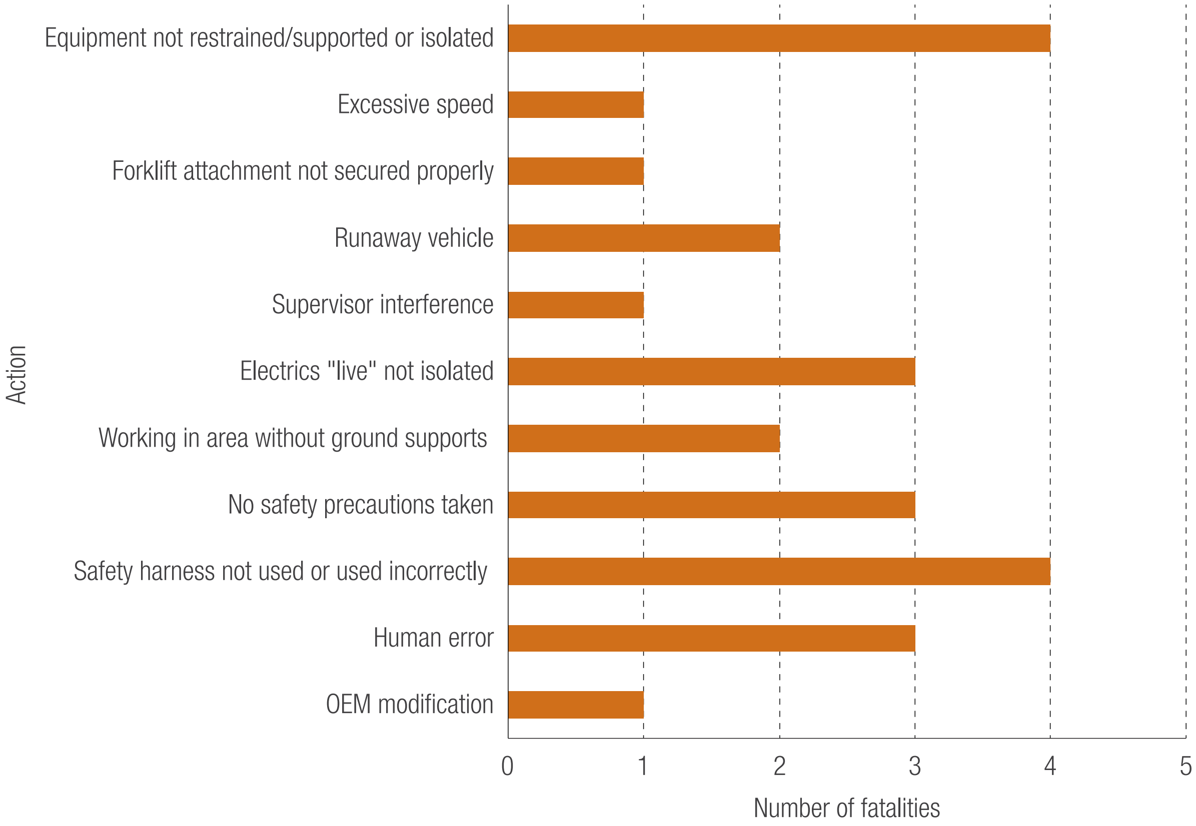

Figure 6 Unsafe trigger action that led to fatal accident, according to investigation report [sample size = 25]

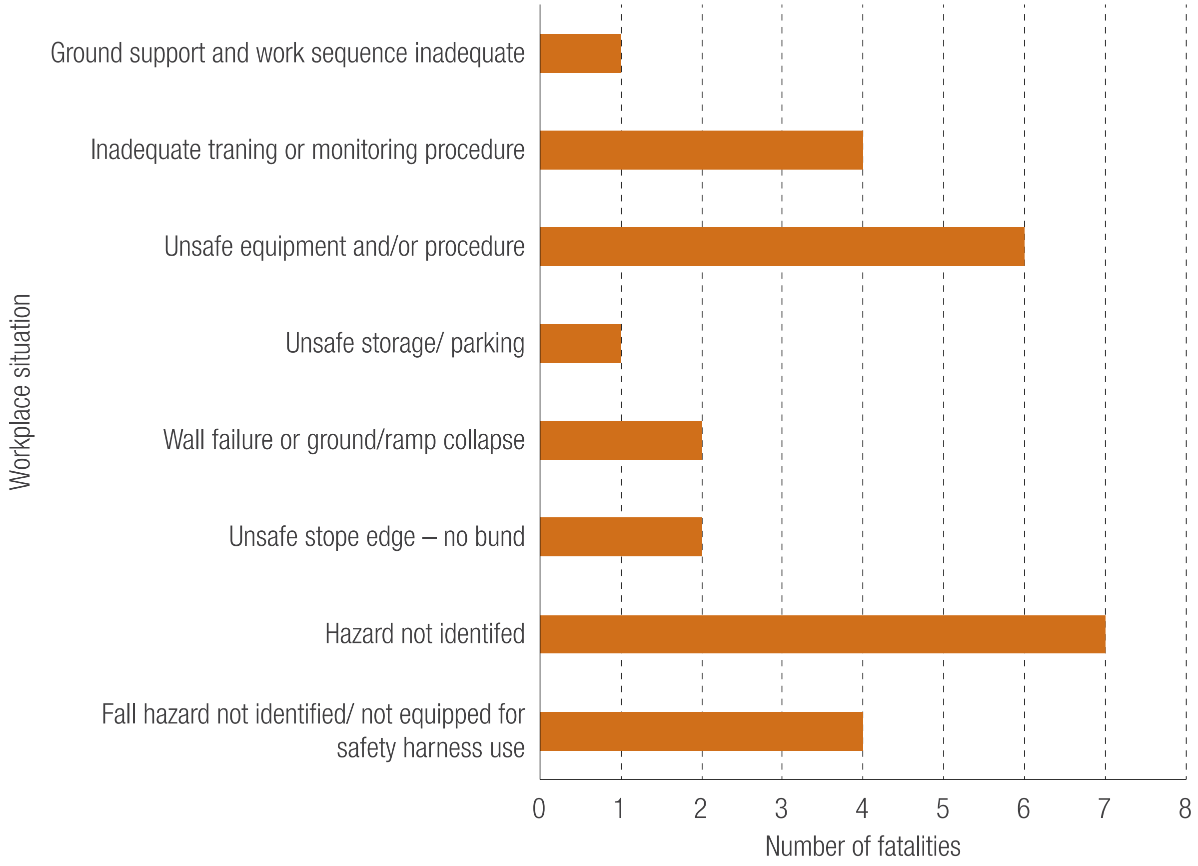

Figure 7 Unsafe workplace situation that led to fatal accident, according to investigation report [sample size = 27]

4.8 Time of day

A wide range of rosters were represented in the investigation reports. It has been suggested that the time of the day is significant for fatal incidents, and this notion is supported by the sample in the review period. Figure 8 shows broad peaks in the number of incidents for the following times:

- **3-6 pm**, the last three hours of the day shift. Note that this cluster is not reflected in the data for the night shift, for which the last two hours of the night shift (4-5 am) appear to be two of the safest hours in the working shift.
- **11 am** (day shift) and **11 pm** (night shift), which is roughly five hours into the working shift, assuming most shifts start at 6 am and 6 pm, respectively.
- Another peak at **3 am** during night shift.

Possible reasons for this distribution include human factors and fitness-for-work issues.

Human factors, such as a person's biorhythms, may influence the likelihood of an error.

- For a standard day shift, a worker may wake early and then work for an extended period of time until lunch. They may become fatigued, lose concentration, and be more prone to accidents at around 11 am. After a lunch break and another long work period, the worker may be focused on finishing up for the day and the shift change, losing concentration around 3-6 pm.
- For a standard night shift, a worker may work an extended period with fatigue setting in around 11 pm before the break at midnight — normally a time when people are in bed. The early hours of the morning, around 3 am, is a time when people are likely to be least alert.

Workers who are fatigued, whether physically or mentally, are more likely to lose concentration than people who are alert. Many mines utilise twelve hour shift rosters on a 24/7 continuous mining system. In particular, fatigue management plans should consider the times listed above as being problematic and include measures to keep people alert (e.g. promote fitness-for-work habits, provide adequate breaks during the shift).

Fitness-for-work issues that affect concentration levels include:

- hydration level, especially in hot workplaces
- regular meals during the shift
- a balanced diet with fresh fruit and vegetables
- exercise and fitness level
- stretching exercises
- moderating alcohol intake
- attention to sleep quality
- avoiding substance abuse
- work life balance.

To maintain concentration and to mitigate fatigue during long shifts, workers should have the opportunity to take breaks from routine tasks. For example, breaks at four-hour intervals for food and rest appear to be appropriate for 12-hour shift operations. Some mines allow workers to take "micro-sleeps" to maintain concentration and alertness before continuing their task. Road safety authorities suggest short breaks every two hours for attention retention, a strategy that could be relevant to mining workplaces.

4.9 Surface or underground

Figure 9 shows the increase in the number of surface workers over the study period from 36,000 to almost 90,000, with the number of fatalities varying between zero and six with an average of three.

The increase in the number of fatalities from 2006 to 2009 may relate to the rapid expansion of the iron ore sector in the Pilbara during the review period, while the decrease at the end of the period may be attributed to the increased level of safety system and risk management developments by the industry. A more disciplined approach to compliance with standards could also be a factor.

Note: Unfortunately, in 2013, the year following the review period, there were three fatal accidents in surface operations — two at iron ore mines and one at a gold mine.

As shown in Figure 10, the number of employees engaged in underground operations more than doubled from less than 4,000 to over 10,000 during the review period. There were 17 fatalities.

In the 1980s and 1990s, underground fatalities exceeded those on the surface. A 1997 review of fatalities in Western Australian mines, which covered 25 fatalities over a three-year period from 1995 to 1997, found that 11 of the 14 underground fatalities related to fall-of-ground incidents.

Although underground workers were over represented by a factor of five when normalised to workforce numbers over the 13-year period, this trend showed signs of reversing. The most recent fatal accidents in the review period have been in the iron ore sector (i.e. surface), with one fatality underground. Possible reasons for this include:

- changes in ground support standards and geotechnical knowledge leading to improved safety performance for underground mining
- improved mine planning and stope scheduling in underground mines
- using remote loading techniques and raise-boring instead of rise-mining
- there are about ten times more workers in surface operations than underground.

Note: Unfortunately, a worker was fatally injured in an underground rock fall in February 2014.

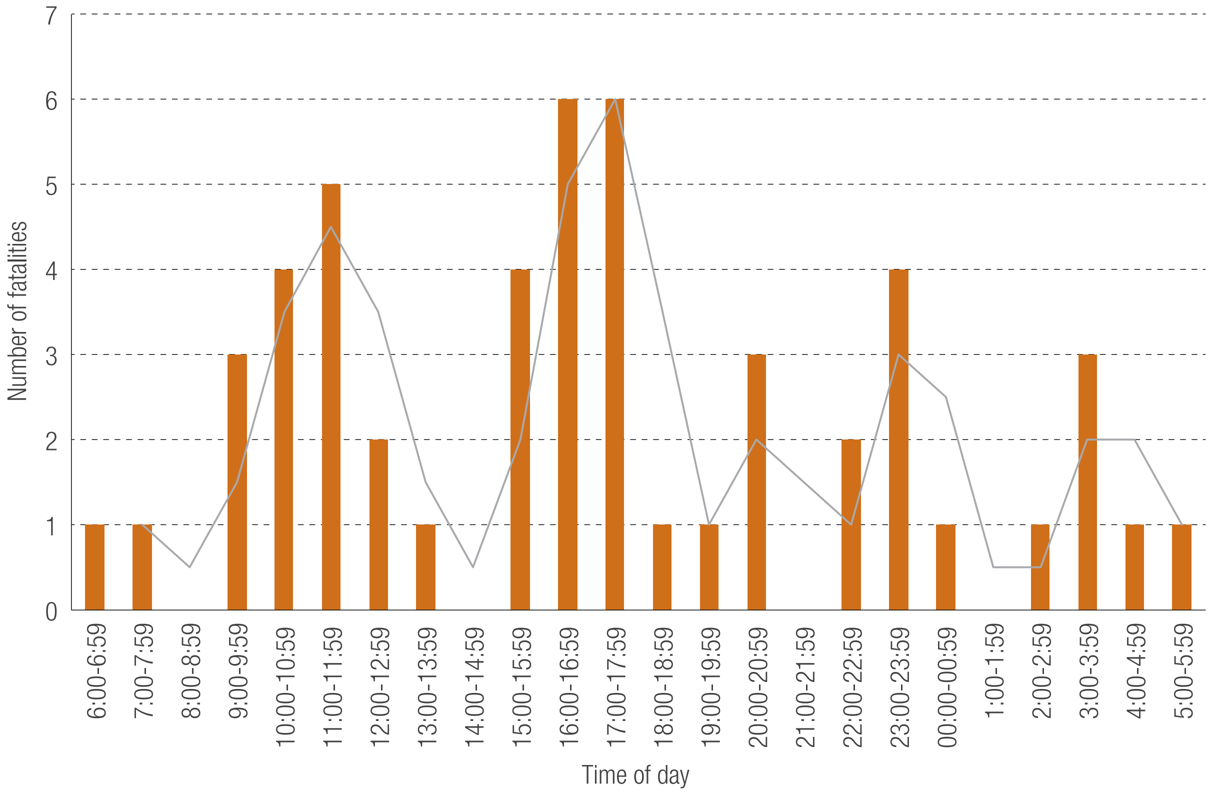

Figure 8 *Frequency of fatalities by time of day (in hourly intervals). The trend line is plotted over the 24-hour period [sample size = 51]*

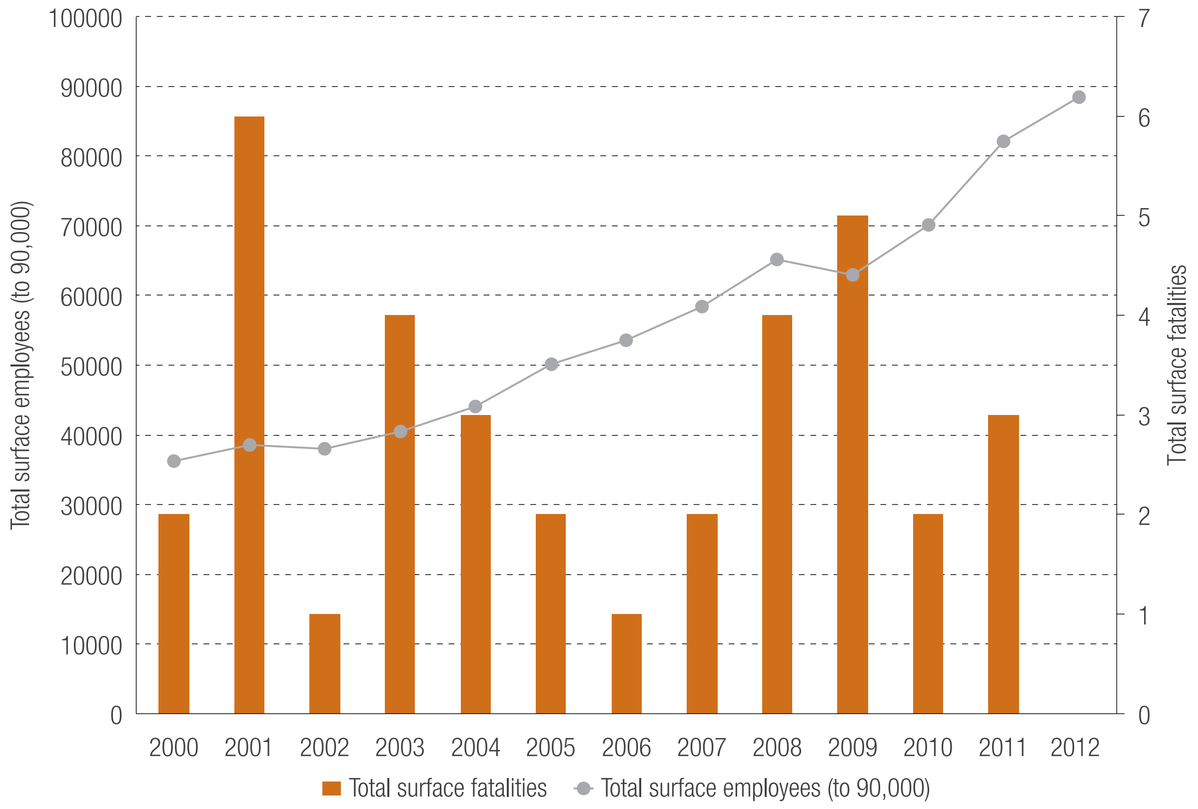

Figure 9 *Surface employees and fatal accident numbers*

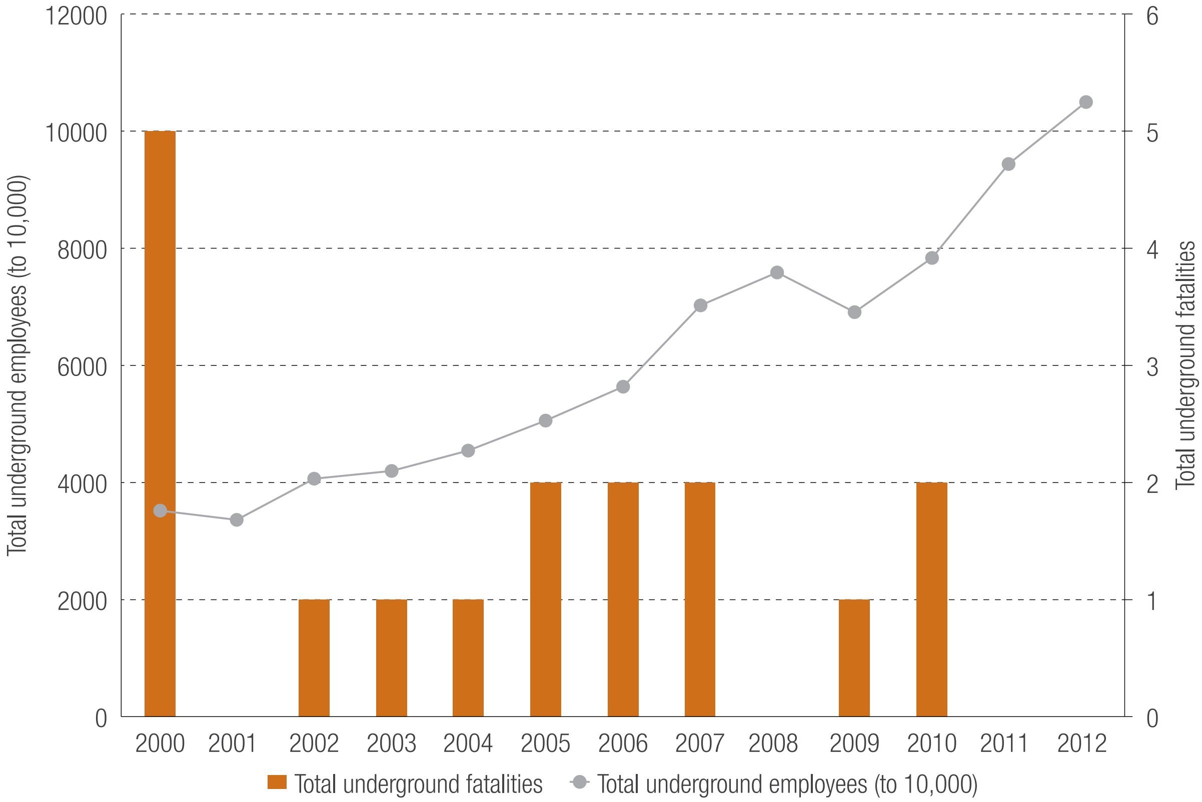

Figure 10 *Underground employees and fatal accident numbers*

4.10 Commodity group

Table 2 shows the number of fatalities by commodity.

Gold and nickel results combined account for well over half of the fatalities (particularly in the earlier years of the review period). This probably reflects similarities in terms of the geological environments and geographic locations, and a significant proportion of underground operations. Most of the gold and nickel fatalities were in the Eastern Goldfields Province of the Yilgarn Craton, where rocks are under significant stress.

Iron ore accounts for a third of the mining fatalities, with the number of fatalities increasing in the later years of the review period as significant projects commenced in the Pilbara. Iron ore is typically mined by open pit methods in large scale operations.

Table 2 Number of fatalities for commodity groups [sample size = 52]

Commodity group	Number of fatalities	Proportion of total fatalities
Gold	19	36.5%
Iron ore	17	33%
Nickel	10	19%
Dimension stone	2	11.5%
Alumina	1	
Diamonds	1	
Hot briquetted iron	1	
Diamonds	1	

4.11 Original equipment manufacturers' procedures

Changes to operating and maintenance procedures provided by suppliers were apparent in six of the fatal accidents.

Four of the accidents involved haul trucks or loaders. Maintenance work was being carried out but in each case there were departures from the recommended procedure for the job. The workers involved had developed different ways of doing the tasks to address local resources and problems, but employers had not approved the changes. In some cases, the alternative method may have been a more efficient way to do the job had it been properly engineered.

An accident at a dimension stone quarry involved an employee entering an automated process area and being caught in machinery. Entry requirements were identified in the supplier's manual.

An accident at a locomotive workshop involved modifications to a scissor lift. Changes were made to the hydraulic circuit without a comprehensive engineering assessment. The scissor lift is understood to have lowered without warning trapping an employee in the scissor arrangement.

Equipment and plant used on mines is usually sourced from major international original equipment manufacturers (OEMs). It is common for OEMs to provide operating and maintenance manuals and procedures, and operators of this type of plant should follow the minimum requirements of the OEM.

Where local circumstances require modifications to equipment or procedures, the OEM should be consulted and any changes should be subjected to a rigorous risk assessment process. It should not be left to workers to change OEM requirements in an ad hoc manner.

4.12 Age of deceased

As shown in Figure 11, there was no clear pattern to suggest that the age group of the deceased was a significant factor. The youngest person who died was 18, and the oldest was 62.

It could be suggested that the younger more inexperienced age group are more at risk, but there is no pronounced difference when compared with other age groups. It should be noted, however, that there is no information on the total number of workers in each age group to normalise the results, and therefore determine whether any group is over-represented.

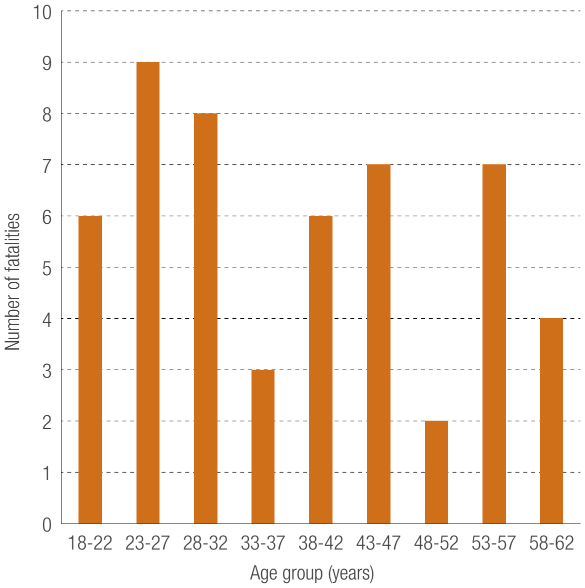

Figure 11 Frequency of fatalities by age groups (5-year intervals) [sample size = 52]

4.13 Roster cycles

A wide range of roster types was identified in the analysis, with the majority being arrangements for two weeks on and one week off. It has been suggested that the roster type may be significant in fatal incidents but this hypothesis is not supported by the sample in the review period. No single roster type was identified as a particular problem. However, it appears that the roster types can be categorised into distinct groups, as shown in Figure 12.

The first roster group is typically represented by even-time rosters, which require four panels of workers. These would typically be 4 days on 4 days off or 1 week on 1 week off rosters. This type of roster is becoming more common in the mining industry. There were 15 fatal accidents in this roster group where a break was due within seven days.

The other major roster group typically has 2 and 1 week rosters, or 9 and 5 day rosters. This group requires three panels of workers and appears to be common for fly-in fly-out (FIFO) sites. There were 27 fatal accidents in the second group.

Longer roster cycles were few in number and had fewer fatalities.

Figure 13 charts the number of days into the roster that the fatality occurred. The longest roster cycle was 28 days. The review did not indicate any particular roster type as being worse than others.

The only trend noted is that there were more accidents near the beginning of the roster compared to the end. This could be because there is insufficient data to normalise — it is not known how many people in the workforce were on which roster over the review period. There is a peak of nine fatalities on day 5, but then only one fatality on day 6. If these two days were averaged, there would be five fatalities on each day, which would match the trend of about four fatalities each day of the roster, for the first ten days or so.

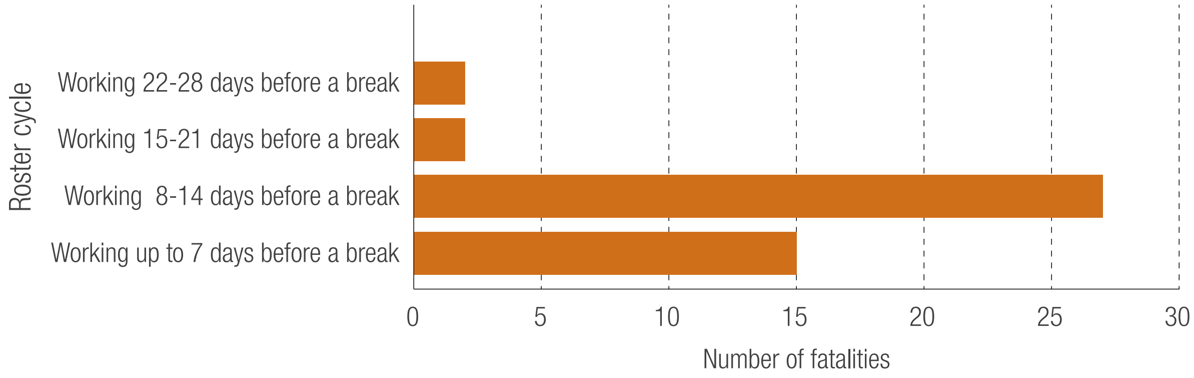

Figure 12 Frequency of fatalities by broad roster groups [sample size = 46]

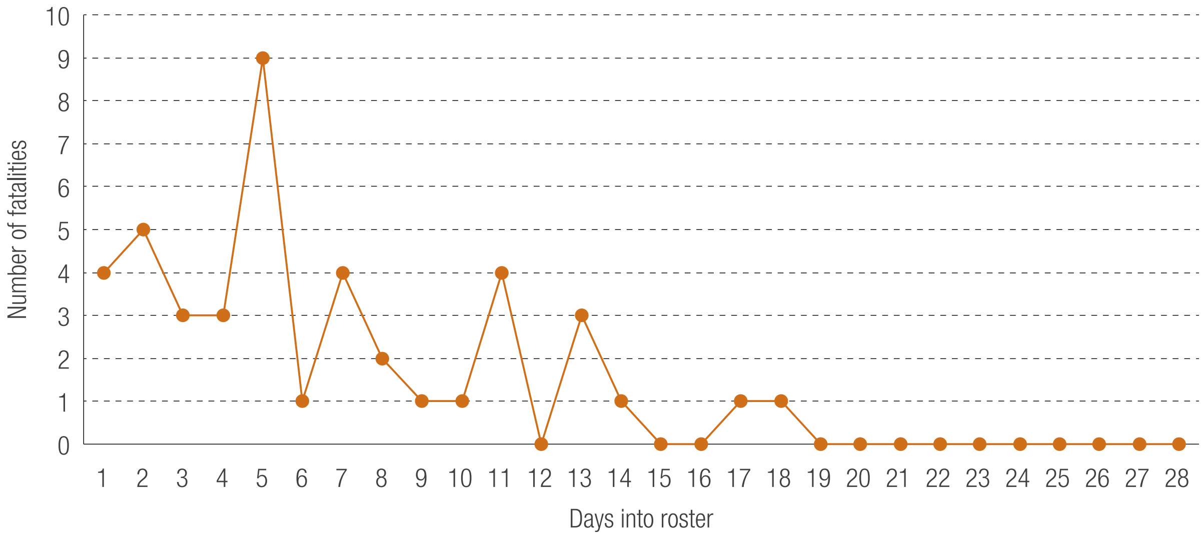

Figure 13 Frequency of fatalities by days into the roster [sample size = 43]

5 Critical activities

5.1 Categorisation

The selection of critical activities is based on the evidence and findings presented in the fatality reports. The top ten critical activities have been highlighted as they led to multiple fatalities and account for over three-quarters of the total fatalities. These scenarios involve a number of repeated single-incident situations, apart from the inrush category, which involved three fatalities in a single incident. Over the review period, only a quarter of the fatalities related to single-incident situations.

The activities and relevant incidents are described below. Sections 5.4 to 5.5 all relate to mobile equipment incidents but they have been separated because different control measures are required to address the circumstances.

5.2 Fall arrest

If there is an edge, hole or gap then people can fall over or into it. The falls reviewed were not just from significant heights (i.e. 10-15 m) but also from just over 1 m, which can also result in a fatal injury (i.e. head injuries). If people are working in an elevated work area and they are not protected correctly, there is the potential to fall. In some cases, people were wearing the correct fall arrest harness but these were not attached to a secure anchor point.

- A worker was not wearing fall arrest equipment while working on a grid floor deck. The deck was not secured with clips and he fell to his death when the deck slipped.
- Demolition work was in progress at a conveyor section of an old plant. The worker was wearing a harness but it was not secured to a fixed anchor point. Part of the structure fell away, causing the employee to fall to his death.
- Scaffolding was being removed following maintenance work. The worker was wearing a harness, which may have been fixed to part of the scaffold. The scaffold fell, taking the worker with it.
- A worker was looking into a process tank during a rehabilitation job. He was not wearing a harness and fell into the tank.
- An elevated work platform (EWP) was being loaded onto a truck. The operator drove the machine to a point where the centre of gravity shifted causing the machine to flip. The operator was in the basket of the EWP, but was not wearing a harness, and was thrown out.
- A worker in an underground mine was working close to a grizzly above an ore pass. He slipped and fell through a gap in the grizzly and down the pass. He was not wearing fall arrest equipment.
- A worker was working in a rise to remove steel ladders. He was not wearing fall arrest equipment and fell to his death.

5.3 Departure from OEM procedures

Most of the fatal incidents for which compliance with procedures was critical involved fitters working on large plant, where there was an OEM procedure but it was not followed. Those involved in workshop maintenance should check whether procedures are available and followed. If not, the applicable work should be subjected to a thorough risk assessment.

- A bucket cylinder was being removed from a loader in a workshop. The sequence of work was inconsistent with the OEM procedure, and the fitters were not qualified riggers.
- A suspension cylinder was being removed from a haul truck in a workshop. The cylinder had not been depressurised as required by the OEM procedure.
- A belly plate was being removed from a dozer. The plate was not secured as required by the OEM procedure.
- A fixed scissor lift in a locomotive shop was being modified by a fitter. No design assessment was made prior to changes to the hydraulic circuitry.
- Maintenance work on the suspension strut of a haul truck was being undertaken and a torque wrench was used to undo a bolt. An extension bar was used on the wrench. This was inconsistent with the procedure and resulted in the wrench being over tensioned. It released and struck the employee.
- An employee entered a work area where automated machinery was operating to make limestone blocks. The operating manual of the equipment required the area to be isolated before entry.

5.4 Run-away vehicles

The fatal run-away vehicle incidents mainly related to inadequate park-up procedures or a loss of control on an incline.

- A truck was travelling down a pit ramp to tip a load for back fill. The slope was down grade to a corner. The driver lost control and the truck picked up speed and collided with a dozer.
- A concrete agitator truck was driving down a decline with a load when the driver lost control and collided with the wall of the decline.
- A haul truck was parked up on a pit ramp for a maintenance issue. There were no chocks or bund in place to prevent a roll back. The truck ran backwards into another truck, with the tray striking the driver's cab and killing the driver.

- A fitter was bringing a bogger out of the mine for repairs. He stopped on the decline and exited the cab to check in the engine bay. The bogger ran away backwards, picked up speed and hit the decline sidewall, crushing the fitter.
- A bogger driver drove his machine into an ore drive. He exited his cab and walked in front of the machine to talk to another operator. The bogger rolled forwards and struck the driver.

5.5 Vehicle over edge

The vehicle-over-the-edge category covers large equipment (mainly haul trucks) going over the back of a waste dump or stockpile area, or to small vehicles tipping over.

- A bogger drove over a stope edge while preparing for backfill operations in an underground stope. There were no bunds or bogging marks in place.
- A bogger drove over a stope edge while preparing to clean up for a survey job. A safety barrier was removed and there were no edge markers in place.
- A dozer drove over the edge of an open pit wall on night shift while doing clean-up work. The work area was not properly demarcated or coned off.
- A truck drove over the edge of a stockpile while trying to tip a load. The approach to the tip edge was sloping downwards and material had been removed from the base of the stockpile.

5.6 Vehicle collisions

The vehicle collisions that resulted in two fatalities are attributed to inadequacies in the layout of roadways, operating pit rules, and operating procedures.

- Two road trains were driving in opposite directions on a mine haul road when a collision occurred. It appears that the trailers of one vehicle snaked across the path of the oncoming unit, causing the collision.
- A haul truck was approaching a junction with the main haul road. There were two other trucks on the haul road. As the driver entered the main traffic flow, he did not see an approaching light vehicle. The driver of the light vehicle was killed in the accident.

5.7 Electrical contacts

Three fatalities during the review period were repeat single incidents where the scenario involved someone working in an open electrical panel and coming into contact with a live circuit, either through their body or a tool.

- An electrician was working on a pump starter box. He made contact with a live component and was found deceased.
- A jumbo operator was trying to reset the power in a pump starter box when he made contact with a live component.
- An electrician was working in a switch panel when he made contact with a live component. He appeared to be kneeling at the time and made contact with the live incoming phase link.

5.8 Rock falls

Rock falls were the highest ranked fatal scenario in 1980s- 90s. Since then, much work has been done in this area but there were still three fatalities during the review period related to unsupported ground.

- A jumbo operator was placing a split set on the boom as part of the bolting cycle. He was beyond the supported area when a rock fell from the backs and struck him.
- An air leg miner was struck by a large rock that fell from the shoulder of a drive. He was beyond the last rockbolt support.
- A jumbo operator was working on support rehabilitation. There was a rock fall associated with a seismic event. The support was incomplete in the area and falling rocks struck the operator.

5.9 Pit wall failures

Pit wall stability can be addressed by improved pit design and monitoring.

- A haul truck was driving up a ramp when there was a wall failure under the ramp. The truck fell to the bottom of the pit, which was full of water.
- A spotter was standing on a berm directing loading operations for grade control when a section of the pit wall failed.

5.10 Inrush situations

Three people were killed in one event when a tailings fill wall collapsed because the hydraulic head behind it exceeded the wall's design capabilities. The tailings rushed into the mine.

- Three workers were fatally injured at an underground mine when a fill retaining wall failed and part of the mine was engulfed with sandfill and water.

5.11 Tyre handling

Issues with tyre handling include potential energy, with tyres falling onto people, and stored energy, with the uncontrolled release of compressed air during tyre inflation.

- Haul truck tyres were being offloaded from a road train. The tyres were stacked vertically on the trailer. A tyre fell over and struck a worker.
- A prospector was changing the wheel on a light vehicle. The rim and tyre were not compatible. It is understood that the tyre was being inflated when the rim blew off.
- A tyre handler was being used to hold and pressurise a haul truck tyre. A worker was standing between the tyre and the frame of the tyre handler when one of the arms broke. He was struck by components that flew off under the pressure of the failure.

5.12 Other critical activities

The remaining fatal accidents involve single incident situations. Information relating to these accidents is available in Mines Safety Bulletins and Significant Incident Reports on the Department's website at www.dmp.wa.gov.au/Resources Safety in the publications section.

5.13 Principal hazard management plans

The fact that a relatively small number of accident types cause the majority of fatal accidents highlights the importance of principal hazard management plans. Principal hazard management plans consider high level hazards at a mine, those that could result in multiple fatalities or repeated single-fatality scenarios. The major principal hazards identified in national model legislation correspond closely to those identified as the ten critical activities over the review period.

Additional principal hazards or major risk areas are fires, explosions and explosives. There was one fatal accident during the review period caused by an explosion and another caused by explosives. There were no fatal accidents due to fire.

6 Areas for improvement

6.1 Hazard identification and risk assessment

It is vitally important that all jobs and tasks are assessed to identify the critical tasks that can result in serious injury. There is a range of techniques available to assist in this process depending on task complexity and the type of work undertaken.

If these critical tasks are not clearly identified, hazard controls may be inadequate and training programs and supervision ineffective in reducing accidents.

The "known hazard and known precaution" concept should be applied. Many incidents are repeat situations where prevention measures are common knowledge. Their successful implementation depends, however, on recognising the hazard in the first place.

6.2 Principal hazard management plans (PHMPs)

The repetitive failures identified in this review match the principal hazards identified by the National Mines Safety Framework. All operators need to have knowledge of the hazards on their site that can cause multiple fatalities and repeat fatalities, and have principal hazard management plans in place to address them.

6.3 Safe work procedures

All repetitive tasks that could result in a fatal or serious injury should be covered by a safe work procedure. This would require a process of task assessment, hazard identification and risk assessment. One-off jobs should be assessed using a risk assessment tool such as a job hazard analysis (JHA) or job safety analysis (JSA) as a minimum. All assessments should be reviewed by the supervisor and, where necessary, a person competent in the tasks.

6.4 Non-compliance with procedures

A significant number of fatal accidents occurred during the review period because available procedures and rules were not followed. This is not to say that the employees were necessarily at fault. It could be that a simple error was made by a person in the operating or supervision hierarchy. A momentary lack of concentration is a potential underlying factor. Effective management of change is also critical if circumstances deviate from those typically encountered and additional hazards are introduced.

Employers should have a system to monitor compliance with standards and apply a fair system of discipline to enforce critical safety procedures.

6.5 Involvement of workers

Workers should be involved in the development of safe work practices as they are likely to be more familiar with the tasks and problems than people removed from the activity. The participative approach involves workers in the risk management process. If provided with sufficient training and motivation, workplace teams are in the best position to effectively undertake hazard identification, risk assessment and risk control activities. Depending on the complexity of the task and risk factors, the input of safety professionals or subject experts may be necessary to ensure all risk factors are considered.

6.6 Training processes – workers and supervisors

This review shows that new and inexperienced workers are at particular risk. The importance of a proper induction and training system at every site and for every job should not be underestimated. Close supervision of new starters is recommended in the first weeks and months of employment.

The hazards associated with critical tasks must be clearly identified in training processes. Workers should be thoroughly checked and assessed to confirm that they understand the importance of working to procedures and rules.

Supervisors in the early years of their development also appear to be an at-risk group. It may be that new supervisors are still developing the skills to ensure that rules and procedures are followed. Staff shortages may also mean that supervisors are given the role with inadequate training and assessment of competence. A good and efficient worker does not necessarily make a good supervisor. The training of supervisors is regarded as a key issue in accident prevention.

6.7 Site familiarisation

Sites need to be conscious of new arrivals, whether experienced or not, and the need for time to familiarise themselves with what is going on, the roster cycles and different working environments — this may include a site tour at night, when things look different. New workers need time to get to know work mates, supervisors and work processes.

6.8 Adequate breaks during the shift

The need for breaks during shifts is a long standing issue. Most workers cannot sustain focused activities for long periods. The likelihood of someone making an error increases with fatigue and lack of concentration. As a minimum, the site's fatigue management plan should be reviewed and decisions made on the breaks that might be required around 3 am, 11 am, 4 pm and 11 pm.

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