

# **‘Too Close for Comfort’ – The Case for Proximity Detection and Vehicle Collision Avoidance Systems**

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## ***Executive Summary***

The increase in the number, physical size and speed of ever-growing mobile mining and support equipment fleets in open cut and underground mines worldwide has created many operational benefits.

The decision to design and manufacture larger and larger mobile mining equipment - trucks, dozers and graders to achieve higher productivity has perpetuated already existing hazards such as poor visibility and so far unresolved risks such as vehicle interaction which still too often result in the accidental collision of vehicles and the death of vehicle occupants or pedestrians.

The need to hasten the development and implementation of proximity detection and collision avoidance systems has been again highlighted in Queensland early this year following a fatality involving the collision of a light vehicle into the rear of a large low loader. Other vehicle related fatalities have occurred since then – it is believed that proximity detection and collision avoidance systems may have helped to prevent them from occurring or at least mitigated the outcomes of these events.

Fatal vehicle/pedestrian interactions also occur in underground mines - Queensland has seen several deaths in recent years where miners were crushed by mobile equipment operating in confined spaces or by vehicles toppling into unguarded stopes.

The statistics here in Queensland and other mining states show that immediate intervention by industry is required to implement a practical strategy that ensures risks from collisions are controlled to ALARA levels. Recent industry workshops conducted by the Queensland Mines Inspectorate<sup>1</sup> have demonstrated the ready availability of a variety of proximity detection systems, suitable for all open cut mines, as well as metalliferous underground mines. Currently available systems include radio frequency identification tags (RFID), Radar, global positioning systems (GPS), WIFI, cameras and a combination of these systems.

Certification of such systems to meet stringent intrinsically safe (IS) requirements in the near future will also enable the introduction of these systems to

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<sup>1</sup> A complete set of the workshop presentations can be obtained from the Departments website see [http://www.dme.qld.gov.au/mines/mining\\_safety\\_health.cfm](http://www.dme.qld.gov.au/mines/mining_safety_health.cfm)

underground coal mines thereby providing a quantum leap in safety to miners working in those areas.

The introduction of proximity devices in underground coal mines will also be accelerated by the recent Coroners Findings relating to the Inquest into the 2007 fatality of a worker in an underground coal mine [2]. The Coroner recommended 'that coal mining operations and the Department (as the approval body) move quickly with manufacturers and other appropriate bodies to have developed, tested and approved proximity detection devices for use in underground coal mines to detect the presence of pedestrians in and around mobile equipment including shuttle cars.'

While many will hail this technology as the only way forward to reduce vehicle collision accident and incidents, it must be understood that proximity detection and collision avoidance systems are not the 'silver bullet' to reduce the number of vehicle collision accident and incidents – instead this technology can and must only ever form one part of a multifaceted strategy to strengthen the mine's safety and health management system. Such a system, as a priority must address organisational factors that encourage the correct attitude towards safe individual and team acts and behaviours, a safe working environment and selection and maintenance of defences such as proximity detection and collision avoidance systems. Non technology based approaches must also form an integral part of the strategy as they in many respects create the conditions in which a proximity detection or collision avoidance system can work in an appropriate manner.

As proximity detection and collision avoidance technology is relatively new and untested, proper and comprehensive scoping of a potential system is critically important, and chosen risk assessment processes must be of sufficient quality and rigour to capture all possible hazards and scenarios, and must be able to test the proposed system with respect to its suitability for the individual mine site. This assessment must also consider the human factor aspects that may be created by the introduction of this type of system to the work environment.

Given the availability of systems for several mining applications and the ongoing effort into the certification of intrinsically safe ug coal proximity systems, it is envisaged that legislation will be drafted in Queensland to ensure appropriate time frames are established for the implementation of this technology.

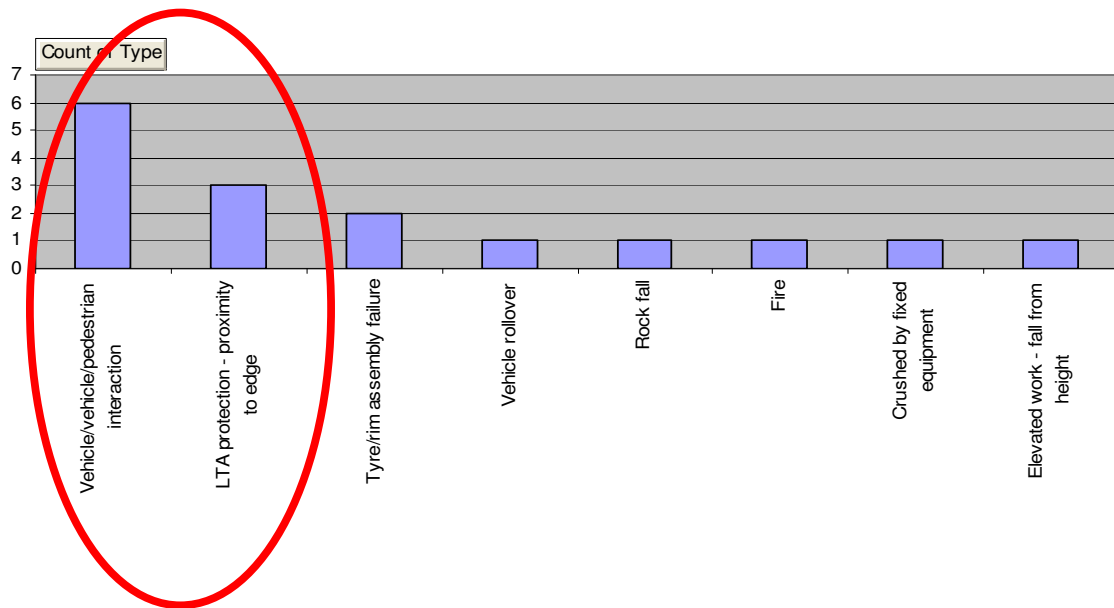
## ***Fatality Statistics***

Several collision type fatalities have occurred in both the metalliferous and coal sectors– over the last 5 years, a total of 17 people have regrettably lost their lives in the Queensland mining industry as shown in Figure 1<sup>2</sup>.

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<sup>2</sup> Annotation in Figure 1 - LTA – less than adequate

Queensland Fatalities - Feb 2004 to May 2009



6 of these deaths were directly attributable to vehicle to vehicle (V2V) collisions, or vehicle to pedestrian (V2P) collisions. This count represents 35% of all fatalities over that time frame. By including 3 other vehicle related deaths that most likely could have been averted with some vehicle based proximity detection technology, the figure climbs to over 50%. While most of the deaths have occurred on open cut mines, there are several that have occurred in ug mines, including underground coal.

Tragically, last year alone, 3 of the 4 mine deaths, or 75%, involved collisions. The nature of mine fatalities in other mining states and internationally follows the same worrying trend with Western Australia also suffering from several collision type fatality accidents [3].

These grim statistics clearly suggest that industry should make the prevention of collision type accidents their 'Number One' top priority.

**Accident Mechanisms**

Table 1 provides a brief description of a number of Queensland fatalities related to V2V or V2P interaction for the period February 2004 to May 2009.

Mine Type	Event
Exploration	Worker driving water truck got out to shut gate and truck rolled back and crushed him against the gate

Mine Type	Event
OC Coal	Mine Worker in light vehicle collided with rear of low loader crushing cab
OC Metalliferous	Passenger lay on ground and was run over by FEL loading gypsum
OC Metalliferous	Air-trac Rock drill fell 20m off bench
OC Metalliferous	Worker walking down haul road run over by FEL transporting aggregate
UG Coal	Mine worker caught between shuttle car and rib
UG Metalliferous	Mine worker suffered crush injury between IT carrier and light vehicle
UG Metalliferous	Mine Worker drove mucking unit into stope

**Table 1**

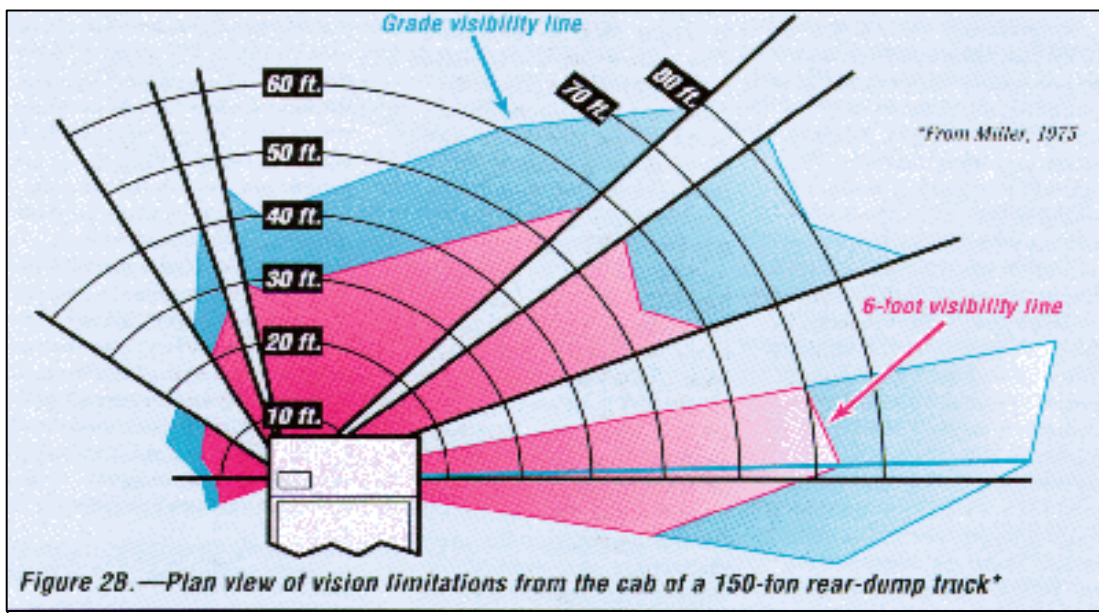


Figure 2 – Illustration of blind spots around a mining truck - from [1]

A similar spread of accident mechanisms can be gleaned from quarterly ‘Serious Accident and High Potential Incidents’ summary statistics issued by Queensland Mines and Energy [4] which described 21 reported collision-type events from February to April 2009. It is likely that many more have occurred but remained unreported.

While there is no single accident mechanism responsible for collision related deaths as such there are however 4 key root and contributing causes can be identified across most accident and incident cases:

1. Less than adequate (LTA) 'workstation' layout, and or compromised overall vehicle design causing blind spots around mobile equipment (as shown in Figure 2).
2. LTA operator situational awareness of other vehicles, pedestrians or infrastructure in close proximity, while mobile equipment is being operated.
3. Ineffective controls to manage collision risks to ALARA levels while mobile equipment is being operated, or conversely a heavy reliance on human behaviour to stay out of harms reach.
4. Risk taking behaviour of operators by entering into no-go zones, while mobile equipment is being operated or serviced, and or LTA situational awareness by pedestrians working in close proximity to mobile equipment.

The last is graphically illustrated through 'continuous miner' fatality statistics provided by MSHA that show that over 70% of fatalities were caused through workers entering 'no go' zones while controlling the machine using a remote controls (ref Figure 3). It is interesting to point out that machine operation by remote control was introduced to reduce the operators' exposure to rockfalls etc while stationed on the machine itself; however this fundamental change in the mode of operation has created a perhaps unforeseen and on the face of it uncontrolled hazard and situation of risk with operators now able to position themselves in immediate crush zones around their equipment.

This data demonstrate that we cannot rely on inherently unreliable human beings behaving in a predictable manner when operating or working in close proximity to heavy equipment. Proximity detection can provide a 'technology barrier' to stop people entering 'no go' hazardous zones thereby preventing this type of accident mechanism.

### ***Current Proximity Detection Technologies***

The Queensland Mines Inspectorate, together with several proximity detection manufacturers and minesites or organisations that have introduced or are trialling proximity detection systems, conducted a series of proximity workshop in August and September 2009. These seminars were held in coal and metalliferous mining regional areas to encourage the maximum possible attendance of industry personnel.

The following available technologies were showcased:

- RFID tags – tags and tag readers
- RADAR systems

- Global Positioning System - GPS
- WIFI
- Cameras
- a combination of the above

While several manufacturers offer working systems for open cut mines using the above, or in some cases a combination of the above (e.g. RFID plus cameras), fewer manufacturers provide systems for underground proximity applications.

Design of underground systems is more challenging given the restricted work environment the systems need to function in, effects of geology and other nearby mine services, and the fact that people often are required to work in very close proximity to operating mobile equipment. This makes the design of detection equipment with narrow recognition tolerances and worker/equipment work interface protocols particularly challenging. The need to have such electronic systems approved as 'intrinsically safe' for underground coal mines is a further complication in bringing working systems to the market. Several companies are either working towards getting the IS approvals or have parts of their systems approved already.

### Mine Site Application

Before a mine considers any particular proximity detection system as part of its overall safety health management system, it is suggested to consider the following model, shown in Figure 4, based around the widely used Incident Cause Analysis Method (ICAM) [5].

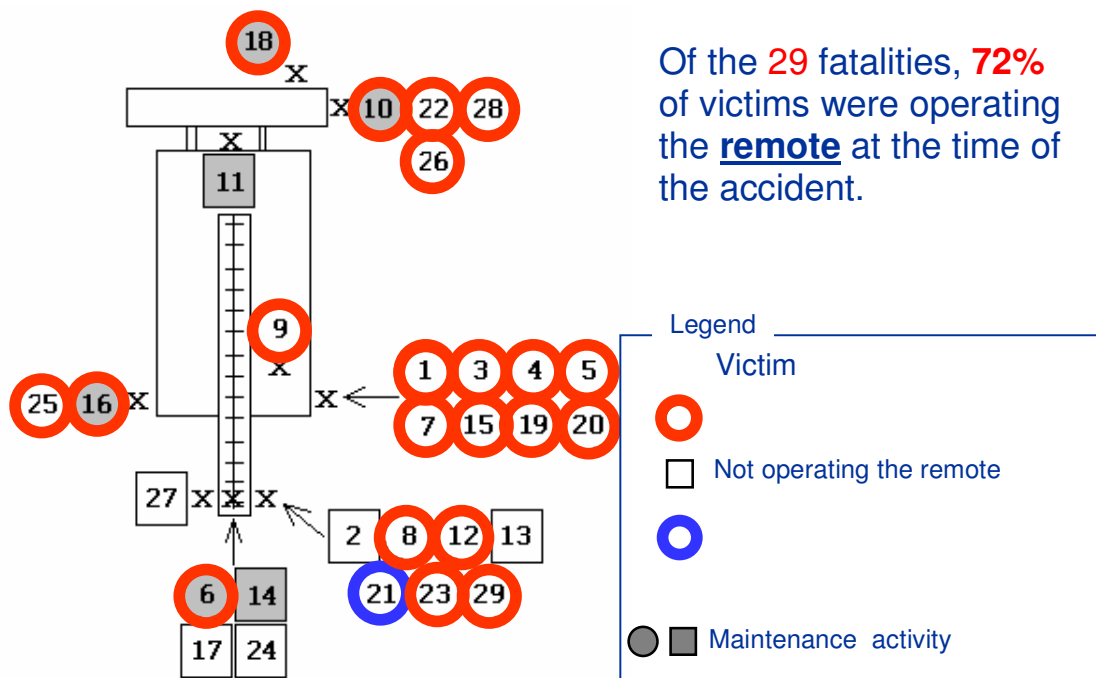


Figure 3 – MSHA – Location of accident victims – remote controlled UG Coal Continuous Miners

ICAM uses the 4 broad categories of 'Organisational Factors', 'Team/Individual Factors', 'Work Environment Factors' and 'Failed Defences Factors' as common building blocks of accident causation. Instead of using this approach to retrospectively explain a particular accident, the model presented in this paper uses the same factor categories proactively or 'in reverse' by challenging the reader as to what must be ensured by each factor to reliably prevent collision accidents.

The model proves particularly valuable as it illustrates that proximity detection systems are a 'last line of defence' and must be part of a broader safety and health management systems approach. Sample suggestions for each factor category are provided below.

Reliable Organisational factors could include:

- Genuine regard/recognition for likely consequences of vehicle collision risks at all levels
- Sufficient \$ Resources & Budget
- Competent people – supervision & teams
- Site specific roles and responsibilities (champions)
- Comprehensive risk reviews using the appropriate risk assessment tools
- Design Standards (Environment & Equipment)
- Installation & Commissioning
- Operation & Maintenance strategies that support the system
- Review/auditing of controls – peer & systems review
- Change management & Communication
- Procedures/training/refresher training

Reliable Team and Individual factors could include:

- Ownership - Peer maturity
- Supervision
- Change management
- Communication – Integration, Roles and Responsibilities
- Awareness
- Safe Operator Acts and Behaviours
- Training & Competencies
- Procedural Compliance
- HazID -Hazard awareness/ perception
- Task planning

Reliable Controlled Environmental factors could include:

- Safe Operating Acts & Conditions

- Speed – operator awareness
- Road Design Standards
- Intersection Design Standards
- Congestion/restriction
- Lighting, Signage
- Barriers – Delineation
- Vehicle design – visibility (ROPS)

Reliable Defences factors could include:

- Proximity Detection systems
- Collision Avoidance systems
- Protection systems - barriers
- Other Warning systems
- Combination of systems (redundancy)
- Emergency Facilities and Resources
- Safe work procedures
- Personal Hazard Awareness
- Induction programs

The model also questions if the risk of crush injuries is adequately controlled to 'as low as reasonably achievable' (ALARA) levels. This could be further analysed by considering the following set of so-called 'TakeHome'<sup>3</sup> questions.

- What level of risk mitigation are the controls pitched at – Elimination... or PPE?
- What quality levels are assigned to the current controls
  - Are the controls actually available?
  - Are the controls reliable, resilient and effective?
  - Do the controls actually address the hazard?
  - Will the controls be used?
  - Will the controls 'survive' the initial accident or incident?
  - Do the controls rely on the intervention of a person, e.g. the operator, or are they automatic?
- Do the controls meet legislative requirements?
- Have you looked at the design of your equipment & workplace?
- How is the effectiveness going to be measured? What KPIs will be used?

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<sup>3</sup> These sample 'Take Home Questions' were presented at the workshops.



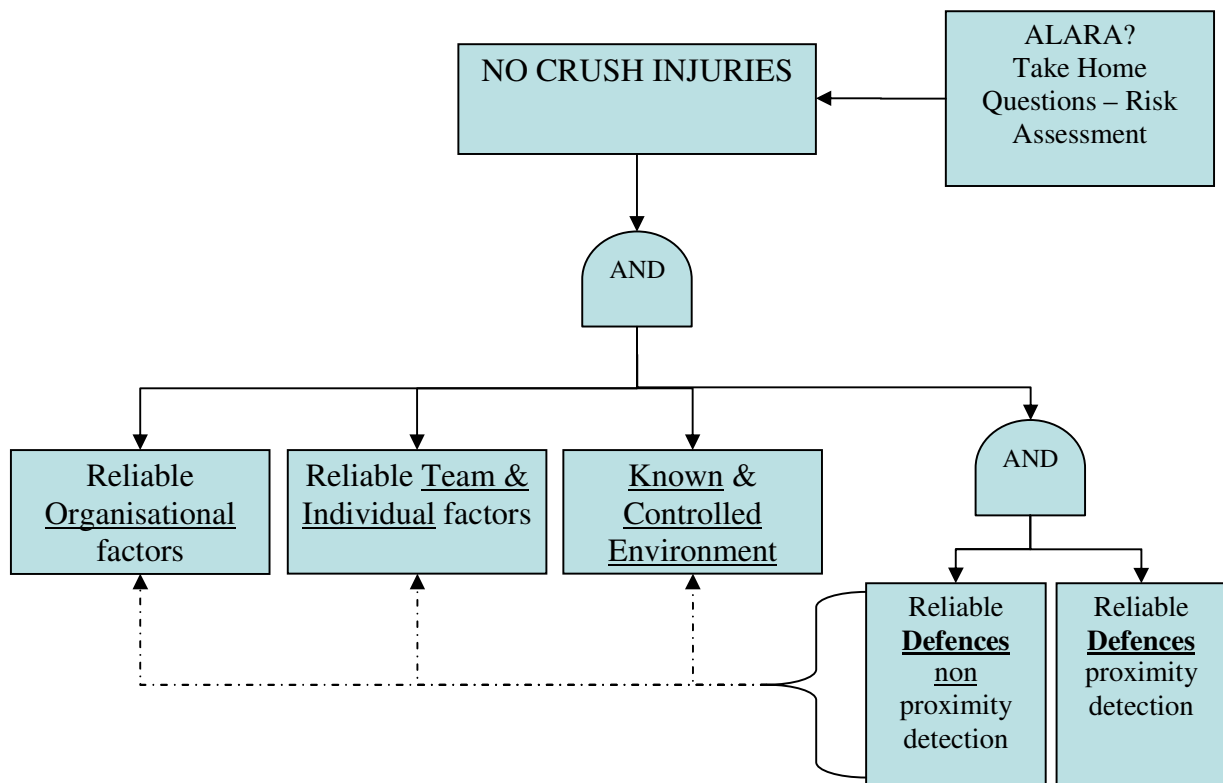


Figure 4 – Reverse ICAM model – Creating a fit for purpose proximity detection strategy

Equally challenging is the selection process for mine site management given the relative inexperience with this new technology across the industry. A small sample of issues that need to be resolved as part of scoping up a system is provided below:

- What types of vehicle interference needs to be managed - Low Speed or High speed collisions, or both?
- What collision scenarios will require management - V2V, V2P, and or V2I<sup>4</sup>?
- What detection capability & range will be required – near and far field?
- Should the system have ‘around the corner’ detection capability?
- What detection sensitivity should the system offer – near/far field, vehicles, people, and stationary objects?
- Should the system provide directional algorithms that can predict if a collision is likely (traffic context interpretation)?
- What types of alarms should be provided, and to whom - audible vs. visual alarms or a combination?
- Should the alarm escalate the greater the threat of a collision becomes?

<sup>4</sup> V2I – vehicle to infrastructure, e.g. powerlines, dump edges etc.

- What type of system is required – Standalone (not requiring any external support) or is a 'dependant' system appropriate and effective?
- How will the system be integrated with other mine management systems?
- Active vs. Passive systems?
- What levels of redundancy does the system provide, or what other systems are required to provide an adequate level of redundancy?
- Is the system fail safe?
- Is operation of the system intuitive & simple?
- How will Normalisation and desensitization of operators be managed as a result of false alarming?
- Importantly – will the system provide too much information which could confuse the operator?
- Will the proposed system create cabin/workstation clutter or create ergonomic issues and impacts?
- Will the proposed system be likely to suffer from interference with other systems and the environment?
- What 'management rules' are required to ensure the system remains operable at all times?
- What types of maintenance programs are required to maintain the system?
- What KPIs are required to measure the effectiveness of the system?
- Should 'machine shutdown' be controlled and if so what rules should be applied to ensure safety?
- What situations will not be safeguarded by the system?
- Are there any 'fatal flaws' in the system selection process?
- What risk assessment process and methodology must be followed to ensure a thorough and comprehensive assessment of hazards, risk, mitigation and effectiveness of the system?
- Who needs to be involved in the risk assessment and system selection process?
- Vehicle Proximity vs Collision Avoidance?

The selection process must also consider the human factor aspects that are created by introduction of a new system to the work environment.

While the above is largely focussed on the technology, the ICAM model also challenges the existence of current (non technology based) defences, such as road and intersection design, separation of haulroads, delineation, signage etc. , and how this operational environment is maintained so it provides safe operating conditions at all times.

These areas are particularly important as they will create the conditions and context in which the operator as well as the technological proximity detection or collision avoidance system must operate.

Of highest importance are the overall organisational factors as they create the preconditions and ongoing management enabling the safe conditions and factors for the 'individual and team', the 'work environment' and the 'defence mechanisms' – technology and non-technology based.

It should therefore be noted that achieving an effective and high reliability proximity detection and collision avoidance capability, considerable effort must be applied simultaneously to each of the 5 inputs, and testing each for its efficacy in dealing with the hazards to ensure that risks are controlled to ALARA levels.

### ***Risk Assessment Approaches***

AS/NZS 4360:2004: Risk Management [6] uses the flowchart, shown in Figure 5 to illustrate the overall risk management methodology.

Critical to successful risk management of vehicle collision hazards and resultant risks, is the initial and proper scoping of the context as it will determine the scale of the assessment, and ultimately the extent and scale of the solution.

Of similar importance is the selection of the appropriate risk assessment method. Given the potential consequence of serious personal injury, or single or even multiple fatality it is recommended that higher level risk assessment methods such as Fault Tree analysis (FTA), Bowtie analysis (BTA), Workplace Risk Assessment and Control (WRAC), Failure Mode and Effect analysis (FMEA) or Hazard and Operability Study (HAZOP) are used.

The use of a trained facilitator to ensure the assessment is complete and fulfils the expectation of the Scope is essential.

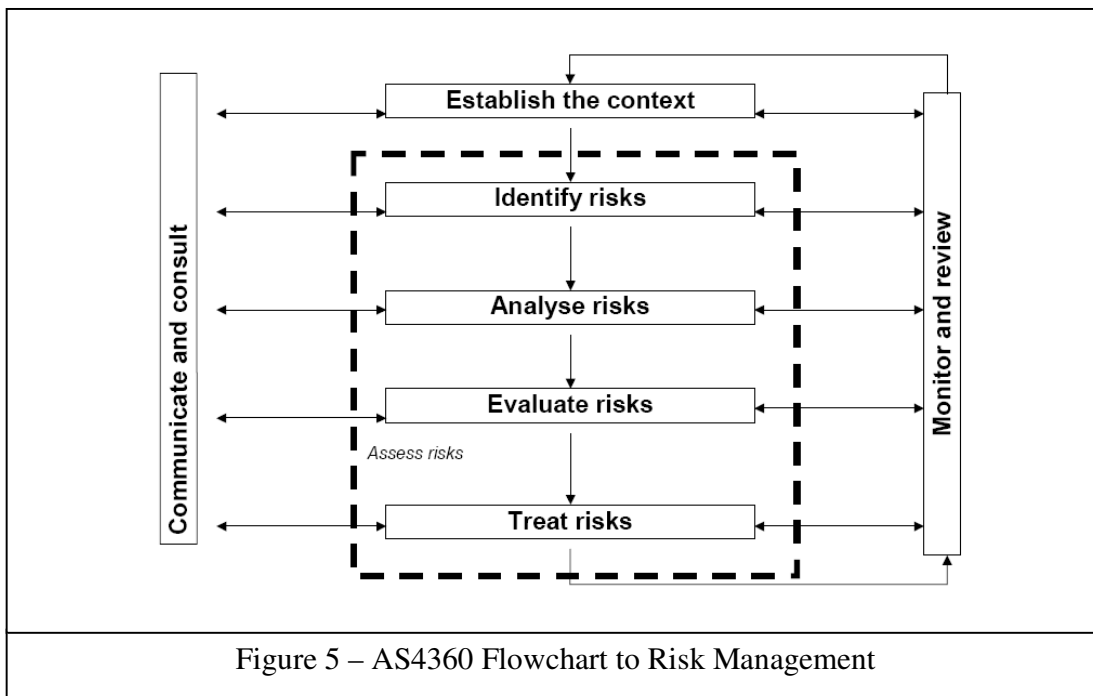


Figure 5 – AS4360 Flowchart to Risk Management

## Summary

A number of recent workshops by the Queensland Department of Mines have demonstrated the availability of proximity detection and collision avoidance systems for open cut and underground metalliferous mines. Development and certification of intrinsically safe systems for use in underground coal mines is anticipated in the near future and is strongly supported by the Coroners Findings of Inquest into the 2007 fatality of an underground coal miner at a Queensland mine which recommends installation of approved proximity detection devices for use in underground coal mines to detect the presence of pedestrians in and around mobile equipment including shuttle cars.

While perhaps seen as the ‘silver bullet’ and best defence to prevent collision type accidents and incidents, mine management must consider a broader strategy that creates the right organisational conditions to enable safe decisions to be made by the equipment operators, creates a safe working environment including non-technology based defences e.g. road design and traffic control, as proactive means of hazard and risk control, and to rely on proximity technology not as a primary, but as a supplementary means to control risk.

Given the availability of systems for several mining applications and the ongoing effort into certification of intrinsically safe underground coal proximity systems, it is further envisaged that legislation will be drafted in the medium term to ensure that all steps are taken to minimise fatalities and serious accidents of the types outlined above.

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