

Guidance Note QGN 27

Collision prevention

Mining and Quarrying Safety and Health Act 1999

December 2017

Reference is made to the following legislation as applicable to a Mine or Quarry in Queensland:

- *Mining and Quarrying Safety and Health Act 1999*
- Mining and Quarrying Safety and Health Regulation 2017

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1 Purpose and Scope

This Guidance Note applies to surface and underground operations and is designed to assist in the identification of hazards, and the development and implementation of controls, to manage the risk to persons from collisions. This includes collisions between vehicles, vehicles and persons, and vehicles and infrastructure.

2 Introduction

The increase in the number, size and speed of vehicles has provided many operational benefits. High potential incidents and unsafe interactions between vehicles (V2V), vehicles and personnel (V2P), and vehicles and mine infrastructure (V2I) still occur. Between 1998 and 2016, 26% of all mineral mine and quarry fatalities were attributable to vehicle collision accidents as shown in Figure 1.

This makes the prevention of such incidents and accidents a high priority for mine management.

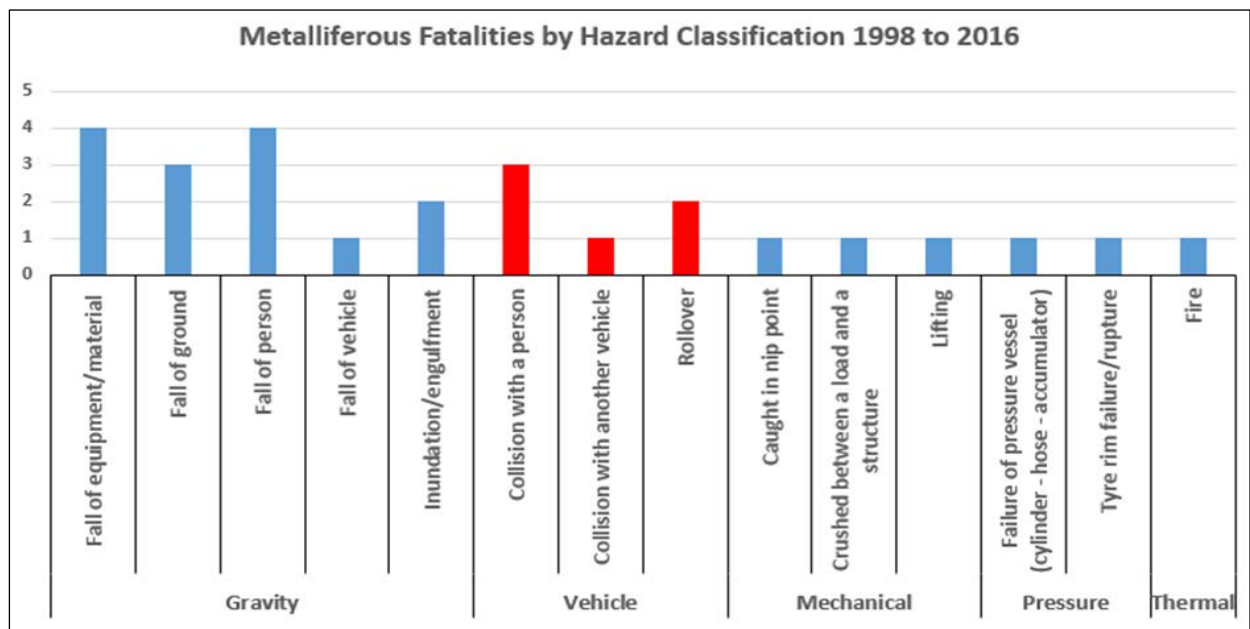


Figure 1 - Qld Mineral Mines and Quarries Mining Fatalities 1998 to 2016

3 Risk Assessment Approach

3.1 Collision scenarios

Vehicle interactions must be considered as part of the hazard identification process at a mine. All collision scenarios, even those that have never occurred at the mine, should be considered.

There are a number of information sources that can be used to identify possible collision scenarios and may include:

- Site inspection of known and possible collision locations.
- Risk assessments identifying traffic management hazards.
- Risk registers.

- Analysis of the movement of mobile plant and pedestrians.
- Previous collision accidents and incidents (internal and external).
- Consultation with workers.
- Available publications on collision avoidance.
- Original Equipment Manufacturer (OEM) information on mobile plant (machine performance parameters e.g. stopping distances, fields of vision etc.).
- Third party presentations on traffic management practices.
- Traffic management and road design content experts.

The sequence of events leading up to a collision scenario should be identified so it is possible to establish when and where in the sequence (in time and space) controls should be applied to prevent the collision. Examples of collision scenarios are given in Figure 2.

Generalisation of scenarios should be avoided - some scenarios may look similar, but the controls to prevent a collision may be different in each situation.

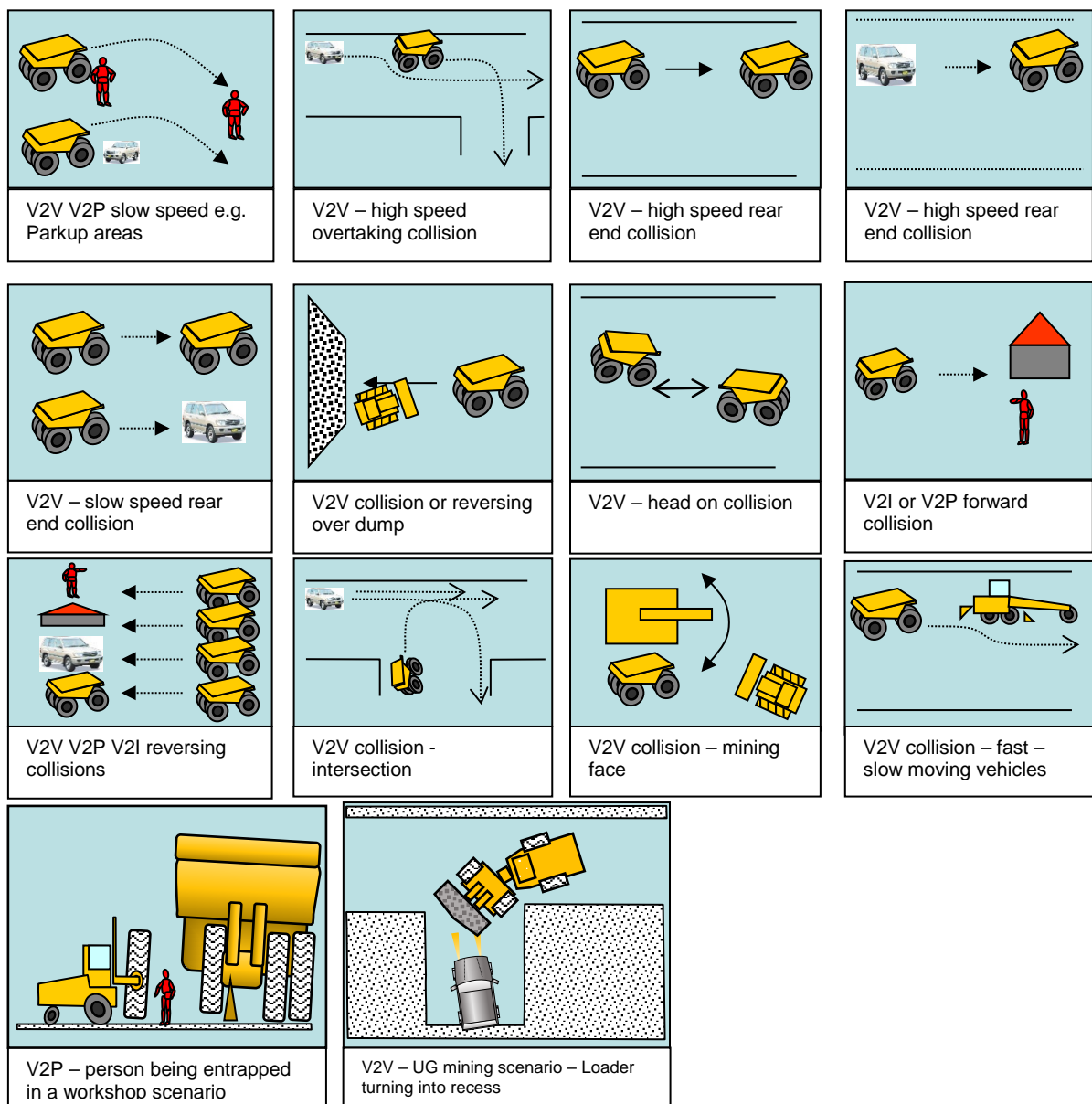


Figure 2 - Collision Scenarios

3.2 Methodology

The legislation requires that for a risk to be acceptable, it must be as low as reasonably achievable and within acceptable limits.

Vehicle collisions are often high consequence events and reasonably foreseeable at sites with mobile plant.

As such a suitable risk assessment method should be used, such as Workplace Risk Assessment and Control (WRAC), or Bowtie.

When undertaking the risk assessment:

- Consider the use of a trained facilitator.
- Apply a systematic approach – refer to Appendix 1.
- Consider technology and innovation - refer to Appendix 2.
- Reference relevant information and data.

3.3 Developing and implementing effective controls

It is important to identify controls that will prevent a collision. Control measures should be focused on elimination, substitution and/or engineering out the hazard. Some of these controls will be critical controls.

A critical control is defined as a control that if removed or not executed exactly as intended, would cause an unsafe situation despite the existence of the other controls.

Steps in identifying critical controls are:

1. Identify likely scenarios.
2. List all controls.
3. Identify critical controls (see definition above).
4. Identify processes to ensure controls are implemented, monitored for effectiveness.

A task should not be carried out unless the critical controls are known, in place and have been checked to ensure effectiveness.

The Site Senior Executive (SSE) must ensure that controls identified as part of the risk assessment process are implemented and monitored to ensure that they are effective.

Examples of monitoring controls for effectiveness and reliability include, but are not limited to:

- The worker and supervisors carry out Inspections and audits taking into consideration the requirements of:
 - Risk assessments.
 - Training and assessment material.
 - Procedures.
 - Standard Work Instructions.
- Ensure system audits include auditing the Traffic Management System (TMS) effectiveness.
- Reporting and analysis of near misses.

An incident investigation is a trigger to review the effectiveness of the current TMS controls.

A sample table and bowtie for a 'Loader impacts on pedestrian while walking on roadway' scenario is provided in Appendix 4.

4 Traffic Management System

To design a site specific TMS which effectively controls the risks of, vehicle interactions (V2V, V2P and V2I), mines must undertake a periodic review of their existing or planned traffic management arrangements.

The TMS is part of the mines Safety and Health Management System and contains a number of elements that document the standards and requirements for collision prevention at a mine.

The management structure should identify persons and document their responsibilities for ensuring the effective implementation and monitoring of the TMS.

The SSE must ensure that all mobile plant on site irrespective of who owns or operates it, complies with the requirements of the TMS.

4.1 Mine design and layout

Initial design decisions will ultimately create the operational environment for all plant and people working within it and should include effective collision prevention controls.

Mine designs and layouts may change over time. The following should be considered:

- Geology and topography of the site.
- Mining method and lifecycle.
- Day to day operational patterns.
- Road and ramp design.
 - Construction methods and materials.
 - Size, width and anticipated loads.
 - Location.
 - Gradients.
 - Intersections.
 - Drainage.
 - Room for safety features (bunds, signage, delineation and emergency run offs).
 - Corners and curves (horizontal and vertical).
- The V2V, V2P and V2I interactions that may occur.
- Learnings from accidents, incidents or other relevant industry information (e.g. safety alerts, bulletins).
- Prevailing environmental and weather conditions.
- Glare, sun and reflected light.
- Size, type and speed of mobile plant and operating limits.
- Location of fixed plant, services, stockpiles, dams, standpipes, pumps, drains, sumps, and other infrastructure.
- Magazines, fuel bays and other hazardous areas.
- Location of offices, crib rooms, workshops and other buildings.
- Position of pedestrian access points.
- Access to and from site.
- Site security.
- Parking bays and hardstands.
- Potential public interaction.
- Ability to separate LV and HV interaction.

To help identify potential and actual vehicle interactions, sites should compile plans and other information that show all mine roads, infrastructure, services and other areas where mobile plant and pedestrians may interact. Such information should be used in risk assessments, preparing work instructions and improving training programs.

It can also be used to examine the impacts from planned changes in road layout before they are actually implemented (Management of Change).

4.2 Selection and procurement of plant

4.2.1. General Plant

The TMS should also incorporate selection and procurement standards that take into account vehicle interaction. These standards must be implemented consistently across the mine:

- Vehicle specifications.
 - Braking system requirements.
 - Warning devices (horns, reversing alarms).
 - Visibility (lights, beacons, reflectors).
 - Identification (unique ID numbers).
 - Operating specification/envelope (gradient, stability, speed, operator visibility).
 - After market accessories that reduce operator visibility.
 - On board communication and cameras.
 - Collision prevention system.
 - OEM manuals, engineering documents and service records.
- Road signage and delineation.
- Operational lighting requirements (fixed and mobile).
- Road construction material.
- High visibility clothing.

Periodic review of existing plant must be conducted to ensure that the plant continues to meet the site standards.

4.2.2. Non mine site plant

The SSE must establish processes to ensure that non mine owned plant to be operated on the mine are used in accordance with the TMS. This should include:

- The plant is fit for purpose and will not be operated outside of its design envelope.
- Maintained to site requirement's (OEM specifications as a minimum).
- Complies with site standards (including any additional safety features).
- Is compatible with plant and systems operated and used on site.
- Training and assessment of operators.

4.2.3. Road Maintenance

The SSE must ensure that mine roads are designed and constructed and maintained to enable safe movement of vehicles about the mine. This should include:

- Inspection and monitoring of road conditions, traffic safety features and drainage controls.
- Availability of suitable construction and maintenance material.
- Correct application of water and or other means of dust suppression.
- Schedule of routine road maintenance and traffic safety features (e.g. bunds, delineators, signs, etc.).
- Fit for purpose road maintenance plant.
- Minimum competency requirements for road maintenance workers.
- References to the site road design standards and requirements.
- Control and management of traffic in areas where road maintenance is being undertaken - include procedures and controls to protect workers involved in road maintenance, particularly workers on the ground (not in plant).

4.3 Collision avoidance systems

Collision avoidance technology type controls may warn of or detect proximity of threats independent of the operator's field of vision, as shown in Figure 3.

These controls may include cameras, infrared, radar, sonar, GPS, and RFID, and are generally designed to give the operator notice of the presence of another vehicle, pedestrian or infrastructure.

While offering a further level of protection, it must be understood that such systems cannot replace existing mine design/layout, engineering and administrative controls and should therefore not be treated as the 'silver bullet' which will eliminate collision type incidents.

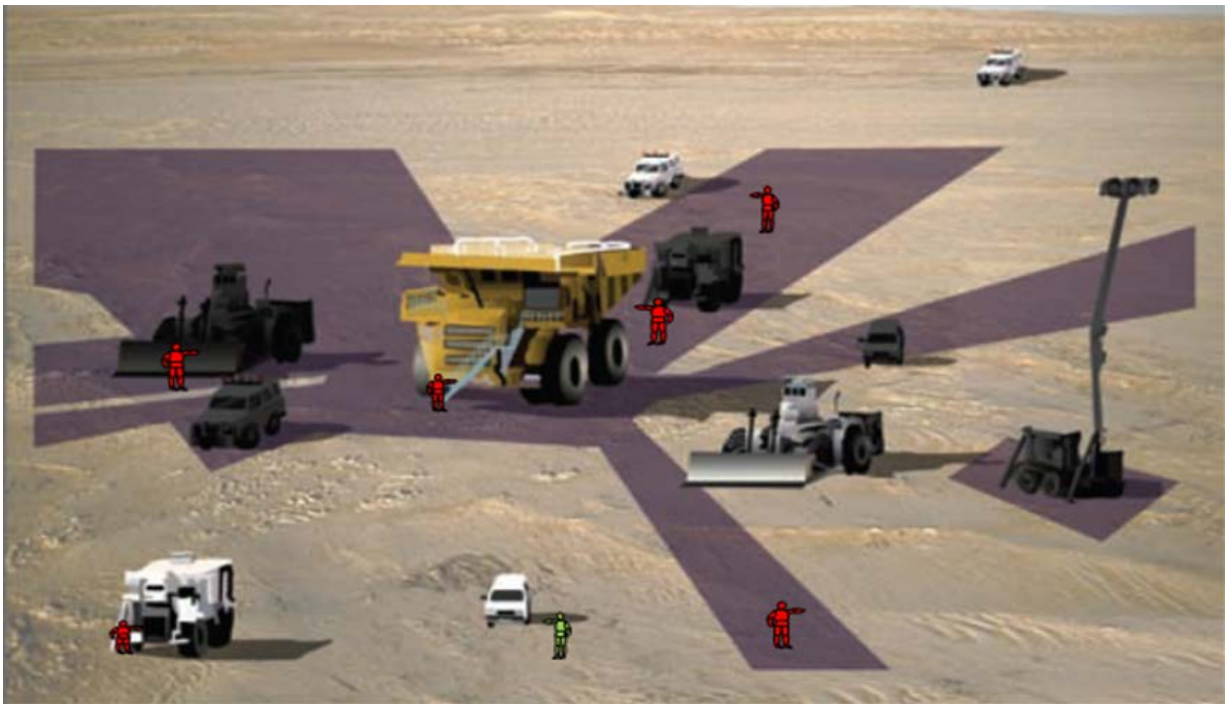


Figure 3 – Blind spots around mining plant

Persons with suitable technical knowledge and competencies must be part of the risk assessments when selecting these technology based controls.

When introducing these controls, undertake a review of the training and assessment requirements for plant operators and other mine workers. This should include:

- Understanding the system, its capabilities and limitations.
- Correct interpretation of information and action to be taken.
- What to do in case of the system failing, i.e. shut down or make safe.
- Training of workers who are required to maintain and monitor the system.

4.4 Traffic management plan

The site should have a current traffic management plan, (TMP), underpinned by risk assessments.

Specifically, the traffic management plan should:

- Form part of the TMS.
- Be documented and auditable.
- List foreseeable site specific vehicle interactions with potential for collisions.
- Set out in detail how these interactions are effectively managed.

- Include a current drawing or plan showing critical information.
- Identify roles and responsibilities to ensure plan is effectively implemented.
- Identify how the controls will be monitored to ensure they are implemented and effective (inspections/audits/KPI).
- Be reviewed:
 - Periodically.
 - When operations and or plant changes.
 - As a result of incidents or accidents (internal or external).
 - When information may indicate the plan is or could be ineffective.

The TMP should be communicated to all workers and form part of the site induction, training and procedures as it applies to workers tasks.

The Operator must ensure that the SSE is provided with suitable resources to ensure the effective implementation of the TMP.

4.5 Traffic management rules

As part of the TMS there will be a need for administrative controls such as traffic rules. These rules must be uniform, consistently applied across the mine and monitored for effectiveness. They should be:

- Documented and enforceable.
- As few as possible.
- Consistent with general Queensland traffic rules.
- Cover worker and pedestrian movement around mobile plant.
- Consistently applied/adhered to by all workers including contractors and public.
- Part of workers training and assessment.

Compliance to a rule can sometimes be difficult, depending on the circumstance and interpretation by the persons involved. Where rules are used to control risk then a process must be implemented to ensure that they create, enable and enhance safe traffic management.

To ensure effectiveness all rules must be:

- Needed to achieve a safe traffic interaction.
- Clear and unambiguous and must never be based on assumptions or conventions.
- Able to be consistently applied.
- Able to be monitored and enforced.
- Able to be understood by workers.
- Checked so they do not inadvertently create a hazard or require a worker to carry out potentially dangerous actions.

As part of developing effective rules, consideration must be given to safe separation and stopping distances for plant based on operator reaction time, mine roads and plant conditions. (Refer to Appendix 3).

4.6 Training and assessment

The TMS must include a process for effective training and assessment for all workers on site, including contractors and visitors, to prevent unwanted vehicle interactions.

All workers must undertake an induction that should include:

- Layout of the mines operation.
- Mine site procedures and practices associated with traffic management.
- Emergency response requirements for vehicle operation.
- An escorted site familiarisation tour.

Workers must be trained and assessed to ensure they demonstrate the skills and knowledge necessary to prevent vehicle collisions as they relate to their tasks and area of operation. As a minimum this training and assessment should be mapped to a recognised training standard and cover:

- The controls and rules to prevent vehicle collisions and how to ensure that they are effective. These can include:
 - Exclusion zones, separation distances.
 - Bund / stop log requirements.
 - Overtaking / passing / give way rules.
 - Ensuring that critical vehicle systems are functional (e.g. brakes, steering, seatbelts, engine management system, collision management system, communication systems).
 - Communication requirements.
 - Tipping rules.
 - Parking rules.
 - Speed limits.
 - Pedestrian rules.
 - OEM specific vehicle limitations and safe operating requirements.
- Critical controls.
- Site familiarisation prior to unrestricted operation to ensure worker is competent.
- Emergency response requirements.
- Extensive in-vehicle practise prior to assessment to ensure competency.

As a minimum a visitor should:

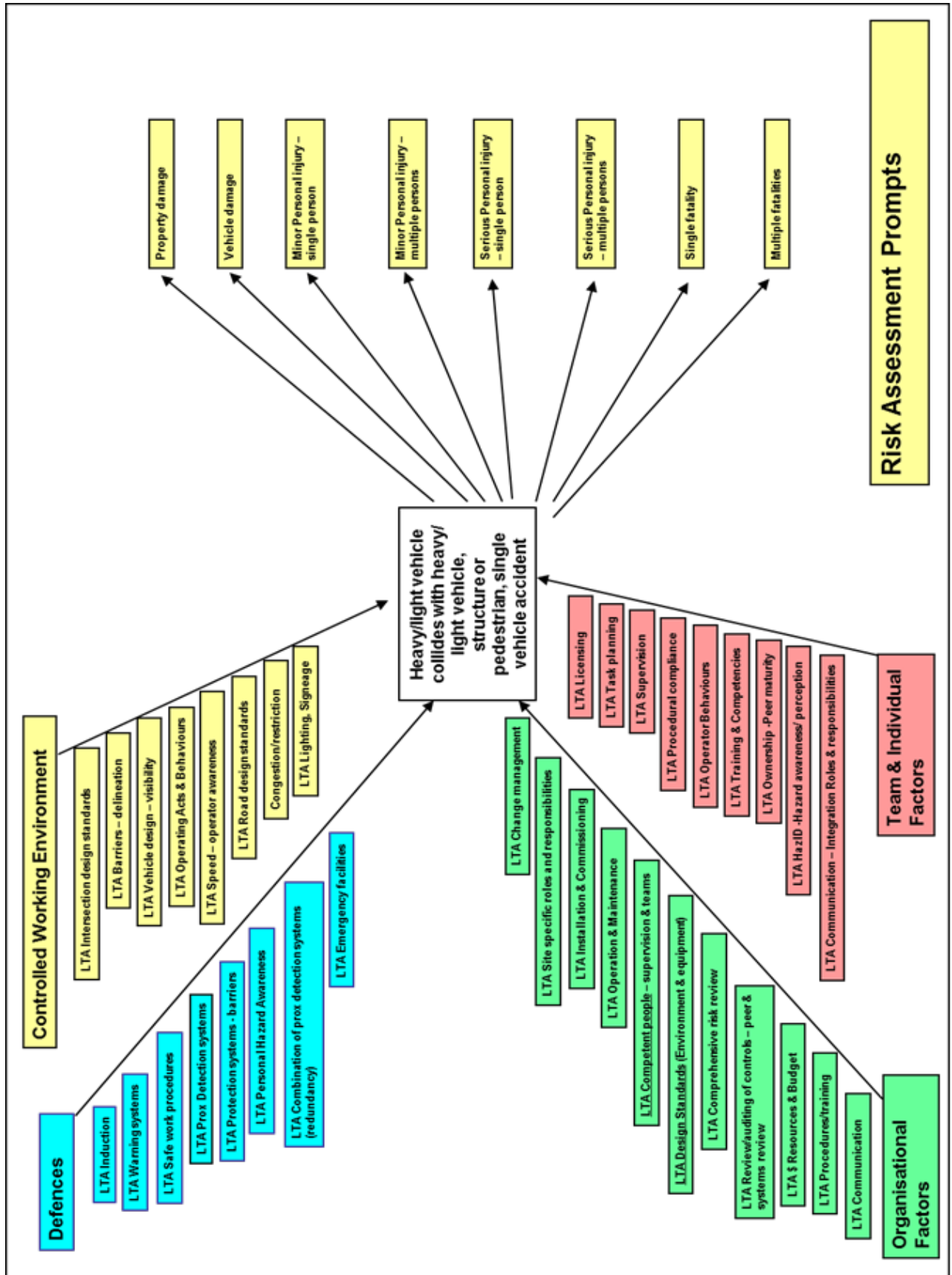
- Be made aware of the site rules.
- Not carry out unrestricted operation of vehicles.
- Be supervised by a competent worker if operating in a restricted mode.

A record of all training and assessment given to workers must be kept as part of worker records. These records must be maintained and be available.

5 Appendices

Appendix 1 – Risk Assessment Prompts

(LTA = Less Than Adequate)



Appendix 2 – Technology Type

Some questions to consider during the selection of a technology type control:

- What can the system do – what can it not?
- Is the system designed for low speed or high speed, or can it handle both speed regimes? (note low and high speed needs to be explicitly defined)
- Is the system aimed at V2V, V2P V2I (vehicle to vehicle, vehicle to person, vehicle to infrastructure) interaction prevention?
- What is the system's detection capability - range and speed – near and far field?
- How sensitive is the system – near / far field, vehicles, people, stationary objects, infrastructure, and under what circumstances will the system not work (e.g. dust, snow, fog, ground conditions)?
- Does the system use directional algorithms to predict likely collisions? Is it able to establish the 'context' around a traffic situation?
- Is it standalone or dependant on other systems – how will it be integrated to the OEM machine?
- Active vs Passive systems - does it rely on the operator to carry out any actions or will it, for instance, slow down the machine automatically?
- Does the system have any redundancy – will it fail to safe and does it have a self-checking mechanism?
- Human interface – is the system intuitive and simple to use and interpret?
- Will use of the system desensitize the operators? (i.e. will it make the operator rely too much on the system as first line of control?)
- How well is the system designed against 'false alarming'?
- How robust is the system against deliberate operator interference?
- How is the system designed to minimise cabin clutter, veiling or other ergonomic issues?
- Will it interfere with other electronic systems of the vehicle, other vehicles and the environment (e.g. fuel stations)?
- Will the system be able to support and enhance the sites 'Golden Rules' and company safety standards?
- How can the effectiveness of the system be measured?
- How will the system be implemented for all contractors' vehicles on site?
- What training, education and assessment will be required for a successful implementation of the system?

Appendix 3 – Effective Separation and Stopping Distances

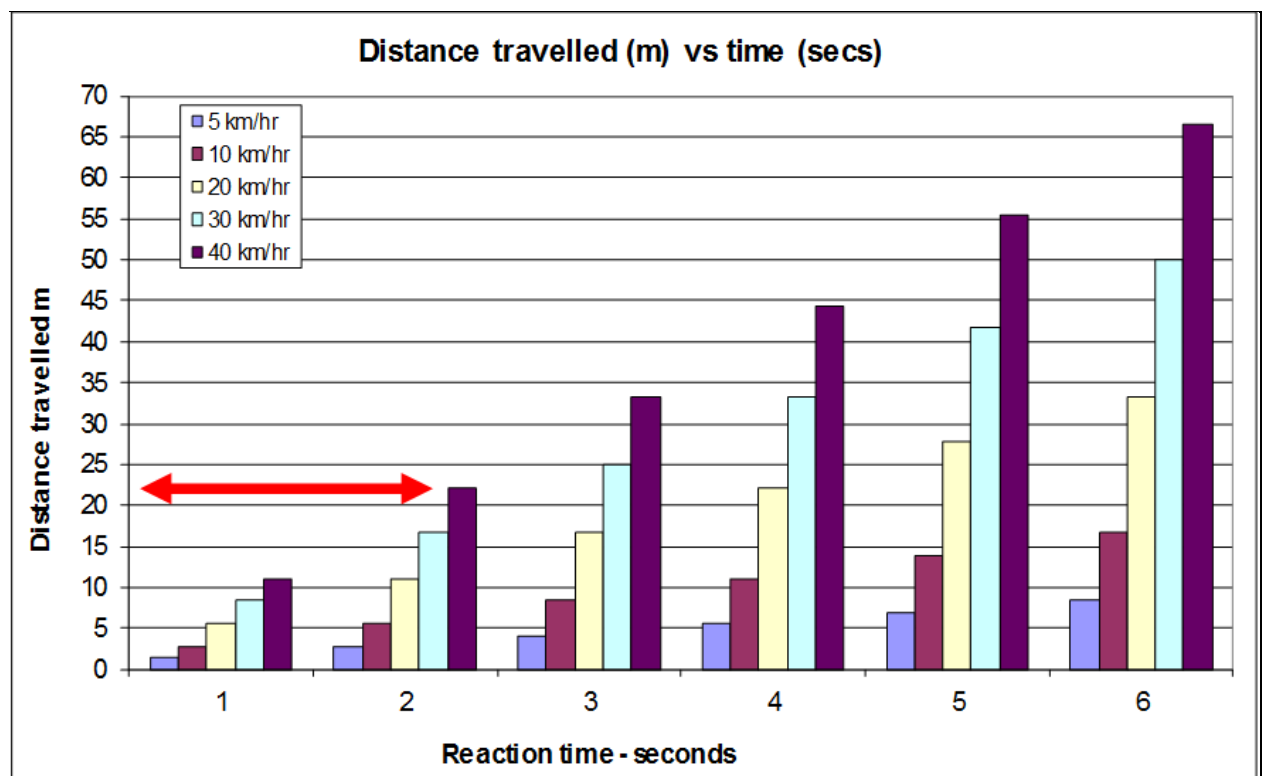
Site separation and stopping distances must be greater than the actual (measured) stopping distance of the vehicle with the longest (worst) braking distance, under the worst road (slippery / wet, downhill), vehicle (maximum speed, fully laden, bald tyres) and operator conditions (operator fatigue, distraction, unfamiliar with situation).

Importantly, the nominated separation distance must also take into account the natural reaction time of the operator, and the mechanical delay time between brake actuation and actual slowing of the vehicle.

Graph 1 below can be used to estimate the effects of distance travelled for different operator reaction times and mechanical delay time. As shown by the red arrow, a vehicle traveling at 40 km/h will have driven 22.2 m for a combined operator reaction and mechanical delay time of 2 secs (irrespective of vehicle type).

If the nominated separation distance was set at 50 m, this would mean that actual braking and stopping of the vehicle would need to be achieved within the remaining distance of 27.8 m ($50\text{ m} - 22.2\text{ m} = 27.8\text{ m}$).

Depending on the vehicle, payload, road conditions, efficiency of braking systems, operator capability etc., this may not be sufficient to prevent a collision. As a result, a greater separation distance must be considered.



Graph 1. Distance travelled vs Operator reaction/mechanical delay time

Appendix 4 – Sample Table and Bowtie

Following is one worked example (table and bowtie) showing how controls may be identified and the requirements for monitoring for effectiveness and reliability. The scenario selected is a loader impacting on a pedestrian walking on a roadway:

- Step 1: Clearly identify the scenario
- Step 2: List all preventative and mitigating controls, (see tables 1a and 1b below)
- Step 3: From the preventative and mitigating controls identify the critical controls, (highlighted in tables 1a and 1b below).
- Step 4: For each control establish how it will be monitored for effectiveness and reliability, (see tables 1a and 1b below).

The above steps must be repeated for all scenarios.

The tables are used as the working documents to identify and list controls and how they will be implemented and monitored. The bowtie is the pictorial representation of information contained in the tables. This allows for easier interpretation and communication to workers.

Table 1a. Loader impacting on a pedestrian walking on a roadway

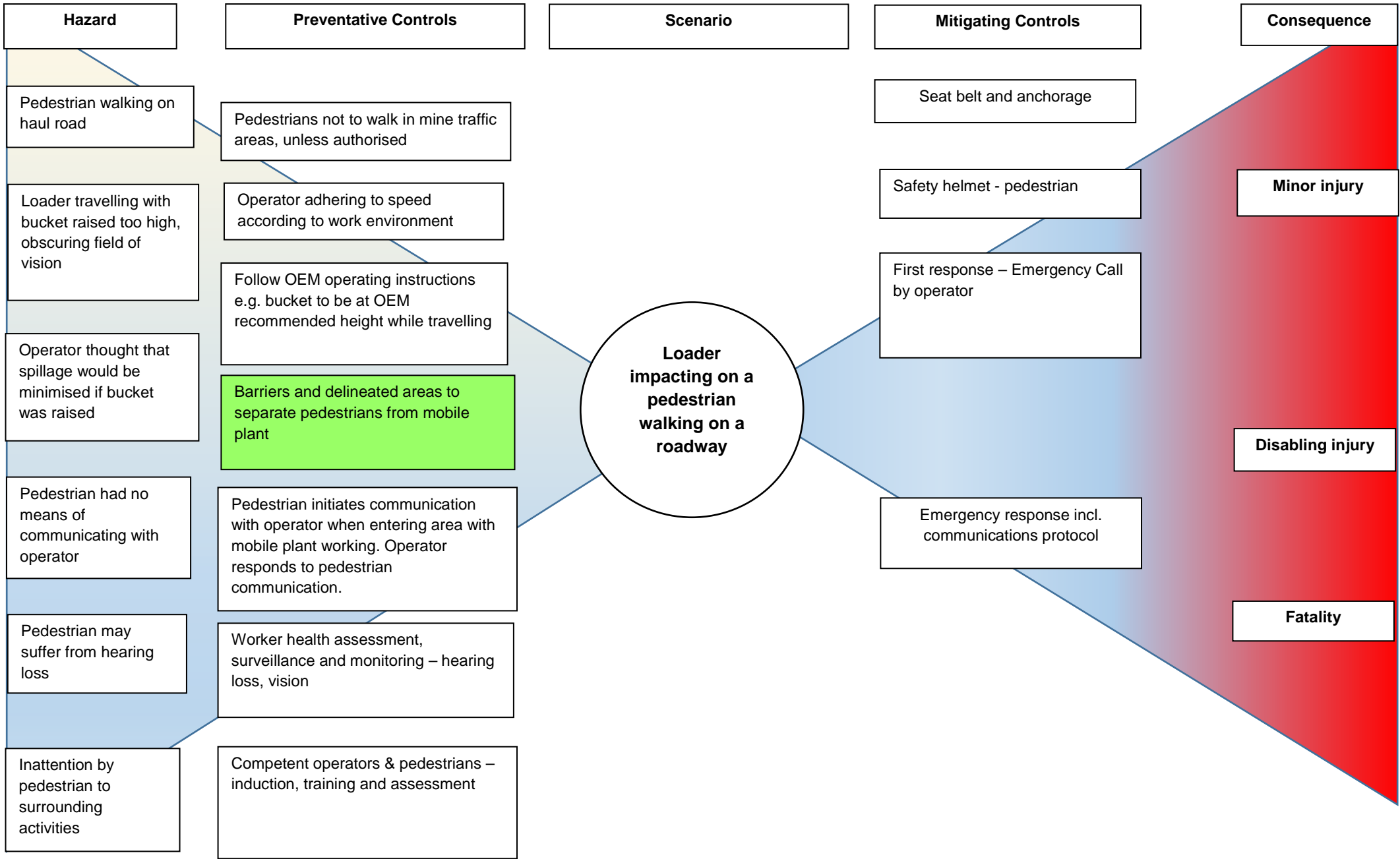
Step 2 – Preventative Controls	Step 4 - Monitoring for effectiveness and reliability
Design	
Designated and maintained pedestrian crossings and delineated walkways (location) , incl. signage and lighting	Planned inspection against standard
Elimination of blind spots – road layout design	Audit against road design standard, work place inspections
Adequate area lighting	Lighting audit, work place observation
Operator’s field of view not to be obstructed by aftermarket ancillary equipment	Change management, commissioning, job observation
Barriers and delineated areas to separate pedestrians from mobile plant	Planned workplace inspection against standard, defined and documented separation barriers , barrier is inspected to ensure it is fit for purpose
Laser barriers / curtains to stop operation if a person enters mobile plant operating area	Maintenance program Prestart checks, auto self-check functions
Reversing alarms & cameras	Prestart check, maintenance check, operator training
Proximity Detection	Prestart check, maintenance check, operator training
Fit for purpose vehicle incl. strobe & flag, reflective vehicle lettering	Maintenance schedule , prestart inspections, procurement protocols
Designated parking areas - spoon drain, reverse parking incl. adequate lighting	Workplace observation, GPS Tracking
Minimise presence of pedestrians in operating areas	Workplace observation, monitoring of compliance with traffic management rules
Competent operators & pedestrians – induction, training and assessment	Training needs analysis review, refresher training, Verification of Competency, Workplace observation
Following OEM service schedule	Audit of maintenance records

Step 2 – Preventative Controls	Step 4 - Monitoring for effectiveness and reliability
Worker health assessment, surveillance and monitoring – hearing loss, vision	Audit of records
Rules – Pedestrian	
<ul style="list-style-type: none"> • Pedestrians to not walk in mine traffic areas, unless authorised • Pedestrians cross at designated points on roadways only 	<ul style="list-style-type: none"> • Checking the number and location are appropriate with regard to the design and layout of the mine traffic framework, planned inspection against standard, observation, CCTV monitoring • Crossing lights maintained • Mobile plant operator reporting of non-compliance, Workplace observation
Follow rules when approaching operating plant	Workplace observation against standard
Wearing high-vis clothing with reflective bands	Mine management, supervision, workplace observation
Pedestrian initiates communication with operator when entering area with mobile plant working	<ul style="list-style-type: none"> • Confirmation of communication received by all affected persons • Prestart checks of communication equipment • Third party monitoring to ensure communication protocols are being maintained
Rules - Operator	
Follow OEM operating instructions e.g. bucket to be at OEM recommended height while travelling	Workplace observation against standard, and OEM operations manual
Adhere to speed limits, taking into account the working environment	GPS tracking, supervision, workplace observation
Following road rules in line with state rules	Workplace observation
Prestart inspection to ensure effective braking, steering systems and other non-negotiable safety systems are checked, including defect management	Supervision, audit of prestart inspection records, audit of defect management process
Operator responds to pedestrian communication	Job observation, training programs, third party monitoring to ensure communication protocols are being maintained

Step 2 – Preventative Controls	Step 4 - Monitoring for effectiveness and reliability
<ul style="list-style-type: none"> • Cab visibility – clean windows prior and during operation cab • Not to be obstructed by items placed obscuring the field of vision • Not to be obstructed by aftermarket ancillary equipment 	Job observation, prestart inspections, housekeeping, audit of change management process
Operator taking into account environmental conditions. E.g. reduce vehicle speed during poor visibility	GPS tracking, real time workplace observations, supervision
Situational awareness – limit opportunities for distraction - not using mobile phone or headsets, music	Workplace observation
Secure all objects in cab	Workplace observation

Table 1b. Loader impacting on a pedestrian walking on a roadway

Step 2 - Mitigating Controls	Step 4 - Monitoring for effectiveness and reliability
First response – Emergency Call Administer First Aid	Personnel training and equipment is up-to-date and tracked, effective communications protocol, emergency drill – at least once a year
Seat belt and anchorage	Workplace observation, training, maintenance in accordance with OEM instructions
Safety helmet	Workplace observation
Emergency response incl. communications protocol	Personnel training and equipment is update and tracked



6 References and Publications

References

- Queensland [*Mining & Quarrying Safety and Health Act 1999*](#).
- Queensland [Mining and Quarrying Safety and Health Regulation 2017](#).

Safety publications

- ICMM Health and Safety Critical Control Management Good Practice Guide
<https://www.icmm.com/en-gb/publications/health-and-safety/health-and-safety-critical-control-management-good-practice-guide>
- ICMM Critical Control Management Implementation Guide
<https://www.icmm.com/en-gb/publications/health-and-safety/critical-control-management-implementation-guide>

Standards

- AS/NZS 4024 Safety of Machinery.
- AS/NZS 4240 Series Remote Control Systems for Mining Equipment.
- AS/NZS ISO 31000 Risk Management – Principles and Guidelines.
- AS61508 Series Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems.
- AS62061 Safety of Machinery – Functional safety of safety related electrical, electronic and programmable electronic control systems.