NSW Resources
Resources Regulator

Technical Reference Guide

Roads or other vehicle operating areas – principal hazard management plan for surface mining operations

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Industry Vehicle Interaction Improvement Resources.
Earth Moving Equipment Safety Round Table (EMESRT) and the International Council for Mining & Metals (ICMM) have published a freely available vehicle interaction improvement body of knowledge with practical resources developed through broad global collaboration of all industry stakeholders. The resources are available to the EMESRT website.

Adverse Vehicle Interaction Advisory Committee (AVIAC)
This Technical Reference Guide has been developed by the Resources Regulator in consultation with the tripartite working group the Adverse Vehicle Interaction Advisory Committee. The committee has representatives from the NSW Minerals Council, Cement Concrete and Aggregates Australia; the Mining and Energy Union, the Australian Workers Union and the Resources Regulator.

Amendment schedule		
Date	Version	Amendment
January 2025	First published	Consultation draft
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1. Introduction

Adverse vehicle interactions are a significant hazard on roads and other vehicle operating areas in mining operations, with the potential to cause fatalities and serious injury. In NSW, mine operators are required to eliminate risks to workers or, when risks cannot be eliminated, ensure they are controlled as low as is reasonably practicable.

1.1. Purpose

This Technical Reference Guide (TRG) provides information to assist mine operators and other duty holders to comply with legislative requirements for a roads and other vehicle operating areas principal hazard management plan (ROVOA PHMP) to avoid adverse vehicle interactions. The ROVOA PHMP must form part of the mine's safety management system (SMS)[1].

1.1.1. Relationship to the Earth Moving Equipment Safety Round Table Vehicle Interaction Improvement initiative

The Earth Moving Equipment Safety Round Table (EMESRT) Vehicle Interaction Improvement project is a world-leading collaborative initiative to reduce the risks associated with adverse vehicle interactions on mine sites.

The TRG has drawn on elements of the EMESRT industry resource models and sought to adapt them to suit the broad spectrum of mining operations maturity in the NSW mine safety regulatory environment. There are specific references and adaptions in this TRG to the International Council of Mining and Metals (ICMM) vehicle interaction maturity model[2] and the layered defence approach for operational effectiveness.

It is important to note this TRG is not a full substitute for the EMESRT vehicle interaction control improvement initiative. Use of the information provided in this TRG may not achieve all the outcomes that can be achieved by using the EMESRT resources and processes. For more information on EMESRT and the Vehicle Interaction Improvement Body of Knowledge please visit the EMESRT website.

Mine operators that use the EMESRT resources and processes in full should satisfy the requirements of this TRG.

1.2. Scope

1.2.1. In scope

This TRG takes a specific approach to minimise and control the risks of adverse vehicle interactions at the surface parts of mining operations where mobile plant is used.

The TRG uses a layered defence approach to help achieve safe operating states for mobile plant.

The TRG covers:

[1] Work Health and Safety (Mines and Petroleum Sites) Regulation 2022 section 32 and Schedule 1 set out specific matters to address and control relating to mobile plant and roads and other vehicle operating areas.

[2] The International Council on Mining and Metals (ICMM)

- mine design and site standards
- effective road conditions
- organisational requirements
- traffic management
- potential for interactions between vehicles, pedestrians and fixed plant
- operator requirements
- assistance from technology
- process to implement and maintain vehicle interaction controls.

1.2.2. Out of scope

The following matters are out of scope for this TRG:

- underground mining operations.
- remote controlled vehicles.
- preliminary operations on exploration licences that do not require a PHMP.

1.3. Interactions with other plans and safety management system

The ROVOA PHMP forms part of a mine's SMS. For more information about safety management systems see the NSW code of practice safety management systems in mines.

Control measures identified in a mine's ROVOA PHMP may interface and/or interact with controls in other health and safety management/control plans. These interplays may degrade the effectiveness of controls. It is important that mines have a process to assess this interplay and have measures in place to address where appropriate.

1.4. Legislative requirements

This TRG provides guidance to mine operators and other relevant work health and safety (WHS) duty holders on how to comply with the legislative requirements regarding a ROVOA PHMP.

1.4.1. Managing risks to health and safety

Section 14(1) of the *Work Health and Safety (Mine and Petroleum Sites) Regulation 2022* (WHS (MPS) Regulation) requires a mine operator to manage risks to health and safety associated with mining operations. They must do so in accordance with Part 3.1 of the *Work Health and Safety Regulation 2017* (WHS Regulation) – Managing risks to health and safety.

1.4.2. Consultation

Part 5 of the *Work Health and Safety Act 2011*, Consultation, representation and participation, requires persons conducting a business or undertaking (PCBUs), when managing risks, to consult workers and other duty holders at the mine. This includes other PCBUs such as contractors. Further information can be found in:

- Section 3.4 of Guide – Preparing a principal hazard management plan and the:

- NSW code of practice: Work health and safety consultation, cooperation, and coordination (August 2022), published by SafeWork NSW
- Contractors and other businesses at mines and petroleum sites guide
- Consulting workers fact sheet.

1.4.3. ROVOA PHMP

The ROVOA PHMP needs to consider other aspects of legislation, including but not limited to:

- section 28 of the WHS (MPS) Regulation - Preparation of a principal hazard management plan
- section 32 of the WHS (MPS) Regulation - Movement of mobile plant
- schedule 1 section 7 of the WHS (MPS) Regulation - PHMP Roads or other vehicle operating areas.

1.4.4. Provide information training and instruction

Section 107 of the WHS (MPS) Regulation –Duty to provide information, training and instruction, requires mine operators to inform workers of the risks to health and safety and train them to ensure they are competent to carry out their tasks.

1.5. Acronyms abbreviations and concepts

1.5.1. Acronyms and abbreviations

Name	Definition/detail
AS	Australian standard
code	code of practice
ISO	International Organization for Standardization
layered defence approach	vehicle interaction layered defence approach
maturity framework	vehicle interaction maturity framework
operational requirements	safe operational requirements
PCBU	person conducting a business or undertaking
PHMP	principal hazard management plan
ROVOA	roads or other vehicle operating areas
Regulator	NSW Resources Regulator

Name	Definition/detail
SMS	safety management system
TARPs	trigger action response plans
TMP	traffic management plan
TRG	technical reference guide
WHS	work health and safety

1.5.2. Concepts

Term	Definition
Erosion factors	Erosion factors cause adverse drift in maintaining the expected safe operational requirements which may lead to potential unwanted vehicle interactions.
Operational controls	Operational controls are control measures specified, implemented and monitored to achieve safe operating requirements and prevent or mitigate erosion factors from occurring. Note: in this document the term 'operational controls' has the same meaning as the EMESRT term 'operational activities'.
Safe operational requirements	Safe operational requirements are performance-based safety outcomes identified by the mine operator that provide safe vehicle interactions at that mining operation.
Traffic management plan	A traffic management plan describes how the mine operator will manage the flow of traffic at the mining operation. This includes design parameters and road rules.
Vehicle interaction maturity framework	The vehicle interaction maturity framework (maturity framework) uses criteria to establish where on the framework the mining operation sits at the time of assessment. This enables the mine operator to identify the next steps in improving its management of vehicle interaction risks.
Vehicle interaction layered defence approach	The vehicle interaction layered defence approach[3] (layered defence approach) describes the actions in the layers of protection to achieve safe operational requirements. The approach has 9 layers of protection. Note: The complexity and level of risk at the mining operation will determine the sophistication of the operational controls implemented and the nature of technology-assisted controls required.

[3] The vehicle interaction layered defence approach is based on the model developed by EMESRT.

2. Risk management and control

Hazard identification, risk assessment and effective implementation of operational control measures are critical steps in ensuring safe work systems and a safe work environment.

2.1. Identifying hazards

Table 1 below includes a non-exhaustive list of matters associated with identifying hazards for roads and other vehicle operating areas, along with possible consequences, illustrating the importance of controlling vehicle interactions

When developing the ROVOA PHMP the mine operator should evaluate the mine's history including, existing WHS systems, previous incidents, mine design, the geotechnical conditions at the mine, mining method, and mobile plant to be used.

Table 1 - Matters to be considered with roads and other vehicle operating areas

Matters	Possible consequence
Collision between heavy mobile plant and: • other heavy plant • light vehicles • public vehicles.	fatality serious injury plant damage.
Collision between mobile plant and people.	fatality serious injury
Collision between mobile plant and fixed structures.	fatality serious injury plant and structure damage.
Uncontrolled movement of plant: • loss of control on road due to - speed - slippery surface - soft floors - vehicle malfunction (e.g., brake failure) • non-stable parking.	fatality serious injury plant damage.
Ergonomic factors: • vibration • awkward postures • fatigue.	serious injury.

2.2. Assessing the risks

The WHS (MPS) Regulation requires that mine operators conduct a risk assessment to identify all aspects of risk to health and safety associated with roads or other vehicle operating areas.

Due to the complex nature of vehicle interaction hazards and how vehicle interaction controls can be dependent on/interfere with each other, a standard risk assessment approach is likely to be inadequate. This TRG has been developed to assist with the development of site risk assessments addressing vehicle interactions by providing a clear and effective structure with specific inputs to be considered.

The risk assessment must be conducted by a person or group that is competent to conduct the assessment on vehicle interactions. The Guide - Preparing a principal hazard management plan provides further details regarding the need for competent persons, a comprehensive and systematic process and choosing risk assessment techniques.

The following documents may also be useful:

- NSW code of practice: How to manage work health and safety risks
- National Minerals Industry Safety and Health Risk Assessment Guideline.

For further information on managing risks under the WHS (MPS) Regulation, including specific obligations for conducting risk assessments, see the Guide - Managing risks in mine and petroleum operations. Risk analysis methods should be documented, maintained and should:

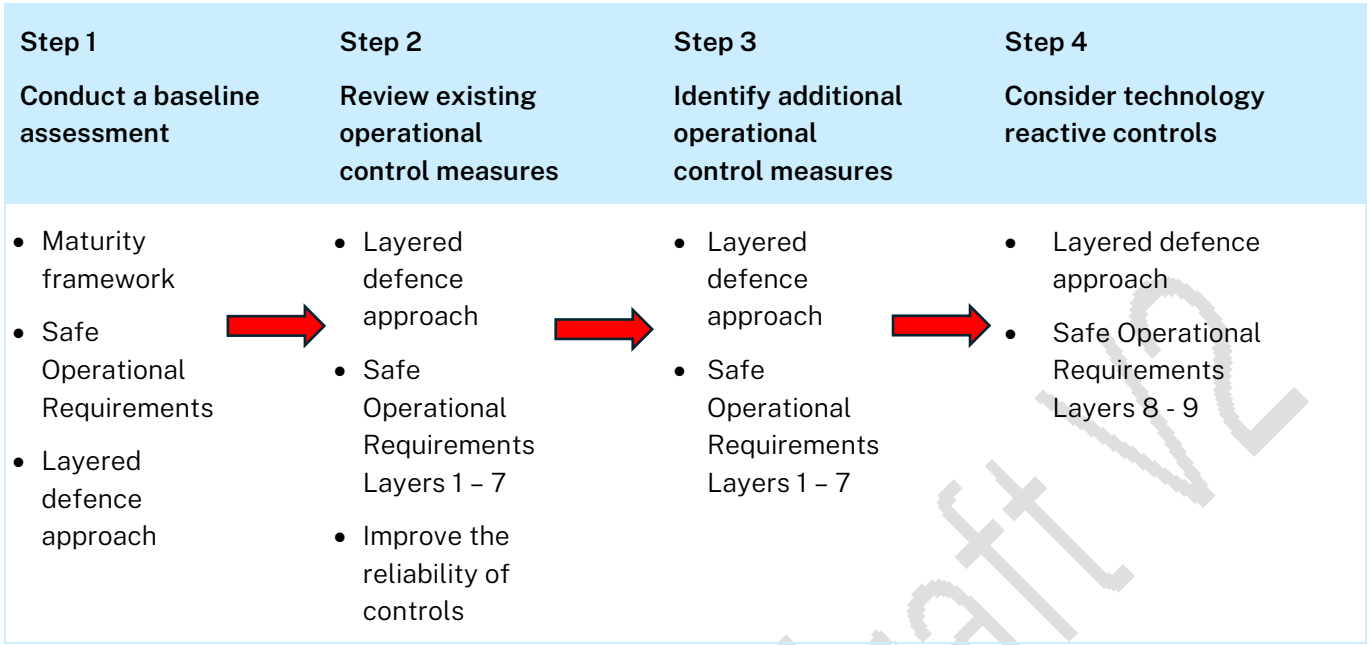
- describe the methods used at the site to identify the level of risk, threats, controls, and consequences (e.g., risk assessments, bow-tie methodology)
- describe methods used to assist in risk evaluation
- justify why they are deemed valid and reliable methods
- include a record of the most recent risk assessments.

2.3. Steps to implement and maintain vehicle interaction control measures

This section provides guidance to mine operators on verifying where they are on the vehicle interaction journey, and how to progress to a safer workplace. There are 4 steps to follow (as shown in Figure 1):

1. conduct a baseline assessment using the maturity framework
2. review existing operational control measures using the layered defence approach
3. identify and implement additional operational controls to achieve safe operating requirements
4. consider implementing reactive technology controls.

Figure 1 - Vehicle interaction improvement model



2.3.1. Step 1 - Conduct a vehicle interaction maturity assessment using the ICMM maturity framework

The vehicle interaction maturity framework[4] (maturity framework) is a good starting point for the mine operator to understand where they are at on the vehicle interaction journey. It provides an important insight and importantly, provides the reasons for change or the 'burning platform' for change.

The maturity framework uses criteria for mine operators to establish where on the framework the mining operation sits at the time of assessment. It is critical this assessment is conducted with the appropriate cross-section of workers and is an honest and true reflection of reality.

All mine operators should aim for 'adaptive' solutions across all layers of (the layered defence approach detailed in step 2, that can adjust and evolve in a complex environment are essential for controlling vehicle interactions.

The mine operator can use the maturity framework as a guide to help strengthen the layered controls implemented at their site. The mine operator using this approach can verify that the safe operational requirements are supported through robust operational control measures, to the point where the layers of operational control measures are enduring and adaptive.

The maturity framework can be used at appropriate stages to assess progression at the mining operation and drive continuous improvement in vehicle interaction safety.

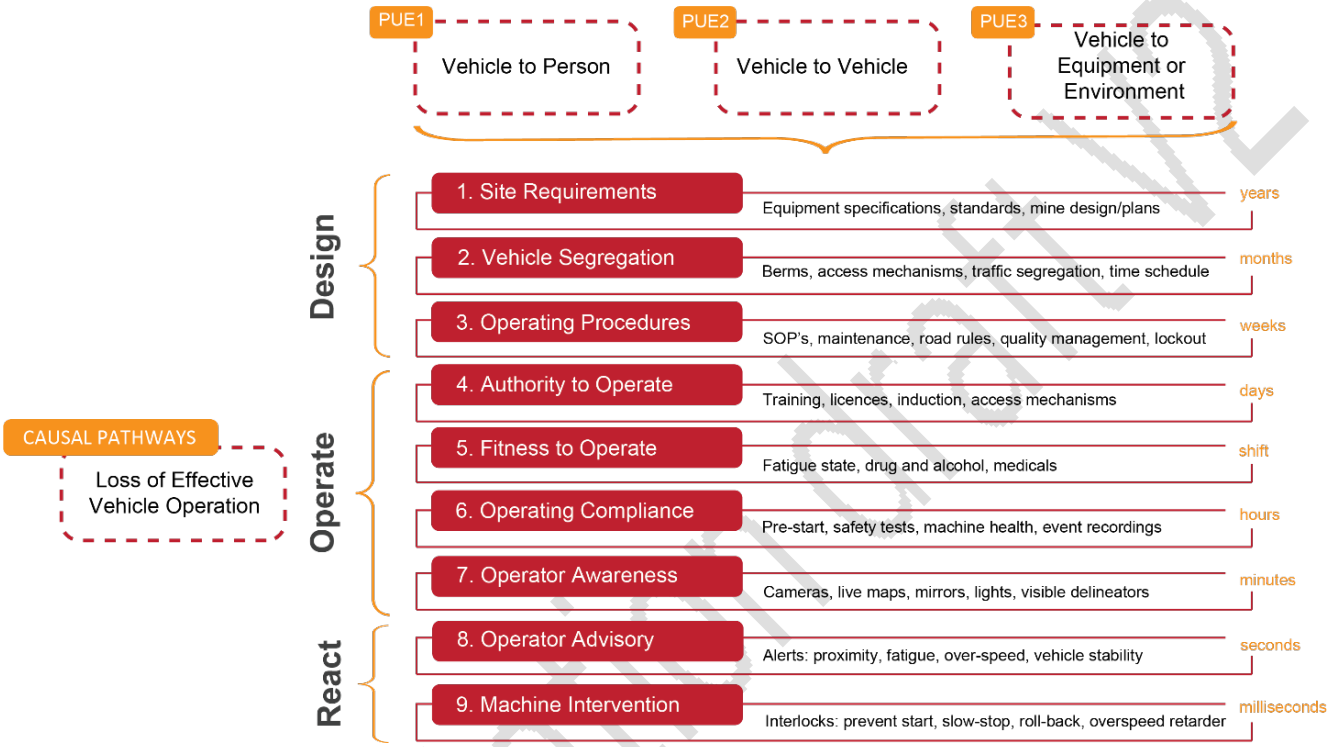
The maturity framework is shown in Appendix A.

[4] The vehicle interaction site maturity framework is based on the model developed by ICMM.

2.3.2. Step 2 - Review existing operational control measures using the layered defence approach

After gaining insight in the maturity of their site through Step 1 above, mine operators should adopt the following 9 layered defence approach (figure 2) to further assess and document their vehicle interaction operational effectiveness.

Figure 2: Vehicle interaction 9 layered defence approach



The layered defence approach is a foundation approach with dynamic interdependence between activities across defence layers (two or more actions may interact and can change over time). It's important to note that layer categories operate in different timeframes (as shown in figure 2) and have a high dependency on human decision making (human factors).

The Regulator recognises that work to improve vehicle interaction operational control measures is complex. Fundamental operational control measures such as design layers 1-3 and operate layers 4-7 need to be in place before considering implementing the reactive technology layers 8-9. To implement layers 8 and 9 well, mine operators need to first understand the effectiveness of layers 1-7 and improve them to meet the safe operational requirements that have been determined by the mine operator.

Below is a detailed breakdown of the layered defence approach with the minimum operational control measures that should be considered and implemented for each layer to be effective. These operational control measures have been effective in eliminating or minimising the potential for fatalities, injuries and incidents arising from hazards related to mobile equipment.

Mine operators should review and adjust their approach and documentation regarding vehicle interaction safe operational requirements according to the layered defence approach below.

Layer 1 – Site requirements (equipment specification, standards, mine design and plans)

Layer 1 of the layered defence approach focuses on site requirements, which should include:

1) **Equipment specifications:** Equipment meets specific safety standards and is suitable for the intended tasks.
2) **Mine design:** Planning and designing the mine layout to minimise hazards, such as optimising traffic flow and maintaining adequate clearance between equipment and personnel.
3) **Standards:** Utilising industry guidelines, standards and regulations to minimise the potential for an unwanted vehicle interaction.

The mine operator should consider the following operational control measures:

- mobile equipment with designed and approved seating, including seatbelts or other restraints devices, should be used to transport personnel
- identification and communication of mobile equipment sight lines and blind spots
- provision of walkways and means of maintaining clearance from pedestrians and other vehicles
- mobile equipment specifications should be prepared by knowledgeable and experienced people who are familiar with production and operating environment demands
- mobile equipment specifications apply when:
  - purchasing new or used equipment
  - transferring equipment to site
  - hiring equipment
  - assessing contractor equipment
- mobile equipment specifications should include:
  - operator access and egress
  - maintainer access
  - towing hooks/lugs designed to handle expected loads
  - brakes
  - steering
  - tyres
  - headlights and clearance lights
  - operator ergonomics for visual displays and vehicle controls
  - indicators, warning lights, horns and alarms of sufficient volume that can be heard in the operating environment
  - vehicle identification numbers (unique, clear and visible) for surface operations
  - mirrors and cameras (where fitted)
  - communications equipment

  - where implemented, operator proximity alerts, advisory and intervention technology
  - fire suppression
  - Roll Over Protection Systems (ROPS)
  - Falling Object Protection System (FOPS) that exceed the maximum expected object force, e.g. when loading in pit or from under an ore or reject bin
  - internal load barriers that protect operators and passengers
  - mobile equipment reversing alarms
- establishment of minimum dimensions and conditions for roadways and mobile equipment work areas with their Traffic Management Plan (TMP) that specifies:
  - established accountabilities or mine planners regarding the design, construction and layout of road networks, and is clearly articulated in relevant site documentation
  - maximum grade
  - curvature and line of sight
  - pavement shape and material
  - guidepost spacing relative to the distance required between travelling vehicles
  - guidepost reflector specification, e.g. red on driving side and white on offside
  - signs and barriers
  - lighting standards
  - intersections designed as far as practical with a ninety-degree angle of approach.

Layer 2 – Vehicle segregation (berms, access control, traffic segregation, time schedule)

Layer 2 of the layered defence approach focuses on vehicle segregation control measures. These control measures are designed to physically separate vehicles from potential hazards and should include:

1) **Berms:** Earth mounds or barriers that prevent vehicles from straying into dangerous areas.
2) **Access mechanisms:** Measures to restrict entry to hazardous zones, ensuring only authorised personnel can enter.
3) **Traffic segregation:** Designating specific routes for different types of traffic (e.g., pedestrian, vehicle).

The mine operator should consider the following operational control measures:

- surface operations road width normally of at least three times the width of the widest vehicle regularly using two-way haul roads
- the construction and maintenance of safety berms or windrows alongside roadway edges or areas where there is a sudden change in terrain, e.g. drop off, water body, or another hazard. The safety berms or windrows should be constructed using suitable (solid) materials and be of a

height, density and profile to enable an effective barrier. The minimum height required is generally half the wheel height of the largest vehicles using the road

- the design and use of safety berms or windrows for delineation and segregation, e.g. at intersection approaches, corners so as not to impede visibility
- physical barrier design and locations used to protect against access to unprotected benches or trenches
- the protection of fixed structures, including overhead power lines, buildings, refuelling areas, elevated structures, bins, etc. during mobile equipment operations
- the approach to bridges and tunnels should clearly signpost the maximum height and width and, if relevant, the maximum load capacity of vehicles that may transit
- a Transport/Traffic Management Plan or equivalent should be developed for surface locations that include:
  - travelling and clearance distance between equipment and people
  - workplace design that, as far as practical, eliminates the interaction between pedestrians and mobile equipment, or assists in maintaining awareness using:
    - segregated or dedicated walkways for pedestrians protected by windrows, bunds or other physical barriers
    - delineation of no-go and danger zones for pedestrians
    - pedestrian crossings in high pedestrian traffic areas
    - horn signals to indicate vehicle operation prior to starting the vehicle, before forward movement, and before reversing (except in operating environments where this may create a hazard)
    - establishing protocols for persons who work around operating mobile equipment to have a positive means of communicating with the equipment operator e.g. in a surface mining environment at least one member of the work party has an operating two-way radio
  - workplace design and operational practice that manages mobile equipment interactions where practical using:
    - separation of light and heavy vehicles using segregated roads
    - use of remote bays, portable remote stands designed to withstand vehicle contact, and sensors that stop equipment when allowable proximity distances are breached for remote controlled mobile equipment
    - park up areas with one-way traffic flow and segregated parking areas for heavy plant and equipment, light vehicles and pedestrians
    - park-up areas with spoon drains, humps (between front and rear axles) or some other method to prevent uncontrolled movement of vehicles
    - one-way traffic in high traffic areas, or installing centre berms or windrows
    - one-way lights or other management system for high traffic intersections.

Layer 3 - Operating procedures (standard operating procedures, maintenance, road rules, quality control, lockout)

Layer 3 of the layered defence approach focuses on operating procedures. This layer aims to establish effective operations through well-defined processes and operational control measures. Key components should include:

1) **Standard Operating Procedures (SOPs):** Detailed instructions on how to perform tasks.
2) **Maintenance:** Regular and systematic upkeep of equipment.
3) **Road rules:** Specific guidelines for vehicle operation within the mine site.
4) **Lockout/tagout:** Isolation procedures to prevent machine operation.

These operating procedures are typically implemented over a period of weeks, allowing for thorough training and integration into daily operations.

Mine operators should consider the following operational control measures:

- a Transport/Traffic Management Plan or equivalent should be developed for surface locations that includes:
  - operator prestart equipment inspection and technology checks, based on original equipment manufacturer or approved engineering advice, and safe operating requirements
  - method of fundamentally stable parking of mobile equipment e.g. park brake, chocks, spoon drains, humps (between front and rear axles)
  - the safe refuelling of the mobile equipment
  - stopping mobile equipment when boarding or dismounting
  - mobile equipment limitations including the maximum loads that may be carried or towed
  - speed limits by equipment type, location and conditions
  - managing changes in road surfaces
  - operating around fixed structures, such as conveyor and bin trestles, building supports, power poles etc
  - minimum personal protective equipment (PPE) requirements including high visibility clothing
  - procedures for pedestrians working in operational areas
  - give-way requirements for mobile equipment operators and pedestrians
  - managing road repair works, including grader operations
  - radio (or other communications) call up protocols
  - procedures for approaching mobile equipment
  - procedures for towing
  - parking in operational areas including the means of isolating equipment and activity from danger of collision during breakdowns, emergencies, infield servicing, refuelling and maintenance
- education and awareness for workers

- shift roster design that includes:
  - defined hours of work and rest requirements, including travel time and a process to manage additional hours of work
  - advice and support for supervisors including fatigue call-ups during shift and how to manage fatigued persons from the workplace
  - a baseline assessment of existing mobile equipment fatigue management.
- mobile equipment related potential emergency scenarios should be identified, and emergency response procedures are to include equipment and response requirements e.g. fire response, trauma first aid, extrication of trapped or pinned personnel; extreme weather; power line contact and potential tyre rapid deflation, etc.
- operator pre-use inspections including highlighted specific machine down items
- method of notifying and managing equipment failures during operations
- scheduled inspection, servicing and maintenance programs for mobile plant and support equipment, e.g. radio communication system including networks; and key systems e.g. proximity detection systems, brakes, tyres and lubrication
- road maintenance practices that will maintain a proper road surface e.g. snow removal, sanding, managed roadway watering for dust management, etc.
- vehicle parking requirements that include parking distances from other equipment and structures
- dust management
- operational requirements should consider the separation of buses from heavy vehicles or the requirement to stop operation of heavy vehicles when buses pass.

Layer 4 - Authority to operate (training, licences, induction, access)

Layer 4 of the layered defence approach focuses on authority to operate. This layer establishes that only qualified and authorised personnel operate vehicles and perform tasks. Key components should include:

1. Training: Comprehensive training programs to enable all personnel to be knowledgeable about operational procedures and protocols.

2. Licences: Issuing and maintaining valid licences for operators to confirm their qualifications and competency.

3. Induction: Conducting thorough induction programs for new employees to familiarize them with site-specific operational requirements and procedures.

4. Access mechanisms: Implementing systems to manage and monitor access to mine vehicle operating areas, validating only authorised personnel can enter.

Mine operators should consider the following operational control measures:

- personnel who operate or work around mobile plant/vehicles should be trained, competent and authorised

- A training plan should include:
  - procedures for worker site induction
  - criteria for selecting and appointing mobile plant/vehicle operators. This should include a physical assessment of capability to reach and operate all controls
  - training needs based on work role, site rules and procedures, licensing requirements, Original Equipment Manufacturer (OEM) guidance and other recognised standards
  - competency assessment criteria, with records retained
  - a periodic review and update of competency requirements, training needs, training content and methods.

Layer 5 - Fitness to operate (fatigue state, drug and alcohol, medicals)

Layer 5 of the layered defence approach focuses on fitness to operate. This layer establishes that personnel are physically and mentally fit to perform their duties safely. Key components include:

1. **Fatigue state:** Monitoring and managing fatigue levels to prevent accidents caused by tiredness. This can include scheduling adequate rest periods and using fatigue detection systems.
2. **Drug and alcohol testing:** Implementing regular testing to establish that employees are not under the influence of substances that could impair their ability to operate effectively.
3. **Medicals:** Conducting regular health monitoring to establish that employees are in good health and capable to operate effectively.

Mine operators should consider the following operational control measures:

- an effective fatigue management system that optimises work rosters
- a health control plan, including drug and alcohol management
- a plan for the introduction of technology to support existing fatigue management activities
- a health control plan.

Layer 6 - Operating compliance (pre-start, safety tests, machine health, event recordings)

Layer 6 of the layered defence approach focuses on operating compliance. This layer establishes that operators are compliant with established operational procedures and protocols. Key components should include:

1. **Pre-start checks:** Routine inspections conducted before operation of machinery to establish it is in effective working condition.
2. **Safety tests:** Regular testing of safety systems and vehicle functions, with self-testing systems preferable that give advice to the operator of abnormal function.

3. **Machine health monitoring:** Continuous monitoring of machinery to detect and address any issues that could compromise safe operational requirements.
4. **Event recordings:** Documenting and analysing incidents and near-misses to identify trends and implement corrective actions.

Mine operators should consider the following operational control measures:

- mobile equipment being used within approved design parameters
- access to operational areas including positive communication methods
- handheld mobile phones should not be used when operating mobile equipment
- assessment of the potential benefits of technology to support or replace existing fatigue management mechanisms for mobile equipment operators
- establishing functional and performance requirements of technology to achieve operational requirements
- applying positive communication where the caller and receiver identify the vehicle and clearly respond
- include shift changeover communication
- monitor proper use of personal protective equipment (PPE)
- use of in-vehicle monitoring systems to monitor driver behaviour
- effective operator responses to mobile equipment faults, alerts and alarms
- seat belts and /or restraints should be worn where fitted.

Layer 7 - Operator awareness (live maps, mirrors, lights, visible delineators, cameras)

Layer 7 of the layered defence approach focuses on operator situational awareness. This layer aims to introduce technologies that provide information to enhance the ability to comprehend the immediate environment and understand potential hazards in the vicinity through providing:

- enhanced situational awareness
- an alert on potential abnormal scenarios
- contextual information of the threat in an abnormal scenario such as:
  a) Where is it?
  b) What is it?
  c) How far away is it?
  d) What is its heading?
  e) How fast is it going?
- Visual confirmation of a potential abnormal situation.

Key components include:

1. **Live maps:** Offering dynamic, up-to-date maps that show the location of vehicles and/or personnel.

2. **Mirrors:** Enhancing visibility around the vehicle to reduce blind spots.

3. **Lights:** Improving visibility in low-light conditions to enable operators to comprehend the environment around them.

4. **Visible delineators:** Marking boundaries and hazards clearly to guide operators on established roadways.

5. **Cameras:** Providing real-time visual information to help operators monitor their surroundings to reduce blind spots.

Mine operators should conduct a review and planning exercise to introduce situational awareness technology for priority vehicles.

Layer 8 – Operator advisory (alerts: proximity, fatigue, over-speed, vehicle stability)

Layer 8 of the layered defence approach focuses on operator advisory controls. This layer aims to provide operators with timely alerts to enhance their situational awareness and identify imminent threats.

Mine operators should consider effective technologies that:

- provide alarms and specific instructions to vehicle operators that enhance the ability to predict potential unwanted interactions
- determine imminent threats of collisions, provide specific reaction instruction signals to vehicle operators and prompt operators to consider other contributing situational factors before reacting to prevent collisions or mitigate significant potential consequences
- outline expected operator responses to mobile equipment faults, alerts, and alarms, and include the use of in-vehicle monitoring systems to monitor driver performance.

Key components include:

1. **Proximity alerts:** Notifications when the vehicle is close to other objects or personnel.

2. **Fatigue alerts:** Systems that monitor the operator's alertness and provide physical and audible alerts to the operator if signs of fatigue are detected.

3. **Over-speed alerts:** Warnings when the vehicle exceeds predetermined speed limits, prompting vehicle operators to reduce speed to the required level.

4. **Vehicle stability alerts:** Notifications about potential stability issues, such as tipping on uneven ground to prompt corrective actions.

Mine operators should consider the following operational control measures:

- determining when and where vehicle operator advisory mechanisms should be installed. This should be done through risk assessments to identify situations where operators or pedestrians should be alerted to hazards or a vehicle's health or operating status

- human factors design in alarming methods and vehicle operator recognition so that specified information and warnings are acted on effectively.

Examples of vehicle operator advisory signals related to vehicles include radar-operated speed alert screens, in-vehicle alarms for over-speeding, exceedance of gradient limits, fire, proximity of other vehicles or pedestrians, and vehicle operator seat vibrators designed to alert fatigued drivers.

Layer 9 - Machine intervention (interlocks, prevent start, slow stop, roll-back prevention, overspeed retarder)

Layer 9 of the layered defence approach focuses on machine intervention. This layer aims to automatically intervene when there is an imminent threat of a collision. Key components include:

Interlocks: Safety mechanisms that prevent vehicles from operating outside the safe operational requirements. Examples include but are not limited to the following:

- prevent start: Systems that prevent machinery from starting if certain safe operational requirements are not met
- slow-stop: Gradual stopping mechanisms to safely reduce vehicle speed to within safe operational requirements
- roll-back prevention: Systems that prevent vehicles from rolling back unintentionally, especially on slopes
- overspeed retarder: Devices that regulate vehicle speed, particularly on downhill slopes, to prevent runaway incidents.
- Vehicle awareness/collision avoidance system: Systems that provide a specific instruction signal to the vehicle to:
  - slow/stop the vehicle
  - then assesses the slow/stop instruction in relation to other contributing factors before reacting to prevent a collision or mitigate significant consequences
  - relinquish intervention to the vehicle operator if they take evasive action
  - provide a manual override to recover after a collision intervention scenario has occurred.

2.3.3. Step 3 - Identify and implement additional operational effectiveness measures to achieve safe operational requirements

Mine operators, after implementing operational control measures detailed in Step 2 above, should;

- systematically review the resilience and reliability of the current operational control measures
- identify and implement any further operational control measures for layered defence approach design layers 1-3 and operate layers 4–7 needed to achieve site specific safe operational requirements
- develop and implement further operational control measures to achieve and maintain safe operational requirements for the mine.

Note: The operational control measures put in place should be proportionate to the risks identified at the mine.

2.3.4. Step 4 - Consider implementing reactive technology mechanisms

Mine operators, after implementing additional operational controls measures to achieve safe operational requirements in Step 3 should consider if reactive technology control measures layers 8–9 are required.

Note: Depending on the risks at a mining operation and the effectiveness of the defence layers 17, further reactive technology measures may not be necessary.

Implementing further operational control measures in layers 8 and 9 of the layered defence approach would depend on a number of risk factors, such as the mine design and the number of opportunities for vehicle interactions.

2.4. Other matters

2.4.1. Traffic management plan

A traffic management plan[5] (TMP) details how the risks associated with plant, pedestrians and vehicle traffic are being managed at site and should form part of the ROVOA PHMP. Mine operators should incorporate the traffic management operational controls identified in layers 2 and 3 of the layered defence approach into a traffic management plan. Key elements typically include:

- **Traffic routes and flow:** Clearly defined routes and traffic flow patterns, including designated areas for heavy vehicles, light vehicles, and pedestrians
- **Access points and parking areas:** Designate specific access points and parking areas for different types of vehicles and personnel
- **Traffic control areas:** Identify areas where traffic control measures are necessary, such as intersections, loading areas, and haul roads
- **Road design and maintenance:** Ensure roads are designed and maintained to accommodate the types and volumes of traffic, with adequate visibility, gradients, and surface conditions
- **Communication protocols:** Establish clear communication procedures for operators, including radio protocols, visual signals, and emergency procedures
- **Speed limits and enforcement:** Implement appropriate speed limits and enforce them through signage, monitoring, and training
- **Emergency procedures:** Outline procedures for responding to traffic-related incidents, including accidents, breakdowns, and emergencies
- **Training and inductions:** Provide comprehensive training and inductions to all personnel on traffic management procedures and safety protocols
- **Monitoring and review:** Regularly monitor the effectiveness of the TMP and conduct periodic reviews to identify areas for improvement

[5] Definition from Resources Safety and Health Queensland Guidance Note QGN 27 Collision prevention (2024)

- **Consultation:** Sites with a high volume of traffic should establish a traffic management consultative committee made up of health and safety representatives, representatives from the operators of mobile plant, supervisors and representatives from any other group sharing the traffic routes and working areas of the vehicles.

Mine operator's TMP should also consider:

- risk assessments
- how it will be documented, verified and audited
- foreseeable site-specific vehicle interactions with potential for collisions
- how these interactions are effectively managed
- how off-site expectations are managed
- current drawing or plan showing critical information
- roles and responsibilities to ensure the plan is effectively implemented
- how the operational controls will be monitored to ensure they are implemented and effective (inspections/audits/KPI)
- review by the mine operator 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.

All workers should be trained in the TMP as part of the site induction, training programs and procedures as it applies to worker tasks.

Road rules may form part of the TMP as administrative mechanisms. Road rules should be uniform, consistently applied across the mine and monitored for effectiveness and should be:

- documented and enforceable
- concise
- inclusive of worker and pedestrian movement around mobile plant
- consistently applied/adhered to by all workers including contractors and public
- part of worker training and assessment.

Road rules should contribute to safe traffic management and should be:

- able to achieve a safe traffic interaction
- clear and unambiguous, and not based on assumptions or conventions
- consistently applied
- monitored and enforced
- understood by workers
- checked so they do not inadvertently create a hazard or require a worker to carry out potentially dangerous actions

- inclusive of safe separation distances for mobile plant, based on operator reaction time, mine roads and plant conditions.

TMP purpose and scope:

- **Risk Reduction:** The primary goal is to identify and mitigate hazards and risks associated with traffic, including vehicle-to-vehicle, vehicle-to-pedestrian, and vehicle-to-infrastructure interactions.
- **Site-Specific:** A TMP should be tailored to the specific characteristics of the mine site, including traffic routes, access points, parking areas, and other traffic control areas.
- **Comprehensive:** It should cover all aspects of traffic management, from road design and maintenance to communication protocols and emergency procedures.
- **Communication:** The plan should be communicated to all site employees, contractors, and visitors, ensuring everyone understands their roles and responsibilities.
- **Regular Review:** The plan should be reviewed and updated regularly to reflect any changes within the operation.

A mine site's TMP supports the safety and efficiency of vehicle and pedestrian movements within the site. Implementing a comprehensive traffic management plan helps to reduce the risk of accidents and improve overall site safety and operational efficiency.

2.4.2. Review of operational control measures

The mine operator as required by section 29 of the WHS (MPS) Regulation must review the PHMP and revise the operational control measures when:

- an audit of the effectiveness of the safety management system for the mine or petroleum site indicates a deficiency in an operational control measure
- a worker is moved from a hazard or assigned to different work in response to a recommendation contained in a health monitoring report
- a notifiable incident occurs.

In its SMS, he mine operator should:

- when reviewing operational control measures, particularly after an incident, do so in the framework of the layer defence approach, i.e. consider which operational control within layers 1–9 of the Layered defence approach failed
- include near miss reporting, fatigue events and operational control review systems where mobile plant is involved.

2.4.3. Interdependency of operational control measures

When choosing the best vehicle interaction operational control measures, mine operators need to identify and understand the interdependence of operational controls put in place using the layered defence approach and with other plans within the safety management system.

Operational control measures established to manage vehicle interactions at mine sites can be complex systems, with many interdependencies arising from different risk controls, multiple business units and individuals. If one part of a complex risk control system is not functioning as

required and goes unnoticed, the risk control measures that depend on it may fail[6]. Human centred design[7] and organisational factors such as risk control system design need to result in resilient processes that are aware of the interdependence and that support the control measures.

2.4.4. Emergency management and incident reporting

The mine operator should include emergency response to adverse vehicle interactions in the mine's emergency plan.

3. Training for vehicle operators and roadway maintenance personnel

This section provides mine operators guidance on training to ensure vehicle operators are competent and authorised as part of the actions to implement the layered defence approach. Many of the actions are reliant on vehicle operators being competent in carrying out correct procedures and processes that are established as part of control measures.

Section 107 of the WHS (MPS) Regulation requires mine operators to ensure that they establish a comprehensive training program that provides appropriate training, assessment, and authorisation to operate all types of vehicles and undertake roadway maintenance.

The PHMP should specify training requirements. It should incorporate, but not be limited to, worker understanding of:

- the roads and other vehicle operating areas
- their responsibilities to drive to conditions
- their responsibility for any passengers they are transporting
- the reporting requirements at the site if/when roads deteriorate.

Workers' training should include the following:

- speed limits
- signage
- blind corners
- wet and uneven roads
- windrows
- clearances from roof and sides
- obstacles
- pipes
- high-voltage cables and other structures

[6] Dekker, S. W. A. (2013). Drifting into failure: Complexity theory and the management of risk. In: Banerjee, S. (Ed.), Chaos and Complexity Theory for management: Nonlinear Dynamics, pp. 241-253. Hershey, PA: IGI Global Business Science Reference

[7] Professor Robin Burgess-Limerick C29001 extension: Case-study of human-centred design of new technology in mining. Minerals Industry Safety and Health Centre University of Queensland 2022

- ensuring good visibility while carrying large loads in and out of the work areas
- comprehensive assessments of the worker's knowledge after training (including documentation
- authorisation based on the worker's ability to carry out the task allocated.

Appendix A – Vehicle interaction maturity framework

This section provides guidance to mine operators on assessing where they are on the vehicle interaction journey. The vehicle interaction maturity framework[8] guides the mine operator through a process of assessing the maturity of mining operation based on the elements of the vehicle interaction layered defence approach.

Using the maturity framework enables the mine operator to identify the next steps in improving its management of vehicle interaction risks to strengthen the mechanisms detailed in the layered defence approach.

Table 2 shows an integrated continuous improvement process starting with a baseline assessment of site maturity. The maturity framework uses criteria for the mine operator to establish where on the maturity framework the mining operation sits at the time of assessment.

The mine operator can use the maturity framework to strengthen the layered operational controls implemented. Through this the mine operator can verify that the Safe Operational Requirements are supported. The mine operator should conduct a maturity framework assessment as a first step before implementing the layer defence approach.

How to use the maturity framework

The maturity framework assessment in table 2 should be conducted by people with suitable experience in managing vehicle integration risks in mining operations. The matrix describes what the people conducting the assessment will see after examining relevant document and discussions with relevant workers on site. The matrix describes what the assessors might see at 5 different levels of maturity for each of 3 groups of layers in the layered defence approach. The levels of maturity escalate from basic compliance (compliance focused) to gold standard (adaptive). Once the assessment team is identified it should:

1. gather and review relevant information on vehicle interaction
2. interview a number of workers involved in managing mobile plant and vehicles
3. determine the level of maturity for the different layers as follows:
    a) general
    b) design
    c) operational
    d) reactive
4. mark the box that most represents the mining operations level. This gives the maturity level for that group.

[8] The vehicle interaction site maturity framework is based on the model developed by the ICMM https://www.icmm.com/en-gb/case-studies/2021/icsv/understanding-vi-maturity

Table 2: Vehicle interaction maturity framework matrix

		1. Compliance focus	2. Exploratory	3. Defined	4. Adoptive	5. Adaptive
General		Company is primarily focused on legislative compliance with regards to vehicle interaction standards and operational requirements.	Company is actively investigating the elimination of unwanted vehicle interactions through mine design, operating procedures, operational technology monitoring and/or intervention.	Company is actively pursuing the elimination of unwanted vehicle interactions through improved mine design operating procedures, low level operational technology monitoring and/or intervention.	Demonstrated success in adopting remote and/or engineering technology to eliminate/mitigate unwanted vehicle interactions. Coupled with the integrated use of digital information to optimise operational designs and monitoring of operational controls.	Implemented leading industry practice in designing remote and/or engineering technology measures to eliminate/mitigate unwanted vehicle interactions. Coupled with the integrated use of digital information to optimise industry innovation of operational designs and monitoring of operational controls.
General	1. Operational design	The operational controls and design requirements are focused on the safety and health of employees and based on legislative compliance as a minimum standard. Vehicle operation effectiveness comply with required legislative requirements as a minimum standard.	The operational controls and design requirements are focused on the safety and health of employees and based on legislative compliance as a minimum standard. Vehicle operational requirements are defined and effectively implemented.	Vehicle interaction is identified as a critical hazard with the company having defined administrative, engineering and design operational requirements and associated controls.	Vehicle interaction is identified as a critical hazard with the company actively integrating all levels of operational controls to eliminate/mitigate unwanted interactions. Operational controls are integrated with technology measures to provide machine intervention and management reporting.	Vehicle interaction is identified as a key critical hazard with the company actively integrating all levels of operational controls to industry leading practices. Technologies are fully integrated with operational controls to provide real time machine intervention and automated management reporting escalation.
Design	2. Vehicle segregation	The operational controls and design requirements are focused on the safety and health of employees and based on legislative compliance as a minimum standard. Vehicle operation effectiveness comply with required legislative requirements as a minimum standard. Vehicles are operated in accordance with legislative requirements and operational requirements with basic situational awareness assistance for the operator.	The operational controls and design requirements are focused on the safety and health of employees and based on legislative compliance as a minimum standard. Vehicle operational requirements are defined and effectively implemented. Vehicles are operated in accordance with legislative requirements and operational requirements. With low level technology implemented to provide improved situational awareness addressing operational specific requirements.	Vehicle interaction is identified as a critical hazard with the company having defined administrative, engineering and design operational requirements and associated controls. Vehicle operational controls are effectively implemented that enables direct operator feedback to support improvement in operator behaviour. With advanced level technology implemented to provide improved situational awareness addressing operational specific requirements.	Vehicle interaction is identified as a critical hazard with the company actively integrating all levels of operational controls to eliminate/mitigate unwanted interactions. Operational controls are integrated with technology measures to provide machine intervention and management reporting. Effective implementation of monitoring technology that enables direct operator feedback to support improvement in operator performance and provides timely supervisory feedback to allow intervention with ongoing operator deviation from expected performance.	Vehicle interaction is identified as a key critical hazard with the company actively integrating all levels of operational controls to industry leading practices. Technologies are fully integrated with operational controls to provide real time machine intervention and automated management reporting escalation. Effective implementation of continuous improvement in operator performance programs to maintain operational leading practices.
Design	3. Operating procedures					
Design	4. Authority to operate					
Operational	5. Fitness to operate	Vehicles are operated in accordance with legislative requirements and operational requirements with basic situational awareness assistance for the operator.	Vehicles are operated in accordance with legislative requirements and operational requirements. With low level technology implemented to provide improved situational awareness addressing	Vehicle operational controls are effectively implemented that enables direct operator feedback to support improvement in operator behaviour. With advanced level technology implemented to provide improved	Effective implementation of monitoring technology that enables direct operator feedback to support improvement in operator performance and provides timely supervisory feedback to allow intervention with ongoing operator deviation from expected performance.	Effective implementation of continuous improvement in operator performance programs to maintain operational leading practices.
Operational	6. Operating compliance					
Operational	7. Operator awareness					

	8. Operator advisory	Vehicles are operated in accordance with legislative requirements and operational requirements with low level advisory technology.	operational specific requirements. Basic technology implemented to provide advisory alerts/alarms addressing operational specific interaction scenarios.	situational awareness addressing operational specific requirements. Advanced technology solutions have been implemented on vehicles with high VI consequence exposure and provide general VI advisory alerts/alarms/machine interventions addressing operational specific interaction scenarios.	Vehicle intervention technology solutions have been installed on vehicles with high consequence incident scenarios and digitally integrated with operational controls and mine design requirements to provide specific VI advisory alerts/alarms/machine interventions addressing operational specific interaction scenarios.	Vehicle interaction technology solutions are functional on all vehicles (including those with lower consequence incident scenarios). They are digitally integrated with operational controls and mine design requirements to provide specific VI advisory alerts/alarms/machine interventions addressing operational specific interaction scenarios. Actively supporting technology development to improve industry leading practice.
React	**9. Machine intervention**	Vehicles are operated in accordance with legislative requirements and operational requirements with low level advisory technology.	Basic technology implemented to provide advisory alerts/alarms addressing operational specific interaction scenarios.	Advanced technology solutions have been implemented on vehicles with high VI consequence exposure and provide general VI advisory alerts/alarms/machine interventions addressing operational specific interaction scenarios.	Vehicle intervention technology solutions have been installed on vehicles with high consequence incident scenarios and digitally integrated with operational controls and mine design requirements to provide specific VI advisory alerts/alarms/machine interventions addressing operational specific interaction scenarios.	Vehicle interaction technology solutions are functional on all vehicles (including those with lower consequence incident scenarios). They are digitally integrated with operational controls and mine design requirements to provide specific VI advisory alerts/alarms/machine interventions addressing operational specific interaction scenarios. Actively supporting technology development to improve industry leading practice.

Appendix B - Safety alerts and investigation reports

Safety alerts

SA23-01 – March 2023 – Unintended movement of haul truck

SA22-05 – October 2022 – Service brakes fail on moving articulated truck

SA21-04 – April 2021 – Worker sustains critical injuries after driving loader over stope edge

SA21-03 – March 2021 - Underground loader makes contact with development drill rig

SA21-02 – February 2021 – Unattended haul truck rolls 65 metres

SA20-09 – October 2020 - Operating mobile plant – incidents and near misses

SA18-13 – December 2018 – Potential fall of excavator over highwall

SA18-10 – July 2018 – Near miss between light vehicle and haul truck

SA16-01 – February 2016 – Driver loses control of light vehicle and crashes in underground mine

SA14-02 – February 2014 – Serious potential incident: underground loader collides with light vehicle

SA10-05 – October 2010 – Water tanker rollover at haul road intersection

SA09-13 – October 2009 – Light vehicle drives off bench in open cut mine

Safety bulletins

SB24-01 – March 2024 – Bulldozer incident increase

SB23-07 – August 2023 – Fitness for work – fatigue

SB22-10 – August 2022 – Mobile lighting plant at mining workplaces

SB22-07 – June 2022 – Collisions on overburden dumps

SB21-06 – September 2021 – Human factors – water carts and cabin interfaces

SB21-04 – June 2021 – Crawler utility vehicle runaway

SB19-10 – October 2019 – Dozer incidents increase despite warnings

SA19-02 – March 2019 – Rise in vehicle collisions raise concerns

SB17-01 – January 2017 – Industry reports more truck rollover incidents

Investigation reports

July 2023 – Investigation report - near collision between haul truck and light vehicle

February 2023 – Investigation report – Death of a worker at West Wyalong quarry

IIR20-14 – November 2020 – Collision between dozer and haul truck

IIR20-02 – January 2020 – Collision between dozer and light vehicle

IIR19-11 – September 2019 – Collision between dozer and light vehicle

IIR19-04 – May 2019 – Collision between semi-autonomous dozer and manned excavator

IIR15-03 – August 2015 – High potential incident. Komatsu 730E dump truck crushes light vehicle