Final report

Regulatory Requirements and Risk Assessment framework for Automated Vehicles in Feedlots

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Abstract

The Australian Road Research Board (ARRB) was engaged by *Meat & Livestock Australia Limited* (MLA) to research regulatory requirements and develop a risk assessment framework for the operation of automated vehicles (AV) in feedlots. MLA have been trialling an autonomous light vehicle termed 'BunkBot', manufactured by Manabotix, to autonomously scan feed bunks to achieve improved results over human operators. In order to integrate an AV vehicle such as the Bunkbot into day-to-day operations, a greater understanding of the regulatory requirements was required and a risk management framework needed to be developed. This report presents a literature review of legislation, standards, and guidelines relevant to the feedlot compared to other domains such as road transport, mining, and aviation. As part of the literature review, workshops and interviews were organised with stakeholders across the feedlot industry in order to gain a better appreciation of their needs and the perspective of AV users in the industry. The review was followed by a visit to a feedlot to observe the BunkBot in operation to gain a better understanding of the operational environment. A Safety Management Plan (SMP) framework was drafted based on the results of the literature review in close collaboration with MLA, and feedlot stakeholders. The SMP includes components such as relevant stakeholders, a Safety Risk Assessment (SRA), Traffic Management Plan (TMP) and an Incident Management Plan (IMP).

This report is intended to be the source document containing the information needed to safely deploy an AV in routine operations of the feedlot.

Executive Summary

Background

MLA project B.FLT.1006 – 'Prototype feedlot autonomous mobile robot for bunk calling' – resulted in the production of an autonomous light vehicle, 'BunkBot', by Brisbane-based robotics company Manabotix. In this project, which was conducted at Mort & Co Lot Feeders Pinegrove Feedlot, the BunkBot, fitted with a Bunk Scanner, autonomously recorded 100 feed bunks throughout the site layout at a nominal operating speed of 10 km/h and over several weeks. After the feed remaining in the feed bunks was determined by vacuuming and weigh-back truthing, it was found that the prototype arrangement had improved precision, accuracy, and bunk score success over human operators. While MLA Project B.FLT.1006 resulted in the development of a working prototype, it was not integrated into the day-to-day bunk calling operation of the feedlot. Mort & Co Lot Feeders Pinegrove Feedlot expressed interest in integrating the system into its routine bunk management practices under both day and night conditions. This formed the basis of the current project B.FLT.1017. As part of the development of the BunkBot, there was a need to gain a better understanding of the regulatory requirements and to develop a risk management framework that could be extended to the use of BunkBot at other feedlots in the future. ARRB is the primary advisor on safety certifications, vehicle licensing and insurance framework, training and technology development related to connected and automated vehicles in Australia and New Zealand.

Aim and Objectives of the Project

The aim of this project was to investigate the regulatory environment and develop a risk assessment framework for Automated Vehicles by Australian feedlots.

The objectives of the project were to:

- review the current regulatory framework for the use of AVs on private properties such as feedlots
- gain a better understanding of the requirements to deploy AV technology in the feedlots through stakeholders' consultation
- develop a framework of a safety management plan, including document checklist, risk assessment, traffic management plan, and incident management plan.
- develop a template for a risk register for AV use case in feedlots.

This report provides insight into the regulatory framework for deploying Automated Vehicles (AVs) into the feedlot and develop a safety management plan for safe operation of the AVs in the feedlots.

Methodology

ARRB conducted a literature review to understand the current regulatory framework for AV operations in feedlots. The literature review contained three key phases including i) a review of relevant legislation and standards, ii) stakeholder engagement from across industry and regulators, and iii) a comparison with other domains such as on road and mining.

Then the risk assessment framework and safety management plan were developed by compiling findings in the literature review, drawing from ARRB's internal expertise and in close consultation with MLA, an automated vehicle vendor and feedlot stakeholder. Included in the safety management plan is a risk register framework which was likewise compiled through consultation with stakeholders and from risk categories identified in the literature.

Results/key findings

The investigation of the AV regulatory environment in feedlots found no unified codes of practice with the possibility to adapt frameworks from other domains, acknowledging the unique operational environment presented by feedlots.

Included is a safety management plan checklist which includes all necessary actions and documentation for deploying AV technology. The report details key components of the checklist including risk registers and safety checklist, traffic management plan and incident management plan.

Benefits to industry

This report provides a framework that will enable the safe use of AVs within feedlots, leading to a more accurate understanding of cattle feeding and increased confidence of feedlot managers to deploy such technology. The summary of legislation, standards and technological maturity presented will help drive the safe trial and deployment of future AVs.

Future research and recommendations

The proposed safety management plan can be utilised for the safe AV operations in feedlots. Given the unique environment each feedlot presents, it is recommended that relevant sections of the SMP are reviewed and audited across the stakeholders.

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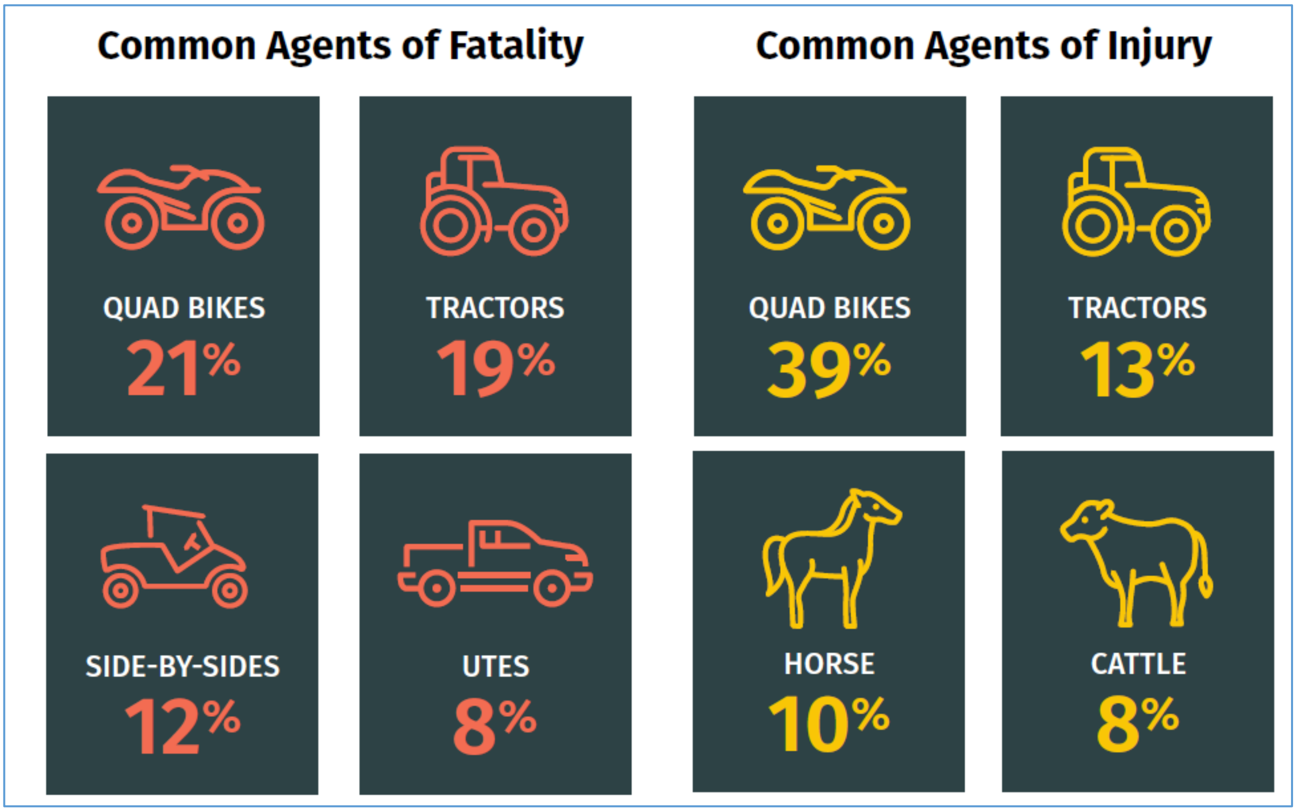
1 Introduction

The use of automation in agriculture and precision farming introduces new machinery and ground-moving vehicles to the agricultural ecosystem. It has been shown that moving machinery is one of the major contributing factors in farm-related fatalities (Armstrong & Howdle 2021). Figure 1-1 provides statistics related to fatality and common injury on Australian farms for 2019 and 2020. This project, which included interviewing more than 220 farmers, found that the majority of fatalities involved the movement of machinery, with more than 50% of injuries related to tractors and quad bikes. The results suggest that reducing human exposure to moving machinery and replacing human-related tasks with automated vehicles (AVs) has the potential to resolve a major safety issue related to farming and agriculture. While the use of AVs can potentially reduce human error-related injuries and fatalities, AVs may also generate new safety challenges because of their operation designs and dynamic driving tasks. AVs need to be integrated into the current safety framework and their challenges need to be addressed and mitigated.

Figure 1-1: Fatalities and injuries in Australian farms (Armstrong & Howdle 2021)



The report reviews the literature related to current regulatory requirements and codes of practice for the use of AVs on private land and the current regulatory framework for agricultural applications, with a focus on the use of AVs in feedlots. The following three main objectives were identified in the review of AV regulatory requirements:

- Identify current local, state, and federal legislation on the operation of AVs.
- Determine stakeholders' perspectives regarding the use of AVs in feedlots.
- Identify the similarities and differences regarding the use of AVs in feedlots and other operational domains such as road, transport, mining, and aviation.

1.1 Background

The application of AVs for agricultural purposes has gained attention in recent years due to the benefits of increased efficiency and productivity, and in overcoming the lack of seasonal labour for farms and feedlots. The use of AVs also has the potential to reduce fatalities and injuries associated with human errors. Although AVs can overcome some of the safety challenges on farms such as reducing fatalities and injuries related to moving machinery and also fatigue, they can potentially generate new safety risks which need to be mitigated. When a new moving machinery system involving the use of AVs is added to the current farm's operational system, new regulations and safety features need to be identified within the system to make the AVs compatible with the rest of the operational system.

This report focuses on the use of AVs in feedlots. The motivation was MLA project B.FLT.1006 - 'Prototype feedlot autonomous mobile robot for bunk calling', which resulted in the development of an autonomous light vehicle, 'BunkBot' (McCarthy et al. 2019). In that project, an AV mounted with a Bunk Scanner over several weeks autonomously read 100 feed bunks throughout the site layout at a nominal operating speed of 10 km/h. This prototype arrangement had improved precision, accuracy, and bunk score success over human operators, after feed remaining in feed bunks was determined by vacuuming and weigh-back truthing.

While MLA Project B.FLT.1006 developed a working prototype, it was not integrated into the day-to-day bunk calling operation of the feedlot. Mort & Co Feedlot has expressed interest in integrating the system into routine bunk management practices under both day and night conditions. Furthermore, they are willing for Pinegrove to serve as a demonstration site for the feedlot industry, with planned monthly tours – which were advertised through the MLA Quarterly Feed E-Newsletter, ALFA E-Newsletter – and by face-to-face visits to all NFAS-accredited feedlots by the ALFA-MLA Technical Services Officer. This forms the basis of project, B.FLT.1017 (McCarthy et al. 2019).

The focus of this report is on moving machinery, including unmanned ground vehicles (UGV) and any other human-driven vehicle which has the capability to drive by itself. In Figure 1-2, the levels of vehicle automation in SAE-J3016 (2021) were adapted to allow performance comparisons with other domains. Although SAE-J3016's definition of in-vehicle automation is defined for on-road vehicles, the same definition can also be utilised for agricultural vehicles (Nam et al. 2021; Nordestgaard 2020). The automation level is divided into six levels: from no automation, SAE Level 0 (i.e. the human is responsible for all tasks) to highly automated (i.e. the machine can operate by itself without human supervision).

The highly automated levels are Level 4 and Level 5 where the human is not responsible for the driving task. The main difference between Levels 4 and 5 is their operational domain. In Level 4, the AV can operate under certain conditions and on specific roads (time of the day, only specific sections and trajectories when the AV can be operated in automated mode), while, for AVs with Level 5, the operational domain is not limited and the vehicle can the AV operate at any time and under any conditions.

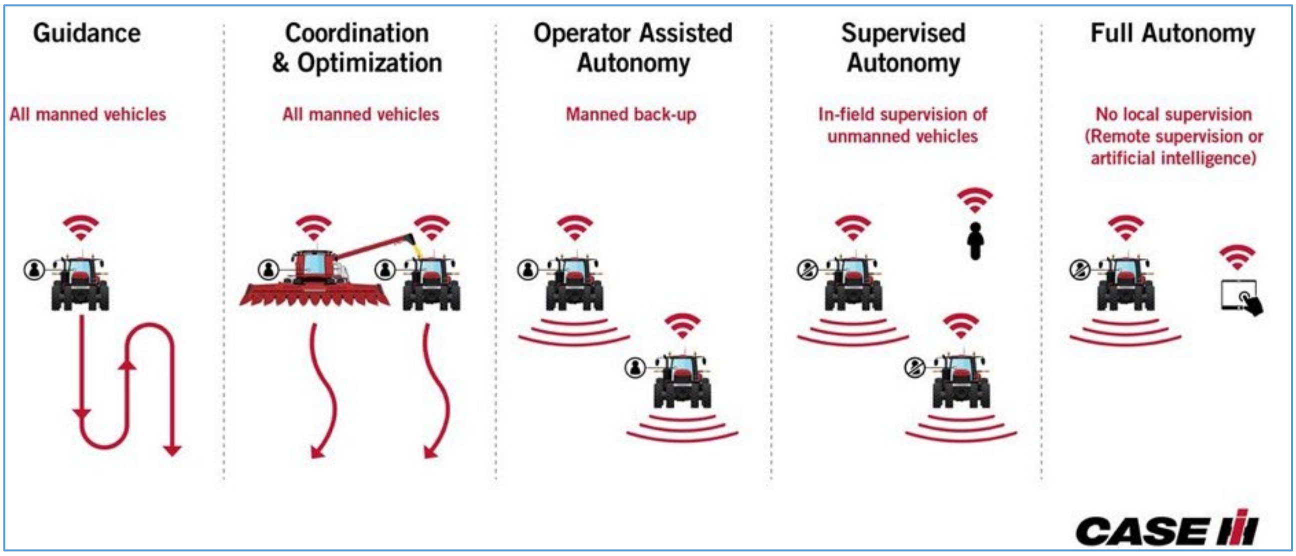
If the system has a fault and cannot operate in Level 4 automation, then it can stop operation in a safe state (i.e. a state that does not cause harm or danger to other agents/users) and request a human operator's input to continue the task. Most AVs used in agriculture have a similar behaviour to Level 4 automation, where there is a task defined to be completed in a certain area (called a geo-fence) and within a pre-defined trajectory.

Figure 1-2: SAE standard level of automation for on-road vehicles (SAE J3016 2021)

	Levels of vehicle automation					
	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Vehicle's role	Nothing	Accelerates and brakes OR steers e.g. cruise control	Accelerates and brakes AND steers e.g. automated reverse parking	Everything, only under certain conditions eg. specific locations, speed, weather, time of day	Everything, only under certain conditions e.g. specific locations, speed, weather, time of day	Everything
Human driver's role	Everything	Everything but with some assistance	Remains in control, monitors and reacts to the driving environment	Must be capable of regaining control on request when vehicle is driving	Nothing when vehicle is driving, but everything at other times	Nothing

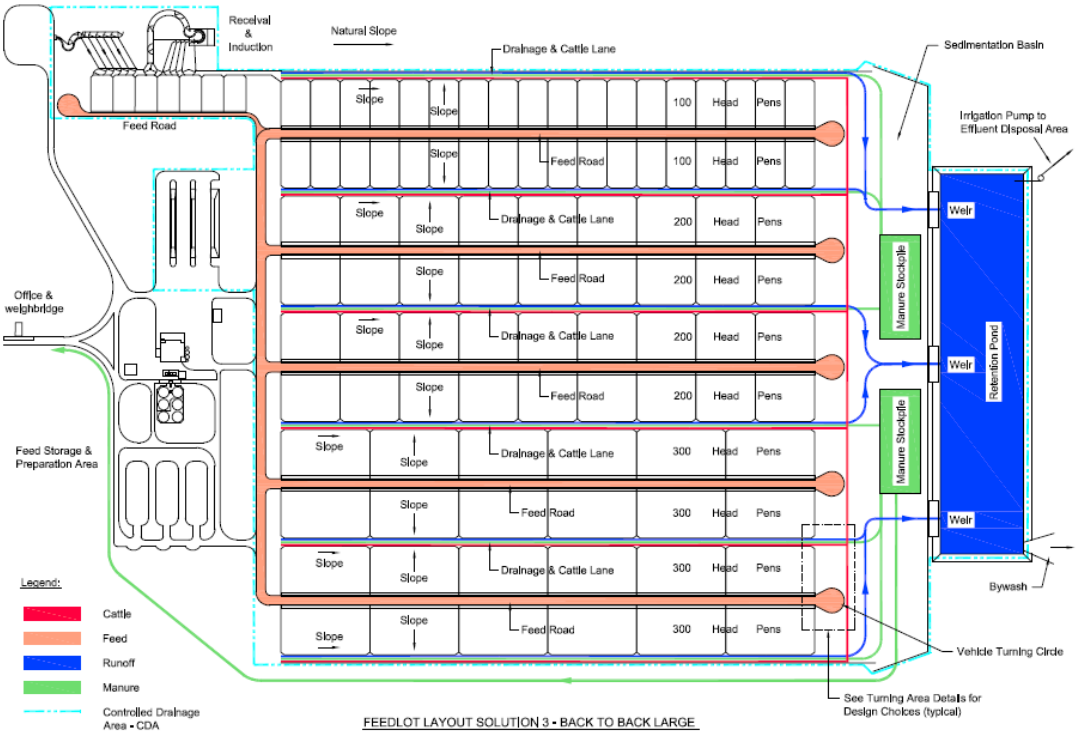
A more applicable definition for the use of AVs in agriculture was reported by Case IH (2018). In this category the automation is described in five levels: guidance, coordination and optimisation, operator-assisted autonomy, supervised autonomy, and full autonomy. This report focuses on full autonomy where no local supervision is needed to operate in the automated mode.

Figure 1-3: Framework for developing automation (Case IH 2018)



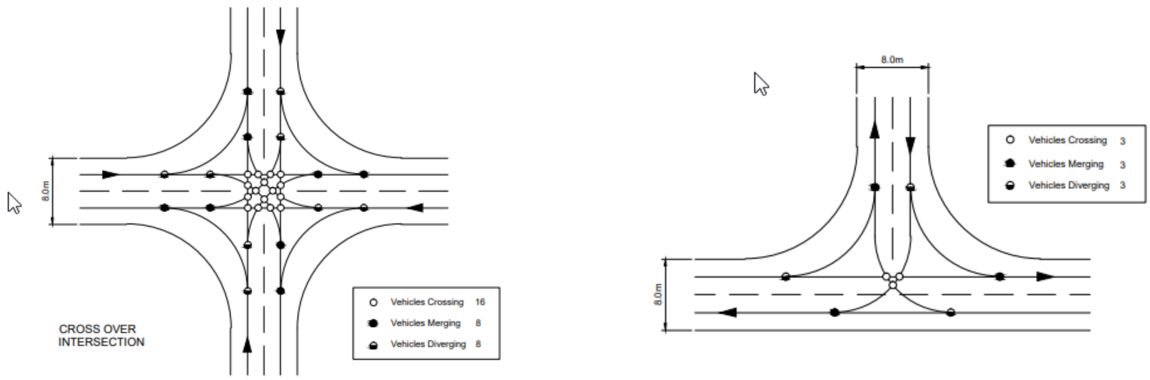
In order to analyse the different conditions that can cause unsafe states for the vehicle and other users, it is important to understand the AV's operational domain. Figure 1-4 presents a conceptual layout of different sections of a feedlot (Jubb et al. 2012). The design in Figure 1-4 includes an access road for the feeding pens/lanes highlighted in orange. The feeding lanes are accessible through the feed road where trucks and other moving machinery can have access to the pen feed bunks. There is also a vehicle turning circle at the end of each feed road to assist in the continuous operation of the feeding vehicles.

Figure 1-4: Conceptual feedlot layout with back-to-back pen configuration (Jubb et al. 2012)



The feeding lanes intersect the main feed road, allowing the vehicles to cross, enter onto, or exit from one direction to another. The movements at these intersections create a risk of conflicts between different users unless the design of the intersections is kept simple. Jubb et al. (2012) suggested the use of T- and 4-way intersections to reduce the complexity of the interaction between users by reducing the driving speed at conflict points as shown in Figure 1-5.

Figure 1-5: Conflict points at 4-way and T- intersections (Jubb et al. 2012)



(a) (b)

The current AV application in the feedlot revolves around feeding applications, including the monitoring of the bunks and automated feeding truck operations as shown in Figure 1-6. The potential operation of AVs in the feeding lane, and conflicted area of the intersection with the feed road, can be seen in the Figure.

Figure 1-6: Example of AV use feedlots

(a) Bunckbot designed by Manabotix (BunkBot 2019)

(b) Feed lot ration auto delivery system concept (Feedlot ration auto-delivery system 2019)

The use of AVs in feedlots is relatively new and has yet to be fully integrated into the day-to-day bunk feeding operation of the feedlot. Previous technology development for feedlots identified the need to understand the regulatory requirements and develop the use of further AV technology at feedlots in the future (McCarthy et al. 2019).

The first step was to investigate the regulatory environment for deploying AVs in feedlots. Stakeholder engagement was then undertaken to find out their requirements and to highlight the challenges associated with developing a safety regulatory framework and AV technology operational domain. Finally, a review of the regulatory requirements for the adoption of AV technology for operation in feedlots was undertaken.

1.2 Literature Review Methodology

The literature review was conducted in three phases, as shown in Figure 1-7. In phase 1, the local, state and federal legislation related to the operation of AVs was reviewed. The literature was sourced from federal and state department websites such as the Department of Agriculture, Queensland Department of Transport and Main Roads (TMR), Transport for NSW (TfNSW), and relevant legislation in each Australian state and territory. In addition, the regulatory code of conduct from Safe Work Australia and previous work related to connected and AVs conducted by the Australian Road Research Board's (ARRB) was reviewed.

Phase 2 involved engagement with relevant stakeholders, including industry and government, who directly or indirectly impact the use of AV in feedlots. This included insurers, lot feeders, vendors, manufacturers, and regulators. A series of workshops were conducted with stakeholders to inform, socialise and seek input about the project. A set of questions were then asked related to each participant's expertise. A range of benefits and potential barriers for AV applications in feedlots were identified.

Finally, in Phase 3, current legislation and standards from other domains were reviewed, including aviation, on-road vehicles, and mining. The feedlot application was summarised and compared with different domains and potential interactions.

The following topics were considered out of scope with the literature review:

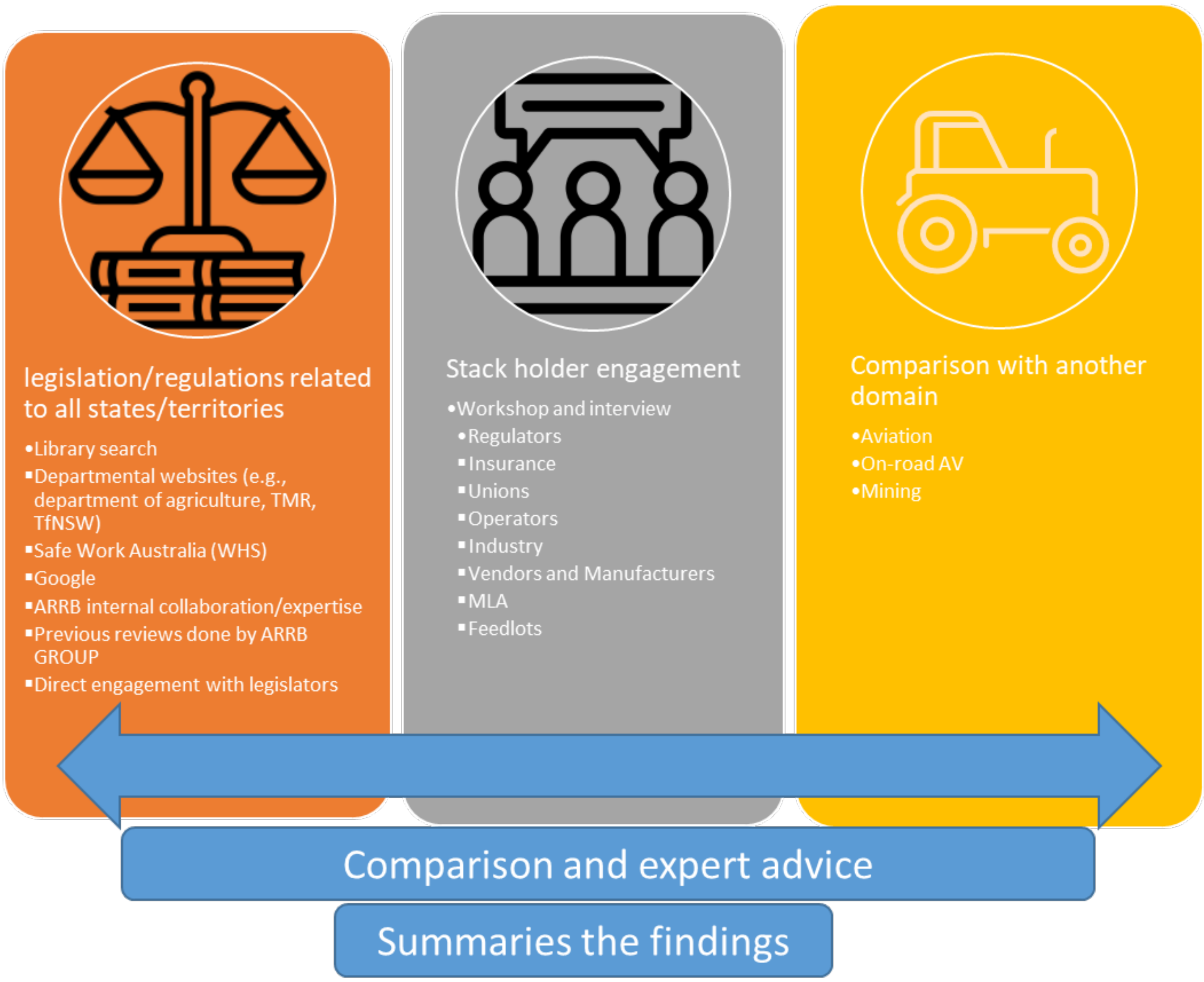
- engineering development and technical aspects of AV design
- articles and reports that reported on AVs without considering safety and regulatory feedback
- technical papers related to functional safety and how automated vehicle algorithms were developed (e.g. path planning, perception algorithms, localisation methods)
- meta-analyses, literature reviews, author opinions, and articles without full text.

The database search was conducted based on the Boolean search that includes 'AND, 'OR' and 'NOT' operators. The following key search words were used to assist in identifying the relevant literature:

- safety.
- autonomous/automated vehicles and machinery.
- safety guidelines.
- risk assessment.
- WHS/OHS.
- autonomous/automated vehicles and machinery.

- light vehicle.

Figure 1-7: elements of the scoping review



2 Review of Regulatory Requirements for AVs on Private Land

This section reviews national and state requirements for utilising AVs on farms and in feedlots. National regulation was reviewed first, with a focus on the health and safety requirements for the workplace on private land. The review then focused on each Australian jurisdiction as well as federal legislation associated with the use of AVs on the farm and farm animals.

2.1 National Safety Regulations for Automated Vehicles in Agriculture

The regulatory framework for the use of AVs in agriculture applications relies on the model Work Health and Safety (WHS) laws. The model WHS laws consist of the WHS Act, WHS Regulations, and Codes of Practice. In this model, the feedlots are considered as places for the breeding and raising of farm animals (Safe Work Australia 2021a).

The automated vehicle is not defined directly in the WHS models. Instead, the AV is defined under the Powered Mobile Plant (PMP) classes (WHS Regulation clause 214 powered mobile plant– general control of risk WHS Regulation clause 215(2) 'Powered mobile plant-specific control measures', (Safe Work Australia 2021b). PMP is defined by the WHS Regulation as any plant that is provided with some form of self-propulsion that is usually under the direct control of an operator. It includes:

- earthmoving machinery (e.g. rollers, graders, scrapers, bobcats)
- excavators
- cranes
- hoists
- elevating work platforms
- concrete placement booms
- reach stackers and forklifts.

The WHS Regulation includes requirements for the registration of plants, plant designs, and high-risk work licenses for plant operation described in (Work Health and Safety Act 2011).

Regulation 212: *A person with management or control of plant at a workplace must ensure that an emergency warning device is positioned on the plant to ensure that the warning device will work to best effect.*

Regulation 215: *If there is a possibility of the plant colliding with pedestrians or other powered mobile plant, the person with management or control of the plant must ensure that the plant has a warning device that will warn persons who may be at risk from the movement of the plant.*

SafeWork Australia provides guidance material and a Code of Practice for using PMPs. The guidance material should be used in conjunction with the *Code of Practice: managing the risks of plant in the workplace* in each state and territory (Safe Work Australia 2021c; Safe Work Australia 2022). Some of the safety areas noted for PMP are listed below:

- Traffic movements in the workplace. For example, vehicles, including mobile-powered plants moving in and around a workplace, reversing, loading and unloading are frequently linked with death and injuries to workers and members of the public.
- Specific controls are required under the WHS Regulation for certain types of plants, such as PMP.
- The WHS Regulation requires duty holders to work through the hierarchy of control measures when managing certain risks.
- The person with management or control of powered mobile plants must manage risks to health and safety associated with the following hazards:
  - the plant overturning
  - objects falling on the operator of the plant
  - the operator being ejected from the plant
  - the plant colliding with any person or object
  - mechanical failure of pressurised elements of plant that may release fluids that pose a risk to health and safety.

- Using air horns for automatic audible alarms in PMPs with long braking distances, for example trucks
- Using audible alarms for potential collision with pedestrians.

SafeWork Australia provides the legislation (Act), Codes of Practice and guidance for delivering a safe workplace. It is the states' and territories' responsibility to consider them in their legislation. The following section summarises the Australian legislation that addresses PMPs.

2.2 State Requirements

Australian states and territories commonly refer to the WHS Act in their legislation. Table 2-1 summarises the legislative framework related to each jurisdiction in Australia. For example, NSW legislation refers to the WHS Act to control the risk of using powered mobile plant in Figure 2-1 (*NSW Work Health and Safety Regulation* 2017).

Table 2-1 Legislative frameworks where PMP is listed

Jurisdiction	Legislative framework	Clause/Number
New South Wales	NSW Work Health and Safety Regulation 2017 https://legislation.nsw.gov.au/view/html/inforce/current/act-2011-010	Part 5.1, Division 7, Subdivision 3 – 214 and 215
Victoria	Victorian Legislation 2017	Part 3.5, Division 5, subdivision 3, 109-110
Queensland	Workplace Health and Safety Queensland 2021	Part 5.1, Division 7, Subdivision 3 – 214 and 215
Western Australia	Work Health and Safety (General) Regulations 2022	Part 5.1, Division 7, Subdivision 3 – 214 and 215
South Australia	Work Health and Safety Regulations 2012	Part 5.1, Division 7, Subdivision 3 – 214 and 215
Tasmania	Work Health and Safety Regulations 2012 version current from 22 December 2021 to date (Tasmanian Legislation 2012)	Part 5.1, Division 7, Subdivision 3 – 214 and 215
Australian Capital Territory	ACT Legislation Register 2021	Subdivision 5.1.7.3
Northern Territory	Work Health and Safety (National Uniform Legislation) Regulations 2021	Part 5.1, Division 7, Subdivision 3 – 214 and 215

The Queensland government provides a comprehensive list of legislation requirements for plant and PMP is under this category. The list of requirements and actions can be found in Section 0 of Workplace Health and Safety Queensland 2021. In addition, the Queensland government noted that "*Effective risk management starts with a commitment to health and safety from those who manage the business. If an incident occurs, you'll need to show the regulator you've used an effective risk management process. This responsibility is covered by your primary duty of care in the Work Health and Safety Act 2011*." (Work Health and Safety Queensland 2021).

Queensland Work Safe also cited training as one of the principles in using rural plant. Staff need to be fully trained in the correct use of rural plant such as quad bikes, motorcycles, vehicles, aircraft, and tractors, and all plant should be maintained in good working order (Work Safe Queensland 2022a).

The Western Australia (WA) government provides an agricultural safety and health checklist to show how safe is the property (WorkSafe WA 2017). Although the checklist does not directly talk about the automated vehicle or any powered mobile plant, some of the remarks related to the tractor can be found in this checklist.

Figure 2-1 NSW legislation addressing the WHS Act clauses for powered mobile plant

214 Powered mobile plant—general control of risk

The person with management or control of **powered mobile plant** at a workplace must in accordance with Part 3.1, manage risks to health and safety associated with the following—

(a) the plant overturning,

(b) things falling on the operator of the plant,

(c) the operator being ejected from the plant,

(d) the plant colliding with any person or thing,

(e) mechanical failure of pressurised elements of plant that may release fluids that pose a risk to health and safety.

Note—

WHS Act—section 21 (see clause 9).

(a)

215 Powered mobile plant—specific control measures

(1) This clause applies to a person with management or control of **powered mobile plant** at a workplace.

(2) The person must ensure, so far as is reasonably practicable, that a suitable combination of operator protective devices for the plant is provided, maintained and used.

Maximum penalty—

(a) in the case of an individual—70 penalty units, or

(b) in the case of a body corporate—345 penalty units.

(3) The person must ensure, so far as is reasonably practicable, that no person other than the operator rides on the plant unless the person is provided with a level of protection that is equivalent to that provided to the operator.

Maximum penalty—

(a) in the case of an individual—70 penalty units, or

(b) in the case of a body corporate—345 penalty units.

(4) The person must ensure that the plant does not collide with pedestrians or other **powered mobile plant**.

Maximum penalty—

(a) in the case of an individual—70 penalty units, or

(b) in the case of a body corporate—345 penalty units.

(5) Without limiting subclause (4), if there is a possibility of the plant colliding with pedestrians or other **powered mobile plant**, the person must ensure that the plant has a warning device that will warn persons who may be at risk from the movement of the plant.

Maximum penalty—

(a) in the case of an individual—70 penalty units, or

(b) in the case of a body corporate—345 penalty units.

(b)

Victorian legislation does not directly reference the WHS Act, but the definition of a PMP is the same. There are comments regarding PMP safety-related incidents in Victorian Occupational Health and Safety Regulations 2017 (Victorian Legislation 2017). While most of the considerations are similar to other states, Victorian Legislation discusses warning devices in the presence of pedestrians.

"*A designer of plant who includes an emergency warning device for the plant must ensure that the design provides for the device to be so positioned on the plant that the device works to best effect*". It is also mentioned that "*If there is a likelihood of powered mobile plant colliding with pedestrians or other powered mobile plant, the designer must ensure that the design of the plant includes a warning device that will warn any person who may be at risk from the movement of the plant".*

2.3 Industry-standard Requirements and Codes of Practice

There are several standards related to AVs which WorkSafe Australia endorses. A summary of those standards is listed in Table 2-2. None of the standards listed in Table 2-2 are mandatory. Therefore, in some jurisdictions such as NSW, technical guidance is offered to practitioners on the application of various safety (and engineering) principles to workplace machinery.

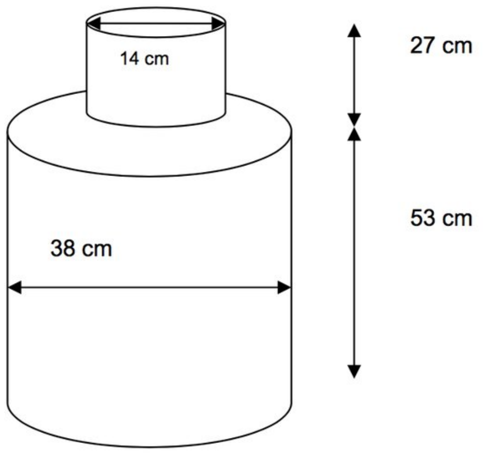
Table 2-2 Potential Workplace Australia-endorsed standards related to AVs

– Australian Standards (AS 4024.1XXX Series including 25 standards) – Framework of designing and operating safe machine systems
• AS 4024.1201 – General principles for design – Risk assessment and risk reduction • AS 4024. 1302 – Safety of machinery – Reduction of risks to health resulting from hazardous substances emitted by machinery – Part 1: Principles and specifications for machinery manufacturers • AS 4024.1302 – Risk Assessment – Practical guidance and examples of methods
Robots
• AS 4024.3301 – Robots and robotic devices – safety requirements for industrial robots – robots • AS 4024.3302 - Robots and robotic devices – safety requirements for industrial robots – robot systems and integration • AS 4024.3303 – Robots and robotic devices – collaborative robots
Driverless Industrial Trucks
• ISO 3691-series covers the basic safety requirements for industrial trucks. • ISO 3691-4 specifies these requirements as a Type C[1] standard for driverless industrial trucks • ISO 3691-4:2020 - Industrial trucks — safety requirements and verification — Part 4: Driverless industrial trucks and their systems
Industrial Mobile Robots (Robotics Industry Association – RIA)
• ANSI/RIA R15.08-1-2020 –Safety Requirements – Part 1 Requirements for the industrial mobile robot (available). • ANSI/RIA R15.08-2 – *Safety requirements for mobile robot systems and systems integration, Part 2 –* not available). • ANSI/RIA R15.08-3 – *Safety requirements for end-users of mobile robots, Part 3 –* not available).

The standard for highly automated vehicles for agricultural machinery and tractors is defined in ISO 18497:2018, which is the primary design standard for farming purposes. The standard specifies requirements for starting and moving Highly Automated Agricultural Machine (HAAM) and associated moving tools. The standard identifies the hazardous situations that HAAM can be involved in and provides a test method for evaluating human detection systems. The mechanism to transfer control to the operator is explained and the requirement for detecting the error in perception functions is also explained in this standard.

A definition of a protective zone around the machine when it operates in the automated mode is provided in ISO18497 (see Figure 2-2). This zone could be dynamic, relying upon the perception system' however, the implementation approach is not explained in the standard.

Figure 2-2 Standard obstacle defined by (ISO 18497 2018)



Efforts have been made to identify the challenges associated with the use of new detection approaches using the standard obstacle (e.g. Steen et al. 2016) who suggested it was difficult to generalise the hazard for the model system using artificial intelligence and deep learning.

[1] Type C standards are machine safety standards dealing with safety requirements for a particular machine or group of machines.

The hazards associated with the definition of the HAAM in ISO18497 are listed in Appendix A. ISO18497, which is the main standard for autonomous agricultural vehicles, is currently under review. It will be re-defined into three series of standards including:

- ISO/DIS 18497-1: Agricultural machinery and tractors – Safety of partially-automated, semi-autonomous and autonomous machinery – Part 1: Machine design principles and vocabulary.
- ISO/DIS 18497-2: Agricultural machinery and tractors – Safety of partially-automated, semi-autonomous and autonomous machinery – Part 2: Design principles for obstacle protection systems.
- ISO/DIS 18497-3: Agricultural machinery and tractors – Safety of partially-automated, semi-autonomous and autonomous machinery – Part 3: Design principles for autonomous operating zones.

The review (Steen et al. 2016) found that the regulatory framework for the deployment of an automated vehicle is not unified. Grain Producers Australia (GPA) proposed a Code of Practice for agricultural mobile field machinery with an autonomous vehicle (GPA 2021). This Code of Practice is still not officially approved, but it is under consideration, and the industry has shown interest in using it. The code was developed by GPA in conjunction with the Tractor and Machinery Association (TMA), with input from AGCO, CNH, John Deere, Kubota and Nufarm Croplands, with extensive industry consultation with the Society of Precision Agriculture Australia (SPAA) and with the support of the Western Australian Department of Mines, Industry Regulation and Safety. The Department of Mines and Petroleum's code of practice – Safe Mobile Autonomous Mining in Western Australia – Code of Practice 2015 was also acknowledged. Input was also received from Australian agricultural industry and global manufacturers during the public comment period.

The distinguishing part of the GPA's Code of Practice is the definition of a specific term for AV rather than PMP. Indeed, the code of practice directly mentions autonomous functions such as scouting vehicles, tractors, sprayers, haymaking and harvesting equipment.

2.4 Summary of Regulatory Requirements

The review found that the Work Health and Safety Act (2011) was the leading source for the safety of automated vehicles in the workplace. While there are standards such as ISO18497 and the AS-4024 series, they are not mandatory. The terms 'automated' or 'autonomous vehicle' have not been defined in the regulation, although it indirectly refers to 'powered mobile plant' (i.e. a machine that can do some of the tasks by itself or under human supervision). Australian jurisdictions are responsible for putting the Work Health and Safety Act (2011) into practice. The safety framework needs to consider the jurisdiction where the AV operates, as some of the requirements may differ across states and territories.

3 Stakeholder Consultation

Stakeholder consultation was undertaken through workshops, phone interviews and emails. To find relative expertise in large organisations such as SafeWork Australia, 'general enquiries' was contacted and a follow up with the responsible department requested. Some of the participants from previous projects were invited, and networks at ARRB and vendors who were working on AVs in the feedlots were contacted. While the preference was for the workshops to last for one hour, some participants preferred a phone call interview which took around 15 to 20 minutes. Other participants were contacted by email to clarify some of the points raised in the interview and to seek further details. The list of participants engaged in the consultation – which was a combination of regulators, industry, vendors, and insurers – is presented in Table 3-1. The stakeholders engaged in the workshops are not identified in this report, with only the sectors and the role of the participants – Safety Organisation (SO), Feedlot Owner (FO), Insurance Organisation (IO), Academic Sector (AS), and Technology Provider (TP) – are reported.

The list of questions and the workshops were set up is summarised in Section 0.

Table 3-1 List of participants in workshops

No.	Organisation	Participant role	Number of participants	Type of interview		
				Phone interview	workshop	e-mail
1	Safety Organisation 1 (SO1)	Operations Manager – Agriculture Unit	1	Y		
2	Safety Organisation 2 (SO2)	High risk work policy	2		Y	
3	Safety Organisation 3 (SO3)	Executive	1	Y		Y
4	Safety Organisation 3 (SO3)	Executive Officer	1		Y	
5	Insurance Organisation (IO1)	Accounts Executive	1		Y	
6	Feedlot Owner (FO1)	R&D Committee	5		Y	
7	Feedlot Owner (FO2)	Manager	1		Y	
8	Academic Sector (AS)	Associate Professor	1		Y	
9	Technology Provider (TP1)	Managing Director	1		Y	
10	Technology Provider 2 (TP2)	Chief Executive Officer	1	Y		

3.1 Qualitative Analysis of Consultation Workshop

The responses to the questions and the remarks from the participants were recorded and transcribed as notes and a set of bullet points for each workshop. The notes were then colour-coded for each organisation and compared with the same topic from other organisations. The key findings are highlighted in the following subsections.

3.1.1 Potential applications for autonomous vehicles

Stakeholders were asked about where they saw further applications for automated technology. Responses were received from those who are hands-on in feedlots and farming (FO1, FO2, SO3). Feedlot-specific applications mentioned included:

- Feeding the cattle by refilling the bunks with automated feed trucks (FO1, FO2).
- Cleaning animal waste from the pens (FO1), noting that this is a much more difficult task due to the high interaction with the cattle (FO2)

Other applications outside the feedlot were mentioned by safety organizations, including:

- drone mustering as a potential avenue but it can be difficult due to the environment being highly variable
- various activities related to the harvest season, including the 'picking and packing' process
- checking fence lines is a routine, time-consuming task that could benefit from automation.

A range of potential benefits were also identified which can direct thinking for further specific applications for AVs. These include:

- Automation will reduce the frequency of errors and the variability of the outcomes of the tasks. This depends on how advanced the technology is. Less precise equipment could have the opposite effect, increasing error and the safety risk (FO1).
- It reduces the need for some training and inductions of people who would otherwise be needed to complete the task (FO1).
- The harvest season is when incidents often occur, so targeted automation could improve safety in this environment (SO3).
- Automation could allow personnel conducting mundane, operational tasks to work on other, more involved tasks, thus improving efficiency (FO1).
- Automating processes could assist during seasonal work such as harvesting, because it is harder to find workers to match the demand (SO3).

3.1.2 Barriers for adoption

Barriers to adoption were identified by five stakeholders, including a mixture of current experiences and foreseeable issues. The barriers identified ranged from engineering to infrastructure, education insurance, etc. This subsection lists the barriers and hesitations, with more complex issues discussed in subsequent sections of this report.

Having a method for safe adoption is a top priority (FO1), including both the interaction between people and automated technology and adhering to animal welfare requirements (FO1, FO2).

Three of the five stakeholders listed the following mindset challenges:

- SO3 argued that the largest barrier to implementing AVs was farmers' resistance to change (FO1). "Why change practices that have worked for decades?" FO2 added that fear of job loss to a machine also should be addressed.
- FO1 noted that the culture for good equipment maintenance needed to be improved in some feedlots – the consequences of poor maintenance of AVs could be higher than expected.
- WHS awareness (SO3).
- SO3 added that there was a need to find the 'right voice' in terms of the relationship between training culture and safety. The example given was resistance to rollover protection being introduced on quadbikes and tractors. and

Engineering barriers identified by technology providers and the academic sector included:

AV operation:

- The AV must be able to adapt to different circumstances at each feedlot.
- Accurate localisation and reducing interactions with the AVs were crucial for operation (AC, FO2).

Infrastructure:

- Different infrastructure challenges were raised by three groups (FO1, FO2 and AC). Poorly-maintained roads and pens can create obstacles along the driving path. Providing better gates and signage could create a safer operational environment. Sheds may need to be built for vehicle storage.

Equipment maintenance:

- The need for maintenance of AVs was raised by four of the five stakeholders with FO2, who have been directly involved with the manufacturer during product development, being the only exception. The lack of availability of specialised technicians in remote areas contributes to this barrier.
- Farmers are used to self-servicing their vehicles (SO3) and the provision of AVs is foreign to them.
- Having remote support for diagnosing software problems could form part of a solution (TP1).

Resources:

- Many people within the FO1 group suggested that economic viability was a potential barrier, with costs for maintenance, repairs and insurance needing to be met up-front. This was backed up by SO3, who suggested that the best way to achieve increased adoption was to focus on the bottom line.

- SO3 also noted the significant time resources required for busy farmers to learn the new technology and work to implement it.

Some barriers for introducing autonomous vehicles into feedlots and other farms were identified as stemming from a lack in regulation:

- TP1 shared that larger manufacturers had withheld from commercialising AVs in Australia for this (lack of regulation) reason. Farmers who were keen to implement the technology were limited by the availability of the product.
- AS and IO highlighted the impact of the lack of regulations on obtaining insurance.

3.1.3 Regulation

Relevant regulation consists of legislation, Australian and international standards, and codes of practice. The stakeholder engagement involved communication with seven stakeholders from different safety organisation across Australia. Much of the direction for determining the regulatory requirements and standards was guided by conversations with these stakeholders. The safety organisations provided the following details regarding regulatory frameworks:

- Each state and territory is responsible for enacting their own legislation, including responsibilities, duties and definitions.
- SafeWork Australia works alongside each of the states. Although it does not have any legislative powers of its own, it has developed a model WHS Act and model WHS Regulations that have been adopted by each state and territory (with minor variations) except for Victoria.
- More specific codes of practice and standards are related to different work domains and practices. Although not legally binding, they aid in compliance with the duties and requirements within the legislation. Codes of practice are published by SafeWork Australia and each of the states and territories.
- Codes of practice relating to autonomous vehicles in mining are available in QLD, NSW and WA but there are no codes of practice for agriculture.
- Safety measures implemented can as address issues such vehicle design and environmental controls such as infrastructure and controlled access.
- The liability for incidents would fall to the 'operator' and for serious incidents leading to death, can amount to industrial manslaughter.

Stakeholders perceived a lack of regulation that deals with the unique challenges introduced by autonomous vehicles in the feedlot environment (FO2, TP1, SO1). The lack of regulation was linked to hesitancy from insurers to become involved (AS) and from businesses wanting to expand into Australia (although the same can be said of most of the world) (TP1).

Regulators tend to be reactive to growing demand as opposed to being proactive in terms of providing a framework for future technology (SO1, SO2). This prompted an Australian collaboration between growers and manufacturers to write *Code of practice – agricultural machinery with autonomous functions* released in 2021 (TP1). The code is written with broadacre equipment for horticulture in mind but will also apply to all field operations, taking lessons from the mining industry in particular. It is in the process of seeking endorsement from state regulators. The document has been circulated through the OECD, it is being used as a template in the UK and USA, and is in the process of seeking endorsements from WorkSafe WA and the other states (TP1). Note that, while it is currently being circulated, at this stage, the code is not currently endorsed or being used by state bodies or WorkSafe Australia. By producing this code of practice, the hope is to prevent over-regulation as has occurred in other countries around the world where constant supervision of autonomous equipment is required.

The release of regulations currently under development could create further implications, including the current review by WorkSafe Queensland of the *Rural plant code of practice 2004*, which is currently in the draft stage and will take into consideration new automated technology (SO1).

3.1.4 Identified risks

FO1, FO2 and SO3 each made comment on some foreseeable risks relating to AVs in feedlots. Most were more concerned with economic and business risks as opposed to health and safety risks. Examples included:

- Having appropriate staff redundancy measures for tasks completed by an AV.
- Loss of expertise because tasks were now being conducted by an AV
- Efficiency losses associated with long-term breakdown of an AV
- Efficiency losses associated with AVs having to regularly stop to avoid obstacles
- Cost of repairs and maintenance of the AVs.

From a health and safety perspective, FarmSafe outlined opportunities for reducing risk by using AVs (Armstrong & Howdle 2021). On farms there has been a rise in runover incidents with fatigue and complacency being key factors across all incident types. Automation can reduce the number of serious incidents associated with these issues.

One other issue raised was the that of child safety, because the AV cannot assume that people will be fully aware of its presence. This extends to any uncontrolled environment where not everyone is aware of operations or they have not been properly inducted.

3.1.5 Insurance considerations

Engagement with stakeholders regarding insurance involved gaining an understanding of current experiences and perceived hurdles to obtaining insurance. To this end, a representative from InsuranceWebb was contacted to gain an understanding of the current landscape and applications.

Most stakeholders were unsure about the process for obtaining insurance and could only speculate. Some key questions/comments included:

- How can appropriate service and maintenance be demonstrated and what makes someone qualified to perform these tasks? (FO1)
- How will insurers react if an automated system is suggested? (FO1)
- Is the type of insurance required dependant on the type of farm? (SO3).

Other issues include:

- In the case of an incident, the expectation is that the insurer would contact the user unless manufacturer error can be proved (SO3).
- Insurers may be told different stories regarding how AVs operate (AS).

FO2 have had initial conversations regarding insuring a vehicle but they were unsure about liability.

The conversation with InsuranceWebb helped shed light on the insurance landscape. Insurance provides three main areas of cover: public liability, professional indemnity and the product itself. For smaller, unregistered AVs, insurance companies will consider it much like other plant which can be considered in a plan grouped with other vehicles and machinery. In the case of an automated truck or other vehicle that needs to be registered, there are additional CTP requirements, so they will probably suggest a motor insurance-type of cover. There is not the same system for vehicle registration and driver licencing that exists with conventional vehicles or even drones. These barriers escalate if the AV was planned to be used on public roads. This makes insuring virtually impossible unless it had standard driver controls and it was registered as such (IO1).

The main barrier to obtaining insurance for AVs is novelty. If ‘off-the-shelf’ insurance plans for automated vehicles are not available, then it is not viable for companies to insure an AV that is so unique. The insurer will consider any requests for insurance on a case-by-case basis, and any related information that can be supplied to the insurer will aid in making an assessment. Some other considerations include (IO):

- whether the vehicle was designed to be automated or is a modification to an existing vehicle
- whether the technology is still under development or whether it is a commercialised product.

SafeWork Australia stated that it was not possible to ‘insure away’ liability or responsibility as defined by the Work Health and Safety Act in each state and territory.

3.1.6 Animal welfare

Animal welfare was raised by many of stakeholders, with the actions required depending on the application of the AV. For bunk calling and feeding tasks, the livestock spends most of its time separated from the vehicle by a fence but interactions with cattle and horses will eventually occur. TP1 noted that animal interaction was the main issue governing the separation of the feedlot operational domain from automation in mining or horticulture. This will need to be addressed in order to properly adapt operational codes of practice. SO3 found it more relevant when considering other potential applications such as drone mustering which involves a lot more interaction.

3.1.7 Education and training

Education and training were identified by five stakeholders as a keyway of overcoming barriers and risks associated with AVs. The following considerations were raised:

- Ongoing training for people who attend the feedlot can be achieved through the induction process (FO1).
- Technical training can enable farmers to perform routine cleaning and maintenance (FO1).

Many barriers directly relating to the provision of education and training were also raised, including:

- Accessibility to training - the vast distances between feedlots contribute to longer time and money resources (FarmSafe).
- The effectiveness of online training in remote areas (SO3).
- Identifying who would provide the training. Trusted manufacturers were suggested as one of the most suitable to undertake this task (SO3).

The importance of education and training also forms a key part in Grain Producers Australia (2021) (TP1).

In current trials, education has been limited to small, ongoing conversations between staff. (FO2)

Nationally-recognised training can be developed to keep up with changing to work practices. ’Skills impact‘ is one avenue that can develop and support accreditation for new roles. Work has already been conducted related to drone operation beyond the line of sight (SO2).

3.1.8 Technical considerations

The current progress with the development of the technology and how it is implemented can have a big impact on risk assessment and safety by design. Stakeholders directly involved in mechatronics research and feedlot owners were engaged for this project. The main theme was the ability to control the environment and how it correlated with the safety and efficiency of AVs. For safe operation, the AV must be able to avoid collisions. The AV can achieve this by safely stopping when it detects any object in its path without the need for further object classification or decision making. It is easy for AVs to perform in the feedlot environment where objects are quite sparse. To optimise performance, and to minimise interactions and downtime, the operating environment should be well controlled (AS).

BunkBot have opted to perform trials outside of working hours to help reduce the frequency of interactions and increase safety. BunkBot is currently using basic object classes such as recognising animals, vehicles and stationary objects. Advancements this will enable the AV to react differently to obstacles such as crawling behind livestock until they move instead of stopping and requiring a person to interact and resume the process (FO2).

3.2 Summary of Workshops and Key Findings

During all the stakeholder consultation, the most common topics of conversation were barriers for the adoption of feedlots, insurance, the ability to properly train staff, and gaining a better understanding of regulation.

Key barriers included maintenance, a fear of job loss, and resistance to change. The infrastructure in the feedlot was seen to present a barrier because of the need to make sure there was appropriate signage, storage facilities for the AV and roads in a suitable condition to allow the vehicle to drive on them. The final major concern for stakeholders was the access to services, and maintenance for the vehicle.

Uncertainty regarding insuring an AV in a feedlot was raised by most stakeholders. There are currently no applicable 'off-the-shelf' insurance covers packages. There is a need develop a solution that is reasonable for most providers. Insurers are also being held back by the lack of regulation to protect themselves.

Regulation specifically for automated vehicles is becoming recognised in fields such as mining but is lacking in agriculture. All regulators consulted referenced AVs as being another piece of 'plant' with current codes of practice being updated to accommodate new technology. A code of practice was developed by industry and manufacturers in Australia in 2021 relating to automated vehicles on farms. Although not yet endorsed by Australian states or national bodies, it is being circulated globally.

Five different stakeholders raised education and training as a key issue, with the main concern being care for the vehicle, whether it be cleaning or maintenance for safe operation. The training process itself needs to be well planned to cater for long distances and the need to generate the greatest impact.

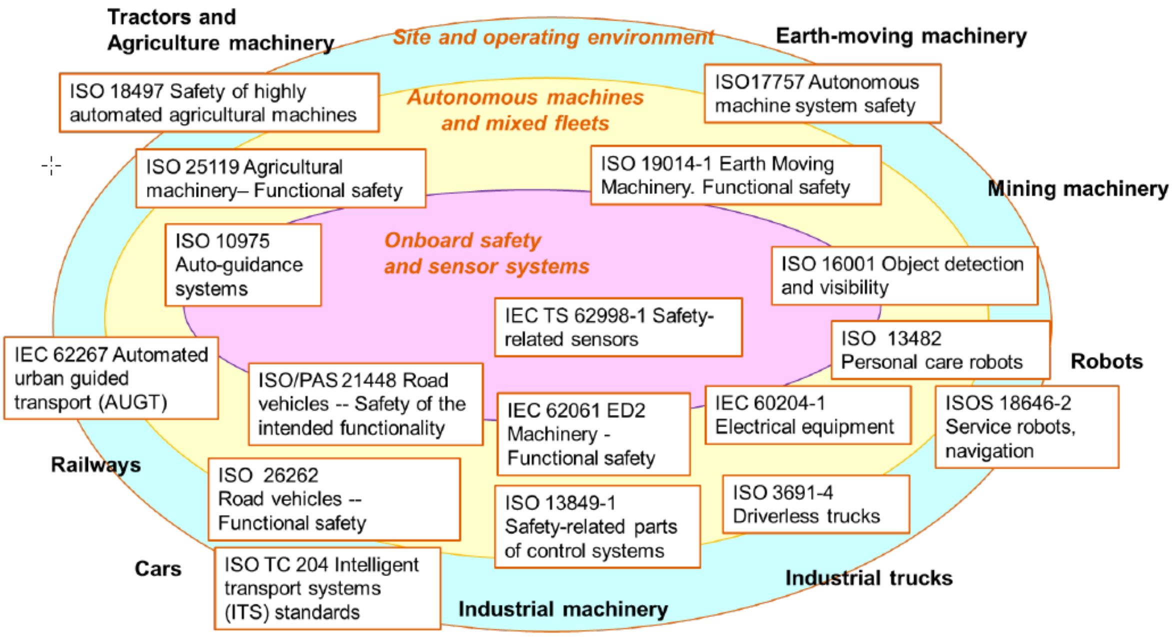
4 Comparison with Other Domains

In this section, current international standards and efforts to define the regulation across different industries and sectors that may interact with the use of AVs in feedlots are reviewed. The international standard and guidelines for other AV use cases is reviewed, followed by a review of current regulatory frameworks for AVs in different sectors, including road transport, mining, and aviation.

4.1 International Standards and Guidelines

The development of machinery towards automated functionality in different industrial sectors is proceeding quickly. This requires defining new standards related to autonomous systems. Figure 4-1 shows the existing ISO and IEC standards and work items related to AVs. Three different approaches for safety concepts in different operating conditions were identified in Tiusanen, Malm & Ronkainen (2020). The first concept relies on on-board safety systems, including sensors and perception systems for indoor applications. The second concept guides separating and isolating the autonomous machinery and using access control to the autonomous operating zone. The third concept relies mainly on the machine operator's ability to understand the situation and react correctly according to the available information.

Figure 4-1: Overview of current standard for automated vehicles
(Tiusanen et al. 2020)

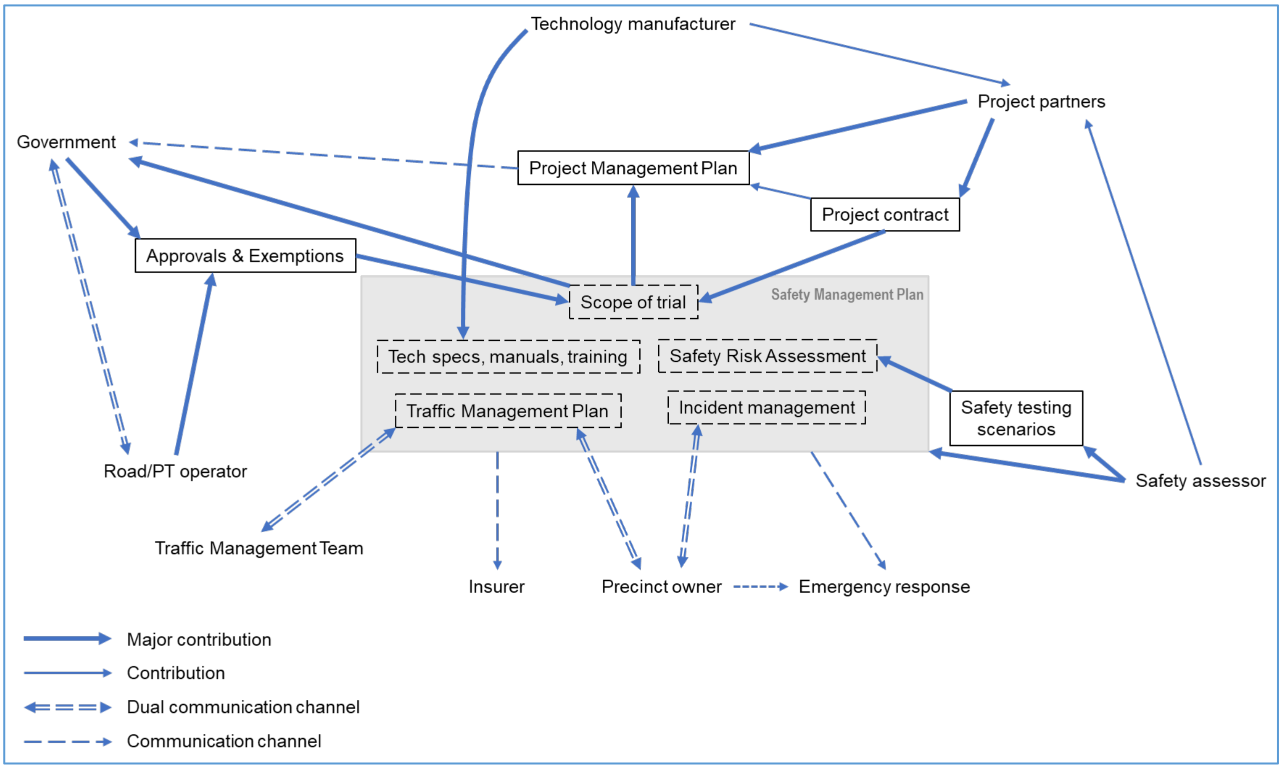


The feedlot use case is addressed under 'Tractors and agriculture machinery' in Figure 4-1 with relative standards being ISO18497:2018, ISO2511:2018 and ISO10957:2009. Tiusanen et al. (2020) claimed that the current standards were mainly addressed at the manufacturers, with responsibilities at the worksite level not properly addressed. From the technology point of view, there seems to be a gap between the safety requirements set in standards and the state-of-the-art in terms of current technology.

4.2 Road Transport

The application of AVs deployed in on-road applications in terms of their exposure to the public and rules/regulations applied on the road network, is complex. Different stakeholders are working to ensure that the new technology will not cause injury and fatalities. The development of a safety management process (SMP) for AVs, and the engagement of different stockholders in terms of their relation to AVs, is presented in Karl & Kutadinata (2019). The workflow illustrates the contributions made by various stakeholders to each of the major components of the SMP. The process also outlines the direction of communication among the stakeholders (see Figure 4-2). It captures the iterative development process in parts of the SMP where the direction of the arrows forms a loop.

Figure 4-2 Safety process management for on-road AV trials (Karl & Kutadinata 2019)

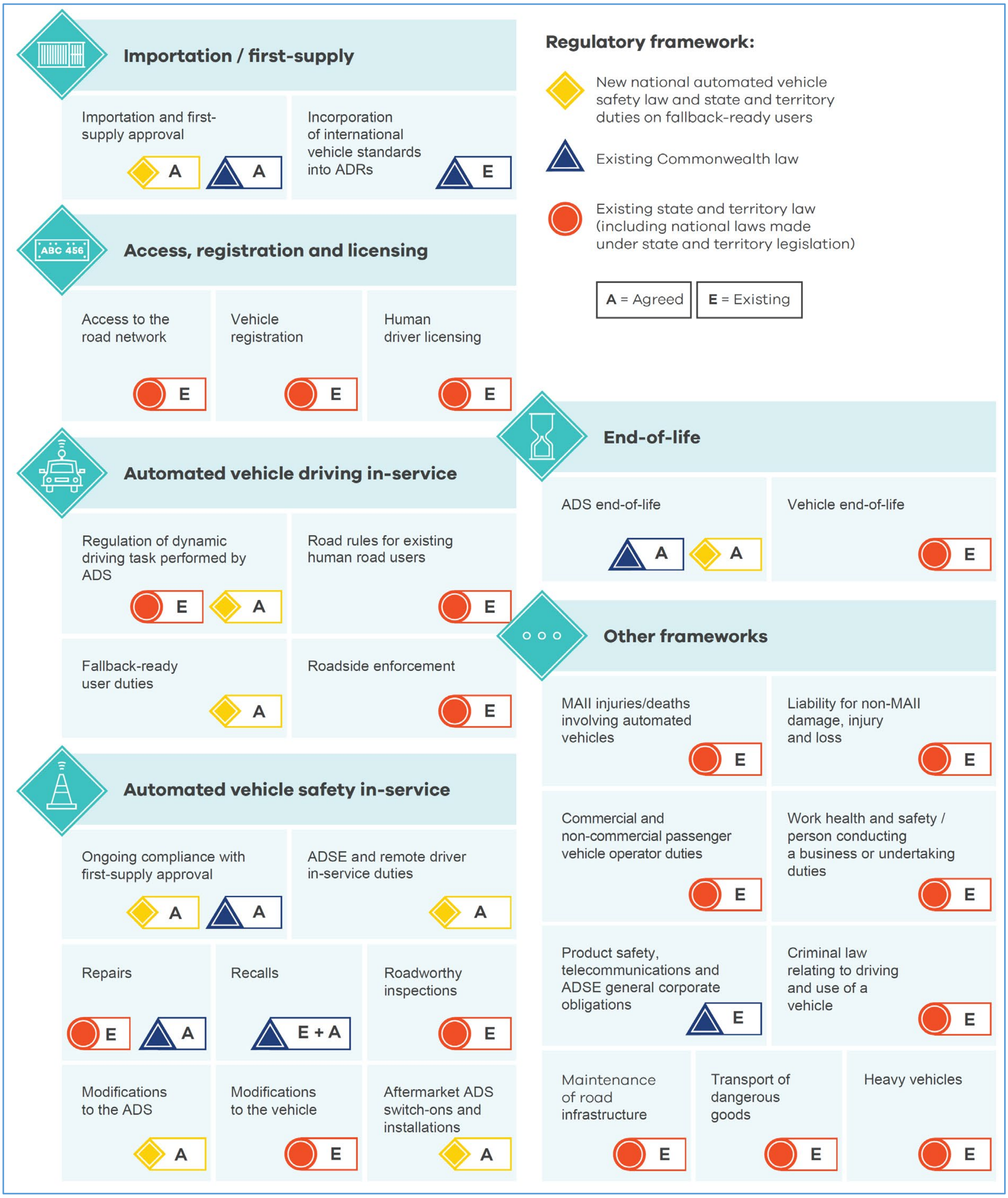


The complexity of communication and maintaining a safe environment for deploying AVs on the road is one of the main barriers addressed in literature (Widen & Koopman 2022; NTC 2020). In Australia, the National Transport Commission (NTC) defines the regulation for on-road automated vehicles. In Feb 2022, NTC released a regulatory framework for automated vehicles in Australia (NTC 2022). The NTC, Commonwealth, and state and territory governments have worked with industry to develop a national framework. It provides a clear signal that there is a pathway to commercially deploying automated vehicles.

Figure 4-3 shows the overall impact level of the current automated vehicle regulation. The framework strikes a balance between aligning with international standards and its adaptation to current Australian regulations. It consists of existing and already-agreed Commonwealth and state and territory regulatory frameworks, including the final recommendations regarding the new in-service Automated Vehicle Safety Law (NTC 2022).

The regulatory framework for the on-road AVs is new. It highlights how a new law across AVs is merged with the embodiment of the current regulations for on-road vehicles. In general, there are two new definitions within the regulatory framework for on-road AV:i) automated driving system (ADS), and ii) automated driving system entity (ADSE). ADS refers to the hardware and software collectively capable of performing the entire dynamic driving task on a sustained basis without human input. The ADSE is the party that will self-certify the safety of the ADS and take responsibility for it over its life. More details can be found in (NTC 2022).

Figure 4-3 Key regulatory frameworks for automated vehicles (NTC 2022)



4.3 Mining

The mining industry's regulations and Codes of Practice have existed for many years, as automated vehicles are widely used. A summary of the regulatory framework for the mining industry is presented in Table 4-1 (SafeWork Australia 2021c).

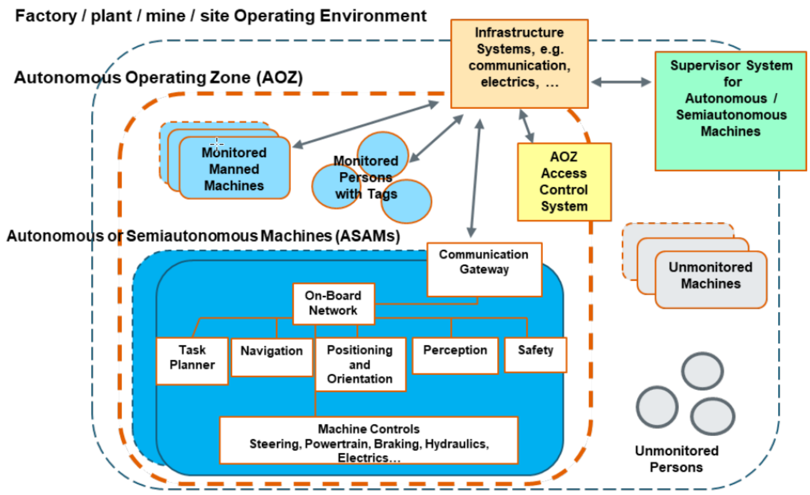
Table 4-1: Work, Health and Safety regulatory frameworks for mining (SafeWork Australia 2021c)

Jurisdiction	Mining legislative framework
New South Wales	Work Health and Safety (Mines and Petroleum Sites) Act 2013) Work Health and Safety (Mines and Petroleum Sites) Regulation' 2014)
Victoria	Chapter 5.3 of the Occupational Health and Safety Regulations (Victorian Legislation 2017)
Queensland	Mining and Quarrying Safety and Health Act 1999) Mining and Quarrying Safety and Health Regulation 2017
Western Australia	Mines Safety and Inspection Act 1994 Mines Safety and Inspection Regulations 1995)
South Australia	Work Health and Safety Regulations 2012)
Tasmania	Mines Work Health and Safety (Supplementary Requirements) Act 2012 Mines Work Health And Safety (Supplementary Requirements) Regulations 2012
Australian Capital Territory	Work Health and Safety Act 2011 ACT Legislation Register 2021
Northern Territory	Work Health And Safety (National Uniform Legislation) Regulations 2021 Mines Work Health and Safety (National Uniform Legislation) Regulations 2011, Chapter 10

Mining typically involves heavy machinery, and this could be unsafe if there was contact with humans. Hence, the interaction between machines and humans are minimised in the mining industry. One of the main ISO standards that governs the automated vehicle in the mining industry is ISO17757:2019 –*Earth-moving machinery and mining – autonomous and semi-autonomous machine system safety*. The standard outlines the various systems and performance metrics required by an autonomous or semi-autonomous machine (ASAM) if it is to operate safely within a mining environment. ISO17757:2019 highlights the interaction of ASAM with other objects within its vicinity and identifies the possible hazards, machine controls and associated protocols.

One of AVs' distinguishing features in the mining industry is their capability to control the level of interaction between AVs and other agents. Indeed, the operating environment in the mining industry allows the elimination of humans, or controls the interaction between AVs and personnel to reduce the collision risk. Figure 4-4 shows the different zones defined in ISO-17757:2019. It clearly shows that, in the Autonomous Operative Zone (AOZ), all the agents are monitored by the supervisor system. This approach limits the AV operational domain when it is in the vicinity of the human to avoid collisions (i.e. the system goes to the stop phase if there is any human detected in the AOZ or close to the AV).

Figure 4-4: Difference between monitored and unmonitored persons and machinery with the AOZ, according to the ASAMS model in ISO 17757



4.4 Aviation

Aviation is another area where regulation is well established. This is due to the type of application or the minimum interaction that drones need to have with human pilots and other agents in the vicinity (Emerging

Aviation Technologies 2020). Despite the growth in drone and uncrewed operations, there have been no reported collisions between drones and crewed aircraft in Australia (Australian Transport Safety Bureau 2017). This significant result is related to the extensive training and a rigorous safety framework that has been developed in the aviation industry (Perez, Clothier & Williams 2013; Australian Government Federal Register of Legislation 2019).

One of the first principles of regulation is licensing and how the drone operator interacts with the system (Civil Aviation Safety Authority (CASA) 2019). For most applications dealing with drones, there is a need for pilots to be trained and have the necessary licences before they can pilot the device. Training is well established and regulated in aviation. As a result, the operator is fully aware of how the system works and of the unsafe situations that may cause potential or imminent danger. Although the definition of AV definition presented in Section 1 is not aligned with the aviation industry, lessons for agriculture can be learnt from the operator's training and licencing materials.

4.5 Comparison Remarks

The major safety challenge in the AV safety framework is associated with the collision between a machine and a human. The failure in most use-cases is caused by various environmental reasons that are often hard to predict (Tiusanen, Malm & Ronkainen 2020). In the mining sector, ISO 17757 2019 suggests reducing the interaction with humans by defining an autonomous operational zone; the AV will operate in a safe state (stop if any unknown interaction is detected).

On the other hand, moving to a safe state for an on-road AV means something different compared to off-road vehicles. Interaction between AVs and other road users (e.g. pedestrians, cyclists, and vehicles) is inevitable for on-road AVs. In road transport, it is required that AVs maintain their controllability for as long as possible and be capable of being moved from the traffic lanes to the side of the road (NTC 2020; SAE J3016 2021). They cannot be stopped in the middle of a busy road when there is a fault situation similar to the powered mobile plant.

In terms of the operation of AVs in agricultural applications, the collision avoidance systems are not as complex as for on-road vehicles. This is because an AV can fully stop in a safe state without keeping the controllability in the failure mode. The level of interaction with humans is not as complex as on-road applications and not as constrained as mining applications. Jubb et al. (2012) describes the minimum infrastructure for the feedlot consisting of the road and intersections. It is worth investigating how the minimum infrastructure in the feedlot meets the AV’s operational design domain for defining a safety framework. One solution is to adapt, or modify, autonomous safe zone practice in mining by defining dynamic zones in order to minimise the interaction with AV.

Training is another consideration. The operator and other supporting personnel need to be fully aware of the AV’s behaviour in its operational design domain. Therefore, high-level training and inductions are suggested so that staff can familiarise themselves with the technology.

5 Safety Management Plan and Risk Register

Safety is first and foremost in the minds of all those concerned with projects related to AVs. The focus of this section is the development of a Safety Management Plan (SMP) and a risk assessment framework for feedlots deploying AVs. The SMP is part of the overall project's documentation, including the Project Management Plan, Risk Register, Traffic Management Plan, and Incident Management Plan. The SMP contents are explained with example applications and relevant regulations for deploying AV technology in feedlots.

The SMP is part of the overall project's documentation, which principally includes detailed planning of how safe AV operation is achievable. This includes expanding the SMP into crucial elements such as Concept of Operations, Risk Register, Traffic Management Plan (TMP), and Incident Management Plan (IMP). Other complementary relevant documentation that needs to be aligned includes the stakeholder engagement and communication plan, various approvals, exemption documentation, manuals, specifications, training, and educational materials. The SMP lists all the key relevant safety risks and how they will be mitigated or eliminated. The safety risks listed in an SMP are typically only those uniquely introduced by the application (in this case, feedlots) and due to the technology being tested. It is noted that the SMP cannot be generalised for all the feedlots and relative risk registers, and documents must be provided individually for each feedlot and use case.

5.1 Content of a Safety Management Plan

The SMP for the trials of AVs is discussed in the National Transport Commission guidelines (NTC 2017). The guideline lists different aspects to be considered when developing an SMP, including (cyber) security, interaction with other road users, interaction with road infrastructure, system failure, fallback procedure, the presence of a human driver (i.e. an operator), data from pre-trial testing, operator training, fitness-for-duty, and vehicle identifiers.

In the same guideline, NTC describes a reporting requirement for incidents involving severe incidents (impact occurred) and other incidents such as near-misses, automated mode disengagements, and public complaints. Although the NTC guidelines have been developed for on-road vehicles, they provide a solid starting point for developing an SMP for feedlot AVs. The proposed adaptation from NTC (2017) for developing SMP in feedlots and private land is presented in Figure 5-1. The Figure outlines the main components that need to be considered by the stakeholders and captures the iterative development process needed to establish an SMP.

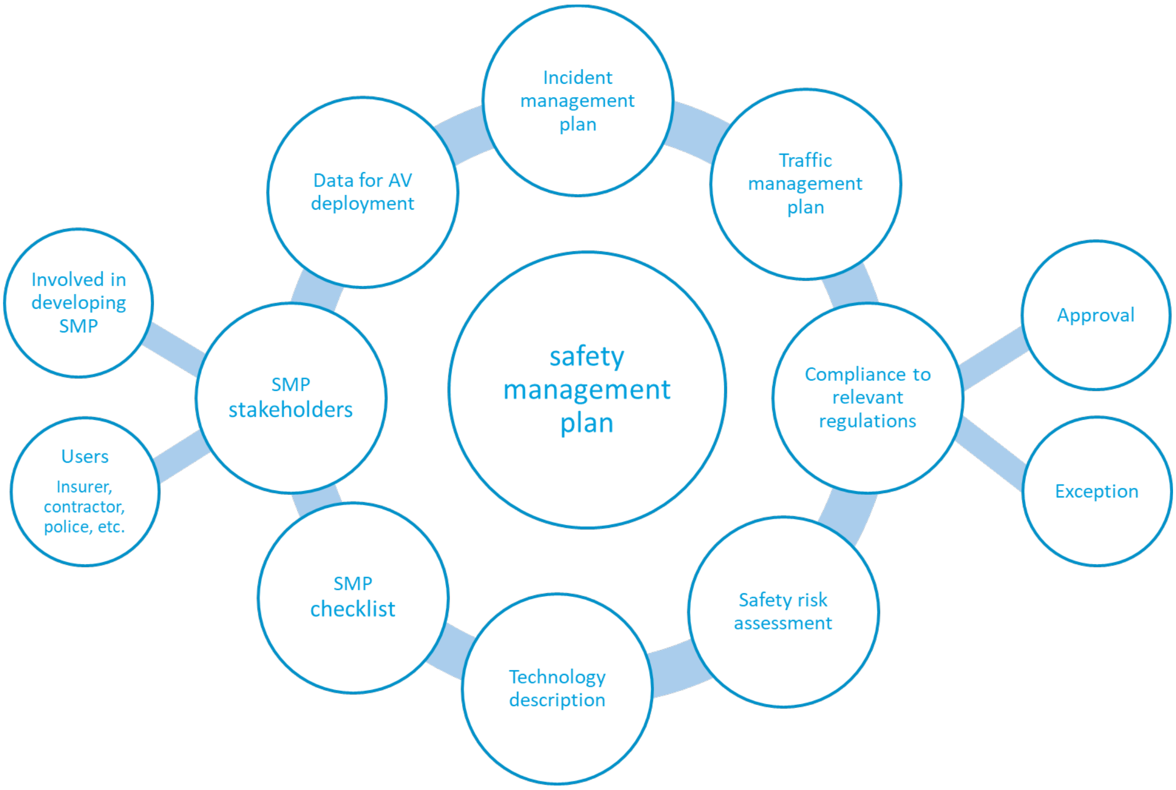


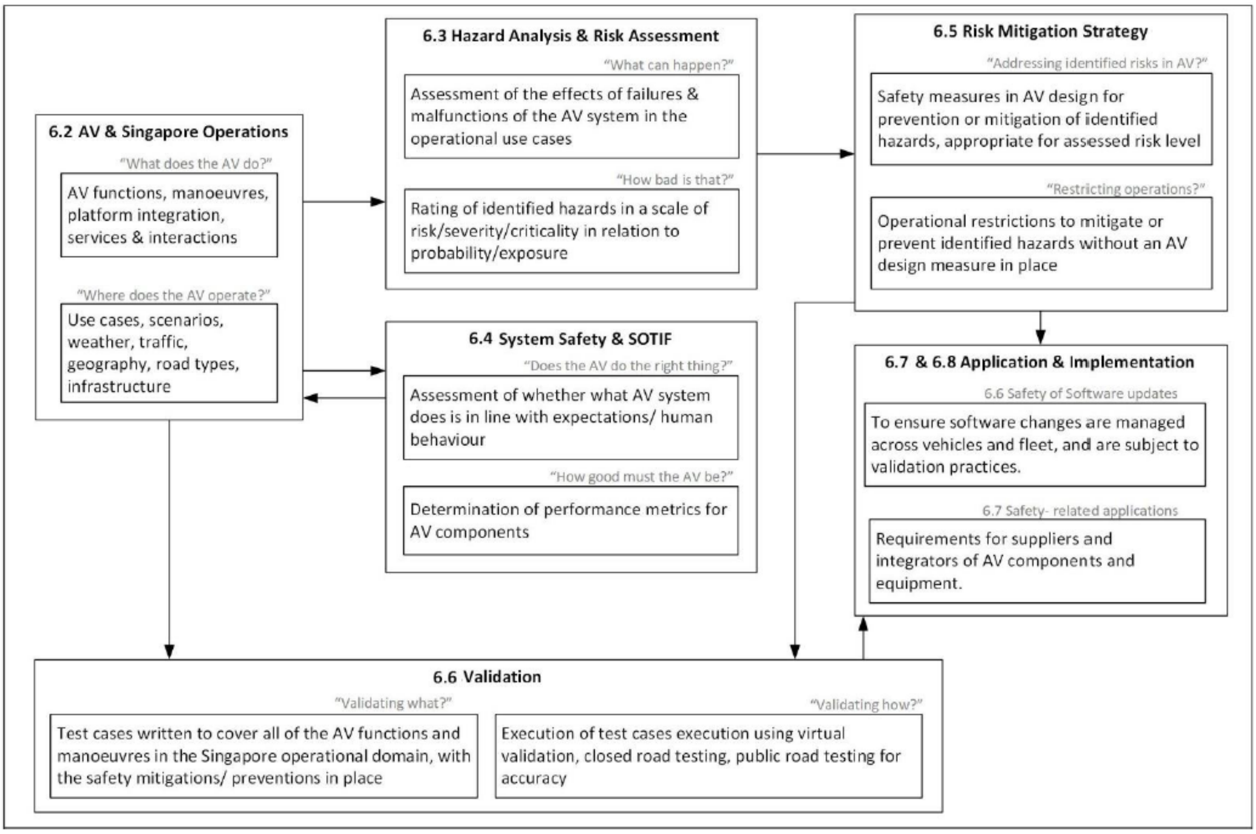
Figure 5-1 Safety management plan components proposed for deploying AV in the feedlots

The essential contents include:

1. **Scope of the project.** The various details of the deployment or trial are explicitly stated, including location, operation details, routes, duration, and timing. The objective is to provide a clear scope of the safety risk assessment process.
2. **Description of technology.** Understanding the technology is naturally required to assess the safety risks that the technology may bring to the workflow. The SMP should include a description of the technology being tested. Aspects that need to be detailed include the specifications, how the technology works and its capabilities (i.e. operational domain).
3. **Compliance.** The SMP should include a section confirming that compliance with relevant regulations is met or if there is a need for exemptions or approvals before the technology can be deployed.
4. **Safety Risk Assessment (SRA).** Arguably, the SRA is the main component of the SMP. The SRA details the identified safety risks introduced as part of the trial and technology. More importantly, each identified safety risk should have an accompanying mitigation and contingency plan to ensure that the risks are either eliminated or reduced to an acceptable level. The responsibilities of each stakeholder need to be identified in the SRA, and the risk mitigations and potential hazards should be periodically reviewed.
5. **Traffic Management Plan (TMP).** A TMP is likely to be produced in line with the specified mitigation plans mentioned in the SRA. The TMP is a supporting document to address or treat the risks addressed in SRA.
6. **Incident Management Plan (IMP).** The contingency plans specified in the safety risk assessment naturally leads to the development of an incident management plan. It provides a record of incidents and the responsibilities of the stakeholders should an incident occurs.
7. **Other relevant information.** The SMP will typically require additional supporting documentation, such as operator training documentation, and pre-deployment testing data to help build a database of information and evidence pertinent to the project's safety.

This use of holistic safety strategies is common practice across the globe, and several notable entities have produced their versions of SMPs, including Mercedes-Benz (2021), Waymo (2018), Ford (2018), and Nvidia (2020), to mitigate damage and protect lives. As an example, Singapore Standards Council (SSC 2019) published a technical reference for AVs (**Error! Reference source not found.**) which provides an overview of the safety management system for AVs. In addition, it provides a flowchart indicating the interaction of the components within a safety management plan. The SSC approach is to provide a validation testbed to allow both the AV operator and the developer to define the functionality and operational domain of the AV technology. The AV operator can communicate directly with the technology provider through the validation process (Clause 6.6) and also provide input through the hazard analysis and risk assessment process (Clause 6.3).

Figure 5-2 Overview of the safety management system (SSC 2019)



5.2 Feedlot Use Case

Autonomous vehicles are already operating across several domains. The feedlot application has been developed in the land domain, where an off-road AV operates based on an unmanned ground vehicle (UGV) platform in the agricultural sector.

An essential component of the SMP is the Use Cases that will be tested, trialled, or deployed in the project. The Use Case would operate in several situations, which, together, are known as scenarios. An example where the Use Case is the automation function – 'driving in feed road' where the bunk scanner reads the level of the feed in the pen feed bunks – is shown in Table 5-1. The situation would be operating at night in rainy weather conditions. This comprises one scenario for testing in the Safety Management Plan.

Table 5-1: Use cases, situations, scenarios, and their mutual dependence

Subject	Definition	Comment	Example
Use case	A specific event in which a system is expected to behave according to a specified function	A use case is a system and driver state, where the 'system' includes the road and traffic environment	Driving on feed road
Situation	One specific level or a combination of specific levels of situational variables	A situation is a state of the environment	Rainy weather + darkness
Scenario	A use case in a specific situation	Use case + situation = scenario	Driving in feed road in rainy weather and darkness

Source: FESTA (2017).

5.3 SMP Checklist and Stakeholder Engagement

The SMP checklist will be a standalone document with sufficient detail to give the reader enough overview of the project. The checklist contains all the necessary actions and documentation for deploying AV technology and understanding the safety risks and treatments. It also includes measures that have been taken to ensure safe operations for the application. The proposed SMP checklist and its components with their description is shown in Table 5-2.

Table 5-2 Draft of SMP checklist

1	Scope of Project		Description
1.1	Project objectives and outcomes	☐	Listing of objectives and desired project outcomes
1.2	Project partners	☐	Listing and details of project partners
1.3	Project scope	☐	Details of project scope
2	Vehicle / Technology		
2.1	The vehicle	☐	Details of the Autonomous Ground Vehicle (AGV)
2.2	The technology	☐	Details of the autonomous technology
2.3	The system (infrastructure, driver, operator)	☐	Details of the autonomous system and interfaces
2.4	Use cases	☐	Details of the use case and scenarios
3	Safety		
3.1	Risk registers and safety checklist	☐	Understanding the risks and the mitigation strategy to reduce the risk
3.2	Traffic management plan	☐	Details of the traffic management plan, treatments
3.3	Incident management plan	☐	Details of the incident management plan
3.4	Data availability	☐	The details of the available data to support safety components
4	Approvals and Compliance		
4.1	Approval from agencies	☐	Approval documentation
4.2	Compliance with guidelines	☐	Compliance acknowledgements
4.3	Insurance	☐	Insurance details
5	Other relevant information		
5.1	Operator details	☐	List of approved operators
5.2	Emergency contacts	☐	List of emergency contacts
5.3	Incident reporting sheet	☐	Details of the incident reporting form
5.4	Insurance certificate of currency	☐	Insurance certificate
6	Appendices		
6.1	Training manuals and the records of trainings	☐	Details of training manuals
6.3	Operating manuals	☐	Details of operating manuals
6.4	Service/maintenance manuals	☐	Details of other manuals

It is important that the SMP checklist is written at a high-level so different stakeholders can engage and provide feedback on it. The SMP should be written with the engagement of the main contributing stakeholders. Generally, two stakeholder groups are engaged throughout the development process. One group is for stakeholders involved in the development of the SMP, and another group consists of users of the SMP. Some examples of stakeholders engaged in the SMP are listed in Table 5-3. Most stakeholders are typically considered as the main stakeholders and directly impact the SMP. However, the user stakeholders, such as insurers, utilise the SMP as safety evaluation evidence and do not directly engage in developing the SMP.

Table 5-3 Stakeholders that are directly and indirectly engaged in the SMP

Stakeholder engagement	
Main Stakeholders:	*Stakeholders considered only as users*
– Government entities: approvals and exemptions – Road/public transport operators: approvals and exemptions – Technology manufacturer: technology-related considerations – Safety assessor: overall safety outlook – Traffic Management Team (if there is any): traffic management plan – Precinct owner: incident management plan – Project partners: scope and overall SMP consideration	*Other:* - Insurer[2] - Emergency response team (police, ambulance, fire brigade) - Feedlot contractors

An auditing from different stakeholders needs to be carried out to evaluate the performance of the executed SMP. The auditing can be carried out on different SMP aspects such as standard operating protocols, ensuring clear routes, routine inspections, traffic management incident reporting and registration of the training process.

The main component of the SMP checklist is the focus of the rest of this report, which includes safety risk assessment, traffic management plan, data for AV deployment, and incident management plan.

5.4 Safety Risk Assessment

The Safety Risk Assessment (SRA) provides a complete safety assessment of the project, along with the planned control measures to reduce the safety risks to appropriate levels (Karl & Kutadinata, 2019). The SRA is one of the critical documents in the safety management plan; it is prescriptive and operationally focused for each phase. For example, typical AV project phases could include different stages such as vehicle storage/transit, preparation, testing, deployment and events. Indeed, the SRA identifies the potential hazards and hazard control measures to be taken for each of the phases.

The aim of the SRA is to achieve a high level of safety in operation. The proposed safety risk checklist considers the AV technology and operation. In terms of AV safety, it reflects technical and security aspects of safety. In the operational phase, it considers interaction with humans, animals and the infrastructure in the feedlot. Different risks in the proposed safety risk assessment were categorised based on observation, previous risk assessments, and hazards identified in the standards. As a result, the following categories were identified and under review for this project:

- electrical
- physical/equipment (e.g. Lidar, EMR, tyre pressure, battery acid)
- system control (e.g. remote stop, communication, sensor obstruction, over speed, unintended movement)
- collision (e.g. human, livestock, infrastructure, vehicles, debris)
- environment (weather, pavement, terrain)
- miscellaneous (unexpected animal behaviour, cyber-attack).

Potential treatments for reducing identified risks have also been addressed. Figure 5-3Figure 5-3 shows an example of the proposed SRA. It highlights scenarios where AVs can be engaged, their risk and hazard control measures, and the responsibilities of stakeholders for deploying the control measures. The comprehensive list of the SRA can be found in Appendix A.4.

[2] Note that, although insurance is usually required for trials, the insurer's involvement in the SMP development is usually only considered as a user, due to them not being directly involved in the development.

Figure 5-3: Safety checklist example (Karl & Seigel 2018)

POTENTIAL HAZARDS	CONSEQUENCES	Likelihood	Consequence	Risk without controls	**HAZARD CONTROL MEASURES** For each identified hazard, list the control measures required to eliminate or minimise the risk of harm. Prioritise using the Hierarchy Of Controls.	Likelihood	Consequence	Residual Risk	**RESPONSIBILITY** Nominate the **one person** who will be ultimately responsible for ensuring that the control measures are in place.
Electrical									
Electrical shorts from wet weather or faulty/loose wiring on BunkBot.	Electrical arcs may result in fire hazard	**2**	**2**	**4**	Follow maintenance guidelines	**1**	**2**	**2**	**Feedlot manager**: Ensure maintenance guidelines are adhered to **Operator**: Follow maintenance guidelines **Manabotix**: Supply appropriate guidelines
Electrical shorts from wet weather or damaged cables in charging station	Electrical arcs may result in fire hazard	**2**	**2**	**4**	Charging station under cover Charging cables and equipment to be checked by trained individual	**1**	**2**	**2**	**Feedlot manager**: Make sure charging station is built to protect components from weather damage. Adhere to regulations for electrical equipment such as testing and tagging. **Operator**: Do not use damaged cables when charging **Manabotix:** NA

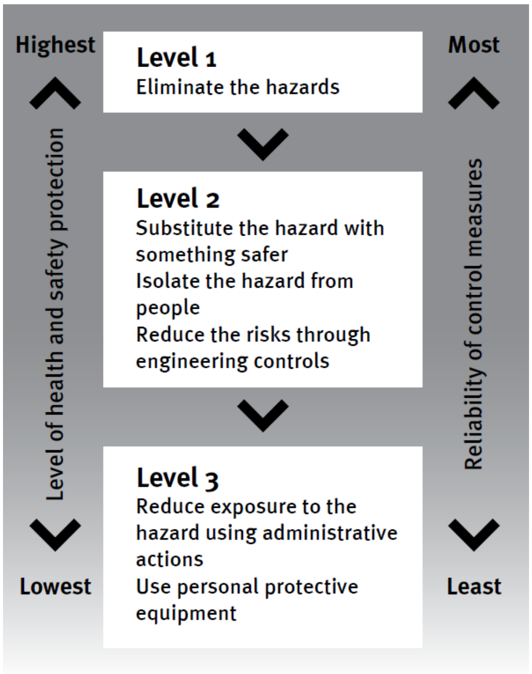
The SRA needs to be reviewed periodically in case the control measures become less effective over time or new data reveals a new type of hazard that needs to be mitigated. In addition, in the case of feedlots, the hazard control measured needs to be reviewed by animal ethics and welfare experts to ensure the treatment does not impact the animals' welfare. MLA has been asked to review the proposed SRA to ensure it aligns with beef cattle industry animal welfare standards and guidelines.

5.5 Traffic Management Plan

As part of the operational safety, a traffic management plan (TMP) is prepared and deployed to support the safe operations of AVs by providing a safe environment to deploy the technology in a routing schedule during testing and deployment periods. In addition, the TMP is designed to become more robust to the risk (i.e. risk-averse), allowing for a more isolated environment during testing. As the project progresses, the TMP needs to be continually assessed to determine if a less stringent TMP is feasible.

Traffic management can involve different treatments on public roads and private lands. A TMP can be costly depending on the level of treatments required. Typically, the suggestion is that the TMPs be conservative at the start. As familiarity with other road users increases, the TMPs can be relaxed as confidence and trust in the behaviour of the AV with other road users builds (Karl & Kutadinata, 2019). WorkSafe Australia provides an onsite traffic management self-assessment toolbox which shows an example of good practice TMPs on private lands (WorkSafe 2019). The aim of the toolbox is to identify and control the associated risk of hazardous scenarios. It details several example control measures in line with the hierarchy of controls (Figure 5-4). These control measures are ranked from the most effective and highest-level to the least effective and lowest level control measures. This is in line with the TMP recommendation from WorkSafe Australia and the timeline consideration for operating AVs in the feedlot.

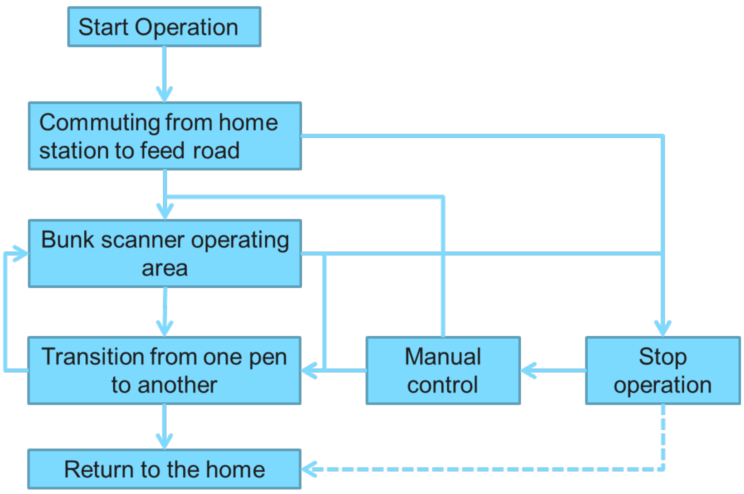
Figure 5-4 Hierarchy of controls in the traffic management plan proposed by WorkSafe (2019)



5.5.1 Dynamic driving task of BunkBot operation

The operation of the BunkBot can be simplified based on the task that BunkBot needs to execute. This simplification helps understand the Dynamic Driving Task (DDT) in which BunkBot is engaged. **Error! Reference source not found.** shows the proposed DDT for the BunkBot. The operation starts from the charging docks, and follows the path from the charging station to the feed roads. Once the BunkBot reaches the first feed road, the operation is on the loop to scan the bunks in each feed road. Next is a stage for the transition from one pen to another, which usually is related to driving to the turning points. This process will continually operate until the BunkBot has visited all the pens. Once the bunk scanner task has been completed, the BunkBot returns to the home station. The BunkBot can stop operation and return to the charging station at any time. The BunkBot also has the capability for remote operation, which means that if the BunkBot operation has been blocked due to a safety event, a remote operator can intervene and take over the control of the BunkBot to continue the operation.

Figure 5-5 Operation of Dynamic Driving Task (DDT) of the BunkBot



The DDT operation of the BunkBot revealed the potential conflicts which may occur during operation. Examples of conflict scenarios and driving scenarios in the feedlots are shown in Figure 5-6. This includes driving in the: i) feed roads, ii) turning points, iii) intersection, iv) shared roads, and v) travelling to and returning from the docking station.

Figure 5-6 Examples of conflict scenarios within the DDT of the BunkBot

(a) (b) (c) (d)

The examples shown in Figure 5-6 show that driving on the feed roads is usually isolated and can be managed in such a way that only the BunkBot operates on the feed road. However, it is not the case at intersections. Figure 5-6b shows the need for complex decision-making for turning left in the intersection or Figure 5-6c shows that there is a limited field of view to capture vehicles coming from behind the field of vision of the BunkBot, close to the intersection. These scenarios need further consideration and will be addressed in Section 5.5.3.

5.5.2 Driving path condition

It is always easy to be confident when driving on high-quality pavements and flat terrain. However, that is not the case in the feedlot. General observations suggest that roads and segments in the feedlot should be considered off-road, and the driving condition needs to be adapted to different terrain and pavement conditions. Considering the requirement of driving offroad based on pavement conditions can reduce the practical operational domain. In this case, the technology provider needs to conduct sufficient tests of the selected route to ensure that the technology can satisfy the requirements of the driving path. Otherwise, the technology provider should advise the feedlot manager regarding alternative paths or changes in the infrastructure for the AV operation.

There is also a need for communication between the technology provider and feedlot manager for situations where there is a modification on the feedlot (e.g. construction, road repairs, movement of cattle across lanes with closed gates, major change across the AV routing trajectory, etc.). This enables the AV behaviour to be adapted to the changes in the environment as they occur.

Adverse weather conditions such as heavy rain can cause a non-drivable environment in the feedlot. This needs to be considered as it can drastically change the safe driving path required. Some examples observed in the feedlot after two days of heavy rain are shown in Figure 5-7. Vegetation growing in the AVs trajectory may cause ‘fake obstacles’ to appear in its perception system, resulting in unnecessary stops. The feedlot operator needs to ensure that routine cleaning within the feed road is undertaken to assure the minimum viable driving conditions for the BunkBot.

Figure 5-7 Examples of the impact of adverse weather on the BunkBot trajectories

5.5.3 Route detailing

As part of the traffic management plan, the driving path needs to be separated to cover the DDT that the AV performs. The operating routes for this task were selected and then divided into the sub-sections associated with the AV's DDT. An example of a traffic management plan is shown in **Error! Reference source not found.**. It visualises the required treatments for approaching each road segment in the AV's trajectory. The same approach can be used for operating AVs in the feedlot. An example of how route detailing can apply to AV operations is also shown in **Error! Reference source not found.**. In this example, the route is separate, and the driving intersection has been pinned. Each road section is labelled separately, and the potential hazard and the required treatment for each road section will be applied.

Figure 5-8 Example traffic management plan for on-road vehicle (Karl & Seigel 2018)

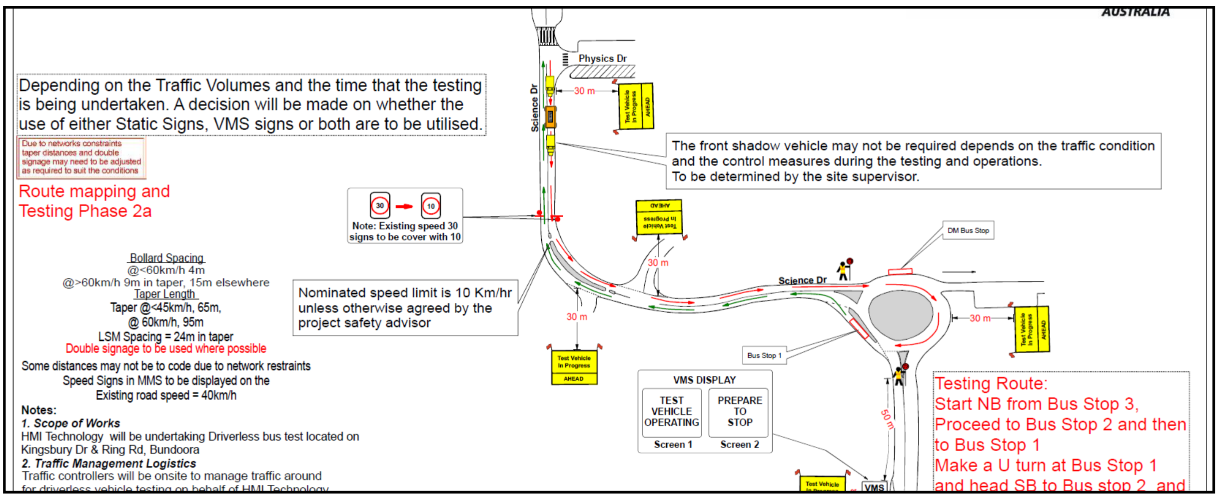


Figure 5-9 shows an example of how route detailing can apply to a feedlot use case. In this example, the routes are separated into feed roads, turning points, shared roads, and intersections. The AV operation mode can change in each situation. The proposed driving mode for AV in the feedlot includes:

- normal mode: driving normal as expected
- cautious mode: moving slower in the presence of objects close to the driving path

- pause mode: waiting for an event to be finished (approach human, waiting in the intersection for other road users, etc.)
- stop mode:(stop operation due to the event or obstruction in the driving path).

Figure 5-9 Examples of driving scenarios for BunkBot and route detailing

The operation on each route needs to be analysed in detail to make sure the required control measures has been applied. An example of general consideration for approaching every route detailing segment is shown in **Error! Reference source not found.**. The treatment can be considered similar to on-road vehicles in locations where there is an interaction with road users, such as intersections and shared roads. However, in locations where the BunkBot operation is isolated, the control measures can be adapted from the mining sector.

Table 5-4 Route detailing consideration for the feedlot operations

Route detailing consideration		Adapted from on-road treatment	Adapted from mining treatment
1	Prior to operation		
1.1	Battery health check		
1.2	Weather condition		
1.3	Set maximum speed for conditions		
2	Shared road	ü	
2.1	Speed adaptation for terrains		
2.2	Slowdown for any objects closer than 7 meters to the pre-defined road		
3	Feed road (restrict working zone)		ü
3.1	Pause operation for any objects closer than 7 meters.		
4	Turning point (restrict working zone)		ü
4.1	Start turning if the area is empty. Otherwise, pause the automation		
5	Intersection	ü	
5.1	Pause with a complete stop at the intersection		
5.2	Make sure the position provides enough field of view from the intersection		
5.3	If there is no moving object with a time to the collision of less than 5 seconds, approach the intersection		
6	Other driving consideration	-	-
6.1	Operators' details		

5.6 Incident Management Plan

An incident management plan (IMP), also known as an emergency response plan, is a document that helps an organisation return to normal as promptly as possible following an unexpected event (WorkSafe 2011). An IMP lists the potential hazardous incidents and their reporting requirements for fast recovery in the event of an incident. shows Some examples of incident types for AVs are listed in Table 5-5 DMPWA[3] (2015). The report notes that requirements need to be aligned with the scenarios that the AV engaged. The requirement can clearly define actions and processes for all stakeholders (DMPWA 2015).

Table 5-5: Example of incident types and reporting requirements (DMPWA 2015)

Incident	Examples	Reporting requirement
Uncontrolled movement	• Breach of the designated area due to a system malfunction	
Uncommand movement	• Starting while "all clear" not in place	
Failure to start moving when so commanded	• Failure to start • Stationery equipment fails to move when commanded by control room	
Failure to stop when so commanded	• Moving equipment fails to stop when commanded by control room • Moving equipment fails to stop when commanded by on-board control system	
Failure to change motion when so commanded	• Failure to change direction when commanded • Failure to change speed when commanded	
"Near miss" with an oncoming vehicle	• Various scenarios similar to "near miss" events for non-autonomous equipment	
Collision with property, equipment or personnel	• Various scenarios similar to "collision" or "struck by" events for non-autonomous equipment, including: - Collision with other mobile equipment - Worker struck by autonomous equipment	
Other autonomous incidents that could lead to injury, harm or damage, in the manager's opinion	• Potentially serious incident involving autonomous system or component, including: - Unexpected switching between autonomous and manual operating modes - Non-standard response during testing	

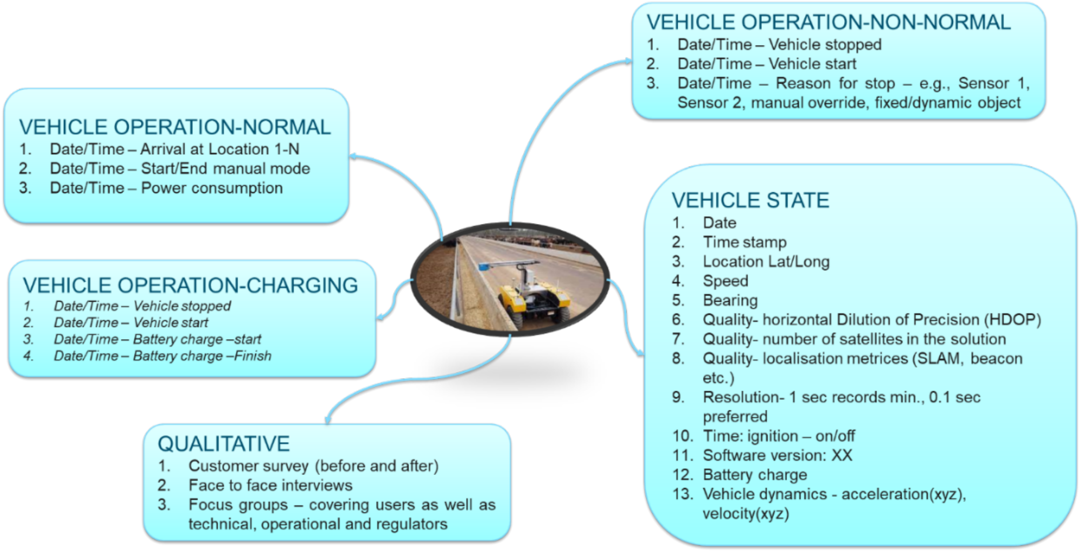
The feedlot needs to extend the HR's incident report to cover incidents for the automated vehicles. An example of an incident report developed by VicRoads for the ADS trial is depicted in Appendix 0.

5.7 Data for AV Deployment

During AV trials, data is typically available from the vehicle and its back office. Other trial data include tracking and logging devices mounted in the test vehicles. Data is collected for several purposes: system improvements, incident reporting and monitoring system performances. An example of trial data from a low-speed autonomous vehicle trial is shown in Figure 5-10 (Karl & Seigel 2018). There could be additional requirements for equipment to be installed to collect independent and qualitative data from trial participants and stakeholders on commercial tests and trials. Such a need could arise from regulatory, exemption, monitoring and compliance requirements in cases of incident reporting and compliance to conditions such as access, speed, etc.

[3] Department of Mines and Petroleum Western Australia.

Figure 5-10 Data requirements for AV deployment



6 Conclusions

This section summarises the key insights and implications of regulatory frameworks for deploying AVs in feedlots. The key findings from reviewing literature and stakeholders' consultation workshop held for this project are highlighted.

6.1 Key Findings: Literature Review and Stakeholder Consultation

The literature review canvassed relevant state and federal legislation, engaged with stakeholders through workshops and interviews, and compared safety frameworks that exist in other operational domains. Five main comments are made based on this investigation:

1. **The investigation of the AV regulatory environment in feedlots has revealed no unified codes of practice**. The stakeholder engagement showed no applicable codes of practice for AVs in the local agriculture environment. SafeWork NSW mentioned that there was no plan for the development of a code of practice in the near future. AVs are not directly mentioned in the overall work health and safety regulatory framework (*Work Health and Safety Act* 2011). This gap is reflected in the industry's request for more clarity in providing an appropriate code of practice that includes AVs (Grain Producers Australia 2021).
2. **AV technology education and training need more consideration –**an important factor raised by the stakeholders. Although legislation has identified proper training as a crucial factor, the details of such training have not been expanded (WorkSafe Queensland 2022a). As an example, in the development of training details, there have been requests by lot feeders for a field diagnostic approach rather than only relying on a remote control system. Because the feedlots are usually in a remote area, access by a trained operator is problematic. The operators need to be trained in the system's technology and the operation of the system in the feedlot. The potential trajectory of AVs, and where the system is used, are also crucial in the development of a safety framework.
3. **Insurance for AVs in feedlots is lacking** – While several reports are related to AV insurance, an overall regulatory framework is not established for the use of AVs in feedlots and farmlands. Consultation with stakeholders revealed no unified process for securing insurance for AV operations on private land. Most AV technologies are in the early stages of development or they are not extensively used in feedlots. The lack of a safety framework makes it more challenging to persuade insurers to cover AVs.

   One critical factor is the type of AVs. Whilst it may be possible to insure light AVs such as BunkBot, covering the insurance and liability for heavy machinery such as an automated truck is challenging.

   The other factor is also linked to the size of the industry. For example, when the number of non-automated insured fleets is large, the insurer is more eager to cover the liability of new technology such as AVs. Furthermore, the complexity of defining terms and conditions covering the operation of AVs on both public and private land is problematic, making it hard to obtain the right insurance policy.
4. **Animal ethics and welfare considerations** – Animal welfare and the ethics related to the interaction with the cattle is another factor that needs to be considered. While cattle are often separated from the feed roads, there are occasions when direct interaction can occur between AVs and cattle. Further investigation is required to gain a better understanding of the interaction between AVs and animals in terms of animal welfare and potential mitigation options. It is expected that lightweight AVs may not be a significant concern in terms of their interactions with cattle; however, the automated truck operational domain may need consideration.
5. **Adaptation of safety frameworks from other domains** – The literature revealed that feedlot operations could adopt some of the safety frameworks already developed in the mining sector. To do that, it is crucial to understand the conflict areas and associated risks to minimise probable hazardous situations.

Since the use of AVs in feedlots is a new issue, safe operation requires more safety-related data to allow a regulatory framework to be developed. MLA supports trials that will result in a better understanding of the different challenges associated with the use of AV technology in the feedlot. The development of a concise safety framework to minimise the risk of this deployment was the subject of the next stage of this project.

The SMP developed using the method presented in this report incorporates findings from the literature review. Including all information in Appendix A will result in a comprehensive and self-contained SMP.

The key safety-related aspects of the SMP are as follows:

1. **Safety Risk Assessment (SRA).** The SRA is an assessment of all potential hazards and planned control measures. It should consider all phases of vehicle use including storage/transit, preparation, testing, deployment and events. Over time, the likelihood and potential consequence for each risk can change; hence, the SRA should be reviewed periodically.
2. **Traffic Management Plan (TMP).** The TMP is used to provide a safe environment to deploy the technology. WorkSafe Australia provides a helpful self-assessment tool showing good practice for SMPs on private land. Route detailing is a key part of the TMP where the driving task is separated into sections. It outlines how the technology, infrastructure, and other road users interact along the route. A conservative TMP is suggested to begin with but it may be relaxed as familiarity grows with the use of AVs and their behaviour.
3. **Incident Management Plan (IMP).** In the event of an incident, an IMP clearly defines actions and responsibilities that should be taken for all stakeholders. It enables fast response, accurate reporting, and a return to normal operation as quickly as possible.

6.2 Benefits to Industry

This work will assist the MLA to prepare a detailed SMP framework for automated vehicles in feedlots. The feedlot industry can develop a safety management plan following the instructions presented in Section 5 in this report. It will also increase awareness of the use of AVs use in feedlots, and their safety outcomes.

A greater understanding of the requirements required to introduce AVs in feedlots will lead to greater confidence in the pursuit of further R&D projects involving AVs, resulting in for more safer and efficient outcomes.

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Appendix A

A.1 Risks and Significant Hazards for Highly-automated Agricultural Machines (HAAM) (ISO 18497:2018)

	Hazard	Hazard situation event
	Mechanical hazard	
	Crushing hazard	Obstacle contact with moving machine or with moving machine part
	Shearing hazard	Obstacle contact with moving machine or with moving machine part
	Cutting hazard	Obstacle contact with moving machine or with moving machine part
	Cutting severing hazard	Obstacle contact with moving machine part
	Drawing or trapping hazard	Obstacle contact with moving machine part
	Impact hazard	Obstacle contact with moving machine or with moving machine part
	Stabbing or puncture hazard	Obstacle contact with moving machine part
	Friction or abrasion hazard	Obstacle contact with moving machine part
	Electric hazards	
	Approach to live parts under high voltage	Contact with overhead power lines
	Hazard generated by neglecting ergonomic principles in machinery design	
	Human error, Human	Missing the compatibility of the implements
	Unexpected start up, unexpected overturn/over speed	
	Failure/disorder of the control system	Obstacle contact with moving machine or with moving machine part
	Restoration of energy supply after an interruption	Obstacle contact with moving machine or with moving machine part
	Errors made by the operator (due to the mismatch of machinery with man characteristic and ability)	Operator's manual
	Impossibly of stopping the machine in the best possible conditions	Obstacle contact with moving machine or with moving machine part
	Failure of the power supply	Obstacle contact with moving machine or with moving machine part
	Failure of the control circuited	Obstacle contact with moving machine or with moving machine part
	Error of fitting	Missing compatibility of implements
Additional hazardous situations and hazardous event due to the mobility		
	Movement when starting the machine	Obstacle contact with moving machine or with moving machine part
	Moving without a driver at the driving position (Machine with on board operator)	Loss of control
	Insufficient ability of machinery to be slowed down, stopped and immobilised	Obstacle contact with moving machine or with moving machine part
	From/to the third person	
	Lack to inadequacy of visual or acoustic warning means	Obstacle contact with moving machine or with moving machine part
	Insufficient instructions for the operator	Missing compatibility of implements

A.2 Workshop Organisation and List of Questions

Get to know the participant and their background

- Good if we could have their contact details and e-mail address for any follow-up

Agenda of the workshop

- Definition of the automated vehicle.
- Scope of the questions an automated vehicle in feedlots.
- We are interested in the feedlot use cases and where the Automated Vehicle (AV) can be deployed (BunkBot video as a demo).

Introduction and explaining the project background

- Big picture of the project.
- The purpose of the meeting.
- Goals that we want to achieve at the end of this workshop.
  - The operation domain and the use-cases that AVs can be deployed in the feedlot.

Workshop questions (*Try to have the follow-up questions***):**

Q1*. What tasks can automated vehicles (AVs) accomplish in the feedlot? (Autonomous vehicles in feeding, cleaning, and moving)*

Q1.1 In which task human supervision is needed for completing the task?

Q1.2 What are the potential human errors in the task?

Q1.3 What are the consequences if the operator cannot accomplish the task? (business loss, product lost, etc.)

Q2. What are barriers existing to using AV to be incorporated as a part of feedlot operation systems? Some examples can be technical limitations, connectivity, electric vehicle range, trained human resources

Q3. Who are the regulators in your field for the tasks in which AVs can be involved? (Example SafeWork Australia)

Q4. Who are the insurers in feedlots? Ask

Q4.1 What expectations and support do you feel are needed from the insurer for operating an AV in the feedlots?

Q4.2 How about the risk associated with the task given to an AV?

Q5. What role should MLA play to make AV more accessible in feedlots?

A.3 Specific Legislation Requirement for Plant Reported from Queensland Government (WorkSafe Queensland 2022b)

Specific legislative requirements for plant		
Powered mobile plant – general control of risk	The person with management or control of powered mobile plant at a workplace must manage the associated risks to health and safety	WHS Regulation 2011, s214
Safe work method statements	Safe work method statements are required for all high risk construction work, including any construction work that is carried out in an area at a workplace in which there is any movement of powered mobile plant	WHS Regulation 2011, s299
Powered mobile plant – specific control measures	The person with management or control of powered mobile plant at a workplace must ensure: • that a suitable combination of operator protective devices are provided, maintained and used • that no person other than the operator rides on the plant unless they are provided with the same level of protection as the operator • that the plant does not collide with pedestrians or other powered mobile plant • that where there is a risk of collision, that the plant has a warning device to warn other persons of the risk	WHS Regulation 2011, s215
Plant that lifts and suspends loads	The person with management or control of the plant at a workplace must ensure that the plant used is specifically designed to lift or suspend the load or, if that is not reasonably practicable, that the plant does not cause a greater risk to health and safety than if specifically designed plant were used. Additional requirements apply for plant not specifically designed to lit or suspend a person	WHS Regulation 2011, s219
Plant not specifically designed to lift or suspend a person	The person with management or control of plant at a workplace must ensure that: • persons are lifted or suspended in a work box that is securely attached to the plant • the persons within the work box remain substantially within the work box • if there is a risk of a fall from a height, that a safety harness is worn • a means of safe exit is provided in the event of a failure in its normal operation	WH Safety Regulation 2011, s220
Preventing unauthorised alterations of interference	The person with management or control of plant at a workplace must prevent alterations to or interference with the plant that are not authorised by the person	WHS Regulation 2011, s205
Proper use of plant	The person with management or control of plant at a workplace must take steps to ensure the plant is only used for the purpose for which it is designed, except where it is determined by a competent person that there is no additional risk to health and safety	WHS Regulation 2011, s206
Proper use of plant controls	The person with management or control of plant at a workplace must take steps to ensure that all safety features and warning devices are used in accordance with instructions, including guarding, operational controls, emergency stops and warning devices	WHS Regulation 2011, s206
Plant not in use	The person with management or control of plant at a workplace must ensure that plant not in use is left in a state that does not create a risk to the health and safety of any person	WHS Regulation 2011, s207
Guarding	The person with management or control of plant must ensure that: • guarding is appropriately fixed (e.g. permanent barrier, interlocked barrier, requiring tools to remove) • is of a solid construction • makes bypassing or disabling as difficult as is reasonably possible. • Guarding must also be of a kind that can be removed to allow maintenance and cleaning at any time that it is not in normal operation	WHS Regulation 2011, s208

Guarding and insulation against heat and cold	• The person with management or control of plant must ensure that any pipe or other part associated with heat or cold is guarded or insulated to eliminate risks to health and safety	WHS Regulation 2011, s209
Operational controls	The person with management or control of plant at a workplace must ensure that operator's controls are: • identified so as to indicate their nature and function • located so that they are readily and conveniently operated • located or guarded to prevent unintentional activation • able to be locked off. • Additional requirements apply when performing maintenance	WHS Regulation 2011, s210
Emergency stop controls	If the plant includes an emergency stop control, the person with management or control of the plant must ensure: • it is prominent, clearly and durably marked and immediately accessible to each operator • any handle, bar or push button is coloured red. • it cannot be adversely affected by electrical or electronic circuit malfunction	WHS Regulation 2011, s191 and s211
Warning devices	Where an item of plant includes or requires a warning device, the person with management or control of the plant must ensure the device is positioned to ensure it will work to its best effect	WHS Regulation 2011, s212
Maintenance and inspection of plant	Plant maintenance, inspection and testing must be carried out by a competent person. Maintenance, inspection and testing must be carried out: in accordance with the manufacturer's recommendations, or if there are no manufacturer's recommendations, in accordance with the recommendations of a competent person, or in the absence of either of the above, annually	WHS Regulation 2011

Source: https://www.worksafe.qld.gov.au/safety-and-prevention/hazards/workplace-hazards/construction/mobile-plant

A.4 Safety Risk Assessment Checklist

The safety risk assessment checklist is a detailed study of potential hazards and consequences related to the operation of Automated vehicles, as outlined in Section **Error! Reference source not found.**. A rank is applied for both the likelihood and consequence for each hazard identified in Figure A-1. The final risk score is the multiplication of the consequence and likelihood scale depicted in Figure A-2. Hazard control measures can reduce the risk score by either reducing the likelihood of a hazard occurring or reducing the consequence should the risk be realised. In practice, steps to reduce likelihood should be prioritised over a reduction in consequence. The safety risk assessment checklist is presented in Table A-1.

Figure A-1 Hazard likelihood and consequence tables

Consequence table

	Consequence				
	1	2	3	4	5
Safety	Ailments not requiring medical treatment	Minor Injury	1 serious injury causing hospitalisation or multiple minor injuries	1 life threatening injury or multiple serious injuries causing hospitalisation	1 death or multiple life threatening injuries
Reputation	Self-improvement review	Internal reviews required to reverse decline in reputation	Scrutiny required in the form of external reviews and/or investigations	Intense public, political and media scrutiny e.g. parliamentary enquiry or legal action	Complete loss of integrity with key stakeholders e.g. would result in loss of funding
Financial	< $50,000	$50,001 - $250,000	$250,001 - $2M	$2M - $10M	> $10M
Organisational Objectives	Very little consequence to achievement of objective	Would require some adjustment to achieve objective	would require significant adjustment to achieve objective	Would threaten achievement of the objective	Would stop achievement of the objective

Likelihood scale

Likelihood	5	Almost Certain	Expected in most circumstances. Has occurred on an annual basis in the past or circumstances are in train that will cause it to happen
	4	Likely	Has occurred in the last few years or has occurred recently in other similar organisations or circumstances have occurred that will cause it to happen in the short term.
	3	Possible	Has occurred at least once in our history or is considered to have a 5% chance of occurring in the current planning cycle.
	2	Unlikely	Has never occurred in our past but has occurred infrequently in other similar organisations or is considered to have around a 1% chance of occurring in the current planning cycle.
	1	Rare	Exceptional circumstances only. Is possible but has very much less than a 1% chance of occurring in the current planning cycle.

It is essential to note that the safety risk assessment checklist list should not remain static. New hazards may be identified or become obsolete, while the likelihood and consequence may also shift.

Figure A-2 Final Risk Score Table

			Consequence				
			1	2	3	4	5
			Insignificant	Minor	Moderate	Major	Catastrophic
Likelihood	5	Almost Certain	5	10	15	20	25
	4	Likely	4	8	12	16	20
	3	Possible	3	6	9	12	15
	2	Unlikely	2	4	6	8	10
	1	Rare	1	2	3	4	5

Low	Medium	High	Extreme

A.5 Traffic Management Plan Toolbox

Onsite traffic management self-assessment tool

Between 2014-2016, 10 workers died from being hit or trapped by mobile plant in Queensland. Additionally, there were 1,200 accepted workers' compensation claims for serious injuries during the same period. Don't let this happen in your workplace.

Traffic management planning

Planning is the first step to ensure work is done safely. A traffic management plan (TMP) details how the risks associated with plant and vehicle traffic are being managed in a workplace. Plans should be regularly monitored and reviewed to ensure they are effective and account for changes in the workplace.

A traffic management consultative team consisting of management, health and safety representatives, safety advisors/officers, workers, contractors and others in the supply chain should be actively involved in planning, developing, monitoring and reviewing traffic management plans.

How to use this tool

This self-assessment tool will assist in reviewing the effectiveness and adequacy of your existing risk management approach for vehicle and mobile plant traffic movements at your workplace. It will also help generate ideas and opportunities to improve your practices.

The self-assessment should be undertaken in consultation with members of your traffic management consultative team.

Once you have completed the self-assessment, refer to **appendix one** for more information about onsite traffic management, including links to guidance material that may assist in addressing any areas where you responded 'no'. Alternatively, contact Workplace Health and Safety Queensland (WHSQ) on **1300 362 128** if you would like a visit from a local inspector/advisor to help you with your onsite traffic management.

Workplace details	
Date of assessment:	
Workplace location and area:	
Person/s conducting self-assessment:	

Queensland Government

A.6 Incident Management Plan Examples

vicroads
ABN 61 760 960 480

ADS trial – serious incident report

This form must be completed when notifying VicRoads of any serious incidents as required as a condition of the Automated Driving System (ADS) permit. Please complete all relevant fields below. If not applicable, please enter **N/A**. If details are unknown please enter **unknown**.

You must specify the nature of the incident and identify all parties and vehicles involved. Any damage to property or injury to persons as a result of the incident, must be recorded and photos included where available.

For an incident that does not result in property damage or injury to persons, you must explain the nature of the incident, what impact it has on the performance of the automated driving system, and provide information regarding any corrective action that has been undertaken following the incident to prevent a reoccurrence.

Please print within the space provided. If you need to include additional information, please specify this in the relevant section and provide as an attachment. This form and any attachments must be submitted to VicRoads at cavtesting@roads.vic.gov.au within 24 hours of becoming aware of a serious incident.

Further information regarding serious incidents and your obligations can be found in the Victorian Guidelines for Trials of Automated Vehicles (Guidelines). Additional copies of this form can be found on the VicRoads website.

Type of serious incident (involving an automated vehicle)

Tick all that apply.

- ☐ Accident
- ☐ Traffic light offence (refer to Part 6 of the Road Safety Road Rules 2017)
- ☐ Give way offence (refer to Part 7 of the Road Safety Road Rules 2017)
- ☐ Railway or tramway level crossing offence (refer to Part 10 of the Road Safety Road Rules 2017)
- ☐ Failure of the automated driving system that would impair the reliability, security or operation of the automated driving system
- ☐ Tampering with, unauthorised access to, modification of, or impairment of the automated driving system
- ☐ Automated vehicle stolen or carjacked
- ☐ Speeding offence

ADS permit information

ADS permit holder name		ADS permit reference	
ADS permit holder address			
Phone number		Email	

Automated vehicle information

Make		Model		Year	
Registration number/Unregistered Vehicle Permit (UVP) number		Registration/UVP jurisdiction			
Vehicle Identification Number (VIN)/Chassis Number					

Vehicle supervisor details

Name of vehicle supervisor at time of incident			
Driver licence number		Jurisdiction/Country of issue	