SAFETY ASSURANCE FOR AUTOMATED DRIVING SYSTEMS CONSULTATION REGULATION IMPACT STATEMENT

May 2018

NTC AUSTRALIA
National Transport Commission

Report outline

Title	Safety Assurance for Automated Driving Systems: Consultation Regulation Impact Statement
Type of report	Regulation Impact Statement
Purpose	For public consultation
Abstract	This Consultation Regulation Impact Statement outlines three key problem risks that need to be addressed to ensure the safe commercial deployment of automated vehicles in Australia. It also identifies and assesses the relative costs and benefits of four options to address the key problem risks. Finally, this paper invites public submissions on the analysis of options and sets out the next steps towards developing a decision Regulation Impact Statement in November 2018.
Submission details	Submissions will be accepted until Monday 9 July 2018 online at www.ntc.gov.au or by mail to: Attn: Automated Vehicle Team National Transport Commission Level 3/600 Bourke Street Melbourne VIC 3000
Key words	Automated driving systems, automated driving system entities, automated vehicles, costs benefit analysis, primary safety duty, Regulation Impact Statement, safety assurance system, sanctions and penalties, Statement of Compliance.
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How to make a submission

Who can make a submission?

Any individual or organisation can make a submission to the National Transport Commission (NTC).

How to submit

To make an online submission please, visit the NTC homepage (www.ntc.gov.au) and select 'Submissions' from the top navigational menu.

Alternatively, you can mail your comments to:

Attn: Automated Vehicle Team
National Transport Commission
Level 3/600 Bourke Street
Melbourne VIC 3000

Publication of submissions

Unless submissions clearly request otherwise, all submissions will be published on the NTC's website. Submissions that contain defamatory or offensive content will not be published. The *Freedom of Information Act 1982* (Cwlth) applies to the NTC.

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Introduction

Automated vehicles are vehicles that include an automated driving system (ADS) that is capable of monitoring the driving environment and controlling the dynamic driving task (steering, acceleration and breaking) with limited or no human input. Automated vehicles promise significant safety and mobility benefits but potentially introduce new road safety risks.

Australia's existing laws and regulations do not recognise automated vehicles or provide assurances of their safe design or operation. Overseas, governments are considering automated vehicle safety assurance, but there is not currently an international consensus approach.

The purpose of this Consultation Regulation Impact Statement (RIS) is to examine the potential problem of automated vehicle safety and assess any government response. The National Transport Commission (NTC) has prepared this Consultation RIS to facilitate consultation with the community to gather evidence on four safety assurance options to address the anticipated risks of commercial deployment of automated vehicles. The RIS seeks to answer:

- What is the role of the Australian Government in assuring the safety of ADSs?
- What is the form of the regulatory system (if any) that underpins this role (the 'safety assurance system')?

Decisions made to date on safety for automated vehicles

In 2017 the NTC consulted on high-level approaches to safety for automated vehicles. Government and industry stakeholders indicated broad support for a safety assurance system based on mandatory self-certification by the entity that is looking to bring the technology to the Australian market (the automated driving system entity or 'ADSE'). In November 2017 transport ministers asked the NTC to develop a RIS to assess the costs and benefits of a mandatory self-certification approach.

Automated vehicle safety – what is the problem?

Under our current regulatory environment, there are risks that when automated vehicles become ready for deployment:

1. ADSs will fail to deliver reasonable safety outcomes.
2. A lack of consumer confidence in the safety of ADSs will reduce or delay their uptake
3. ADSEs will face inconsistent and/or uncertain regulatory barriers to the supply of ADSs in the Australian market.

These risks may need to be addressed to support the uptake and safe operation of automated vehicles on Australian roads and unlock their broader benefits.

Options to address the problem

This Consultation RIS assesses four options to address the problem statement. They are:

- Option 1: Current approach – This is the baseline option, using existing legislation and regulatory instruments, with no explicit regulation of ADSs.
- Option 2: Administrative safety assurance system – A safety assurance system based on mandatory self-certification that relies on existing legislation and regulatory instruments. The safety assurance system will be implemented through administrative means.

- Option 3: Legislative safety assurance system – A safety assurance system based on mandatory self-certification. This would include new or amended legislation to allow for the inclusion of specific offences and compliance and enforcement options, and a regulatory agency with responsibility for administering automated vehicle safety.
- Option 4: Legislative safety assurance system + primary safety duty – A safety assurance system that includes all of the elements of option 3, plus a primary safety duty on ADSEs.

Safety assessment criteria

Options 2, 3 and 4 require companies to self-certify their ADSs. The NTC is proposing 11 safety criteria that the applicant must self-certify against, to demonstrate its processes for managing safety risks:

1. Safe system design and validation processes
2. Operational Design Domain
3. Human Machine Interface
4. Compliance with relevant road traffic laws
5. Interaction with enforcement and other emergency services
6. Minimal risk condition
7. On-road behavioural competency
8. Installation of system upgrades
9. Testing for the Australian road environment
10. Cybersecurity
11. Education and training

The NTC is proposing three other obligations on ADSEs to manage liability for events such as road traffic law breaches and crashes:

1. Data recording and sharing
2. Corporate presence in Australia
3. Minimum financial requirements

Assessing the reform options

There is uncertainty around:

- the level and nature of the risks posed by automated vehicles
- the future world in which the regulatory framework will operate
- the impacts of the options themselves.

Given the degree of uncertainty and lack of relevant information, a quantitative cost-benefit analysis was not possible. Instead, the assessment is based on qualitative information around key impact categories and assessment criteria. The options were assessed against five impact categories:

- Road safety
- Uptake of automated vehicles
- Regulatory costs to industry
- Costs to governments
- Flexibility and responsiveness

Our assessment concludes that:

- Option 4 exhibits the most positive impacts, with large improvements to road safety and flexibility and responsiveness impacts, and moderate improvements to uptake of automated vehicles.
- Option 3 presents similar results but somewhat lesser improvements to road safety and flexibility and responsiveness impacts compared with option 4. Option 3 does, however, present somewhat greater certainty around regulatory costs than option 4.
- Option 2 exhibits similar impacts to option 3 but to an equal or lesser extent in all impact categories.
- Options 2, 3 and 4 all result in an overall benefit relative to option 1.

We also tested the materiality of two benefit categories to broadly indicate a relative weighting of the benefits versus the possible expected costs. These materiality tests found that, under a range of plausible assumptions, an effective safety assurance approach will provide:

- significant road safety benefits in terms of reducing the number and severity of road crashes
- significant economic benefits resulting from earlier and higher uptake of automated vehicles.

Given the relative strength of the possible road safety benefits, the overall assessment of options should be viewed with a heavier weighting towards those options that deliver the greatest road safety benefits.

What is the preferred option?

Based on a set of conditions and preferences that are most likely to eventuate, we have identified option 4 as the preferred option. Option 4 strikes a reasonable balance to address the identified problem, such as the need to:

- ensure that automated vehicles entering the Australian vehicle fleet are reasonably safe to avoid the potentially high social cost of poor road safety outcomes
- provide users with reassurance that automated vehicles are reasonably safe so that a lack of confidence does not become a barrier to the uptake of automated vehicles
- create a suitable regulatory environment that is flexible and responsive and does not impose unreasonable costs so that ADSEs can enter the Australian market.

It is possible that the relative benefits and costs of the options will change as the future unfolds and existing uncertainties become resolved.

This Consultation RIS tests this preferred option under a range of different deployment scenarios. The RIS also sets out the relevant conditions under which other options might perform better.

Consultation

We will update our analysis and re-assess this preferred option based on any new information provided as part of the consultation process for this RIS. We will prepare a decision RIS for the consideration of transport ministers in November 2018.

Any individual or organisation can make a submission to the NTC by **Monday 9 July 2018**.

1 Context

Key points

- Automated vehicles will soon be available for commercial deployment in Australia.
- Automated vehicle technology is new and emerging, with significant uncertainties and potential risks.
- Automated vehicle technology has the potential to deliver significant road safety and other benefits.
- Australia's existing laws and regulations do not recognise automated vehicles or ensure their safety or safe operation.
- Automated vehicle safety assurance is being considered in markets around the world, but there is no international consensus.

This chapter details some of the expected benefits and risks of automated vehicles, outlines the Government's approach to creating a regulatory framework, and introduces the policy work to date to develop a safety assurance system for automated vehicles. The chapter ends with information about this Consultation Regulation Impact Statement (RIS) and some key terms and concepts that will feature in the document.

1.1 Introduction – what are automated vehicles?

Automated vehicles are vehicles that include an automated driving system (ADS) that is capable of monitoring the driving environment and controlling the dynamic driving task (steering, acceleration and breaking) with limited or no human input.

This could include:

- vehicles based on existing models, with automated functions
- new vehicle types with automated functions
- after-market devices or software upgrades that add automated driving functions to existing vehicles.

New vehicles with high levels of automation are expected to arrive on our roads from 2020. These vehicles will increasingly take control of the driving task away from human drivers in certain circumstances and environments.

Automated vehicles promise major safety and community benefits and offer the possibility of fundamentally changing transport and mobility. However, the supply and use of automated vehicles also raises new risks.

Australia's transport ministers, through the Transport and Infrastructure Council (the Council)[1] have 'agreed that Australian governments will aim to have end-to-end regulation in place by 2020 to support the safe deployment of automated vehicles' (Transport and Infrastructure Council, 2017, p. 3).

[1] The Transport and Infrastructure Council brings together Commonwealth, state and territory and New Zealand ministers with responsibility for transport and infrastructure issues, as well as the Australian Local Government Association.

1.2 Background

1.2.1 Road crashes in Australia

Human error and dangerous human choices cause up to 94 per cent of serious crashes (National Highway Traffic Safety Administration, 2015, p. 1).[2]

In 2017 there were 1,225 deaths on Australian roads from 1,131 road crashes (BITRE, 2018, p. 1). There is currently no nationally consistent road crash injury data in Australia due to state/territory methodological differences; however, a 2017 research report estimated that there were 32,300 serious injuries that resulted in hospitalisation and 224,104 minor injuries sustained from road crashes in 2016. There were also an additional 453,552 crashes that resulted in only property damage (Litchfield, 2017, p. 19).

Road crashes have a major impact on Australians. They result in a number of costs for individuals and society, including:

- costs to individuals and their families associated with death or rehabilitation and care
- costs on other road users associated with clean up and any resulting delays
- costs for society more broadly from death and injury of members of the public
- costs to productivity from lost workforce participation due to death or injury.

The total social cost of road crashes in Australia for 2016 was estimated at $33.16 billion. This estimate includes:

- $10.2 billion in fatality costs (based on an average cost per fatality of $7.8 million)
- $13.58 billion in injury costs (based on an average cost per serious injury of $310,094 and $3,057 per minor injury)
- $9.38 billion in property damage costs (inclusive of $5.54 billion in vehicle repair costs, $2.29 billion in insurance administrative costs, $1.55 billion in travel delay costs) (Litchfield, 2017, p. 22).

All Australian governments have committed to reduce fatal and serious injury crashes on Australian roads. This commitment is expressed through the *National Road Safety Strategy*, which identifies 'improving the safety of our vehicle fleet' as a key activity (Transport and Infrastructure Council, 2014, p. 5).

1.2.2 Benefits and risks of automated vehicles

While the quantification of the benefits and risks of automated vehicles is fundamentally uncertain, research suggests that, overall, automated vehicles are expected to improve road safety, travel times, highway and intersection capacity, fuel efficiency, emissions per kilometre, travel choices, mobility, accessibility and opportunities for sharing (Milakis, et al., 2017, p. 324).

Arguably, the most significant anticipated benefit of increasing vehicle automation is improved safety. Automated vehicles will reduce human errors or potentially eliminate them completely. As such, the uptake of increasingly automated vehicles is widely considered an emerging opportunity to improve the safety of the Australian vehicle fleet (see Appendix G for evidence of the expected benefits of automated vehicles).

Automation of the vehicle fleet is also expected to affect ways in which products and services are offered, delivering more compelling products, better applications for consumers and new revenue streams for companies. Additionally, increasingly automated vehicles

[2] Data from the United States in the National Motor Vehicle Crash Causation Survey.

could facilitate the anticipated switch from traditional car ownership models to a shared driverless model, which could reduce the costs of travel by up to 78 per cent on a per mile basis (based on US modelling) (Accenture Digital, 2014, p. 4).

However, these expected benefits will be predicated on consumer uptake of automated vehicles, which is currently uncertain. The appetite for automated vehicles will be driven by:

- how safe they are
- cost
- the extent that they provide other benefits such as enhanced mobility and more productive road networks
- the flexibility of regulatory regimes
- the evolution of innovative mobility business models
- the uptake of complementary innovations such as connectivity, electrification and sharing mobility.

Many identified impacts – such as impacts on fixed vehicle costs, congestion, travel comfort, transport infrastructure, overall energy consumption and air pollution, public health and the jobs and investment – are uncertain (Milakis, et al., 2017, p. 325).

The supply and use of automated vehicles also raises new risks, and these are heightened due to the new and emerging nature of the technology. For example, safety engineers anticipate that systemic technical errors, or failure to properly maintain and service the ADS, could become significant hazards, akin to human error (Kira, 2017, pp. 7, 17).

The automotive industry has noted that 'before the safety and environmental benefits of automated and connected vehicles can be realised a number of matters need to be considered – one of the most important of which is the regulatory environment' (Federal Chamber of Automotive Industries, 2017, p. 4). The Government's regulatory approach is discussed below.

1.2.3 Regulatory environment

Governments currently regulate road transport to ensure safety and security outcomes. Current transport regulations cover vehicle standards, the operation and roadworthiness of vehicles and driver licensing. General consumer and product liability laws provide additional consumer protections.

Motor vehicle safety laws and regulations are shared between the Commonwealth government and state and territory governments. The Commonwealth government administers the *Motor Vehicle Standards Act 1989* and the Australian Design Rules (ADRs) to control the safety of new and imported vehicles at the point of first supply. State and territory governments administer licensing, registration and roadworthiness (via in-service vehicle standards). Finally, the National Heavy Vehicle Regulator administers the Heavy Vehicle National Law (HVNL) and is responsible for regulating the in-service heavy vehicle standards. These laws and regulations are described further in Appendix D.

Current Australian transport legislation assumes there is a human driver. It does not provide for an ADS to be in control of the vehicle, rather than a human driver.

1.2.4 National reform program for automated vehicles

To unlock the benefits and manage the risks associated with introducing automated vehicles, Australian governments will aim to have end-to-end regulation in place by 2020. Such regulation will provide 'a flexible approach while automated technology continues to progress and international standards are being developed' (Transport and Infrastructure Council, 2017, p. 3).

The Council has agreed to a phased national regulatory reform program led by the NTC, to facilitate the introduction of light and heavy vehicles with greater levels of automation onto Australian roads. The NTC's national reform program includes reforms aimed at supporting trials and demonstrations of existing automated technology:

- **Automated vehicle trial guidelines** (completed May 2017): Developing national guidelines to govern conditions for trials of vehicles with automated functions (National Transport Commission, 2017a).
- **Automated vehicle exemption powers review:** Supporting state and territory governments in reviewing current exemption powers to ensure legislation can support on-road trials.
- **Clarifying control of automated vehicles** (completed November 2017): Developing national enforcement guidelines to clarify regulatory concepts of *control* and *proper control* for automated vehicles (National Transport Commission, 2017d).

The program also includes four reforms intended to develop the end-to-end regulatory approach for commercial deployment of automated vehicles:

- **Safety assurance system for automated vehicles:** The subject of this RIS.
- **Changing driving laws to support automated vehicles:** Developing legislative reform options to clarify the application of current driving laws to vehicles with automated functions, and to establish legal obligations for automated driving system entities (ADSEs). We will submit reform options to the Council in May 2018.
- **Automated compulsory third party insurance review:** Reviewing motor accident injury insurance schemes to identify any eligibility barriers for occupants of an automated vehicle, or those involved in a crash with an automated vehicle.
- **Regulating government access to C-ITS and automated vehicle data:** Developing options to manage government access to cooperative intelligent transport systems (C-ITS) and automated vehicle data that balance road safety and network efficiency outcomes and efficient enforcement of traffic laws with sufficient privacy protections for automated vehicle users. We will submit recommendations to the Council in May 2019.

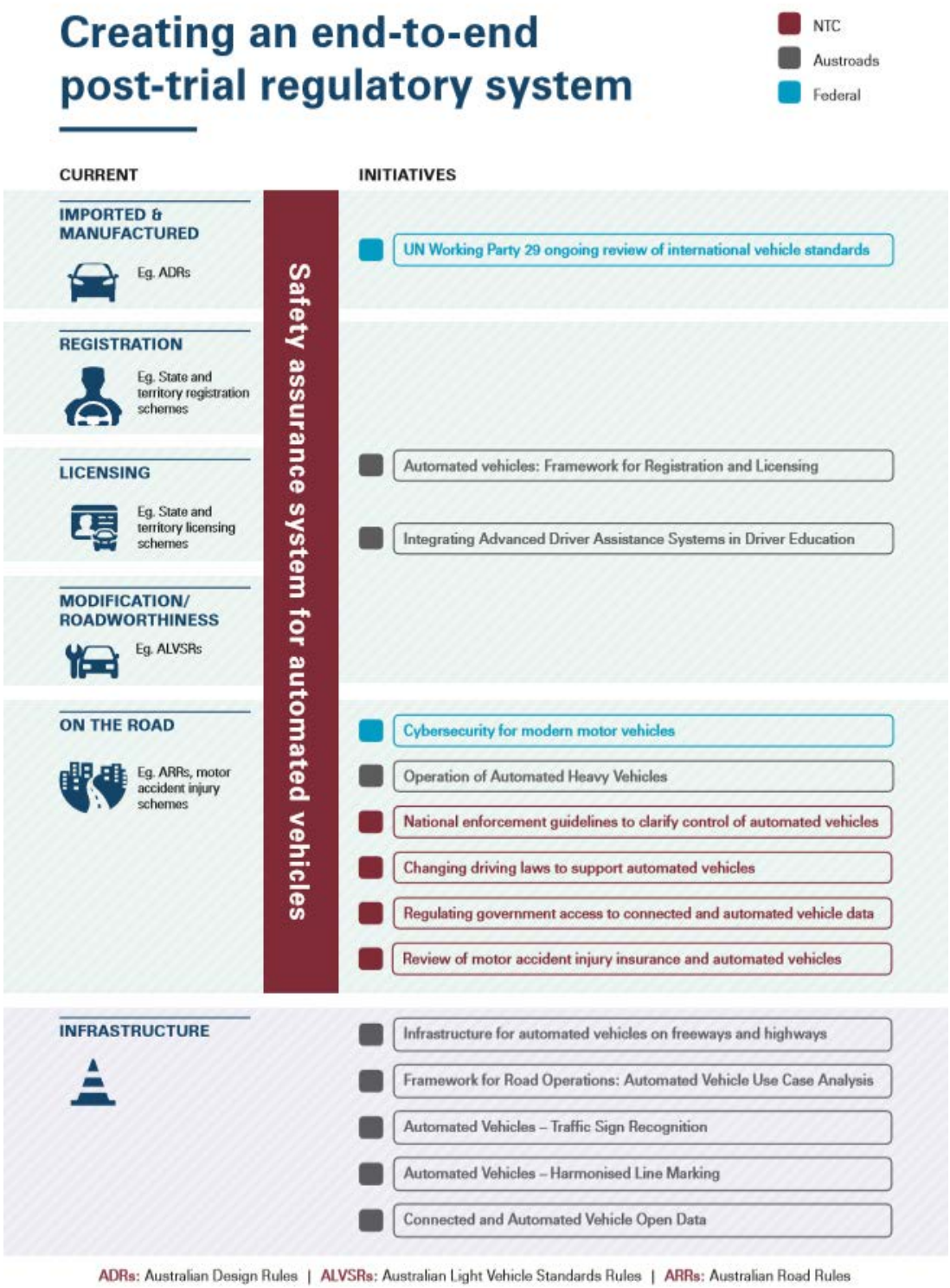
In addition to these NTC projects, the following work is being undertaken by other agencies:

- The Commonwealth Department of Infrastructure, Regional Development and Cities (DIRDAC) continues to participate in developing new and updated United Nations vehicle standards and are participants in UN Working Party 29 on the harmonisation of vehicle regulations.
- Austroads is undertaking a project to assess how registration and licensing operations can best be aligned with a safety assurance system. Austroads' assessment suggests that the impacts on registration and licensing are likely to be minimal, given that the safety assurance system will operate nationally and not through registration processes. However, registration databases, including information available on the National Exchange of Vehicle and Driver Information System, could capture essential information about the ADS. The NTC notes that detailed work will be undertaken by a national registration working group in 2018 to finalise new registration fields.
- Every state and territory in Australia is supporting and is involved in trials and demonstrations of connected and automated vehicles (Austroads, 2017a).

The NTC continues to collaborate closely with the Commonwealth, state and territory governments, local governments and Austroads to ensure an integrated regulatory system for deploying vehicles with automated functions can be delivered.

Figure 1 shows the existing end-to-end regulatory process and the projects underway at each stage to prepare for more vehicles with automated functions.

Figure 1. End-to-end regulatory process and projects



These initiatives are focused on ensuring Australia can maximise the potential opportunities and benefits that come with more automated vehicles. A nationally consistent approach will also reduce costs, provide certainty to industry, promote innovation and competition and ensure that Australians have early access to the newest technologies.

1.2.5 The safety assurance system for automated vehicles project

The safety assurance system for automated vehicles reform is intended to examine the role of governments in automated vehicle safety. In November 2016 transport ministers agreed that the NTC should 'develop a national performance-based assurance regime designed to ensure the safe operation of automated vehicles.' Ensuring that automated vehicles can operate safely on Australian roads under Australian conditions is a key step in allowing greater numbers of these vehicles.

In June 2017 the NTC published a discussion paper, *Regulatory options to assure automated vehicle safety in Australia*. The paper consulted on four regulatory options for safety assurance (Figure 2):

1. **Continue the current approach** – no additional regulatory oversight, with an emphasis on existing safeguards in Australian Consumer Law and road transport laws.
2. **Self-certification** – manufacturers make a Statement of Compliance against principles-based safety criteria developed by government. This could be supported by a primary safety duty to provide safe automated vehicles.
3. **Pre-market approval** – ADSs are certified by a government agency as meeting minimum prescribed technical standards prior to market entry.
4. **Accreditation** – an accreditation agency accredits ADSEs. The accredited party demonstrates it has identified and managed safety risks to a legal standard of care (National Transport Commission, 2017b, p. 70).

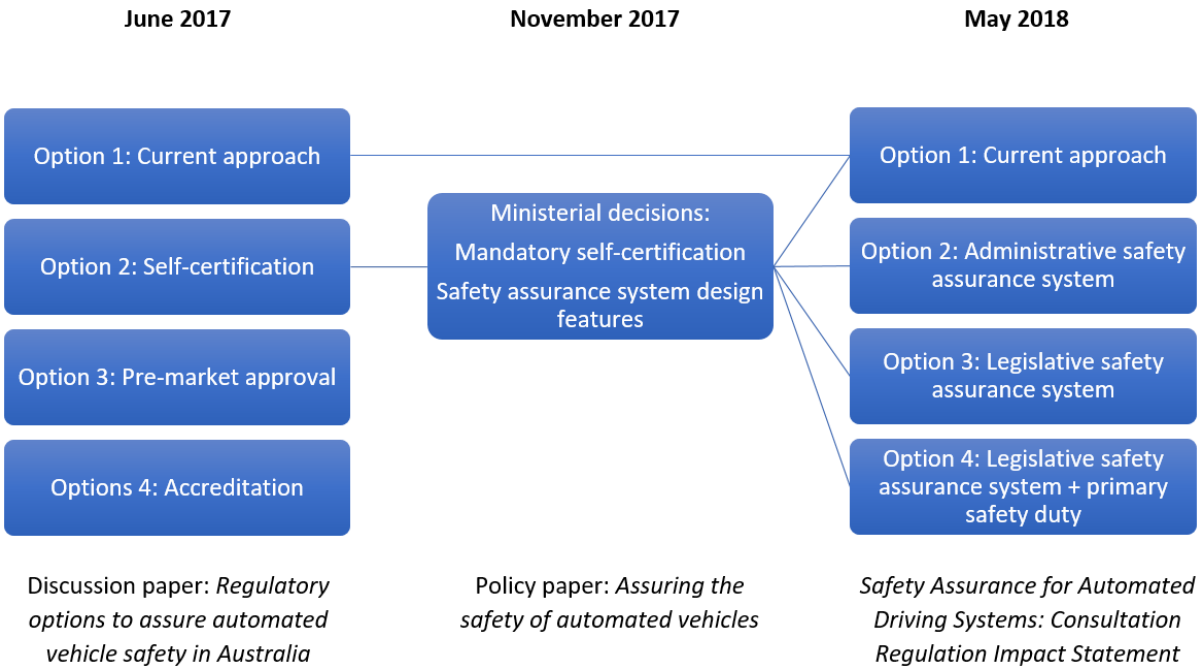
We received 27 submissions to the discussion paper, including submissions from road and transport agencies, manufacturers, automobile clubs, insurers and law firms.[3] Submissions clearly indicated that the community expects governments to have a role in ensuring automated vehicles are safe. There was also strong support for a mandatory self-certification approach.

Following consultation and after consideration of the various policy complexities, we released the policy paper, *Assuring the safety of automated vehicles*. This paper recommended – subject to assessing benefits and costs – a mandatory self-certification approach to ensuring automated vehicle safety, with consideration of a primary safety duty (National Transport Commission, 2017c, p. 3). The mandatory self-certification model is designed to provide assurance to the government and the community that companies developing automated driving technology are managing safety risks appropriately while also allowing for ongoing innovation. The liability/responsibility for safety would still remain with the vehicle manufacturer or the ADSE.

In November 2017 the Council agreed to this recommendation.

[3] Publicly available submissions to the safety assurance system are available on the NTC website at: https://www.ntc.gov.au/current-projects/safety-assurance-system-for-automated-vehicles/.

Figure 2. Safety assurance system for automated vehicles project



The safety assurance system is part of the broader national reform program for automated vehicles outlined above. Importantly, the safety assurance system is being developed in conjunction with the changing driving laws reform project which, among other things, will specify the situations in which an ADS may drive a vehicle in place of a human driver.[4] Driving laws will only be changed to allow this when the approach to safety is clear. This will provide certainty that allowing an ADS 'driver' will not result in unsafe vehicles operating on public roads.

1.2.6 Design features of the proposed safety assurance system

Our November 2017 policy paper, *Assuring the safety of automated vehicles*, presented the design features of a proposed safety assurance system outlined in Table 1 (National Transport Commission, 2017c, p. 2) subject to an assessment of costs and benefits.

Table 1. Design features of the proposed safety assurance system

1. The safety assurance system will be administered by a government authority, preferably on a national basis. Approval decisions may be made on the advice of a single national government panel consisting of the Commonwealth, states and territories, the NTC, the National Heavy Vehicle Regulator and Austroads.
2. The safety assurance system will manage principles-based safety criteria that capture key safety risks associated with automated vehicles. The safety criteria should include matters relating to:
    - the safe operational design domain of the vehicle
    - the human–machine interface
    - on-road behavioural competency, including compliance with traffic law, interaction with vulnerable road users
    - cybersecurity

[4] Information on the 'Changing the driver laws to support automated vehicles' project is at http://ntc.gov.au/current-projects/changing-driving-laws-to-support-automated-vehicles/.

- driver training
- the provision of data, including interaction with enforcement agencies.

3. ADSEs (such as manufacturers) will be required to submit a Statement of Compliance that demonstrates how each of the agreed safety criteria has been managed. A Statement of Compliance must be submitted and approved before the relevant ADS or function can be introduced into the market.
4. The ADSE remains responsible for testing and validating the safety of the ADS or function. The role of government in the safety assurance system is to satisfy itself that the applicant has processes in place to identify and manage the safety risks. It is not envisaged that the safety assurance process will conduct independent testing or validation activities.
5. To support national consistency and cross-border travel, state and territory road managers will be notified of a safety assurance outcome, but approval of a road manager should not be required for the ADS to operate unless the ADS forms part of a vehicle that would otherwise require a permit or exemption to access the road network. This is consistent with the current arrangements for new light vehicles.
6. All in-service modifications to the ADS that have a significant impact on safety performance or material compliance with the original safety assurance system approval, including over-the-air software updates of the vehicle, are anticipated to require approval by the safety assurance system before that significant modification is introduced into the market.

To meet the design features, the safety assurance system should, subject to the cost-benefit analysis, be based around an initial and continuing safety assurance process of:

- initial safety assurance – which involves the ADSE demonstrating compliance against a set of safety criteria for an ADS type on a case-by-case basis
- continuing safety assurance – which involves the ADSE ensuring that the ADS continues to comply with the safety requirements.

The proposed safety criteria that ADSEs must self-certify against are outlined in chapter 4.

The safety assurance system is intended to apply only to ADSs that are responsible for the dynamic driving task (see section 1.4 for definitions of key terms), and any significant modifications to ADSs.

The design of the safety assurance system ensures that it does not capture driver assistance technologies such as automated electronic braking and lane-keeping technologies that are already available on the market today.

This RIS will examine the costs and benefits of options to implement such a safety assurance system.

1.2.7 International developments

Our discussion paper *Regulatory options to assure automated vehicle safety in Australia* outlined a number of international developments relating to the regulation of vehicles with automated functions (National Transport Commission, 2017b, p. 40; National Transport Commission, 2017c, p. 8). International approaches to regulating safety are still in the early stages of development.

There is currently no internationally agreed approach, and many national agencies are currently focused on supporting trials and developing technologies. After discussions with a broad range of national governments throughout 2017, the NTC has concluded that:

- Most national governments agree each jurisdiction must resolve automated vehicle safety regulation at a domestic level. International standards are only expected to

address the technical components to be incorporated into any domestic regulatory process.

- There is no emerging international consensus on how to assure the safety of automated vehicles, or the role of government to assure the safety of automated vehicles.

The mandatory self-certification approach agreed to by Australian transport ministers in November 2017 appears to impose greater regulatory oversight than the approach currently adopted in the United States (US) at the federal level (which favours voluntary certification, with minimal government oversight) but significantly less regulatory oversight than the direction that Germany, Japan, Korea and some US states are heading towards (who favour a pre-market approval approach). Other national governments – including France and the United Kingdom – are still formulating a policy position.

Critically, the design of the safety assurance system should enable industry to demonstrate safety by referencing approvals, tests or validation processes undertaken by other national governments if the standards and processes are commensurate with the safety expectations and requirements in Australia. In this regard, safety regulation in Australia can align with a diverse range of safety assurance processes in other countries wherever possible.

1.3 About this consultation Regulation Impact Statement

A RIS is required for all government decisions that are likely to have a measurable impact on businesses, community organisations or individuals. A RIS involves analysing the potential impacts of new policy proposals and regulatory options required for implementation, and ultimately presents an evidence base for decision making on regulatory options.

The Office of Best Practice Regulation[5] advised the NTC that a Council of Australian Governments RIS would need to be completed prior to the Transport and Infrastructure Council making a decision on the appropriate form of safety assurance for automated vehicles.

This consultation RIS uses a multi-criteria analysis approach, as full monetisation of costs and benefits is not appropriate or possible in the case of emerging automated vehicle technology. Where available, quantitative data has been used. This multi-criteria analysis approach is consistent with the Office of Best Practice Regulation's cost-benefit analysis guidelines.

We have prepared this consultation RIS to gather evidence and facilitate consultation with the community. We will use the evidence and views gathered from this consultation to prepare a decision RIS, with our final analysis of the options for a safety assurance system. We will deliver this decision RIS to the Council for decisions by November 2018.

Consultation allows individuals and organisations to express their views and contribute to robust analysis. This helps the Council determine the best approach for achieving better community outcomes as well as broader growth and productivity objectives.

1.3.1 Objectives

This consultation RIS seeks feedback on the:

- problems to be addressed
- feasibility of the policy options to mitigate the safety risks associated with deploying vehicles with ADSs
- impacts of policy options on industry, governments and the community

[5] The role of the Office of Best Practice Regulation and principles of best practice regulation are provided in the appendices.

- approaches to measuring these impacts
- conclusions on the most cost-effective solution to the identified problem
- proposed safety criteria for the Statement of Compliance.[6]

1.3.2 Scope

The scope of the consultation RIS includes assessing regulatory reform options that address identified problems. The reform options present a range of plausible approaches for a safety assurance system based on mandatory self-certification, building on earlier work and public consultations on assuring automated vehicle safety.

The consultation RIS also provides proposed safety criteria for the Statement of Compliance for public feedback.

The following areas are **outside the scope** of this paper:

- an assessment of existing or new entities that could undertake any required government agency roles in a safety assurance system (this assessment will be dependent on the option chosen and is expected to take place as part of separate work looking at institutional arrangements).
- detailed compliance and enforcement options, including sanctions and penalties (the compliance and enforcement approach will be considered once a regulatory approach is agreed in the RIS).
- a detailed analysis of how a safety assurance system would affect existing vehicle registration and driver licensing regimes (Austroads is examining this issue in parallel with the NTC's work).
- detailed project planning and implementation of a safety assurance system. (rhis assessment is expected to take place in the next phase of work once the council has agreed a preferred model).
- safety assurance of automated rail vehicles or non-standard road vehicles such as land-based drones.

1.3.3 Structure

The rest of this RIS will follow the below structure:

- a definition of the problem that proposed regulations are intended to address and the case for government intervention (chapter 2)
- a description of the options for assessment (chapter 3)
- a description of the proposed principles-based safety criteria that would form part of the safety assurance system (chapter 4)
- a description of the methodology used to assess the options (chapter 5)
- an assessment of the options (chapter 6)
- a summary of the assessment of the options, our preferred option and testing of the assessment under different deployment scenarios (chapter 7)
- details on how to provide feedback on this consultation (chapter 8).

[6] The design features of the safety assurance system agreed by the Council in November 2017 include a requirement that ADSEs submit a Statement of Compliance against principles-based safety criteria for approval before the relevant automated driving system or function, or significant modification, can be introduced into the market. This consultation RIS outlines the proposed criteria against which the ADSE will be required to submit a Statement of Compliance.

1.4 Key terms and concepts

This section outlines the key terms and concepts used in this RIS. These are largely based on the SAE International Standard J3016.

Automated vehicles are vehicles that include an 'automated driving system' capable of performing the entire dynamic driving task including steering, acceleration, braking and monitoring the driving for sustained periods of time (a more expansive definition is provided in the glossary).

Automated driving system (ADS) means the hardware and software that are collectively capable of performing the entire dynamic driving task on a sustained basis. It is a type of driving automation system used in vehicles operating in conditional, high and full automation mode.

Automated driving system entity (ADSE) means the legal entity responsible for the ADS. There will only be one ADSE for each ADS type going through a safety assurance system; that is, the ADSE is the applicant in the safety assurance process. This could be the manufacturer, operator or legal owner of the vehicle, or another entity that is seeking to bring the technology to market in Australia.

Dynamic driving task means all the operational and tactical functions required to operate a vehicle in on-road traffic.

The **levels of driving automation**[7] range from 'no automation' (level 0) in which the entire dynamic driving task is performed by the human driver, through to 'full automation' (level 5) in which all aspects of the dynamic driving task can be undertaken by the ADS on all roads at any time and no human driver is required.

Levels 0–3 describe systems that cannot undertake the entire dynamic driving task and require a human driver to perform all or part of the dynamic driving task, although they may include a driving automation system that takes control of parts of the dynamic driving task.

This consultation RIS is concerned specifically with vehicles that have ADSs (levels 3-5). For simplicity, these types of vehicles will be referred to throughout this consultation RIS as 'automated vehicles' unless a more specific clarification is warranted. Table 2 outlines an adaption of levels 3–5 SAE levels of driving automation.

Table 2. Adapted SAE levels of automation: levels 3–5

Level 3: Conditional automation
The ADS undertakes the entire dynamic driving task for sustained periods in defined circumstances. The human driver does not have to monitor the driving environment or the ADS but must be receptive to ADS requests to intervene and any system failures.
Level 4: High automation
The ADS undertakes the entire dynamic driving task for sustained periods in some situations, or, all the time in defined places. The human driver does not have to monitor the driving environment and the driving task or to intervene when the ADS is driving the vehicle.
Level 5: Full automation

[7] The levels of driving automation are based on SAE International Standard J3016, *Levels of Driving Automation*. SAE International, initially established as the Society of Automotive Engineers, is a U.S.-based, globally active professional association and standards developing organisation for engineering professionals in various industries. Principal emphasis is placed on transport industries such as automotive, aerospace, and commercial vehicles.

All aspects of the dynamic driving task and monitoring of the driving environment are undertaken by the ADS. The ADS can operate on all roads at all times. No human driver is required.

Operational design domain (ODD) means the specific conditions under which an ADS is designed to function (for example, geographic, roadway, environmental, traffic, speed, or temporal limitations), including, but not limited to, driving modes (for example, on fully access-controlled freeways).

Safety assurance system means a regulatory mechanism to provide oversight of the safety performance of an automated vehicle to assure it can operate safely on the network.

The glossary explains other technical terms used.

2 Problem statement and need for government intervention

Key points

- There are risks that ADSs will fail to deliver reasonable safety outcomes.
- Current regulatory barriers are insufficient to manage these risks. Without sufficient regulation, poor-quality systems could be introduced into the market, resulting in avoidable crashes.
- If consumers lack confidence in the safety of automated vehicles, this will reduce or delay their uptake.
- The supply of ADSs in the Australian market could be delayed if manufacturers or ADSEs face inconsistent and/or uncertain regulation.
- The presence of these market and regulatory failures, and the expectations of Australian communities and industry to address them, show that government intervention is warranted.

This chapter outlines the problem the consultation RIS seeks to address and demonstrates the need for government intervention to address it.

2.1 The problem

In our current regulatory environment, when automated vehicles become ready for deployment there are risks that:

- ADSs may fail to deliver reasonable safety outcomes
- a lack of consumer confidence in the safety of ADSs may reduce or delay their uptake
- ADSEs may face inconsistent and/or uncertain regulation to supply ADSs to the Australian market.

These risks need to be addressed to support the uptake and safe operation of automated vehicles on Australian roads and unlock their broader benefits.

Each of the three parts of the problem are considered below with an outline of the available evidence.

2.2 ADSs may fail to deliver reasonable safety outcomes

Automated vehicles are widely expected to improve road safety in the future by reducing human error. However, the safety benefits, or risks, of deploying ADSs are highly uncertain. There are also new risks associated with introducing automated vehicles.[8] This includes after-market devices that could be used to add automation to existing vehicles.

ADSEs have a commercial incentive to ensure ADSs operate safely. However, there is a risk of a gap between what an ADSE believes is necessary to achieve this (in terms of automation or vehicle design) and what is socially optimal (in terms of reducing crash risk). This could eventuate for the following reasons:

[8] Appendix A provides an overview of the three types of safety risks that may arise with introducing automated vehicles.

- ADSEs, automated vehicle owners and other relevant after-market agents are unlikely to bear the full economic cost of a crash caused by an unsafe automated vehicle. Broader unaccounted for social costs (or externalities) include the cost of traffic congestion (loss of productivity for those caught in a crash), other road users' pain and suffering, emergency responder and clean-up costs, medical treatment costs, lost workforce participation and road asset damage.
- ADSEs, automated vehicles owners and other relevant after-market agents may lack the necessary skills and judgement to assess what is safe in Australian-specific road contexts, particularly initially.

Without specific safety regulation and effective after-market mechanisms (such as insurance and legal liability), there is a risk of market failure to deliver a socially desirable level of safety risk management.

2.2.1 Existing regulations to manage safety risk

Vehicle safety is currently managed via a range of regulatory tools including the ADRs and driver licensing.[9] These are outlined in Appendix D.

Automated vehicles do not fit within the current regulatory framework, which assumes a human driver. The ADRs do not yet capture automated functionality. The ADS will drive the vehicle in place of a human driver. For human drivers, driver licensing is a way of ensuring that vehicles are driven safely. There is no existing equivalent regulatory mechanism to ensure the ongoing safe performance of an ADS 'driver'. As well, there are limits on the degree to which existing after-market mechanisms will result in ADSEs and other relevant parties internalising all social costs.

2.2.2 Evidence of automated vehicle safety risk

In automated vehicle trials and in early commercial deployments of vehicles with partial automation, there have been some crashes, including a small number of fatalities.

While most of these crashes have been attributed to 'the other driver' or a third party rather than the ADS, they highlight that there are safety risks. This is particularly true in the early commercial deployment stage as automated vehicles mix with the conventional human-driven vehicle fleet and other road users.

Some high-profile cases of automated vehicle crashes are set out below. These examples demonstrate the safety risks and the need to ensure that an ADS has adequate safeguards. Other manufacturers conducting automated vehicle trials have also had safety incidents. We have selected these examples because they received significant international attention.

[9] Current regulations are supported by vehicle supplier self-regulation and a mature market where consumers can make their expectations clear through informed purchasing choices.

Tesla Model S crash – 7 May 2016

The first fatal accident involving a vehicle operating at partial automation occurred in the US state of Florida on 7 May 2016.[10] The occupant of a Tesla Model S car was killed in a crash with a truck while the car was operating in 'autopilot mode'[11] (Yadron & Tynan, 2016).

The crash occurred when the truck turned in front of the Tesla at an intersection and the car failed to apply the brakes. An investigation by the National Transportation Safety Bureau (NTSB) found that the 'truck driver's failure to yield the right of way and a car driver's inattention due to overreliance on vehicle automation are the probable cause of the fatal … crash' (National Transportation Safety Bureau, 2017). The NTSB also found that the 'automated vehicle control system was not designed to, and did not, identify the truck crossing the car's path or recognize the impending crash'. The NTSB concluded that:

> *System safeguards, that should have prevented the Tesla's driver from using the car's automation system on certain roadways, were lacking and the combined effects of human error and the lack of sufficient system safeguards resulted in a fatal collision that should not have happened. (National Transportation Safety Bureau, 2017)*

Waymo trials

Waymo (formerly Google's self-driving car project) has trialled a range of automated vehicles in the US. Over eight years they have driven more than eight million kilometres on public roads and across four states.

Between February 2015 and August 2017, Google (and Waymo) filed 25 traffic accident reports to the Californian Department of Motor Vehicles for incidents involving automated vehicles (State of California Department of Motor Vehicles, 2017). Only one of these crashes resulted in minor injuries to the vehicle occupants when their vehicle was rear-ended by a car whose driver failed to brake at a traffic light.

All but one of the crashes were attributed to either the driver of another vehicle or the driver of the automated vehicle while it was operating in manual mode (with the ADS disengaged). In February 2016 a Google vehicle operating in automated mode attempted to avoid sandbags blocking its path and struck a bus. The Google vehicle sustained minor body damage but there were no injuries (Ursom, 2016). Alphabet (the parent company of Google and Waymo) stated, 'In this case, we clearly bear some responsibility, because if our car hadn't moved there wouldn't have been a collision' (McFarland, 2016).

A study by the Virginia Tech Transportation Institute found that the crash rate for Google's 'self-driving' cars of 3.2 crashes per million miles (1.99 crashes per million kilometres) was lower than the US national crash rate of 4.2 crashes per million miles (2.61 crashes per million kilometres) (Blanco, et al., 2016, p. 19).

We have described a range of problem scenarios. They illustrate a broad range of safety risks that could arise from deploying automated vehicles at various stages in its lifecycle. These scenarios would not be dealt with effectively under the existing regulatory framework.

[10] A second fatal accident involving a vehicle operating at partial automation occurred when a Volvo XC90, being operated by Uber, struck a pedestrian on 18 March 2018 in Tempe, Arizona (Yadron & Tynan, 2016). The vehicle was operating in autonomous mode, but with a human driver at the wheel, at the time of the accident. In response to the accident, Uber removed its self-driving vehicles from public roads in various cities where they were operating (Marshall, 2018). At the time of publication this incident was being investigated.

[11] Autopilot mode is a driver-assist feature that requires the driver to keep their hands on the steering wheel at all times.

Design risk: Importation/manufacturing

Scenario 1: ADR-compliant vehicle with an ADS

A new vehicle model incorporates an ADS and complies with all the current ADRs. The manufacturer claims the ADS is safe but has not tested it against any safety criteria or provided any evidence to support its claims.

Design risk: Modification/roadworthiness

Scenario 2: After-market fitment of an ADS

Nick purchases an ADS and has it installed in his non-automated vehicle. The ADS has not gone through any safety assessment and is unsafe because it is unable to identify cyclists. Nick does not know this and assumes the ADS is safe because it is available for purchase in Australia. His vehicle crashes into a cyclist, causing significant injury.

Organisational risk: Modification/roadworthiness

Scenario 3: Vehicle owner does not accept over-the-air software update

Deepa drives a vehicle that is capable of operating at high automation. She receives a notification that a safety critical software update to the ADS is available and should be installed. Deepa decides not to accept the update and the ADSE does not take any action to manage the risk.

Organisational risk: Modification/roadworthiness

Scenario 4: Vehicle repair affecting the ADS

Ben notices a scratch on the front bumper of his automated vehicle and takes the vehicle to a repairer. While repairing the scratch, the repairer damages the sensors on the front of the car.

Following the repair, Ben sets the vehicle to operate at high automation. The damaged sensors no longer accurately detect the distance between Ben's vehicle and the vehicle in front. The ADS does not diagnose a problem. As a result, Ben's vehicle runs into the back of another vehicle.

Operational/use risk: On-road operation

Scenario 5: Localised and systemic road traffic law breaches

Meg lives in Victoria. She owns an automated vehicle that fails to stop at a red light when operating at high automation. A number of other vehicles with this ADS in Victoria have failed to stop at a red light. Both the ADSE and Victoria Police are aware of these incidents.

Organisational risk: Vehicle disposal/end of life

Scenario 6: Outdated ADS

A manufacturer has two ADSs – system A and system B. System A is a couple of years old and the manufacturer no longer wants to invest in updating it because it is keen to sell more of system B. The manufacturer stops maintaining system A. Vehicles with this ADS become progressively less safe as newly discovered problems are no longer fixed by the ADSE.

Sarah owns a vehicle that incorporates system A and is unaware that the manufacturer has stopped supporting her vehicle's ADS.

2.3 Lack of consumer confidence in ADS safety may reduce or delay their uptake

Consumers can play a role in creating a safer vehicle fleet through their purchasing decisions. However, there is a risk that automated vehicle markets may not operate efficiently if consumers cannot adequately make a judgement about the quality or safety risks of the ADS.

Consumers are likely to look for a trusted independent third party to provide a level of assurance that the systems are safe. Consumers may also assume that an ADS that is available for purchase has passed some kind of safety assessment.

If buyers cannot distinguish between safe and unsafe automated vehicles this could distort market outcomes. In particular, there is a risk it could reduce sales of relatively safer automated vehicles, which may be more expensive. This risk is more likely to be an issue in the short term before ADSEs can show evidence of their safety record, or in some way signal the safety of their products to consumers.

A lack of consumer confidence due to a real or perceived safety risk could undermine the uptake of safe ADSs. This could cause a delay in realising their anticipated benefits. Such a delay could also have flow-on effects to other policy objectives that result in lost opportunities for the Australian economy.

2.3.1 Evidence that lack of consumer confidence in ADS safety may reduce or delay their uptake

The Australasian New Car Assessment Program (ANCAP) is the leading, independent vehicle safety authority in Australia and New Zealand. Its role is to build consumer confidence through research, testing and promotion of technology. ANCAP told us that 'consumer expectations and understanding are factors that can influence…the uptake of autonomous driving technology' (ANCAP, 2017, p. 4).

There is research indicating that individuals are 'concerned' about using automated vehicles and in particular about the safety consequences of equipment or system failure (Schoettle & Sivak, 2014, p. 11–14). In a survey of 505 Australians, the authors found that more than half of respondents were 'very concerned' (27.9 per cent) or 'moderately concerned' (29.5 per cent) about driving or riding in a vehicle with high automation. Over three-quarters of respondents were 'very concerned' or 'moderately concerned' about the safety consequences of equipment or system failure. Additionally, over 70 per cent were 'very concerned' or 'moderately concerned' about 'Legal liability for drivers/owners' and 'Self-driving vehicles getting confused by unexpected situations'.

Evidence from the aviation industry shows that public attitudes towards safety are likely to be influenced by the perceived effectiveness of the regulatory regime. A survey of 1,019 people by the Civil Aviation Safety Authority (CASA) found that the public 'generally believe Australia has a good safety record and attribute the low number of aircraft incidents to CASA's efforts and believe there are good regulations in place' (Civil Aviation Safety Authority, 2014, p. 4). Around 80 per cent considered that commercial flights were as safe or safer than five years earlier, and the most common reasons cited for improved safety were more advanced technology, improved airport security/screening and new safety rules.

These surveys suggest that regulation can play a role in influencing the community's perceptions of safety, and therefore potentially affect the community's use of that mode of transport or product/technology.

Market demand is therefore likely to be influenced by how much potential users of automated vehicles are reassured by the presence of a regulatory system.[12]

2.4 ADSEs may face inconsistent and/or uncertain regulation to supply ADSs in the Australian market

If the role of government in assuring the safety of automated vehicles has not been decided by the time these vehicles are commercialised, this could create uncertainty for industry, insurers and consumers. The supply and uptake of automated vehicles could be delayed and the realisation of potential benefits will be limited.

Without a national approach to automated vehicle safety, industry may face unnecessary regulatory costs and consumers may be prevented from realising the full benefits of automated vehicles.

There are risks that:

- regulatory expectations will be uncertain in terms of who is being regulated, what they are required to do and what sanctions and penalties they may be exposed to
- states and territories will adopt their own regulations to manage risks leading to inconsistent regulation of automated vehicles across states and territories. This will in-turn increase the regulatory burden on ADSEs.

The requirements for automated vehicle suppliers could still be unclear or uncertain. This uncertainty could result in unnecessary administrative and delay costs. This may be a significant barrier to supply, ultimately denying consumers access to the product.

Uncertain regulatory expectations in terms of who is being regulated, what they are required to do, and what sanctions and penalties they may be exposed to can impose a burden on regulated entities.

If new automated vehicles are certified for sale as nonstandard vehicles, as required under the existing regulatory approach, prospective owners face additional uncertain registration requirements (see the description of the registration process in section 3.3.2 for further detail). This uncertainty could result in unnecessary administrative and delay costs for consumers that may affect demand for automated vehicles.

Inconsistent regulation will lead to unnecessary costs for ADSEs and potentially for government. The market for automated vehicles will be a national market, and inconsistency between state and territory regulatory arrangements may impose additional and unnecessary costs on ADSEs. These costs could include costs of proving compliance with different technical standards, testing procedures and roadworthiness requirements. Furthermore, unnecessary regulatory costs pose an economic disincentive for the technology and automotive industries to invest in Australia.

Inconsistent regulation could also constrain cross-border activity and potentially obstruct safety innovation.

Inconsistent regulation may also cause unnecessary costs to government. State- or territory-based road managers may apply different technical standards, testing procedures and roadworthiness requirements.

[12] Uptake may also be limited by other factors such as a lack of awareness about ADS technology. A survey by EastLink of more than 15,000 Victorian motorists showed that the majority of survey respondents had very little or no knowledge about automated vehicles (EastLink, 2017).

2.4.1 Evidence of inconsistent and/or uncertain regulation to supply ADSs

In the absence of new automated vehicle-specific regulation, ADSEs face uncertainty over the safety requirements they must meet at the certification stage, as well as uncertainty of their obligations on an ongoing basis while ADSs are in-service.

National consistency was a key objective across many of the submissions to the NTC's discussion paper *Regulatory options to assure automated vehicle safety in Australia*. The Australia & New Zealand Driverless Vehicle Initiative (ADVI) submission provided a concise summary of why national consistency matters:

> *It is important that Australia is an early adopter of AV technology and proactively [implements] and pursues opportunities. This requires a single approval process in place of the current fragmented approach currently provided through the involvement of nine (9) governments. Australia comprises about 1.5% of global vehicle sales and cannot afford this level of complexity if it is to realise the significant benefits that may be achieved. (ADVI submission, p. 7)*

Governments have an incentive to be seen as leaders in facilitating new technologies and industries that will provide jobs and export revenues. Every state and territory in Australia is currently involved in trials of connected and automated vehicles (Austroads, 2017a). Three states have introduced new or amended laws to support these trials. While these trials have been limited in their scope to operations not crossing state or territory borders, it does demonstrate that different approaches are already evolving. There is some risk that these could manifest into inconsistent state- or territory-based regulations if an agreed national approach were not to proceed.

In consultation with a small supplier of automated vehicle technologies, the NTC was advised of the following:

- The certification exemption system is inefficient and unworkable for small companies.
- Conditional registration is different in every state and territory, and this is a barrier.
- The split between state and federal vehicle regulation is a regulatory burden because ADRs and conditional registration create two layers of potentially inconsistent regulation.
- There needs to be a nationally consistent approach.

Consultation questions

1. To what extent has the consultation RIS fully and accurately described the problem to be addressed? Please provide detailed reasoning for your answer.
2. What other factors should be considered in the problem statement?

2.5 Need for government intervention

The problem statement outlines both market and regulatory failures that are not adequately addressed by Australia's current regulatory framework, suggesting that government intervention is warranted.

Governments have an existing role regulating vehicle and road safety and therefore there is a public expectation that governments will provide safety assurance in an environment of uncertain outcomes. Governments would be justified in taking a proactive role to provide oversight of automated vehicle safety because the technology is new and the safety performance of these vehicles is uncertain.

Existing safeguards to manage the safety of vehicles with automated functions, including consumer guarantees and vehicle recall powers under the Australian Consumer Law, may not capture all of the new safety risks relating to the ADS. Risks relating to the operational design domain, legal accountability, cybersecurity and human performance requirements, among others, would remain unregulated.

If the role of government in assessing the safety of vehicles with automated functions has not been decided by the time automated vehicles are commercialised, this could create uncertainty for industry, insurers and consumers.

Submissions to the NTC's discussion paper on *Regulatory options to assure automated vehicle safety in Australia* clearly confirm that the community expects governments to have a role in ensuring automated vehicles are safe (National Transport Commission, 2017c, p. 12).[13]

Consultation also revealed a general acceptance for industry to manage safety risks and to self-regulate at this early stage with a system of government oversight consistent with the safety assurance design features (see section 1.2.5). Without a regulatory response, governments will not have a mechanism to know that automated vehicles are safe.

Consultation questions

3. Has the consultation RIS provided sufficient evidence to support the case for government intervention? What else should be considered and why?
4. To what extent have the community and industry expectations of a regulatory response been accurately covered?

[13] Publicly available submissions to the safety assurance system are available on our website at: https://www.ntc.gov.au/current-projects/safety-assurance-system-for-automated-vehicles/.

3 Options to address the problem

Key points

- This consultation RIS presents four options.
- Option 1 is the baseline option. It does not introduce a safety assurance system. It uses existing regulatory processes to manage the safety of automated vehicles.
- Options 2, 3 and 4 introduce a new system to ensure automated vehicles are safe and require an ADSE to manage safety risks by self-certifying against principles-based safety criteria. We call this a 'safety assurance system'.
- Option 2 introduces a safety assurance system using administrative arrangements under existing regulation. It requires an ADSE to self-certify against principles-based safety criteria.
- Option 3 introduces a safety assurance system with a dedicated national agency for automated vehicle safety, with specific offences and compliance and enforcement tools.
- Option 4 includes all the elements of option 3 as well as a general duty on ADSEs to ensure safety ('primary safety duty').

This chapter sets out the key features of the four options under consideration in this RIS and how they would work in practice.

3.1 Introduction

In November 2017 the Transport and Infrastructure Council agreed to the development of a national safety assurance system for automated vehicles based on mandatory self-certification. The key design features of the safety assurance system were agreed after public consultation, but this agreement was subject to completing RIS.

This RIS considers four options. Option 1 is the baseline against which we assess the other three options. Option 1 does not provide for a safety assurance system. In contrast, options 2, 3 and 4 all provide for a safety assurance system with differing levels of regulatory oversight.

Each of the reform options to introduce a safety assurance system (options 2, 3 and 4) require ADSEs to self-certify ADSs against principles-based safety criteria in a Statement of Compliance. The proposed safety criteria are set out in chapter 4.

The safety assurance system applies both at 'first supply' of an ADS and while it is on the roads ('in-service'). The ADSE will be responsible for initial and ongoing adherence to their Statements of Compliance.[14]

The mandatory self-certification approach makes the ADSE, rather than government, responsible for testing and validating the safety of the ADS. As noted above, the ADSE must complete a Statement of Compliance explaining how it will address principles-based safety criteria. The role of government is to establish the safety criteria, assess the Statement of Compliance and satisfy itself that the applicant has adequate processes in place to manage safety risks.

[14] The design features of the proposed safety assurance scheme are described in detail in Chapter 4.

3.2 Options

The four options we assess in this RIS are:

- **Option 1: Current approach (the baseline option)** – does not introduce a safety assurance system. It uses existing regulatory processes to manage the safety of automated vehicles.
- **Option 2: Administrative safety assurance system** – introduces a safety assurance system using administrative processes under existing regulation. It requires an ADSE to self-certify against principles-based safety criteria.
- **Option 3: Legislative safety assurance system** – introduces a safety assurance system with a dedicated national agency for automated vehicle safety. It requires an ADSE to self-certify against principles-based safety criteria. It includes offences and compliance and enforcement tools that are specific to safety assurance.
- **Option 4: Legislative safety assurance system + primary safety duty** – introduces a safety assurance system with a dedicated national agency for automated vehicle safety. It requires an ADSE to self-certify against principles-based safety criteria. It includes offences and compliance and enforcement tools that are specific to safety assurance and a general duty on ADSEs to ensure safety ('primary safety duty').

Table 3 identifies the RIS options to be assessed and the key regulatory features they aim to provide.

Table 3. RIS options and key regulatory features

	Option 1: Current approach	**Option 2: Administrative safety assurance system**	**Option 3: Legislative safety assurance system**	**Option 4: Legislative safety assurance system with a primary safety duty**
Regulatory controls at first supply	✓ (but conditions undefined)	✓	✓	✓
Regulatory controls for registration and in-service performance	× (not specifically for automated vehicle functionality)	✓ (but limited offences and compliance and enforcement tools to enforce controls)	✓	✓
Safety assurance system specific offences and compliance and enforcement tools	×	×	✓	✓
Primary safety duty	×	×	×	✓

The rest of this chapter will describe the key regulatory features of each option in detail.

3.3 Option 1: Current approach (the baseline option)

3.3.1 Description of the option

Option 1 does not introduce a safety assurance system. It uses existing regulatory processes to manage the safety of automated vehicles.

Option 1 relies on existing laws and systems as well as those that are expected to be in place by 2020. This includes new national vehicle standards (ADRs) to align with evolving international automated vehicle standards, described in Appendix D. DIRDAC has advised that, subject to the normal consultation arrangements for new vehicle standards and ministerial approval, a new ADR (90/00) may be introduced in mid-2018 to begin this process, followed by a revision (ADR 90/01) in late 2018 to align it fully with the current level of international standards as developed through the UN. This proposed change means that vehicles with an ADS would not be compliant with the ADRs. Automated vehicles would need an exemption from the ADRs. If this change does not proceed, option 1 could not be effective.

Under this option the current system for managing new and imported vehicles and their in-service performance would continue. The safety of ADSs would be managed through existing safeguards (such as ADRs, road rules and the Australian Consumer Law).

This option is the starting point for comparison. This option:

- requires an exemption for a vehicle with an ADS from the ADRs *without* clarity about what the requirements would be for an exemption[15] (Commonwealth role)
- requires assessment of individual vehicles under state/territory-based registration processes (state and territory role)
- lacks any mechanisms for regulating in-service performance
- does not define the role of the ADSE and hence has limited offences or compliance and enforcement tools for the ADSE
- may not adequately capture automation achieved through software upgrades or use of after-market devices.

3.3.2 How it would work

Regulatory controls at first supply

DIRDAC has advised that ADSs would not meet the proposed new ADR (90/01).

This means that until the international standards evolve further, vehicles with an ADS would be categorised as a nonstandard vehicle.[16] A nonstandard vehicle may not be supplied to the market (120 penalty units) unless it has gone through the exemption process. This

[15] In the longer term it is likely that certainty would increase. Exemptions may no longer be required because the ADRs could be updated with ADS standards to align with any international standards that are developed. DIRDAC's view is that UN timetable for developing a comprehensive suite of standards for automated vehicles may be shortening, with timing more likely to be in parallel with this project's milestones rather than 10–15 years away as previously thought. This means a transition to international standards will need to be a consideration for all options in this Consultation RIS. UN standards will be largely centred around pre-market requirements and some limited in-services requirements, with countries left to cover all other aspects of automated vehicle use on a national basis.

[16] Section 5 of the Motor Vehicle Standards Act provides that ***nonstandard****,* in relation to a road vehicle or a vehicle component, means not complying with the national standards and not taken to comply with the national standards by virtue of an approval given under subsection 10A(2).

allows a nonstandard vehicle to be supplied to the market in prescribed circumstances or with the written approval of the relevant minister.[17]

There are no existing 'prescribed circumstances' that would apply to an ADS. This means the requirements for an exemption are not clear or certain.

Regulatory controls for in-service performance

A certified nonstandard vehicle would need to be registered by states and territories. State and territory registration systems and processes vary. Registration requirements for a nonstandard automated vehicle would include conditions. These conditions may differ from jurisdiction to jurisdiction.

States and territories could advise DIRDAC whether they would grant conditional registration to nonstandard vehicles with an ADS. Registration could be subject to conditions requiring that the registered vehicle operator does not make unauthorised modifications to the ADS and accepts ADS updates.

The varying and uncertain registration processes would cause significant regulatory uncertainty for ADSEs and ADS consumers. There would also be administrative burdens in obtaining exemptions and registration from state or territory road managers, which are not designed for large-scale, commercial deployments.

Regulation of in-service safety performance would be limited to existing vehicle performance standards, which do not specifically consider an ADS.[18]

Compliance and enforcement

This option would not create safety assurance system specific offences and compliance and enforcement measures. It would not clearly define the role of the ADSE.

Existing sanctions and penalties could be applied to manufacturers for systemic failures to meet pre-market technical requirements. These include vehicle recalls, the withdrawal of approval to supply the nonstandard vehicle to the market and/or monetary fines.

Sanctions and penalties for noncompliance with conditional registration requirements, such as withdrawal of registration, would affect the registered owner or operator rather than the ADSE.[19] This could lead to private owners of vehicles being penalised (for example, through removing a vehicle's registration) for system issues that are beyond their control.

Option 2: Administrative safety assurance system

Option 2 introduces a safety assurance system (as outlined in Table 1) using existing regulatory processes to manage the safety of automated vehicles.

It requires an ADSE to self-certify against principles-based safety criteria. It relies on existing regulatory processes as well as those expected to be in place by 2020.[20] We describe the proposed safety criteria and ask consultation questions on them in chapter 4.

This option:

- requires an exemption for a vehicle with an ADS from the ADRs *with* clarity about what the requirements would be for an exemption [21] (Commonwealth role)

[17] Motor Vehicle Standards Act., s. 14.

[18] For example, the Australian Light Vehicle Standards Rules 2015, and the Heavy Vehicle (Vehicle Standards) National Regulation.

[19] In some cases, the registered operator or owner and the ADSE may be the same.

[20] This includes a new ADR (90/01), which DIRDAC has advised is likely to be in place by mid-2018. This proposed change means that vehicles with an ADS would not be compliant with the ADRs. Automated vehicles would need an exemption from the ADRs. If this change does not proceed, option 2 could not be effective.

- requires an ADSE to self-certify against principles-based safety criteria (these are set out in chapter 4)
- requires assessment of individual vehicles under state/territory-based registration processes (state and territory role)
- lacks any mechanisms for regulating in-service performance
- has limited sanctions and penalties on the ADSE.

3.3.3 How it would work

Options 1 and 2 would operate very similarly. The key difference is that at the first supply stage, option 2 provides greater regulatory certainty for ADSEs about the requirements for a vehicle with an ADS to be certified.[22]

Like option 1, option 2 relies on the introduction of the proposed new Australian Design Rule (90/00) and if this change does not proceed options 2 could not be effective. The proposed new ADR would mean a vehicle with an ADS would be a nonstandard vehicle and require an exemption. However, in option 2, the 'prescribed circumstances' for supplying a nonstandard vehicle to market would be compliance with the safety assurance system.[23] This approach would ensure that ADS safety risks are addressed in an ADSEs' Statement of Compliance. It provides ADSEs with clarity on the regulatory requirements to obtain certification.

Conditions of approval could also include a requirement that the manufacturer/ADSE ensures continued compliance with the requirements under the safety assurance system. This could include obtaining approval under the safety assurance system for any significant modifications to the ADS.

As per option 1, this option does not create safety assurance system specific offences and compliance and enforcement measures. This would make it difficult to target the responsible party in all scenarios.

3.4 Option 3: Legislative safety assurance system

3.4.1 Description of the option

Option 3 introduces a safety assurance system through legislative changes, with specific offences and compliance and enforcement measures. A dedicated national agency would oversee automated vehicle safety.

This option:

- requires an ADSE to self-certify against principles-based safety criteria (these are set out in chapter 4)
- includes offences and compliance and enforcement measures that are specific to safety assurance to enforce compliance with the safety assurance system (through new or amended legislation)
- includes the appointment of a government agency with responsibility for administering the safety assurance system
- recognises and regulates the ADS (and the ADSE) separately from the vehicle.

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[21] In the longer term it is likely that certainty would increase. Exemptions may no longer be required because the ADRs could be updated with ADS standards to align with any international standards that are developed.

[22] Motor Vehicle Standards Act, s. 14.

[23] ibid., s. 14A(1)(a). Section 42 provides a regulation-making power.

The ability to regulate the vehicle and the ADS separately would ensure the ADS goes through a safety process. An ADS might be added to a certified vehicle. Without an ability to regulate the ADS separately from the vehicle there would not be requirements for a safety process. The ADS will be driving the vehicle in place of a human driver so a regulatory system that does not provide an ability to ensure it is safe presents a significant safety risk.

This ability to regulate the ADS separately from the vehicle also means that there is a better ability to target the correct party if an ADS is unsafe. Innocent parties are less likely to suffer consequences from an unsafe ADS. For example, if the ADS and vehicle are regulated as a whole and the ADS is faulty, the vehicle might be deregistered or recalled. Separate regulation would allow a vehicle with manual controls to be operated with the ADS disengaged if required.

There would need to be relevant offences and compliance and enforcement measures to ensure the ADS remains disabled if it has not been approved under the safety assurance system.

3.4.2 How it would work

New or amended legislation would recognise an ADSE as being responsible for:

- submitting a Statement of Compliance for an ADS
- in-service safety of the ADS, where appropriate.

This option is likely to include a legislative mechanism for states and territories to identify and refer intelligence (for example, breaches of road traffic laws) to the national agency responsible for the safety assurance system. Such advice would be relevant to the responsible agency's consideration of sanctions and penalties, including whether approval of the ADS should be removed. This option could also include a mechanism for the national body to provide information back to the states and territories to assist with managing road safety.

Regulatory controls at first supply

Vehicle type approval under the *Motor Vehicle Standards Act* would continue to be required. If the proposed new ADR is introduced (as DIRDAC has advised is likely), vehicles with an ADS would be classified as nonstandard. To overcome this, the legislation would specify that vehicle types that include a safety assurance system approved ADS would not need to meet this rule. They would be classified as a standard vehicle provided they meet other relevant ADRs.

This would simplify the registration process for states and territories and create certainty for ADS vehicle owners. The vehicle would be registered as a standard vehicle without the need for conditions.

Regulatory controls for registration and in-service performance

ADR-compliant automated vehicle models with an approved Statement of Compliance, would be classified as standard automated vehicles and could be registered using standard registration processes.

The new or amended legislation would allow a national body to regulate the ADSE and the in-service performance of the ADS. It could require that the ADSE maintains ongoing compliance with its Statement of Compliance and report safety-critical events such as breaches of the road rules, crash data, near-miss data and cybersecurity vulnerabilities and other related events to the national body.

Safety assurance system specific offences and compliance and enforcement measures

To support the effectiveness of the safety assurance system the legislation would provide specific offences and compliance and enforcement measures.

The legislation would create a range of offences to underpin the mandatory features of the safety assurance system (see Appendix B for indicative sanctions and penalties). These may include but are not limited to:

- failure to lodge a Statement of Compliance to the relevant agency prior introducing an ADS to market
- false or misleading information provided in the Statement of Compliance
- failure to lodge a Statement of Compliance to the relevant agency of an in-service modification that results in a vehicle operating at a higher level of automation
- failure to inform the relevant agency of a significant safety risk or issue related to the ADS
- failure to follow a legal direction of the relevant agency in relation to the ADS
- failure to maintain ongoing adherence to the Statement of Compliance
- failure to provide data or meet reporting requirements.

Specific offences and compliance and enforcement measures allow the regulatory agency to target the appropriate parties and behaviours. Governments would otherwise need to rely on existing mechanisms such as vehicle recalls or withdrawal of registration. These may not target the appropriate parties or provide the appropriate level of response to a safety breach.

3.5 Option 4: Legislative safety assurance system + primary safety duty

3.5.1 Description of the option

Option 4 introduces a safety assurance system with a dedicated national agency for automated vehicle safety.

This option incorporates all the design elements of option 3 but also includes a primary safety duty relating to ADSs while they are in-service. This option captures additional safety risks/unsafe behaviours to those addressed in option 3 through additional regulatory obligations on parties.

This option:

- requires an ADSE to self-certify against principles-based safety criteria (these are set out in chapter 4)
- includes sanctions and penalties that are specific to safety assurance to enforce compliance with the safety assurance system (through new or amended legislation)
- includes the appointment of a government agency with responsibility for administering the safety assurance system
- recognises and regulates the ADS (and the ADSE) separately from the vehicle
- introduces a primary safety duty on ADSEs, which would include coverage of in-service performance of the ADS.

3.5.2 Primary safety duty

A primary safety duty would provide an overarching and positive general safety duty on the ADSE to ensure the safety of the ADS so far as reasonably practicable.

This duty would support the mandatory self-certification approach as an ongoing duty throughout the life cycle of the ADS. It would aim to ensure that in-service safety risks and hazards that are not identified through the safety assurance system process are managed and that unsafe behaviours that are not otherwise captured by prescribed offences are prevented.

A primary safety duty would not be prescriptive and would therefore accommodate significant advances in safety technology. It would also provide industry with flexibility in how they manage risks compared with more prescriptive requirements.

In addition, a primary safety duty allows for more proactive enforcement because risk-related behaviour can be addressed before an incident occurs.

A primary safety duty to ensure automated vehicle safety could be based on a number of existing models. In this consultation RIS, the high-level principles of the primary safety duty are based on the model work health and safety (WHS) law.

The model WHS law applies a 'primary duty of care' requiring a person conducting a business or undertaking to, so far as is reasonably practicable, ensure the health and safety of workers and others who may be affected by the carrying out of work (Safe Work Australia, 2016).

A similar concept could be applied to automated vehicles to require the ADSE to take reasonably practicable steps to ensure the safety of an ADS. Sanctions and penalties would apply to the ADSE if it breaches the duty. This approach would:

- be consistent with other safety laws
- provide a strong focus on safety beyond simple self-certification
- provide a 'catch all' if new safety risks were identified that were not part of the original safety assessment criteria
- ensure that safety standards increase over time as technology and practice improve
- allow for a proactive approach to compliance rather than relying on a breach of the self-certification prior to addressing a safety concern.

Compliance and enforcement powers could include options such as formal warnings, improvement notices, enforceable undertakings and prohibition orders, along with fines and imprisonment. The compliance and enforcement options would be both commensurate with the risk and the ability of the duty holder to address that risk. Penalties could be similar to those for breaches of WHS or HVNL laws. More detail on compliance and enforcement measures, along with penalties from other schemes, are set out in Appendix B. Detailed consideration of sanctions and penalties, including their magnitude, will be undertaken once a preferred policy option has been agreed.

3.5.3 How it would work

A primary safety duty would be administered by a national body and triggered by an incident, near-miss or other behaviour indicating a risk involving an ADS. In such events, the national body could investigate the causes of the incident, near-miss or unsafe behaviour to determine responsibility.

The national body would then determine whether the risk could reasonably have been managed and whether the duty holder knows, or ought to reasonably know, about:

- ADS hazards or risks and ways of eliminating or minimising them

- the availability of suitable ways to eliminate or minimise the hazards or risks.

The national body could apply specific and targeted sanctions or penalties to the relevant duty holder.

3.5.4 Parties covered by the primary safety duty

The NTC proposes that the primary safety duty should only cover ADSEs – that is, the party seeking to bring the technology to market in Australia. This means that the in-service safety risks of bringing a particular ADS type to market are borne by only one party in the new safety assurance system. The ADSE should have the best understanding of and most control over the safety risks. As they are a new party, they are also not well covered by existing legislation.

The NTC considered whether other parties should also be covered by the primary safety duty. Our view is that vehicle manufacturers (where this is different from the ADSE), commercial operators, registered operators/owners and vehicle repairers would not need to be covered for the following reasons:

- The vehicle manufacturer is covered by existing recall powers for faults that they have responsibility for and may have no ability to control the operation of the ADS.
- Commercial operators of vehicles are commonly covered by their own legislation (taxi or point-to-point and heavy vehicle legislation) and are also covered by WHS law because the vehicle is being used as a workplace (a primary safety duty already applies through WHS law).
- The registered operator/owner of the vehicle has limited ability to manage risks created by an ADS other than to follow the ADSE's instructions, including applying software updates as required.
- Vehicle repairers are covered by existing consumer laws.

Consultation question

5. Are the four options clearly described? If not, please elaborate.

4 Proposed safety criteria for the Statement of Compliance

Key points

- The NTC proposes 11 principles-based safety criteria as part of a safety assurance system.
- ADSEs would be required to self-certify that they comply with these safety criteria in a Statement of Compliance.
- The criteria are principles-based to balance safety and innovation.

This chapter sets out the proposed safety criteria for a safety assurance system based on mandatory self-certification.

4.1 Context

In November 2017 transport ministers agreed to a mandatory-self certification approach to safety assurance for automated vehicles, as well as key design features for a safety assurance system (as set out in Table 1). This agreement was subject to analysing legislative options through a RIS (this document is the consultation version of the RIS).

One of the safety assurance system design features considered by ministers was a requirement for ADSEs to submit a Statement of Compliance demonstrating their management of a set of safety criteria before an ADS could be introduced into the market.

As options 2, 3 and 4 outlined in the previous chapter all incorporate a safety assurance system, they all require an ADSE to self-certify against safety criteria in a Statement of Compliance. We set out the proposed safety criteria below, and seek feedback on their appropriateness.

4.2 Overview

This chapter outlines the proposed safety criteria against which the ADSE will be required to submit a Statement of Compliance for approval before an ADS or function, or significant modification, can be introduced into the market. The ADSE, rather than government, will be responsible for testing and validating the safety of the ADS or function and documenting these processes. The role of government is to satisfy itself that the applicant has processes in place to identify and manage the safety risks.

The NTC is proposing 11 safety criteria that require the applicant to demonstrate its processes for managing safety risks. The NTC is also proposing three other obligations on ADSEs to assist relevant parties to appropriately assign criminal and civil liability for events such as road traffic law breaches and crashes.

These criteria were developed with the aim of balancing safety and innovation. As such, the criteria are generally outcomes-based rather than prescriptive.

Not all safety criteria are necessarily relevant to each ADS, function or significant modification. If the applicant considers that a safety criterion or other obligation is not relevant, the applicant must explain why. Over time, elements of these criteria may transition to ADRs. In these circumstances, the applicant could refer to compliance with the relevant ADR(s) to explain why a particular criterion is not relevant, or as evidence of meeting the criterion.

This chapter outlines only the information an ADSE must provide in the Statement of Compliance. Full descriptions of the safety criteria and obligations, as well as information about how they were developed and potential criteria that were considered but not proposed, is at Appendix C. Stakeholders should refer to this appendix if providing feedback to us about the safety criteria.

4.3 Principles-based safety criteria: requirements for the Statement of Compliance

4.3.1 Safe system design and validation processes

The applicant must explain why it chose particular design, validation and testing processes, and how these ensure a safe technology is developed. For choice of system design, the applicant could explain how the ADS will be disengaged when its safety is affected by maintenance, repairs, physical modifications or other safety-critical issues.

The applicant should document decisions relating to the choice of design, validation and testing processes and include empirical evidence or research to support the safety assertions made. Such documentation could explain why particular processes were chosen. Where applicable, the applicant should use guidance, industry best practices, design principles and standards developed by established standards organisations.

4.3.2 Operational design domain

The applicant must identify the operational design domain (ODD) of the ADS and demonstrate how it will ensure the ADS is:

- able to operate safely within its defined ODD
- incapable of operating in areas outside of its defined ODD
- able to transition to a minimal risk condition when outside its defined ODD.

This could include documentation outlining the process for assessing and testing the ADS's functionality both within and outside the defined ODD.

The applicant should also outline how it will review and manage changes to the defined ODD. Major changes to the ODD are likely to be significant modifications requiring the applicant to submit a new Statement of Compliance for approval before introducing the change into the market.

4.3.3 Human-machine Interface

The applicant must outline how the human-machine interface (HMI) will facilitate interaction between the ADS and relevant parties (both internal and external to the vehicle) that allows the vehicle to operate safely.

In relation to human drivers and occupants, the information communicated by the HMI should include, but is not limited to:

- informing the human driver if the ADS is engaged and the level of automation engaged
- requesting that the human driver take back control of the vehicle with sufficient time for the human driver to respond. In addition, the applicant should outline the safeguards to ensure a fallback-ready user is actually ready to take back control. This could include monitoring by the ADS of human readiness to take back control and alert systems where such readiness is not apparent
- drawing attention to potential safety risks related to human monitoring and having to be ready to re-engage with the driving task

- indicating whether the ADS is functioning properly or experiencing a malfunction.

In relation to parties external to the vehicle, information such as the ADS's state of operation should be communicated by the HMI via an external communication interface. This could take the form of an external screen.

The applicant must also outline how it tests and assesses the HMI and make reference to any appropriate international standards or agreed guidelines for HMIs.

4.3.4 Compliance with relevant road traffic laws

The applicant must demonstrate how it will ensure the vehicle operates in compliance with relevant road traffic laws when the ADS is engaged. In particular, they must demonstrate how the ADS will comply with:

- current road traffic laws in each state and territory
- amendments to the relevant road traffic laws when they come into force.

This could include documentation outlining the process for assessing and testing the ADS's compliance with current road traffic laws and the process for updating the ADS to comply with amendments to those laws.

The applicant must also demonstrate how the ADS will respond in a safe way where strict compliance with relevant road traffic laws is not possible. This requirement closely links with the on-road behavioural competency criterion.

4.3.5 Interaction with enforcement and other emergency services

The applicant must demonstrate how it will ensure that police can access accurate information about whether the ADS is engaged at a given time and the level of automation engaged. The applicant should also demonstrate how it may facilitate police access to this information in real time at the roadside.

The applicant must demonstrate how it will ensure safe interaction with emergency services more broadly when the ADS is engaged.

4.3.6 Minimal risk condition

The applicant must demonstrate how the ADS will detect that it cannot operate safely and ensure a minimal risk condition is reached.

This could include documentation outlining the process for assessing and testing the ability of the ADS to detect and respond to such circumstances. The minimal risk condition is likely to vary depending on the reason why the ADS cannot operate safely and on the level of automation engaged. Therefore, a range of approaches to bring the vehicle to a minimum risk condition may need to be considered.

4.3.7 On-road behavioural competency

The applicant must demonstrate how the ADS will appropriately respond to foreseeable and unusual conditions that may affect its safe operation. This could include documentation outlining the process for assessing and testing the ADS's object and event detection and response and crash avoidance capabilities, and its ability to respond to unusual events within its ODD.

4.3.8 Installation of system upgrades

The applicant must demonstrate how it will manage system upgrade risks. This includes ensuring safety-critical system upgrades to the ADS are installed and do not result in the operation of an unsafe ADS.

The applicant must explain how it will notify registered owners/operators that an update has been installed, or is available and needs to be installed. The applicant must also demonstrate how it will:

- detect failures to install upgrades (including failures of automatic updates and failures by registered owners/operators to take action when an upgrade is available)
- detect system failures once upgrades are installed
- ensure the ADS is safely disengaged if such failures occur.

This could include documentation outlining the process for assessing and testing the ADS's ability to:

- update automatically and notify the registered owner/operator of the update
- notify the registered owner/operator of available system upgrades
- detect and respond to failures to install upgrades
- detect and respond to any system failures following the installation of upgrades.

4.3.9 Testing for the Australian road environment

The applicant must demonstrate how it has considered the Australian road environment in designing and developing the ADS, including its forward planning processes to ensure compliance with changes to the road environment (such as changes to road infrastructure).

This could include documentation outlining the process for assessing and validating the response of the ADS to the Australian road environment such as interaction with road signs in various states and territories and interaction with Australian flora and fauna.

4.3.10 Cybersecurity

The applicant must demonstrate how it has designed and developed an ADS that minimises the risks of cyber intrusion and how it will detect and minimise the consequences of intrusions that occur.

This could include outlining how any best practice guidance for vehicle cybersecurity (domestic and international) has been considered and incorporated into the design and development of the ADS.

4.3.11 Education and training

The applicant must outline the education and training that will be provided to relevant parties and how this will minimise the safety risks of using and operating ADSs. Education and training should take into account different types of vehicles (including light and heavy vehicles) and different types of vehicle users. Without limiting the education and training to be provided, such education and training should consider:

- training human drivers to safely disengage and re-engage the ADS and the driving task
- informing human drivers of their obligations, particularly any fallback-ready user obligations
- informing human drivers of the ADS's capabilities, including any restrictions of the automated technology such as the ODD
- facilitating the maintenance and repair of an ADS, including after a crash before it is put back in service
- facilitating employee, dealer and distributor understanding of the technology and operation so relevant information can be accurately conveyed to consumers and purchasers

- ongoing education as required, including education and training to end users who are not the original vehicle owner.

The development of education and training should be well documented. Such documentation could be used to explain the reasons for the particular education and training chosen and how it will facilitate proper and safe use of the automated technology.

4.4 Other obligations on ADSEs: requirements for the Statement of Compliance

4.4.1 Data recording and sharing

The applicant must outline the data it will record and how it will provide the data to relevant parties. Without limiting the data to be recorded and shared, the applicant must explain how it will ensure:

- the vehicle has real-time monitoring of driving performance and incidents, including event data records in the lead up to any crash or near-miss that identifies which party was in control of the vehicle at the relevant time
- the vehicle can provide road agencies with crash and near-miss data
- relevant parties (including police) receive information about the level of automation engaged at a point in time
- individuals receive data to dispute liability (for example, data showing which party was in control for the purposes of defending road traffic infringements) when the individual makes a reasonable request and the provision of information aligns with privacy regulation
- data is provided in a standardised, readable and accessible format when relevant
- data is retained to the extent necessary to provide it to relevant parties. The amount of time data is retained for may depend on the purpose(s) the information could be used for (for example, law enforcement or insurance)
- data is stored in Australia.

4.4.2 Corporate presence in Australia

The applicant must provide evidence of its corporate presence in Australia.

4.4.3 Minimum financial requirements

The applicant must provide evidence of its current financial position, its grounds for claiming it will have a strong financial position in the future and the level of insurance held.

Consultation questions

6. Are the proposed safety criteria and obligations on ADSEs (detailed in chapter 4 and Appendix C) sufficient, appropriate and proportionate to manage the safety risk?
7. Are there any additional criteria or other obligations that should be included?

5 Method for assessing the options

Key points

- The NTC uses a multi-criteria analysis to assess the costs and benefits of the four options.
- Our multi-criteria analysis is primarily qualitative because there is a lack of relevant quantitative information.
- Our multi-criteria analysis uses five impact categories:
  - road safety
  - uptake of automated vehicles
  - regulatory costs to industry
  - regulatory costs to government
  - flexibility and responsiveness.

This chapter sets out the methodology used in this RIS to assess the costs and benefits of the four options described in chapter 3. The assessment of these options is set out in the chapter 6.

5.1 Multi-criteria analysis approach

The NTC uses a multi-criteria analysis approach to assess the options for a safety assurance system outlined in chapter 3. This allows a combination of quantitative and qualitative information to be assessed against criteria related to expected impacts (costs and benefits) of different policy options.

A multi-criteria analysis approach is commonly used where full monetisation of costs and benefits is not appropriate or possible. Automated vehicles use technology that has not previously been regulated, either in Australia or elsewhere, and their future is uncertain. This means there is a lack of empirical data, making a fully quantitative cost-benefit assessment approach not possible. However, where available, quantitative data has been used. This multi-criteria analysis approach is consistent with the Office of Best Practice Regulation's cost-benefit analysis guidelines.

We use the following method to assess the expected impacts of the options and to identify a provisionally preferred option:

1. Identify key impact categories and assessment criteria.
2. Identify individuals or groups who are likely to be affected by the reform options.
3. Assess options using a multi-criteria analysis approach.
4. Assess the materiality of the impact categories to determine if one should be given more weight than others.
5. Test the validity of the outcomes of this assessment by:
   - testing the outcome against different deployment scenarios.
   - indicating the factors that might lead governments to prefer a different option.

We use the key impact categories and associated assessment criteria (Table 4) to identify and compare the costs and benefits of each of the reform options against option 1 (the

baseline option). This allows for a qualitative comparison of the relative effectiveness of the four policy options.

5.1.1 Timeframe for assessment

The assessment considers the impacts of the options over a 10-year timeframe from 2020 to 2030. The 2020 starting point reflects the Australian government's aim to have end-to-end regulation in place by 2020 to support the safe deployment of automated vehicles (Transport and Infrastructure Council, 2017, p. 3). The 2030 end date reflects the 'interim' nature of this regulatory proposal.

5.2 Impact categories and assessment criteria

We selected five impact categories for the multi-criteria analysis. We selected these five impact categories for the following reasons:

1. **Road safety** – having safe vehicles on Australian roads is a fundamental and accepted standard under existing regulation and will continue to be under any new regime to regulate automated vehicles.[24]
2. **Uptake of automated vehicles** – the potential benefits of automated vehicles such as improved road safety, mobility, freight productivity and reduced road congestion cannot be fully realised without the uptake of automated vehicles into the Australian vehicle fleet.
3. **Regulatory costs to industry** – a safety assurance system will have regulatory costs to ADSEs. If the costs are too high, automated vehicles may not be introduced and used widely in Australia.
4. **Regulatory costs to government** – a safety assurance system will have upfront and ongoing costs to government; these costs need to be proportionate to the benefits.
5. **Flexibility and responsiveness** – ADS technology and international regulatory approaches are still developing. Any regulation needs to be sufficiently flexible to allow for this development.

Table 4 outlines the five impact categories and the assessment criteria for each impact category.

Table 4. Impact categories and assessment criteria

Impact category	Assessment criteria
1. Road safety	a. Covers ADS safety over the vehicle lifecycle, including at first supply and in-service b. Covers parties that have not sought approval under the safety assurance system but who would be an ADSE if they sought approval c. Ensures there is always a clearly recognised legal entity responsible for risks associated with automated vehicles d. Ensures responsibility sits with the party best able to manage the risk

[24] See, for example, the *National Road Safety Strategy 2011–2020*, which is the commitment of federal, state and territory governments to an agreed set of national goals, objectives and action priorities setting out a path for action to reduce fatal and serious injury crashes on Australian roads. Available at http://roadsafety.gov.au/nrss/.

Impact category	Assessment criteria
	e. Addresses safety risks that may not have been specifically considered at first supply f. Proactively addresses emerging ADS risks before the safety issue eventuates g. Supports the introduction of targeted compliance and enforcement options, including sanctions and penalties for noncompliance by the ADSE h. Allows the national body responsible for the ADS to monitor and respond to in-service ADS safety i. Supports information sharing between jurisdictions and the national body responsible for ADS safety to allow for a quicker and more targeted response to identified safety issues
2. Uptake of automated vehicles	a. Provides community assurance that automated vehicle safety risks have been comprehensively addressed b. Provides clear and consistent regulatory expectations to facilitate market entry, including national consistency and alignment with international requirements
3. Regulatory costs to industry	a. Results in low upfront and ongoing compliance, administrative and delay costs b. Provides clear and consistent regulatory expectations to industry about its responsibilities and what is required to comply c. Supports an approach that is consistent across all jurisdictions and is aligned with international requirements
4. Regulatory costs to government	a. Minimises upfront structural, organisational and regulatory change to implement the model, including a minimal impact on existing processes and minimal regulatory layers b. Supports efficient ongoing administrative processes including, if required, mandatory self-certification, safety assurance system assessments, registration and responding to breaches c. Clearly defines roles and responsibilities of states, territories and the Commonwealth (and a separate national agency if applicable) for regulating automated vehicle safety
5. Flexibility and responsiveness	a. Can be implemented by 2020 b. Allows for transition as international approaches evolve c. Allows flexibility for industry by focusing on safety outcomes, minimising prescriptive requirements, remaining technology-neutral and allowing innovative solutions d. Allows flexibility for government in addressing emerging safety risks e. Allows for regulation of the ADS separate from the vehicle

5.2.1 Choice of road safety assessment criteria

We assess each of the four options against nine road safety assessment criteria. The criteria were chosen to address new road safety risks that would arise from introducing ADSs.

The chosen road safety assessment criteria aim to ensure that each option is assessed against a variety of road safety risks that would arise at different times in the life cycle of the ADS. This includes road safety risks that may arise because someone other than the ADSE, such as the vehicle owner or a repairer, does or fails to do something. For example, a vehicle owner might fail to install a software upgrade or a mechanic might make a repair that affects the ability of the ADS to function correctly.

The road safety assessment criteria reflect stakeholder input from previous NTC consultation on the road safety risks that would arise from introducing ADSs.

5.2.2 Choice of uptake assessment criteria

We assess each of the four options against two uptake criteria. The criteria were chosen to assess the extent to which each of the four options would be likely to increase the uptake of automated vehicles in Australia by promoting consumer and business confidence.[25]

Criterion a provides community assurance that automated vehicle safety risks have been comprehensively addressed. This criterion focuses on community uptake of automated vehicles and the idea that consumers are more likely to use automated vehicles if they are confident that they are safe. A reform option that provides this assurance is likely to increase consumer confidence and increase the uptake of automated vehicles.

Research suggests that government approval regulation on the safety of a product decreases uncertainty about available products. This means consumers are more willing to change to a new product (such as automated vehicles) than if there is no approval regulation. Approval regulation causes businesses to provide more information about a product than they would otherwise (Carpenter, et al., 2010). Regulation that enhances information availability can also improve safety outcomes (Jin & Leslie, 2003). Additionally, availability of information increases consumer confidence in the product and may increase their willingness to change more quickly to a new product (Carpenter, et al., 2010).

Criterion b provides clear and consistent regulatory expectations to facilitate market entry, including national consistency and alignment with international requirements. This criterion focuses on manufacturers' willingness to enter the Australia market. If they have certainty about the regulatory requirements and the requirements are consistent with international requirements, they are more likely to enter the Australian market because it is not unduly complicated or burdensome to do so.

There is evidence that government regulations affect business confidence, which in turn may affect their willingness to enter or stay in a market (ABS, 2015, Branstetter, et al., 2014, NAB, 2018). Evidence suggests that inconsistent or uncertain regulation – whether across Australian states and territories or between Australia and other countries – may slow or deter entry to the market, which would delay the widespread use of automated vehicles in Australia. Inconsistent regulation in the US has slowed progress in the industry (Clayton UTZ, 2016, p. 9).

The uptake of automated vehicles may also be affected by the extent to which the regulatory process is efficient and minimises cost implications on purchasing and operating automated vehicles.

[25] NAB (2018) found that the three issues with greatest effects on business confidence were 'Pressure on margins', 'Outlook for your business' and 'Wage costs'.

5.2.3 Choice of regulatory costs to industry assessment criteria

We assess each of the four options against three regulatory cost to industry assessment criteria. The assessment criteria were chosen to assess the extent to which each option would reduce new regulatory costs for industry.

Criterion a results in low upfront and ongoing compliance, administrative and delay costs. This assessment criterion is based on the Office of Best Practice Regulation's definition of substantive regulatory costs.[26]

Criterion b provides clear and consistent regulatory expectations to industry about its responsibilities and what is required to comply. This assessment criterion recognises that clear and consistent regulatory expectations for industry about what is required to comply allows for streamlining of processes and reductions in costs.

Criterion c supports an approach that is consistent across all jurisdictions and aligned with international requirements. This assessment criterion recognises that consistent regulatory requirements reduce business costs. It removes the costs associated with multiple, variable regulatory processes and allowing businesses to streamline processes

5.2.4 Choice of regulatory costs to government assessment criteria

We assess each of the four options against three regulatory costs to government assessment criteria. The criteria were chosen to assess the extent to which each of the four options would be likely to affect regulatory costs to government.

Criterion a minimises upfront structural, organisational and regulatory change to implement the model, including a minimal impact on existing processes and minimal regulatory layers. This criterion recognises that costs relating to building the systems, capabilities and capacities are not likely to be recovered from industry. This means they are likely to be borne by the relevant governments, and ultimately by the community through taxes. It also recognises that multiple regulatory layers add to costs.

Criterion b supports efficient ongoing administrative processes including, if required, mandatory self-certification, safety assurance system assessments, registration and responding to breaches. This criterion recognises that a failure to create efficient ongoing administrative processes is likely to result in duplicated or delayed processes and increase costs to governments or industry if the system is based on a cost-recovery model.

Criterion c clearly defines roles and responsibilities of states, territories and the Commonwealth (and a separate national agency if applicable) for regulating automated vehicle safety. This criterion recognises that a failure to clearly define the roles and responsibilities of relevant governments is likely to result in inefficiencies, duplication of processes and increased costs to government.

5.2.5 Choice of flexibility and responsiveness assessment criteria

We assess each of the four options against five flexibility and responsiveness assessment criteria. The assessment criteria were chosen to assess the extent to which each option will provide flexibility and responsiveness to allow for the uncertainty about regulating automated vehicles.

The criteria are intended to capture the benefits of options that do not exclude certain market structures or prevent future adaptation of the regulatory framework.

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[26] It defines these as follows: compliance costs are 'costs incurred to deliver the regulated outcomes being sought', administrative costs are 'costs incurred by regulated entities primarily to demonstrate compliance with the regulation', delay costs are 'the expenses and loss of income incurred by a regulated entity through one or both of: an application delay…[and] an approval delay…' (OBPR, 2016, pp. 2,3).

Criterion a can be implemented by 2020. This criterion reflects manufacturer predictions that vehicles with conditional or high automation may be available for commercial deployment by 2020.[27] The Transport and Infrastructure Council agreed that Australian governments will aim to have end-to-end regulation in place by 2020 to support the safe deployment of automated vehicles.[28]

Criterion b allows for transition as international approaches evolve. This criterion reflects the fact that international regulation of automated vehicles is in its infancy. It aims to ensure Australia's regulatory approach is sufficiently flexible to allow it to easily change to align with international approaches as they develop.

Criterion c allows flexibility for industry by focusing on safety outcomes, minimising prescriptive requirements, remaining technology-neutral and allowing innovative solutions. This criterion aims to allow for industry innovation by avoiding prescriptive requirements about how a safety outcome must be achieved.

Criterion d allows flexibility for government in addressing emerging safety risks. This criterion recognises that because ADS technology is still being developed not all safety risks can be predicted. The regulatory model needs to be sufficiently flexible to allow for government to address safety risks as they emerge.

Criterion e allows the ADS to be regulated separate from the vehicle. This criterion recognises that an ADS is the 'driver' of the vehicle. It allows for the recognition of the vehicle even if the ADS has not been approved. This might be useful to allow for the sale of ADS-enabled vehicles in regions where infrastructure may not support automated functions.

Consultation question

8. Do you agree with the impact categories and assessment criteria? If not, what additional impact categories or assessment criteria should be included?

5.3 Individuals and groups likely to be affected

To assess the costs and benefits of the safety assurance system reform options it is important to identify the individuals and groups affected by the reform.

Table 5 outlines the key groups and individuals that are most likely to be affected by the reform options. Our public consultation process allows all affected individuals and groups to give their view and provide evidence on their preferred reform option.

Table 5. Groups likely to be affected

Impact category	Affected individuals and groups
1. Road safety	▪ Road users, including vulnerable road users such as cyclists and pedestrians ▪ General public (through wider costs of crashes) ▪ Public and private providers of transport, emergency response, health, infrastructure and insurance services (secondary beneficiaries)

[27] See Figure 7 for a timeline of manufacturers predicted release of automated vehicles.

[28] Transport and Infrastructure Council, 2017, p. 3.

2. Uptake of automated vehicles	▪ Consumers and users of automated vehicles ▪ ADSEs ▪ Mobility service providers, road managers (secondary beneficiaries) ▪ Professional drivers (disadvantaged)
3. Regulatory costs to industry	▪ ADSEs ▪ Manufacturers (where these are different from the ADSE)
4. Regulatory costs to government	▪ Commonwealth government ▪ State and territory governments and the National Heavy Vehicle Regulator ▪ National body responsible for administering the safety assurance system (options 3 and 4 only)
5. Flexibility and responsiveness	▪ ADSEs ▪ Commonwealth government ▪ State and territory governments and the National Heavy Vehicle Regulator ▪ National body responsible for administering the safety assurance system (options 3 and 4 only)

Consultation question

9. Has the consultation RIS captured the relevant individuals or groups who may be significantly affected by each of the options? Who else would you include and why?

5.4 Multi-criteria analysis

We use a comparative analysis scale to assign each option a rating against each impact category. Table 6 shows the scale we use to indicate an option's comparative advantage or disadvantage compared with the baseline (option 1).

Table 6. Comparative analysis scale

Very negative impact	Negative impact	Neutral	Ambiguous / uncertain	Improvement	Large improvement
The option would likely result in a **large decline** compared with the baseline option	The option would likely result in **some (limited or moderate) decline** compared with the baseline option	The option would likely have a **negligible impact** compared with the baseline option	The option could result in an **improvement or decline** compared to the baseline option	The option would likely result in **some (limited or moderate) improvement** compared with the baseline option	The option would likely result in a **large improvement** compared with the baseline option

We then test the validity of the outcomes of this assessment, by:

- examining outcomes against different deployment scenarios
- assessing the factors that would lead to a different preferred option.

A provisionally preferred option is set out in chapter 7. This will be re-assessed based on evidence gathered through the consultation process.

6 Assessment of the options

Key points

- Based on our assessment, options 2, 3 and 4 all resulted in an overall benefit relative to option 1.
- Option 4 exhibits the most positive impacts, with large improvements to road safety and flexibility and responsiveness impacts, as well as moderate improvements to the uptake of automated vehicles.
- Option 3 presents similar results but somewhat lesser improvements to road safety and flexibility and responsiveness impacts compared with option 4. Option 3 does, however, present somewhat greater certainty around regulatory costs than option 4.
- Option 2 exhibits similar impacts to option 3 but to an equal or lesser extent in all impact categories.
- We seek feedback on our assessment of the options and further information or data that may help to clearly describe or quantify their impacts.

The purpose of this chapter is to assess the costs and benefits of the four options set out in chapter 3 using the methodology outlined in chapter 5. The following chapter will summarise and test the assessment outcome.

6.1 Assessment provided in this chapter

In this chapter we provide our provisional assessment of the options. We use the multi-criteria analysis described in chapter 5 to rate the options against each of the five impact categories:

- road safety
- uptake of automated vehicles
- regulatory costs to industry
- regulatory costs to government
- flexibility and responsiveness.

6.2 Road safety impacts

In any policy option or regulatory approach aimed at improving road safety, government and the community look for whether it reduces, or is likely to reduce, the number or severity of crashes.[29]

Automated vehicles provide an opportunity to improve the safety of the Australian vehicle fleet (see Appendix G for evidence on the expected benefits of automated vehicles). The US Department of Transport attributes the cause of 94 per cent of all crashes to 'human choice'.

[29] Ideally, if sufficient, reliable data were available, the overall impact of the options on the road safety impacts could be measured by multiplying

- the number and severity of crashes averted as a result of the option, by
- the average cost of a crash.

While there are a variety of estimates of the costs of different crash severities it would be extremely challenging to estimate the extent to which the different options avert crashes or reduce their severity.

The introduction of automated vehicles into the Australian vehicle fleet has the potential to reduce or remove the risk of human error to improve road safety.

Improving road safety through introducing automated vehicles relies on an option that addresses specific safety risks to:

- prevent ADSs with unacceptable safety risks from entering, or remaining in, the market. (a failure to prevent ADSs with an unacceptable safety risk from entering or remaining in the market risks lowering, rather than raising, the safety of the Australian vehicle fleet)
- lower the safety risks of ADSs by raising the safety standards of an ADSE's internal processes
- bring forward the uptake of vehicles with ADSs that have acceptably low safety risks to achieve safety benefits earlier.

Each of the three options to implement a safety assurance system (options 2, 3 and 4) progressively introduce greater levels of regulatory control that are specifically targeted at reducing safety risks.

6.2.1 Assessment of options against road safety assessment criteria

Table 7 summarises the extent to which we consider each of the four options addresses the road safety assessment criteria.

Table 7. Assessment of options against road safety assessment criteria

	Option 1	Option 2	Option 3	Option 4
a. Covers ADS safety over the vehicle lifecycle, including at first supply and in-service	×	✓ (partial only, not in-service)	✓	✓
b. Covers parties that have not sought approval under the safety assurance system, but who would be an ADSE if they sought approval	×	×	✓	✓
c. Ensures there is always a clearly recognised legal entity responsible for risks associated with automated vehicles	×	×	✓	✓
d. Ensures responsibility sits with the party best able to manage the risk	×	×	✓	✓
e. Addresses safety risks that may not have been specifically considered at first supply	×	×	×	✓
f. Proactively addresses emerging ADS risks before the safety issue eventuates	×	×	×	✓
g. Supports the introduction of targeted compliance and enforcement options, including sanctions and penalties for non-compliance	×	×	✓	✓

	Option 1	Option 2	Option 3	Option 4
h. Allows the national body responsible for the ADS to monitor and respond to in-service ADS safety	×	×	✓	✓
i. Supports information sharing between jurisdictions and the national body responsible for ADS safety to allow for a quicker and more targeted response to identified safety issues	×	×	✓	✓

We consider option 4 clearly provides the greatest road safety benefits based on the road safety assessment criteria.

Option 1 does not meet any of the nine road safety assessment criteria.

Option 2 only partially meets one criterion by covering ADS safety at first supply to market but not once the ADS is in-service.

Option 3 provides significant road safety improvements compared with options 1 and 2. A number of the road safety assessment criteria are met. However, it fails to address two road safety assessment criteria we consider are critical to ensuring an ADS is safe. These are:

- addresses safety risks that may not have been specifically considered at first supply
- proactively addresses emerging ADS risks before the safety issue eventuates.

Option 4 meets all the road safety assessment criteria. The addition of a primary safety duty on an ADSE would create an overarching and positive general safety duty on the ADSE to ensure the safety of the ADS as far as reasonably practicable. This would require an ADSE to address safety risks that may not have been specifically covered or identified at first supply and to proactively address safety risks before they eventuate. In contrast, option 3 only provides specific and targeted penalties related to risks identified at first-supply.

Overall, options 3 and 4 both rate more highly than option 2 because they would be supported by clear organisational roles and responsibilities, recognition of the ADSE as having legal responsibilities and a set of specific compliance and enforcement options, including sanctions and penalties.

We rate option 4 higher than option 3 because it addresses more of the safety criteria. Specifically, the primary safety duty is expected to capture and address new or unexpected safety risks that are not addressed in the Statement of Compliance (criterion e), and manage emerging safety risks before an incident occurs (criterion f). This ensures safety standards increase over time as technology and practice improve, and allows for a proactive approach to compliance rather than relying on a breach of the self-certification prior to addressing a safety concern.

By way of example, we consider option 4 would better address the safety risks in scenarios 2–6 of the example problem scenarios described in chapter 2 because the primary safety duty obliges ADSEs to take additional steps to ensure the safe operation of an ADS. An example of the differences in how options 3 and 4 would work is given below.

Scenario 5: Localised and systemic road traffic law breaches: Under option 3, the ADSE's Statement of Compliance would need to address compliance with road traffic laws and the ADSE could be sanctioned for failure to comply with the Statement of Compliance. Under Option 4, the ADSE would also be obliged to ensure safety so far as reasonably practicable, even if the ADS continued to comply with the Statement of Compliance. Systemic breaches of driving laws may be indicative of a breach of the primary safety duty.

The extent to which the safety benefits of option 4 are greater than for option 3 will ultimately depend on the degree of additional safety risk addressed by the primary safety duty, and we are specifically seeking stakeholder feedback on this issue.

Consultation questions

10. Does our analysis accurately assess the road safety benefits for each reform option? Please provide any further information or data that may help to clearly describe or quantify the road safety benefits.
11. What additional safety risks do you consider the primary safety duty in option 4 would address compared with option 3?

6.3 Uptake impacts

The uptake impact category acknowledges that the potential benefits of automated vehicles (such as improved road safety, mobility, freight productivity and reduced road congestion) cannot be fully realised unless automated vehicles are widely used in Australia.[30]

The different regulatory options may provide varying levels of community confidence that automated vehicles are acceptably safe. An option that provides the community with confidence that automated vehicles are safe seems likely to result in automated vehicles being used in Australia more rapidly and making up a larger share of the Australian vehicle fleet. If this occurs, the safety and other wider benefits of automated vehicles may be greater and realised sooner.[31]

The extent that reform options would affect business and consumer confidence would be influenced by a range of factors including:

- real and perceived safety outcomes
- consumers' understanding of the effectiveness of each option to ensure acceptable safety.[32]

6.3.1 Assessment of options against uptake assessment criteria

Table 8 summarises the extent to which we consider each of the four options addresses the uptake assessment criteria.

Table 8. Assessment of options against uptake criteria

	Option 1	Option 2	Option 3	Option 4
a. Provides community assurance that automated vehicle safety risks have been comprehensively addressed	×	✓	✓	✓

[30] Ideally, if sufficient, reliable data were available, the overall impact of the options on the uptake and penetration of automated vehicles would be measured by multiplying

- the proportion of the vehicle fleet that has an automated driving system, by
- the average benefit of automated vehicles.

However, this data is not yet available, so we need to consider the logic that explains how the reform options would affect consumer confidence and therefore the uptake and penetration of automated vehicles.

[31] See G for a discussion of the safety and other benefits of automated vehicles.

[32] Not all consumers are likely to have a comprehensive understanding of this and so there may not be a clear distinction between the levels of consumer confidence that could be attributed to each option.

	Option 1	Option 2	Option 3	Option 4
b. Provides clear and consistent regulatory expectations to facilitate market entry, including national consistency and alignment with international requirements	×	✓	✓	✓

Our uptake impact assessment outcomes show that the three reform options (options 2–4) all represent an overall benefit compared with the baseline option.

Options 2–4 would all provide community assurance that automated vehicle safety risks have been addressed. Of all the options, option 1 would deliver the least consumer assurance.

It is difficult to assess the differences in levels of community confidence that automated vehicles are safe between options 2, 3 and 4. While options 2–4 have all been rated similarly, it is likely that options 3 and 4 would provide greater community assurance than option 2. This is because options 3 and 4 provide for specific compliance and enforcement mechanisms, including penalties. The existence of penalties for failure to comply could increase community confidence that ADSEs will provide accurate information about safety risks. An increased level of community confidence based on a particular reform option would be reliant on community education about the reform.

Options 2–4 provide clear and consistent regulatory expectations to facilitate market entry, including national consistency and alignment with international requirements. In contrast, option 1 has a clear enough process – the established ADR exemption process – but there is presently no clarity or consistency on what is required to satisfy this process.

We consider that options 3 and 4 may have clearer and more consistent regulatory expectations compared with option 2. Option 2 has clear and consistent regulatory expectations from the safety assurance system safety criteria. However, it still requires the ADSE to get an exemption from the ADRs and gain conditional registration. The conditions placed on registration may not be predictable or consistent and may vary between states and territories.

Consultation question

12. Does our analysis accurately assess the uptake benefits for each reform option? Please provide any further information or data that may help to clearly describe or quantify the uptake benefits.

6.4 Regulatory costs to industry impacts

The regulatory cost to industry impacts category recognises that a safety assurance system will have regulatory costs for industry. If regulatory costs are too high, automated vehicles may not be introduced and used widely in Australia.[33]

[33] Ideally, if sufficient, reliable data were available, the overall impact of the options on the regulatory costs to industry and individuals would be measured by multiplying

- the number of ADS certification/ SAS applications, and
- the number of ADS registrations, by
- the average compliance, administrative and delay costs per process.

There is currently not sufficient data to calculate reliable regulatory cost estimates. Instead the NTC has used qualitative information to complement assumed quantitative estimates.

In a RIS, existing regulatory costs are only applicable to the extent that they form the baseline option against which reform options are assessed. Our assessment of regulatory costs to industry is based on costs that would be incurred in direct response to the reform options (options 2–4).

6.4.1 Assessment of options against regulatory costs to industry assessment criteria

Compliance costs

We consider that compliance costs may be incurred by industry, specifically manufacturers or ADSEs. These include:

- upfront or ongoing investments into compliance systems beyond what would have been invested in the absence of a safety assurance system
- costs of training employees beyond what would have been incurred in the absence of a safety assurance system.

In a RIS, compliance costs are only relevant where affected parties face new costs to do what is required by the regulation. Compliance costs are therefore measured against the baseline option (option 1).

Options 2–4 require the industry to build internal systems and capabilities that involve additional compliance costs:

- Option 2 requires the industry to be able to: demonstrate that the ADS meets the required standard and prepare a Statement of Compliance. To do this, the industry may need to invest in their internal systems (for example, functional structures and governance) and capabilities (for example, employee training).
- Option 3 would include the same compliance costs as option 2 and would also create additional costs to develop systems and employee capabilities **to ensure compliance with the Statement of Compliance**.
- Option 4 would include all the compliance costs of options 2 and 3. In addition, it would include costs to develop systems and employee capabilities **to ensure compliance with primary safety obligations**.

Options 2–4 impose compliance costs because they require the industry to build internal systems and capabilities to meet additional regulatory requirements. We expect that total compliance costs for each option would be driven by the magnitude of the additional regulatory burden imposed. Therefore, we would expect option 4 to have the highest compliance costs, followed by option 3 and then option 2. However, the quantum of total compliance costs associated with each option is unclear.

Administrative costs

We consider that administrative costs may be incurred by industry, specifically manufacturers or ADSEs. These include:

- time to prepare relevant documentation for the approval process
- the cost of making an application for approval, including any fees or charges paid
- costs incurred to test the ADS and/or conformity of the production process
- costs of sharing automated vehicle data with government – for example, information about whether an ADS was engaged when a crash occurred or information about ADS failures
- any additional record keeping costs
- administrative steps necessary to satisfy primary safety duty obligations (option 4 only).

Each option requires industry to do certain things that incur administrative costs:

- Option 1 requires that ADSEs seek exemptions from the ADRs. ADSEs would also be required to register automated vehicles as nonstandard vehicles without defined and certain processes.
- Option 2, similarly, requires that ADSEs seek exemptions from the ADRs and register automated vehicles as nonstandard vehicles. However, in contrast to option 1, it has clear and consistent regulatory expectations, as defined in the safety assurance system safety criteria. ADSEs would be required to prepare and submit a Statement of Compliance that addresses the specified safety assurance system safety criteria.
- Option 3 would not require ADSEs to obtain an exemption from ADRs or register an ADS as a nonstandard vehicle on a vehicle-by-vehicle basis. Option 3 requires ADSEs to maintain compliance with their Statements of Compliance, which may involve activities such as monitoring performance, sharing automated vehicle data with government (in certain circumstances) and/or responding to enforcement directives (sanctions and penalties). Each of these activities will incur additional administrative costs.
- Option 4 defines ADSEs as the duty holders under the primary safety duty. This obligation introduces new administrative costs in addition to those described in option 3.[34] Primary safety duty obligations may differ between ADSEs because a primary safety duty is performance-based and can be tailored to be fit for purpose. Therefore, administrative costs to ADSEs are variable and uncertain across the industry as a whole.

The administrative costs of option 1 are uncertain because there would be no defined standards for which an ADS would be assessed against. This would make the application process uncertain and potentially costly for industry.

This uncertainty makes it difficult to judge whether the administrative costs for options 2–4 would be higher or lower than option 1. However, the safety assurance system provides an ADSE with a degree of certainty about the regulatory requirements, which option 1 does not.

It is also unclear whether the administrative costs would be greater for option 1 with its uncertain requirements, or for the remaining options with their more certain requirements. In practice, the administrative costs may depend on how closely the assessment requirements under option 1 resembled those of the safety assurance system.

Options 3 and 4 would provide a more streamlined administrative process than options 1 and 2 by removing the requirements to obtain ADR exemptions and individually register automated vehicles on a vehicle-by-vehicle basis.

Under option 4, we expect that ADSEs, as duty holders, would incur higher administrative costs than under option 3. However, it is unclear whether the administrative costs under option 4 would be higher or lower than those of options 1 or 2.

Delay costs

Delay costs are expenses and loss of income incurred because of an application and/or approval delay. We consider delay costs may be incurred by the ADSE.

Option 1 provides less certain regulatory requirements than options 2–4, which involve well-defined safety assessment criteria under the safety assurance system. We consider that the increased certainty about what is required, for both the ADSE and those making the assessment, means ADSEs are likely to incur fewer delay costs under options 2–4. There is no reason to believe that delay costs would be significantly different between options 2, 3 and 4.

[34] For example, option 4 may involve additional costs to maintain risk management records to comply with primary safety duty obligations. Option 4 may also involve further costs associated with sharing information in the event of a primary safety duty investigation.

Table 9 summarises the extent to which we consider each of the four options addresses regulatory cost to industry assessment criteria.

Table 9. Assessment of options against the regulatory costs to industry assessment criteria

	Option 1	Option 2	Option 3	Option 4
a. Results in low upfront and ongoing compliance, administrative and delay costs	✓ (partially meets criterion) Lowest (baseline) upfront compliance costs. Uncertain, but potentially higher ongoing administrative and delay costs	✓ (partially meets criterion) Higher upfront compliance costs but lower administrative and delay costs than option 1	✓ (partially meets criterion) Higher upfront compliance costs and potentially lower administrative costs than options 1 Lower delay costs than option 1	× Highest upfront compliance costs. Higher administrative costs than option 3 expected, but uncertain as compared against options 1 and 2 Lower delay costs than option 1
b. Provides clear and consistent regulatory expectations to industry about its responsibilities and what is required to comply	×	✓	✓	✓
c. Supports an approach that is consistent across all jurisdictions and is aligned with international requirements	×	✓	✓	✓

6.4.2 Summary of regulatory costs to industry impact assessment

There is significant uncertainty about the upfront and ongoing compliance, administrative and delay costs for each option.

Of the three types of regulatory costs, we anticipate that administrative costs would be the most significant because administrative costs:

- include significant regulatory requirements such as testing the ADS and/or conformity of the production process and preparing relevant documentation
- can be incurred multiple times, whereas the bulk of compliance costs may be dominated by once-off upfront costs.

Our preliminary conclusions are based on the qualitative assessment of the options against the relevant assessment criteria. This conclusion may change if new information becomes available through consultation. The conclusions are as follows:

- Options 1, 2 and 3 partially meet criterion a. Option 1 has the lowest (baseline) upfront compliance costs; however, the ongoing administrative and delay costs are uncertain and potentially higher compared with the other options.
- Option 2 would have higher upfront compliance costs and possibly lower administrative and delay costs compared with option 1.
- While option 3 would provide a more streamlined administrative process than options 1 and 2, it also introduces new administrative costs relating to maintaining compliance with the Statement of Compliance.
- Option 4 introduces additional administrative costs relating to the ADSE's role as a duty holder under the primary safety duty. Obligations under this duty are variable, therefore, administrative costs to ADSEs are also variable and uncertain across the industry as a whole.
- Options 2, 3 and 4 require the industry to build internal systems and capabilities that involve compliance costs. These costs increase with increasing regulatory requirements, with option 4 expected to have the highest compliance costs.
- There is uncertainty around the significance of delay costs.
- Options 2, 3 and 4 fully meet criterion b by providing clear and consistent regulatory expectations to industry about its responsibilities and what is required to comply, whereas option 1 does not meet this criterion.
- Options 2, 3 and 4 also fully meet criterion c by supporting an approach that is consistent across all jurisdictions and aligned with international requirements. Again, option 1 does not meet this criterion.

Consultation questions

13. Does our analysis accurately assess the regulatory costs to industry for each reform option? Please provide any further information or data that may help to clearly describe or quantify the regulatory costs.
14. Are there any specific regulatory costs to industry that we have not considered?

6.5 Regulatory costs to government impacts

The regulatory costs to government impact category recognises that a safety assurance system would have upfront and ongoing costs to government. These costs need to be proportionate to the benefits.[35]

In this impact category we consider regulatory costs to:

- the Commonwealth government and/or a national agency administering the safety assurance system
- state and territory road managers and the National Heavy Vehicle Regulator.

[35] Ideally, if sufficient, reliable data were available, the overall impact of the options on costs to governments would be measured by multiplying

- the number of pre-approval applications for automated driving system (by vehicle/system type), and
- the number of for automated driving system registrations (by individual vehicles/systems), by
- the average administrative costs per process.

There is currently not fully sufficient data to calculate reliable regulatory cost estimates. Instead the NTC has used qualitative information to complement assumed quantitative estimates.

Governments will face a range of ongoing and once-off administrative costs. This includes costs associated with building the necessary systems, capabilities and capacities.

The current vehicle certification process involves fees and charges to recover costs. Government costs for administering the safety assurance system may also be fully, or in part, recovered from the industry through fees and charges.

To the extent that fees and charges cover government costs, these fees and charges become administrative costs to the applicants (the ADSEs). Where costs are not fully recovered, governments bear the cost. More detail is provided on costs at different levels of government in Appendix .

6.5.1 Assessment of options against regulatory costs to government assessment criteria

Table 10 summarises the extent to which we consider each of the four options addresses the regulatory costs to government assessment criteria.

Table 10. Assessment of options against the regulatory costs to government assessment criteria

	Option 1	Option 2	Option 3	Option 4
a. Minimises upfront structural, organisational and regulatory change to implement the model, including a minimal impact on existing processes and minimal regulatory layers	✓	✓	×	×
b. Supports efficient ongoing administrative processes including mandatory self-certification, safety assurance system assessments, registration and responding to breaches	×	✓ (partial, does not support registration and responding to breaches)	✓	✓
c. Clearly defines roles and responsibilities of states, territories and the Commonwealth (and a separate national agency if applicable) for the regulation of automated vehicle safety	×	×	✓	✓

The overall government costs are largely uncertain at this time.

We expect that the most significant cost components would be related to administering the current certification exemption process and administering the safety assurance system. However, these costs are likely to be recovered from ADSEs through fees and charges. The extent of any fees or charges has not yet been determined.

There is significant uncertainty around other potentially significant government costs. These include monitoring, investigating and enforcing in-service safety incidents. However, these activities could also be costed and recovered through fees and charges. Currently, there is insufficient information to estimate these costs.

The significant once-off cost components include upfront investments into administrative systems, the cost of training employees and costs related to regulatory change. Again, there is currently insufficient information to estimate these costs.

While costs are unclear, administrative costs are likely to be recovered from ADSEs through fees and charges. Under the current certification system, the applicant pays fees and charges so that overall administrative costs are recovered. The extent of any fees or charges has not yet been determined.

Based on current knowledge, the overall comparative costs to government for the three reform options (options 2–4) are ambiguous compared with the baseline option.

The preliminary conclusion may change if new information becomes available.

Consultation question

15. Does our analysis accurately assess the costs to government for each reform option? Please provide any further information or data that may help to clearly describe or quantify the costs to government.

6.6 Flexibility and responsiveness impacts

The flexibility and responsiveness category reflects the high level of uncertainty associated with ADS technology and international regulatory approaches. These are still developing. Any Australian regulation needs to be sufficiently flexible to allow for this uncertainty and for the regulatory system to respond and adapt.[36]

In assessing the costs and benefits of any regulatory measure there is always a degree of uncertainty about the future world in which the regulatory framework will operate. The level of uncertainty is higher for anticipatory regulation of emerging technologies such as automated vehicles.

The regulatory approach needs to be flexible enough to provide for the high level of uncertainty. It needs to accommodate:

- a variety of business and operating models[37] – a failure to provide flexibility for future business models could restrict innovation and be costly to the economy
- an unknown technological mix – it is unclear which type of ADS technologies are more likely in the short and medium term.

6.6.1 Assessment of options against flexibility and responsiveness assessment criteria

Table 11 summarises the extent to which we consider each of the four options addresses the flexibility and responsiveness assessment criteria.

[36] For example, there is uncertainty about the level and nature of the systematic risks posed by automated vehicles, the future world in which the regulatory framework will operate (for example, future automated vehicles market structures, uptake and market penetration rates, future road safety outcomes, technological change and its effectiveness) and the impacts of the options themselves (for example, the behavioural response to reform options and their effectiveness).

[37] For example, solely private ownership, solely commercial fleets or mixed private ownership and commercial fleets.

Table 11. Assessment of options against flexibility and responsiveness criteria

	Option 1	Option 2	Option 3	Option 4
a. Can be implemented by 2020	✓	✓	✓ (possible but challenging)	✓ (possible but challenging)
b. Allows for transition as international approaches evolve	✓	✓	✓	✓
c. Allows flexibility for industry by focusing on safety outcomes, minimising prescriptive requirements, remaining technology-neutral and allowing innovative solutions	×	✓ (somewhat)	✓	✓
d. Allows flexibility for government in addressing emerging safety risks	×	×	×	✓
e. Allows for regulation of the ADS separate to the vehicle	×	×	✓	✓

The flexibility and responsiveness impact assessment outcomes show that each of the three reform options provide an overall benefit as compared with the baseline option with an improvement increasing from options 2 through to 4.

Consultation question

16. Does our analysis accurately assess the flexibility and responsiveness for each reform option? Please provide any further information or data that may help to clearly describe or quantify the flexibility and responsiveness of the options.

7 Summary of assessment and preferred option

Key points

- The multi-criteria analysis shows that option 4 has the most positive impacts.
- Our assessment of the options gives a heavier weighting towards options that deliver greater road safety benefits.
- To test the validity of the outcomes of the multi-criteria analysis we analysed how the options responded to possible future uptake scenarios. Options 3 and 4 performed stronger in high-uptake scenarios, and option 2 performed strongest in low-uptake scenarios.
- We considered a range of factors that could be relevant for government in choosing an option.
- The above assessments led us to a preferred option of option 4.
- There is significant uncertainty in these assessments. The NTC is seeking further evidence as part of the consultation process and will re-assess this preference following consultation.

In chapter 7 we summarise the multi-criteria analysis undertaken in the previous chapter.

We also test the validity of the outcomes of this analysis by analysing how the options respond to four possible future scenarios. This is to account for a lack of certainty about how many people will use automated vehicles, and future business and ownership models. The scenarios provide for varying levels of uptake and spread across the vehicle fleet of automated vehicles in Australia and for different ownership models.

We then consider the most relevant factors for government in choosing a regulatory approach for automated vehicles and decide which factors are most plausible and persuasive.

Lastly, we use the multi-criteria analysis and scenario testing, and the factors we consider most relevant to choosing a regulatory approach, to come to a preferred option of option 4.

7.1 Summary of multi-criteria analysis

Table 12 summarises the outcomes of the multi-criteria analysis undertaken in chapter 6.

Table 12. High level multi-criteria analysis

Impact category	Option 1	Option 2	Option 3	Option 4
Road safety	This option represents the baseline option	The option would most likely result in **limited improvement** in road safety outcomes compared with the baseline option	The option would most likely result in a **moderate improvement** in road safety outcomes compared with the baseline option	The option would most likely result in a **large improvement** in road safety outcomes compared with the baseline option
Uptake of automated vehicles	This option represents the baseline option	The option would most likely result in a **limited improvement** compared with the baseline option	The option would most likely result in a **moderate improvement** compared to with baseline option	The option would most likely result in a **moderate improvement** compared with the baseline option
Regulatory costs to industry	This option represents the baseline option	The option would most likely result in **limited improvement** (lower costs) compared with the baseline option	The option would most likely result in a **moderate improvement** (lower costs) compared with the baseline option	The option could result in an **improvement or decline** compared with the baseline option
Regulatory costs to government	This option represents the baseline option	The option could result in an **improvement or decline** compared with the baseline option	The option could result in an **improvement or decline** compared with the baseline option	The option could result in an **improvement or decline** compared with the baseline option
Flexibility and responsiveness	This option represents the baseline option	The option would most likely result in **limited improvement** in flexibility and responsiveness outcomes compared with the baseline option	The option would most likely result in a **moderate improvement** in flexibility and responsiveness outcomes compared with the baseline option	The option would most likely result in a **large improvement** in flexibility and responsiveness outcomes compared with the baseline option
Summary	This option represents the baseline option	**Overall impacts:** Moderate improvement compared to with baseline option	**Overall impacts:** Moderate improvement compared to with baseline option	**Overall impacts:** Large improvement compared to with baseline option

The analysis is provided for consultation purposes, but the NTC acknowledges that there is a high degree of uncertainty due to a lack of clear evidence on which to base a number of these assessments. We are seeking additional evidence and will update the analysis in the final decision RIS.

Our analysis shows that all of the reform options (options 2–4) resulted in overall benefits compared with option 1 (baseline option).

Option 4 has the most positive impacts, with large improvements to road safety and flexibility and responsiveness impacts, moderate improvements to the uptake of automated vehicles, and an ambiguous/uncertain impact to regulatory costs and costs to government.

Option 3 has similar results but somewhat lesser improvements to road safety and flexibility and responsiveness impacts compared with option 4. Option 3 does, however, present somewhat greater certainty around regulatory costs than option 4. Option 2 exhibited similar impacts to option 3 but to an equal or lesser extent in all impact categories.

7.1.1 Comparing costs and benefits of the reform options

To assist our analysis, the NTC developed two materiality tests (as detailed in Appendix E) that show that, under a range of plausible assumptions, an effective safety assurance approach will provide:

- significant road safety benefits in terms of reducing the number and severity of road crashes
- significant economic benefits resulting from earlier and higher uptake of automated vehicles.

These benefits should be considered against the quantum of regulatory costs (or cost savings) and the costs to governments imposed by the reform options. Our testing of key materiality benefits in Appendix E notes that, based on current information, the assessment of these costs is highly uncertain. But these costs do appear to be a fraction of the value of the benefits that could be realised, in particular the road safety benefits.

If we accept the relative strength of the possible road safety benefits, the overall assessment of options should give a heavier weighting towards those options that deliver the greatest road safety benefits.

While the uptake benefits appear to be significant, there is limited information available to differentiate the options relative to this impact category. As such, no general weighting need be applied.

7.2 Impacts of options under various automated vehicle uptake scenarios

It is unclear how many people will use automated vehicles. It is also unclear if private vehicle ownership will be common for automated vehicles as is the case with conventional vehicles. Some analysts predict that shared vehicle ownership will become more common and replace private ownership.

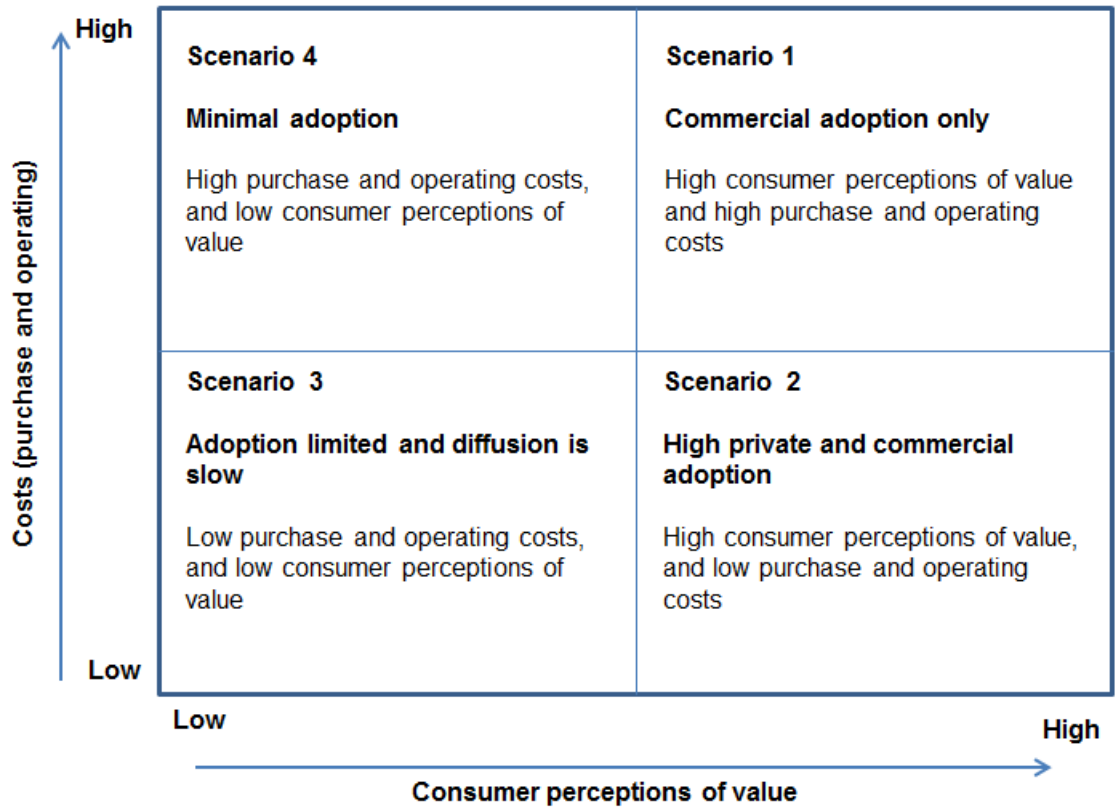
To test the validity of the outcomes of the multi-criteria assessment, in this section we analyse which options respond best to four possible future uptake scenarios. The scenarios provide for varying levels of uptake, ownership models and spread across the fleet of automated vehicles in Australia. Each scenario is plausible and might require different features from a regulatory system.[38]

[38] At this stage, it is difficult to know which scenario would be most likely to eventuate, but we can identify and monitor the factors that would influence consumer perceptions of automated vehicle benefits and costs. Factors

The following scenarios are set out in Figure 3.[39]

- commercial adoption only (top-right quadrant)
- high private and commercial adoption (bottom-right quadrant)
- adoption limited and diffusion is slow (bottom-left quadrant)
- minimal adoption (top-left quadrant).

Figure 3. Automated vehicle uptake scenarios



Scenario 1: Commercial adoption only (top-right quadrant)

Up-front purchase costs are high and ownership of automated vehicles is limited to commercial operators.[40] Commercial operators are likely to require similar fleet vehicles (for example, taxi fleets). This means there would only be a moderate level of new automated vehicle applications each year.

Impacts of options

influencing consumer perceptions of automated vehicle benefits include the effectiveness of regulations to ensure safety, safety record, enhanced mobility (particularly for people cannot drive or cannot afford to own a vehicle), extent of complementary benefits (for example, increased productive/leisure time, comfort), ability to overcome technological obstacles. Factors influencing automated vehicle costs include the efficiency of the regulatory environment, global development and demand (product development and market forces), increased vehicle sharing, complementary developments/deployment of connectivity, electrification and sharing.

[39] These scenarios are established using a quadrant framework where four scenarios are established by the relationship of: Costs of purchasing and operating automated vehicles, which also captures the technological path (where costs are expected to reduce over time), consumer perception of value (benefits) of automated vehicles, which also captures the development of business models, such as increased vehicle sharing.

[40] Commercial operators could offset these costs against savings from reduced costs for human drivers.

Under this scenario, there might be 100–200 new automated vehicle applications per year.[41] The regulatory processes under options 1 and 2 (ADR exemption processes and conditional registration) may become overly burdensome. Options 3 and 4 would deliver greater regulatory efficiency through clearly targeted and streamlined regulatory processes.

With an increasingly shared vehicle fleet, the overall number of registered vehicles would fall, but each vehicle would travel more kilometres each year. This could present risks to in-service performance, which are only addressed under options 3 and 4. In-service performance is most comprehensively addressed by option 4 because the primary safety duty provides for new risks that were not identified in the Statement of Compliance.

Scenario 2: High private and commercial adoption (bottom-right quadrant)

Private and commercial consumers recognise and value the benefits of automated vehicles and upfront costs fall quickly. Commercial automated vehicle applications are widespread and automated driving functionality is included in all new vehicles suitable for private use (similar to air-bag, electronic stability control and satellite navigation rollouts). Automated vehicle saturation of the new vehicle market occurs relatively quickly, within 10–15 years. As the existing vehicle fleet is replaced there is automated vehicle saturation of the in-service vehicle fleet in the subsequent 10–15 years.

Impacts of options

The strong demand for automated vehicles from both commercial operators and private users means there is demand for a wide variety of vehicle types. This will ensure a high level of new automated vehicle applications.

The overall fleet of registered vehicles would remain at similar levels to today, or even increase, as more potential owners realise the benefits of automated vehicles.

Options 3 and 4 would deliver significantly greater regulatory efficiency than options 1 and 2 because of the clearly targeted and streamlined regulatory processes (new vehicle approvals under the safety assurance system and standard vehicle registration).

Depending on the types of safety issues associated with widespread private and commercial automated vehicle uptake, option 4 may provide a necessary additional level of coverage of safety risks. The primary safety duty provides for new risks that were not identified in the Statement of Compliance.

Scenario 3: Adoption limited and diffusion is slow (bottom-left quadrant)

Anticipated benefits of automated vehicles do not eventuate, automated vehicles are involved in a number of fatal crashes, and consumer confidence in the technology falls. Despite being reasonably affordable, consumer ambivalence leads to limited uptake and demand for human-driven vehicles remains. The fleet becomes increasingly mixed, but automated vehicle replacement of human-driven vehicles does not occur.

Impacts of options

Under this scenario there are significant automated vehicle safety issues, but purchase costs are relatively low.

While demand for automated vehicles would be restrained, the low cost could attract consumers who may not choose to, or be able to, comprehensively assess the safety risks of automated vehicles before purchasing them. This possibility emphasises the need for an effective safety assurance system and a primary safety duty

An effective safety assurance system that comprehensively addresses in-service safety performance would be imperative to protect public safety and to instill consumer confidence. Only options 3 and 4 would provide this protection.

[41] This is based on the current number of new vehicle applications of around 400 per year.

Depending on the types of safety issues, option 4 may provide a necessary additional level of coverage of safety risks.

Scenario 4: Minimal adoption (top-left quadrant)

The cost of automated vehicles remains high and anticipated benefits do not eventuate. Private consumers remain concerned about high costs and safety risks, and commercial automated vehicle business models are not viable. Commercial and private consumers renew their preference for human-driven vehicles.

Impacts of options

Under this scenario, where automated vehicle purchase costs remain high and significant safety issues are prevalent, demand for automated vehicles is likely to be low. The regulatory costs of options 1 and 2 may be substantially lower than the higher once-off costs associated with options 3 and 4.

Given the identified safety issues in this scenario, some form of safety assurance would be necessary to protect the small number of consumers who choose to buy automated vehicles. Option 2 could provide adequate safety assurance while avoiding additional unnecessary regulation that would be better suited where automated vehicle volumes are higher.

7.2.1 Summary of scenario analysis

Our analysis of the scenarios is that options 3 and 4 perform more strongly than options 1 and 2 in situations where there is a significant level of demand for automated vehicles (scenarios 1–3).[42]

Depending on the types of safety issues associated with different levels of demand for automated vehicles and dominant business models (for example, private, fleet or mixed-ownership models), option 4 may provide a necessary additional level of coverage of safety risks.

Where automated vehicle demand is relatively low because costs remain high and consumers perceive benefits to be low (scenario 4), option 2 may provide the most suitable approach. In the short term, automated vehicle demand may also be low because technology and markets are in their infancies. This early phase may exhibit similarities with the minimal uptake scenario.

7.3 Relevant factors for government in choosing an option

Different options could be preferred under different conditions. We have compiled a list of possible factors and conditions that could lead decision-makers to different preferred options. We seek your feedback on the validity of these factors.

Option 2 would be preferable if governments consider that:

- it is appropriate to take a cautious, incremental approach to regulation because of the uncertainty about the future including international regulatory approaches
- a more robust Australian regulatory regime could be perceived as a disincentive for suppliers/operators to enter the market
- the ability to recall or deregister vehicles is sufficient to mitigate uncertain future risks, at least initially

[42] Significant levels of demand are likely to occur if consumers see high benefits in automated vehicles (scenario 1: commercial adoption, and scenario 2: high private and commercial adoption). It is also likely where consumer perceptions of value are low but purchase costs are also low (scenario 3: limited adoption).

- a self-certification system that does not include specific sanctions and penalties and does not cover in-service safety would be successful to achieve an acceptable level of safety, at least initially
- there would be sufficient time to implement additional regulatory measures (for example, options 3 or 4) if need is shown once the technology is introduced into the Australian market
- the public will accept this regime as providing sufficient reassurance about the safety of automated vehicles so as not to undermine the uptake of the technology.

Option 3 would be preferable if governments consider that:

- self-certification on its own is insufficient to achieve an acceptable level of safety
- the deregistration or recall powers under option 2 are inadequate because they have the potential to punish the wrong party (end consumers)
- consumer law is insufficient to ensure ADSEs are held to account for safety failures without additional offences and penalties being imposed
- a suite of appropriately targeted sanctions and penalties would be a sufficient additional factor to change the behaviour of ADSEs to achieve acceptable safety outcomes
- the additional cost, both in terms of government administration and compliance costs imposed on ADSEs are outweighed by the additional safety benefits achieved
- it is possible to formulate requirements, offences and penalties so they do not require ongoing revision and updating as ADS technology and the market for it evolve
- implementing penalties to supplement the self-certification system if the need arises would be too slow and unduly risk safety either because technology may evolve very rapidly or because it would take a long time for governments to implement penalties as an incremental regulatory step above option 2
- additional costs of implementing this regime are likely to be low because it will only need positive action by governments if ADSEs breach legal requirements
- it is broadly in line with regulatory regimes in key international markets and would not discourage potential suppliers from entering the Australian market
- it is likely to lead to greater uptake of automated vehicles than option 2 because the public view it as providing better assurance about the safety of automated vehicles.

Option 4 may be preferable where governments consider that:

- the potential and unknown safety risks associated with ADSs are so significant that a primary safety duty is required to provide ADSEs with an additional incentive (over and above options 2 and 3) to manage the safety of the products and services they provide
- a proactive regulator is required to deal with potential issues as they arise
- options 2 and 3 cannot cover all foreseeable future safety risks, and the broad nature and flexibility of a primary safety duty is needed to manage these
- they only have one chance at implementing a complete regulatory regime, and an incremental approach is not a feasible option
- additional costs associated with this option are likely to be relatively low due to the primary safety duty applying to ADSEs only
- this option would not be significantly more onerous than regulatory approaches in key international markets and would not discourage potential suppliers from entering the Australian market

- this option would significantly enhance the public's confidence in automated vehicles (over and above 0ptions 2 and 3), and this enhanced confidence would potentially translate into higher uptake rates.

7.3.1 The NTC's view on relevant factors for government

Overall, we consider that the factors that would suggest option 4 as the preferable option are more plausible and persuasive than those favouring the other options. We consider that option 2 may not provide adequate means of ensuring that ADSEs ensure safety. The use of targeted sanctions and penalties alone in option 3 is also unlikely to result in sufficient safety outcomes because they do not provide sufficient incentive to ADSEs to address emerging safety risks. Option 3 is also unlikely to provide sufficiently flexible enforcement and compliance mechanisms and risks resulting in overly complex legislation aimed at covering all possible risks and frequently needs updating to cover new identified safety risks.

Option 4 could enhance actual and perceived safety compared with options 2 and 3 via a primary safety duty. In addition to improving actual safety outcomes, this may also increase the public's confidence in automated vehicles. This enhanced confidence might increase uptake and saturation of automated vehicles in the Australian fleet. Compared with option 3, option 4 may result in simpler legislation because a primary safety duty reduces the need to anticipate all risks and provide targeted sanctions for actions that lead to the risk. It may also reduce the need for frequent legislative amendment to cover newly identified safety risks. Compared with option 3, which only provides for targeted sanctions and penalties, a primary safety duty is more likely to result in sufficient in-service safety outcomes because it provides an incentive for ADSEs to address emerging safety risks. It is more likely to give government sufficiently flexible enforcement and compliance mechanisms to ensure that ADSEs consider and address safety risks that emerge once the automated vehicle is in service. We also consider that the additional regulatory costs of option 4 over option 3 will be limited, as a primary safety duty will only be applicable to ADSEs.

Consultation questions

17. Do you consider the relevant factors and conditions for government in choosing an option to be valid? Are there any factors and conditions you do not agree with?
18. Do you agree with our view on the relevant factors and conditions for government in choosing an option?

7.4 Conclusion – provisionally preferred option

The four options have been assessed in a highly uncertain environment where governments are taking regulatory action in anticipation of an unknown future.

This degree of uncertainty makes it impractical to carry out a quantitative cost-benefit analysis. Instead, we conducted a multi-criteria qualitative assessment of the likely benefits and costs of each option, informed by supplementary quantitative information and testing where available.

The two materiality tests (detailed in Appendix E) show that, under a range of plausible assumptions, an effective safety assurance approach will provide:

- significant road safety benefits in terms of reducing the number and severity of road crashes
- significant economic benefits resulting from earlier and higher uptake of automated vehicles.

Given the relative strength of the possible road safety benefits, we consider the overall assessment of options should give heavier weighting to options that deliver the greatest road safety benefits. Options that exhibit strong road safety benefits (options 3 and 4) should be viewed more favourably than options that have low regulatory and government costs (potentially option 2 in some circumstances).

Our multi-criteria analysis concludes that option 4 exhibits the most positive impacts, in particular showing improvement against the baseline option for each of the nine criteria under the road safety impact category. Costs to industry are limited to ADSEs rather than those further down the supply chain or individual vehicle owners, and are minimal in comparison with the road safety benefits expected.

We also analysed which options respond best to four possible scenarios. The scenarios provide for varying levels of uptake, ownership models and spread across the vehicle fleet of automated vehicles in Australia. Each scenario is plausible and might require different features from a regulatory system. In three of the four scenarios we assessed, options 3 and 4 appear as performing more strongly than options 1 and 2. This was for scenarios where there is a significant level of demand for automated vehicles. Depending on the types of safety issues associated with different levels of demand for automated vehicles and dominant business models (for example, private, fleet or mixed-ownership models), option 4 may provide a necessary additional level of coverage of safety risks.

There are several factors that governments must consider in choosing a regulatory approach for automated vehicles. They affect which option is considered preferable. We outlined the factors that we considered relevant to each option.

Based on these assessments we consider that option 4 is preferable. Option 4 strikes a reasonable balance between the following requirements:

- the need to ensure that automated vehicles entering the Australian vehicle fleet are reasonably safe to avoid the potentially high social cost of poor road safety outcomes
- the need to provide users with reassurance that automated vehicles are reasonably safe so that a lack of confidence does not become a barrier to the uptake of automated vehicles
- the need to limit regulatory costs to industry and government
- the need to ensure regulation is consistent and certain so that ADSEs can supply ADSs to the Australian market without excessive cost.

The relative benefits and costs of the options may change as existing uncertainties become resolved. We acknowledge the significant uncertainties involved in these assessments and will reassess our provisional preference in light of any new information from the consultation process.

Consultation questions

19. Has the consultation RIS used an appropriate analytical method for assessing the benefits and costs of the options? What else should be considered?
20. On balance, do you agree that the preferred option best addresses the identified problem? If not, which option do you support?
21. How does your choice of option better address the problem than the preferred option?

8 Consultation and next steps

Key points

- Any individual or organisation can make a submission to the NTC.
- We are seeking submissions on this consultation RIS by **Monday 9 July 2018**.

8.1 Comment sought on the consultation RIS

Comment is now sought on this consultation RIS, the regulatory options it assesses and their potential impacts.

We encourage you to make a submission outlining your views on the RIS assessments and any evidence or experiences that may support or contradict those assessments. Your views will be essential in developing a decision RIS that will support our recommendations to the Transport and Infrastructure Council in November 2018.

8.2 Consultation questions

The following questions are intended to assist stakeholders in their assessment of the options:

1. To what extent has the consultation RIS fully and accurately described the problem to be addressed? Please provide detailed reasoning for your answer.
2. What other factors should be considered in the problem statement?
3. Has the consultation RIS provided sufficient evidence to support the case for government intervention? What else should be considered and why?
4. To what extent have the community and industry expectations of a regulatory response been accurately covered?
5. Are the four options clearly described? If not, please elaborate.
6. Are the proposed safety criteria and obligations on ADSEs (detailed in chapter 4 and Appendix C) sufficient, appropriate and proportionate to manage the safety risk?
7. Are there any additional criteria or other obligations that should be included?
8. Do you agree with the impact categories and assessment criteria? If not, what additional impact categories or assessment criteria should be included?
9. Has the consultation RIS captured the relevant individuals or groups who may be significantly affected by each of the options? Who else would you include and why?
10. Does our analysis accurately assess the road safety benefits for each reform option? Please provide any further information or data that may help to clearly describe or quantify the road safety benefits.
11. What additional safety risks do you consider the primary safety duty in option 4 would address compared with option 3?
12. Does our analysis accurately assess the uptake benefits for each reform option? Please provide any further information or data that may help to clearly describe or quantify the uptake benefits.
13. Does our analysis accurately assess the regulatory costs to industry for each reform option? Please provide any further information or data that may help to clearly describe or quantify the regulatory costs.

14. Are there any specific regulatory costs to industry that we have not considered?
15. Does our analysis accurately assess the costs to government for each reform option? Please provide any further information or data that may help to clearly describe or quantify the costs to government.
16. Does our analysis accurately assess the flexibility and responsiveness for each reform option? Please provide any further information or data that may help to clearly describe or quantify the flexibility and responsiveness of the options.
17. Do you consider the relevant factors and conditions for government in choosing an option to be valid? Are there any factors and conditions you do not agree with?
18. Do you agree with our view on the relevant factors and conditions for government in choosing an option?
19. Has the consultation RIS used an appropriate analytical method for assessing the benefits and costs of the options? What else should be considered?
20. On balance, do you agree that the preferred option best addresses the identified problem? If not, which option do you support?
21. How does your choice of option better address the problem than the preferred option?

8.3 When to submit

We are seeking submissions on this Consultation RIS by **Monday 9 July 2018**.

8.4 How to submit

Any individual or organisation can make a submission to the NTC.

To make an online submission, please visit www.ntc.gov.au and select 'Submissions' from the top navigation menu. Or post your comments to:

Att: Automated Vehicle Team
National Transport Commission
Level 3/600 Bourke Street
Melbourne VIC 3000

Where possible, you should provide evidence, such as data and documents, to support your views. If you have any questions about the submission process, you can email the Automated Vehicle Team at automatedvehicles@ntc.gov.au. Unless you clearly ask us not to, we will publish all submissions online. However, we will not publish submissions that contain defamatory or offensive content. The *Freedom of Information Act 1982* (Cwlth) applies to the NTC.

8.5 Next steps

We will consider evidence provided through submissions in developing the decision RIS and recommendations for transport ministers to consider in November 2018.

A number of further issues will need to be assessed once a preferred approach is agreed, including:

- any new institutional arrangements to support the preferred approach
- any changes to existing legislation or new legislation
- any additional compliance and enforcement measures to support the preferred approach.

Appendix A Safety risks associated with automated vehicles

The NTC has identified three types of safety risks associated with automated vehicles:

- design risks
- organisational risks
- operation/use risks.

A.1 Design risks

Inadequately designed and tested automated driving systems (ADSs) or associated modifications have the potential to lead to crashes. New risks or hazards could include:

- technological failure (malfunction due to poor design)
- cyber security failure (for example, hack or attack due to poor design)
- software updates introducing new safety issues (poor quality control, or the update is not supported by the vehicle's operating system)
- failure to function as expected in approved operating environments/conditions (system not up to the task)
- the ADS not being suited to Australian environmental or driving conditions
- the after-market system does not integrate safely with the existing vehicle
- the vehicle meets design criteria but still causes a safety risk in operation.

These types of risks would be best managed by the vehicle manufacturer or the automated driving system entity (ADSE).

A.2 Organisational risks

Organisational risks include:

- failure by the ADSE to address safety issues that emerge over time (software or hardware) – for example, through lack of appropriate support
- failure to monitor the performance of the system
- failure to adapt the system to changes in regulation over time
- failure to adapt the system to changes in the road environment over time
- insolvency of the ADSE
- the ADSE no longer supports legacy versions of the ADS
- the company deploys an ADS (native, after-market or through software upgrade) that has not been through the self-certification process
- failure to monitor and issue security updates as required.

These types of risks would be best managed by the vehicle manufacturer or the ADSE.

A.3 Operational/use risks

Operational/use risks include:

- use in inappropriate environments/conditions

- technological failure (degradation of hardware due to poor maintenance/repair)
- cybersecurity failure (for example, hack or attack due to failure to follow security protocols)
- software updates (failure to apply)
- divided/competing or contradictory responsibilities (between the driver and the ADS)
- unclear responsibilities of human drivers in different vehicles
- after-market fitment and vehicle modifications adversely impacting the ADS's performance
- vehicle repairs adversely impacting he performance of the ADS due to error or lack of understanding of the ADS's operation
- repairers unable to assess impact the of repairs to an ADS.

These types of risks would be best managed between a number of players including the vehicle manufacturer or the ADSE, ADS repairers and registered vehicle owners or operators.

Appendix B Compliance and enforcement for safety assurance

B.1 Compliance and enforcement measures relating to safety assurance

The purpose of a compliance and enforcement regime is to encourage desirable behaviour and punish undesirable behaviour. It is important that the maximum penalty adequately reflects the serious nature of the offence and appropriately balances fairness with deterrence.

Existing national safety laws and the NTC's Compliance Review of the Heavy Vehicle National Law (National Transport Commission, 2015) provide guidance on potential categories of compliance and enforcement tools that could be used within a safety assurance system. These include the following:

- **Improvement notices** are administrative sanctions that are educational rather than punitive. This tool could be applied when the relevant agency determines that the offender's actions could improve through education. Under the Heavy Vehicle National Law (HVNL), an improvement notice requires the offender to remedy the contravention within a set timeframe. Failure to remedy the contravention is an offence incurring a maximum penalty of $10,000 (but the initial contravention is not). Example: an improvement notice issued to address an identified safety risk with an automated driving system (ADS) technology.
- **Formal warnings** provide an alternative sanction to initiating proceedings for noncompliance in circumstances in which the offender has taken all reasonable steps to prevent the breach and was unaware of its occurrence. They do not necessarily require court proceedings; however, the formal warning can only be used where it is proportionate to the offence (formal warnings should not be used in relation to substantial or severe contraventions of safety). Example: a formal warning is issued to a technology provider who installed after-market ADS technologies without lodging a Statement of Compliance; it was a one-off breach and the technology has a low safety risk.
- **Infringement notices** are issued by an enforcement agency alleging a breach of law and providing the alleged offender an opportunity to pay a fixed amount rather than proceed to court. Infringement notices are generally used for less serious offences. Example: offences related to record keeping.
- **Court-imposed penalties** are used for more serious offences that do not have an infringement option and require court adjudication. Safety assurance legislation could empower courts to impose financial penalties, restrict operations or impose conditions designed to enhance safety. The courts also have the power to prohibit the worst or repeat offenders through prohibition orders. Example: the automated driving system entity (ADSE) failed to lodge a compliance statement for an in-service ADS modification that results in unsafe outcomes of serious consequence.
- **Withdrawals of permission to operate** are applied when the ADSE's behaviour is egregious and other sanctions or penalties are unlikely, or have not, changed unsafe behaviours. Withdrawal of permission to operate may also be appropriate if the ADSE shifts assets and resources out of Australia. The Western Australian Heavy Vehicle Accreditation Scheme provides some guidance on what grounds could be included for withdrawing permission:
  - not submitting a compliance statement

- falsifying documents regarding accreditation
- refusing to take part in a random or triggered audit
- refusing to cooperate with or obstructing a Main Roads Western Australia officer/auditor when conducting a random audit
- failure to resolve a major non-conformance
- any combination of the above.

These examples of types of penalties and sanctions most likely relate to a range of offences that underpin the mandatory feature of the safety assurance system. These include, but are not limited to:

- failure to lodge a Statement of Compliance to the relevant agency for an ADS prior to market introduction
- failure to lodge a Statement of Compliance to the relevant agency for an in-service modification that allows a vehicle to operate at a higher level of automation
- providing false or misleading information in the Statement of Compliance
- failure to inform the relevant agency of a significant safety risk or issue related to the ADS
- failure to follow a legal direction of the relevant agency in relation to the ADS.

In addition, a range of safety assurance offences covering the in-service safety of the ADS and relating to the ADSE's Statement of Compliance could be included, such as the ADSE's:

- failure to maintain ongoing compliance with its Statement of Compliance
- failure to report breaches of the road rules, crash data, near-miss data, cybersecurity vulnerabilities and other safety-critical events to the national agency.

Maximum penalty levels

Maximum penalty levels require further consultation and analysis. The HVNL Penalties Matrix,[43] approved by the Transport and Infrastructure Council in 2015, aligns penalty levels across the HVNL. The levels of penalties in the HVNL are based on risk and the likely impact behaviours will have on road safety. A similar approach could be adopted for monetary penalties in the safety assurance system.

As a guide, Table 13 sets out maximum penalty levels in the HVNL.

[43] National Transport Commission, 2015, Heavy Vehicle National Law Penalties Matrix Process and Demerit Point Assessment Process (Melbourne).

Table 13. Risk categories and their associated penalties in the HVNL[44]

Current HVNL risk category	Current HVNL maximum penalty
Minor – minimal risk/impact	$1,000–$3,000
Substantial – some/marginal risk/impact (not an appreciable risk)	$4,000–$6,000
Severe – appreciable/significant risk/impact	$8,000–$10,000
Critical – critical/serious risk/impact	$15,000–$20,000

The HVNL Penalties Matrix has agreed principles to determine maximum penalty levels, which could also be used as a guide in developing monetary penalties in the safety assurance system:

22. Maximum penalty levels should be set at a level that gives courts the ability to tailor a particular penalty to a level that will deter and punish a worst-case offence, including repeat offences.
23. Maximum penalty levels should aim to provide an effective deterrent to the commission of the offence and should reflect the seriousness of the offence within the relevant legislative scheme.
24. Offences should reflect the degree of seriousness of the violation in safety, equity and infrastructure degradation terms.
25. A higher maximum penalty will be justified where there are strong incentives to commit the offence, or where the consequences of the commission of the offence are particularly dangerous or damaging. Safety risks should attract the most serious penalties.
26. A maximum penalty should be consistent with penalties for existing offences of a similar kind or of a similar seriousness.

Further research and consultation is required to determine whether maximum penalties, comparable with the HVNL, would be appropriate for breaches of the safety assurance system requirements, given the potential size of an automated vehicle fleet that could be approved under a single Statement of Compliance.

B.2 Sanctions and penalties relating to primary safety duty offences

Sanctions and penalties for breaches of a primary safety duty should be commensurate with the risk and ability of the duty holder to address that risk. The Model Work Health and Safety (WHS) Act and the Rail Safety National Law (RSNL) provide indicative benchmarks for penalty levels for a primary safety duty.

The Model WHS Act and the RSNL grade breaches of the duties based on the risk of death or serious injury or illness posed by noncompliance. Table 14 outlines current offence categories in both regimes, with each category imposing a maximum penalty proportionate to the severity of the risk.

Both the Model WHS Act and the RSNL apply the same three offence categories for breaches of the health and safety duties under sections 19–29 of the Model WHS Act and sections 52–56 of the RSNL respectively. However, there are differences in the quantum of

[44] National Transport Commission, 2015, Heavy Vehicle National Law Penalties Matrix Process and Demerit Point Assessment Process (Melbourne), p. 6.

fines and maximum fines. As Table 14 illustrates, there are maximum fines for the most serious offences of up to $600,000 under the Model WHS Act and $300,000 under the RSNL for an individual's breach, and $3 million for a body corporate's breach.

Penalties, including imprisonment for the most serious cases under offence category one, are a key component of deterrence and complement other types of enforcement action, such as improvement notices. Maximum penalties reflect the severity of the offences and have been set at levels high enough to cover the most extreme instances of noncompliance.

Table 14. Offence categories and maximum penalties in Model WHS Law and the RSNL[45]

	Category 1: Breach of duty creating risk of death or serious injury or illness (reckless)	Category 2: Breach of duty creating risk of risk of death or serious injury or illness	Category 3: Other breach of duty
Conduct	A person engages in conduct that exposes an individual to whom the duty is owed to a risk of death or serious injury without a reasonable excuse	A person fails to comply with the safety duty and that failure exposes an individual to a risk of death or serious injury or illness	A person fails to comply with the safety duty
Fault element (intent)	The person is reckless as to the risk to an individual of death or serious injury or illness	n/a (strict liability)	n/a (strict liability)
Burden of proof	The prosecution must prove: (a) the person had a safety duty; and (b) the person, without reasonable excuse, engaged in conduct that exposed an individual to whom that duty is owed to a risk of death or serious injury or illness; and (c) the person was reckless as to the risk to an individual of death or serious injury or illness	The prosecution must prove: (a) the person had a safety duty; and (b) the person failed to comply with that duty; and (c) the failure exposed an individual to a risk of death or serious injury or illness	The prosecution must prove: (a) the person had a safety duty; and (b) the person failed to comply with that duty
Model WHS Act maximum penalties	Individual (other than as a person conducting a business) – $300,000 and/or five years' prison Individual as a person conducting a business – $600,000 and/or five years' prison Body corporate – $3 million	Individual (other than as a person conducting a business) – $150,000 Individual as a person conducting a business – $300,000 Body corporate – $1,500,000	Individual (other than as a person conducting a business) – $50,000 Individual as a person conducting a business – $100,000 Body corporate – $500,000
RSNL maximum penalties	Individual – $3 million or five years' prison or both Body corporate – $3 million	Individual – $150,000 Body corporate – $1,500,000	Individual – $50,000 Body corporate – $500,000

[45] (National Transport Commission, 2015a)

Maximum penalties for breaching the primary safety duty should be aligned where possible with the maximum penalties available under the national safety laws. This includes uptake of a hierarchy of penalties based on the risk and nature of the harm or damage caused. Therefore, if a primary safety duty is adopted, we expect to see a similar range of offence categories and quantum of fines for individuals and corporations in the safety assurance system.

Appendix C Proposed safety criteria for the Statement of Compliance

Options 2, 3 and 4 introduce a safety assurance system. One of the features of this system is a requirement for automated driving system entities (ADSEs) to self-certify against specified safety criteria in a Statement of Compliance, before an automated driving system (ADS) or function, or significant modification, can be introduced into the market. The ADSE, rather than government, will be responsible for testing and validating the safety of the ADS or function and documenting these processes. The role of government is to satisfy itself that the applicant has processes in place to identify and manage the safety risks. This broad approach was agreed to by transport ministers in November 2017, subject to analysis through a Regulation Impact Statement.

The NTC is proposing 11 safety criteria that require the applicant to demonstrate its processes for managing safety risks:

1. safe system design and validation processes
2. operational design domain (ODD)
3. human–machine interface (HMI)
4. compliance with relevant road traffic laws
5. interaction with enforcement and other emergency services
6. minimal risk condition
7. on-road behavioural competency
8. installation of system upgrades
9. testing for the Australian road environment
10. cybersecurity
11. education and training.

The NTC is proposing three other obligations on ADSEs to assist relevant parties to appropriately assign criminal and civil liability for events such as road traffic law breaches and crashes:

1. data recording and sharing
2. corporate presence in Australia
3. minimum financial requirements.

These criteria were developed with the aim of balancing safety and innovation. As such, the criteria are generally outcomes based rather than prescriptive.

Not all safety criteria are necessarily relevant to each ADS, function or significant modification. If the applicant considers that a safety criterion or other obligation is not relevant, the applicant must explain why. Over time, elements of these criteria may transition to Australian Design Rules (ADRs). In these circumstances, the applicant could refer to compliance with the relevant ADR(s) to explain why a particular criterion is not relevant, or as evidence of meeting the criterion.

In developing the proposed safety criteria, the NTC considered:

- previous feedback and input from a range of stakeholders, including government and industry

- the United States National Highway Traffic Safety Administration's (NHTSA) strategy on regulating automated vehicle safety, *Automated Driving Systems 2.0: A Vision for Safety*[46] (and the earlier version of the policy, *Federal Automated Vehicles Policy*[47])
- the State of California Department of Motor Vehicles' (California DMV) regulations relating to the deployment of autonomous vehicles for public operation[48]
- the *Draft resolution on the deployment of highly and fully automated vehicles in road traffic*, a document submitted to the UNECE Global Forum for Road Traffic Safety's (WP.1) March 2018 meeting by the WP.1 chair and deputy chairs[49]
- the *Draft Recommendation on Software Updates of the Task Force on Cybersecurity and Over-the-air issues of UNECE WP.29 IWG ITS/AD* (WP.29 document) (December 2017)
- the June 2017 report by the Ethics Commission on Automated Driving set up by the German Federal Ministry of Transport and Digital Infrastructure[50]
- the German *Road Traffic Act*, which allows drivers to operate vehicles with conditional and high automation.[51]

This appendix also outlines select criteria the NTC considers should be excluded, and criteria more suitable for legislation. These are discussed because they were raised by stakeholders, or have been included in other regulatory regimes.

The safety criteria outlined in chapter 4 and this appendix are proposed criteria only. They are subject to further amendments and refinement based on stakeholder feedback and work undertaken as part of the NTC's changing driving laws to support automated vehicles project.

C.1 Principles-based safety criteria

C.1.1 Safe system design and validation processes

Description of criterion

The system design, validation and testing processes should be chosen with the objective of developing an ADS free of safety risks so far as reasonably practicable. The system design process should consider appropriate risk mitigation measures over the vehicle lifecycle, based on the ODD.[52]

Requirements for the Statement of Compliance

The applicant must explain why it chose particular design, validation and testing processes, and how these ensure a safe technology is developed. For choice of system design, the applicant could explain how the ADS will be disengaged when its safety is affected by maintenance, repairs, physical modifications or other safety-critical issues.

The applicant should document decisions relating to the choice of design, validation and testing processes and include empirical evidence or research to support the safety assertions made. Such documentation could explain why particular processes were chosen.

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[46] Available at: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf.

[47] Available at: https://www.transportation.gov/sites/dot.gov/files/docs/AV%20policy%20guidance%20PDF.pdf.

[48] Refer to: https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/auto.

[49] Available at: https://www.unece.org/fileadmin/DAM/trans/doc/2018/wp1/ECE-TRANS-WP1-2018-4e.pdf.

[50] Available at: https://www.bmvi.de/SharedDocs/EN/publications/report-ethics-commission.pdf?__blob=publicationFile.

[51] Available at: https://www.gesetze-im-internet.de/stvg/.

[52] The ODD is discussed in criterion 2.

Where applicable, the applicant should use guidance, industry best practices, design principles and standards developed by established standards organisations.

Comparison with other relevant regulatory systems

The NHTSA's *Automated Driving Systems 2.0* suggests following a robust design and validation process based on a systems-engineering approach with the goal of designing ADSs free of unreasonable safety risks. The NHTSA encourages entities to document the entire process to ensure all design choices, and associated testing, are traceable and transparent. The NHTSA also discusses the development of validation methods that could appropriately mitigate safety risks.

The California DMV's regulations require certification that the manufacturer has conducted testing and validation and is satisfied that the vehicles are safe for deployment on public roads.

C.1.2 Operational design domain

Description of criterion

The ADS must have a defined ODD and be unable to operate in areas and conditions outside of its defined ODD.

The ODD is the set of conditions under which an ADS is intended to function and can safely operate. This includes, but is not limited to, road types (highway, low-speed public street, etc.), geographic area, speed and environmental conditions (weather, time of day, etc.).

This criterion links with the on-road behavioural competency criterion, which refers to changes in the external operating environment that could affect the ODD.

Requirements for the Statement of Compliance

The applicant must identify the ODD of the ADS and demonstrate how it will ensure the ADS is:

- able to operate safely within its defined ODD
- incapable of operating in areas outside of its defined ODD
- able to transition to a minimal risk condition when outside its defined ODD.

This could include documentation outlining the process for assessing and testing the ADS's functionality both within and outside the defined ODD.

The applicant should also outline how it will review and manage changes to the defined ODD. Major changes to the ODD are likely to be significant modifications requiring the applicant to submit a new Statement of Compliance for approval before introducing the change into the market.

Comparison with other relevant regulatory systems

In *Automated Driving Systems 2.0*, the NHTSA notes that the ODD criterion will support the safe introduction of ADSs on public roads by providing the flexibility to limit the complex driving task to a confined ODD. The Netherlands Vehicle Authority similarly notes that in circumstances where software is undertaking the driving task, it is necessary to have a 'stepped admission' based on the software's learning curve. The ADS's ODD is likely to be quite narrow during initial deployment and its complexity can increase over time.[53]

The WP.1 March 2018 document similarly refers to automated vehicles only operating within the ODD.

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[53] Gerden Febbes, *How to get a driving license for an automated vehicle: The contribution from a Vehicle Authority for legislation for automated systems*, The Netherlands Vehicle Authority, October 2017.

C.1.3 Human-machine interface

Description of criterion

The HMI must facilitate interaction between the ADS and a range of relevant parties that allows the vehicle to operate safely.

In automated vehicles, the HMI is no longer limited to the interaction between the vehicle and the driver. As the ADS undertakes the driving task, it must convey additional information about its intentions and performance through both an internal and an external interface.

The internal HMI should communicate relevant information between the ADS and the human driver, operator and occupant(s). The external HMI should communicate relevant information between the ADS and parties external to the vehicle (such as pedestrians and bike riders). Both the internal and external HMI could communicate information about the ADS's state of operation, including by way of relevant signage.

Requirements for the Statement of Compliance

The applicant must outline how the HMI will facilitate interaction between the ADS and relevant parties (both internal and external to the vehicle) that allows the vehicle to operate safely.

In relation to human drivers and occupants, the information communicated by the HMI should include, but is not limited to:

- informing the human driver if the ADS is engaged and the level of automation engaged
- requesting the human driver take back control of the vehicle with sufficient time for the human driver to respond. In addition, the applicant should outline the safeguards to ensure a fallback-ready user is actually ready to take back control. This could include monitoring by the ADS of human readiness to take back control and alert systems where such readiness is not apparent
- drawing attention to potential safety risks related to human monitoring and having to be ready to re-engage with the driving task
- indicating whether the ADS is functioning properly or experiencing a malfunction.

In relation to parties external to the vehicle, information such as the ADS's state of operation should be communicated by the HMI via an external communication interface. This could take the form of an external screen.

The applicant must also outline how it tests and assesses the HMI and make reference to any appropriate international standards or agreed guidelines for HMIs.

Comparison with other relevant regulatory systems

NHTSA's *Automated Driving Systems 2.0* includes an HMI criterion. The NHTSA's criterion similarly refers to considering the various interactions the ADS may encounter.

The WP.1 March 2018 document refers to automated vehicles being equipped with an appropriate HMI for communication with internal and external road users.

The report by the German Ethics Commission on Automated Driving states that automated technology must be designed to ensure efficient and reliable human–machine communication. In particular, the need for immediate handover of control from the ADS to the human driver should be avoided.

C.1.4 Compliance with relevant road traffic laws

Description of criterion

When the ADS is engaged, the vehicle must operate in compliance with relevant road safety and traffic laws.

There are variations in the road safety and traffic laws between the different Australian states and territories. In addition, these laws are not static. Amendments are made from time to time to the Australian Road Rules (model law that forms the basis of the road rules in each state and territory). Amendments are also made to the road rules of each state and territory independent of any amendments to the Australian Road Rules.

There may be circumstances where strict compliance with relevant road traffic laws is not possible – for example, where the vehicle needs to cross a solid line to pass roadworks, or a cyclist. In such circumstances, the ADS must ensure the vehicle responds in a safe way.

Requirements for the Statement of Compliance

The applicant must demonstrate how it will ensure the vehicle operates in compliance with relevant road traffic laws when the ADS is engaged. In particular, how the ADS will comply with:

- current road traffic laws in each state and territory
- amendments to the relevant road traffic laws when they come into force.

This could include documentation outlining the process for assessing and testing the ADS's compliance with current road traffic laws and the process for updating the ADS to comply with amendments to those laws.

The applicant must also demonstrate how the ADS will respond in a safe way where strict compliance with relevant road traffic laws is not possible. This requirement closely links with the on-road behavioural competency criterion.

Comparison with other relevant regulatory systems

The California DMV's regulations require manufacturers to certify that the autonomous vehicle technology is designed to detect and respond to roadway situations in compliance with relevant laws (including changes to those laws). The NHTSA's *Automated Driving Systems 2.0* provides that the development of ADSs should account for all traffic laws, which includes developing processes to update and adapt ADSs to address new or revised legal requirements.

The WP.1 March 2018 document refers to the ADS complying with applicable domestic traffic rules.

C.1.5 Interaction with enforcement and other emergency services

Description of criterion

The ADSE must provide police with information that would assist with road traffic law enforcement. This includes information about the level of automation engaged and whether the human driver or the ADS was in control at a particular time.

Where reasonably possible, police should be able to access such information in real time at the roadside. The reference to 'where reasonably possible' has been included to balance the views of police that real-time information at the roadside is necessary for effective enforcement of road traffic laws with the views of other stakeholders that this may not always be possible. The NTC welcomes feedback on this approach.

The ADS must also interact with emergency services more broadly when it is engaged. This should include moving out of the way of emergency services vehicles and following the directions of enforcement officers.

Requirements for the Statement of Compliance

The applicant must demonstrate how it will ensure that police can access accurate information about whether the ADS is engaged at a given time and the level of automation

engaged. The applicant should also demonstrate how it may facilitate access by police to this information in real time at the roadside.

The applicant must demonstrate how it will ensure safe interaction with emergency services more broadly when the ADS is engaged.

Comparison with other relevant regulatory systems

Other relevant regulatory systems generally capture interaction with enforcement as part of data recording and sharing requirements. For this criterion, the comparison with other relevant regulatory systems is discussed under the 'Data recording and sharing' obligation in section C.3.1.

C.1.6 Minimal risk condition

Description of criterion

The ADS must bring the vehicle to a minimal risk condition when it cannot operate safely. The ADS may be unable to operate safety where there are system faults, including as a result of a crash, where there is a deterioration of vehicle hardware or where the ADS is outside its ODD.

At lower levels of automation, the ADS may achieve the minimal risk condition by notifying the driver to take back control consistent with the requirements in the HMI criterion. At higher levels of automation, the ADS may need to bring the vehicle to a minimal risk condition without human intervention, such as coming to a controlled safe stop.

Following a crash, the actions necessary for the ADS to return to a safe state are likely to depend on the severity of the crash. Communication with emergency services through an automatic collision notification system (if such technology exists) may help to reduce any harm resulting from the crash.

Requirements for the Statement of Compliance

The applicant must demonstrate how the ADS will detect that it cannot operate safely and ensure a minimal risk condition is reached.

This could include documentation outlining the process for assessing and testing the ability of the ADS to detect and respond to such circumstances. The minimal risk condition is likely to vary depending on the reason why the ADS cannot operate safely and on the level of automation engaged. Therefore, a range of approaches to bring the vehicle to a minimum risk condition may need to be considered.

Comparison with other relevant regulatory systems

The NHTSA's *Automated Driving Systems 2.0* includes a fall-back (minimal risk condition) criterion. This criterion similarly requires the ADS to detect circumstances where it cannot operate safely and to outline the strategies or approaches to transition to a minimal risk condition. The NHTSA also includes a separate criterion relating to safety post-crash.

The report by the German Ethics Commission on Automated Driving states that in emergencies the vehicle must enter into a 'safe condition' without human assistance (Ethics Commission, 2017, p. 13).

C.1.7 On-road behavioural competency

Description of criterion

When the ADS is operating, the vehicle must detect and appropriately respond to a variety of foreseeable and unusual conditions that may affect its safe operation. An appropriate response could include the ADS disengaging or bringing the vehicle to a safe stop.

The ADS must detect and respond to other vehicles, vulnerable road users (such as pedestrians, bike riders and animals) and objects that could affect the vehicle's safe operation.

The ADS must also detect and respond to unusual events that occur within the ODD, changes to the external operating environment and new or changed hazards introduced into ODD. These could include temporary speed zones and traffic controls such as variable speed signs and police manually directing traffic.

Requirements for the Statement of Compliance

The applicant must demonstrate how the ADS will appropriately respond to foreseeable and unusual conditions that may affect its safe operation. This could include documentation outlining the process for assessing and testing the ADS's object and event detection and response and crash avoidance capabilities, and its ability to respond to unusual events within its ODD.

Comparison with other relevant regulatory systems

The NHTSA's *Automated Driving Systems 2.0* includes an object event detection and response criterion. This criterion similarly covers detecting and responding to other vehicles, vulnerable road users and objects that could affect the vehicle's safe operation, and addressing a wide variety of foreseeable encounters.

The WP.1 March 2018 document broadly refers to responding to foreseeable and unusual conditions. It provides that the ADS should prioritise road safety and aim to compensate for human errors of road users both inside and outside the vehicle.

C.1.8 Installation of system upgrades

Description of criterion

The ADS must be disengaged, at least temporarily, if safety-critical system upgrades are not installed or system failures are detected following the installation of upgrades.

If the ADS is updated automatically by the ADSE, the registered owner/operator must be notified.

If the registered owner/operator needs to install the upgrade, the ADSE must inform registered owners/operators that over-the-air software updates or other system upgrades are available and how to access these upgrades. The ADSE should explain to registered owners/operators why a particular system upgrade is required when it is provided.

Requirements for the Statement of Compliance

The applicant must demonstrate how it will manage system upgrade risks. This includes ensuring safety-critical system upgrades to the ADS are installed and do not result in the operation of an unsafe ADS.

The applicant must explain how it will notify registered owners/operators that an update has been installed, or is available and needs to be installed. The applicant must also demonstrate how it will:

- detect failures to install upgrades (including failures of automatic updates and failures by registered owners/operators to take action when an upgrade is available)
- detect system failures once upgrades are installed
- ensure the ADS is safely disengaged if such failures occur.

This could include documentation outlining the process for assessing and testing the ADS's ability to:

- update automatically and notify the registered owner/operator of the update

- notify the registered owner/operator of available system upgrades
- detect and respond to failures to install upgrades
- detect and respond to any system failures following the installation of upgrades.

Comparison with other relevant regulatory systems

The California DMV's regulations require the manufacturer to notify the registered owner that updates are available and to explain how to access the updates. The NTC considers that only notifying the registered owner/operator may not be sufficient. The ADSE must also take action where updates are not installed because the registered owner/operator may be unable to install an update or be unaware that an update is available. This could occur where there is insufficient cellular or other network coverage for the ADS to receive or install an over-the-air software update. Therefore, the ADSE is likely to be better placed to manage the risk of an update not being installed than the registered owner/operator.

The December 2017 WP.29 document recommends imposing obligations on the original equipment manufacturer (OEM) relating to over-the-air software updates. For example, OEMs should ensure that registered owners/operators are informed of any updates and can provide approval to an update being executed. Where legally obliged, OEMs should ensure it is possible for updates to be executed automatically.

C.1.9 Testing for the Australian road environment

Description of criterion

The ADS must detect and respond to elements of the road environment that are unique to Australia.

Certain road infrastructure differs in Australia compared with other parts of the world. For example, road signs in Australia are different from those in Europe. Many European countries are signatories to the Vienna Convention on Road Signs and Signals, which aims for basic and consistent sign features.[54] Australia is not a signatory to the Convention. There are also differences in road signs between the Australian states and territories.

Australia is also the home to unique flora and fauna not found in other parts of the world, which the ADS may need to detect and respond to during a journey. There may also be environmental conditions specific to Australia, depending on the ODD.

Requirements for the Statement of Compliance

The applicant must demonstrate how it has considered the Australian road environment in designing and developing the ADS, including its forward planning processes to ensure compliance with changes to the road environment (such as changes to road infrastructure).

This could include documentation outlining the process for assessing and testing the response of the ADS to the Australian road environment such as interaction with road signs in various states and territories and interaction with Australian flora and fauna.

Comparison with other relevant regulatory systems

This criterion is not specifically included in other relevant regulatory systems the NTC reviewed. However, the California DMV's regulations require certification that vehicles are safe for deployment on public roads specifically in California.

[54] Austroads, *Assessment of Key Road Operator Actions to Support Automated Vehicles*, May 2017. See: https://www.onlinepublications.austroads.com.au/items/AP-R543-17.

C.1.10 Cybersecurity

Description of criterion

The ADS must be designed and developed to minimise the risk and consequences of cyber intrusion.

As vehicles become increasingly automated, there are more opportunities for a cyber intrusion to occur. A cyber attack compromising the back-end servers of the ADS could disrupt the whole automated fleet. A sophisticated attack may also actively control the entire driving task in order to commit crimes, including acts of terrorism.

Requirements for the Statement of Compliance

The applicant must demonstrate how it has designed and developed an ADS that minimises the risks of cyber intrusion and how it will detect and minimise the consequences of intrusions that occur.

This could include outlining how any best practice guidance for vehicle cybersecurity (domestic and international) has been considered and incorporated into the design and development of the ADS.

Comparison with other relevant regulatory systems

The NHTSA's *Automated Driving Systems 2.0* includes a vehicle cybersecurity criterion. The NHTSA suggests that entities should incorporate cybersecurity considerations into the design of the ADS and consider established best practices for cyber vehicle physical systems when doing so.

The California DMV's regulations require the manufacturer to certify that autonomous vehicles meet current industry standards to help defend against, detect and respond to cyber attacks.

The report by the German Ethics Commission on Automated Driving more broadly notes that automated driving is justifiable only if cyber intrusions do not destroy consumer confidence in road transport.

C.1.11 Education and training

Description of criterion

Relevant parties, such as human drivers, occupants and repairers, as well as dealers and distributors, must receive adequate education and training to ensure safe deployment of ADSs.

Education and training is likely to minimise the safety risks of the new technology by addressing changes to vehicle operation.

Requirements for the Statement of Compliance

The applicant must outline the education and training that will be provided to relevant parties and how this will minimise the safety risks of using and operating ADSs. Education and training should take into account different types of vehicles (including light and heavy vehicles) and different types of vehicle users. Without limiting the education and training to be provided, such education and training should consider:

- training human drivers to safely disengage and re-engage the ADS and the driving task
- informing human drivers of their obligations, particularly any fallback-ready user obligations
- informing human drivers of the ADS's capabilities, including any restrictions of the automated technology such as the ODD

- facilitating the maintenance and repair of an ADS, including post-crash before it is put back in service
- facilitating employee, dealer and distributor understanding of the technology and operation so relevant information can be accurately conveyed to consumers and purchasers
- ongoing education as required, including education and training to end users who are not the original vehicle owner.

The development of education and training should be well documented. Such documentation could be used to explain the reasons for the particular education and training chosen and how it will facilitate proper and safe use of the automated technology.

Comparison with other relevant regulatory systems

The California DMV's regulations require the preparation of a consumer or end user education plan. Among other matters, the education plan must identify the restrictions of the autonomous technology and contain copies of sections of the vehicle owner's manual that outline the responsibilities of the operator and the manufacturer.

The NHTSA's *Automated Driving Systems 2.0* suggests that entities should develop and maintain education and training programs for employees, dealers, distributors and consumers to address the anticipated differences between automated and conventional vehicles.

The report by the German Ethics Commission on Automated Driving more broadly notes that 'the proper use of automated systems should form part of people's general digital education' (Ethics Commission, 2017, p. 13).

C.2 Select criteria that have not been included

The following criteria have been raised by stakeholders and/or have been included in other relevant regulatory systems. For the reasons outlined below, the NTC does not consider the applicant's Statement of Compliance needs to address these criteria.

C.2.1 Ethical considerations

Description

ADSs may face safety dilemmas with ethical implications. In the earlier version of its automated vehicle policy, *Federal Automated Vehicles Policy*, the NHTSA noted that the choice made by an ADS could result in different outcomes for different road users in the same set of circumstances. The NHTSA suggests there may be situations when the achievement of safety, mobility and legality objectives will come into conflict. As such, the NHTSA states it is important to consider whether ADSs should apply particular decision rules to resolve conflicts between these objectives.

The report by the German Ethics Commission on Automated Driving relevantly notes the following:

- The guiding principle is to avoid accidents. Automated technology must be designed in such a way that critical situations do not arise in the first place.
- The protection of individuals takes precedence over other considerations. If hazardous situations are unavoidable, protecting human life is the top priority.
- Decisions in situations where a choice must be made between one human life and another cannot be programmed. However, general programming to reduce the number of personal injuries may be justifiable. Decisions based on attributes such as age and gender are prohibited.

Some stakeholders also suggested including ethical considerations as a safety criterion.

Reasons for exclusion

The NTC considers that concerns regarding safety dilemmas with ethical implications are already largely captured by the safety criteria. Therefore, a separate ethical considerations criterion is not necessary and may create confusion and significant overlap without achieving additional safety benefits.

In a conference paper, two Swedish academics proposed that as long as an ADS can 'estimate its own operational capability for handling surprising situations, and adjust its own tactical behaviour accordingly', safety dilemmas with ethical implications may be resolved.[55] The paper notes that ADSs can plan driving in a way that any risk of surprising and unsafe situations is acceptably low. This includes considering things like vehicle speed and distance to surrounding objects according to operational capabilities.

With this in mind, the NTC's proposed safety criteria relating to ODD, compliance with relevant road traffic laws, on-road behavioural competency and minimal risk condition offer a framework for addressing safety dilemmas with ethical implications. These criteria recognise the operating capabilities of the ADS and address its ability to:

- detect and appropriately respond to a variety of foreseeable and unusual conditions affecting its safe operation
- achieve a minimal risk condition when it cannot operate safely
- prioritise safety over strict compliance with road traffic laws where necessary.

While the safety criteria may not assist the ADS with choosing one human life over another in the rare and dire situations where this choice may need to be made, the report by the German Ethics Commission on Automated Driving notes this is not a decision that can be programmed in any case.

The NTC also notes that a criterion relating to ethical considerations is no longer included in the current version of the NHTSA's policy, *Automated Driving Systems 2.0*. The NHTSA notes that 'there is currently no consensus around acceptable ethical decision-making given the depth of the element is not yet understood nor are there metrics to evaluate against'.[56]

The NTC will consider including an ethical considerations criterion if there is clearer international consensus and understanding of acceptable ethical decision making by an ADS beyond what is captured by other safety criteria.

C.2.2 Crashworthiness

Description

The NHTSA's *Automated Driving Systems 2.0* includes a crashworthiness criterion. The criterion provides that, in the event of a crash, the occupant protection level should maintain its intended performance level, and vehicles with an ADS should be crash-compatible with conventional vehicles.

This criterion was raised by some stakeholders.

Reasons for exclusion

[55] Rolf Johansson and Jonas Nilsson, *Disarming the Trolley Problem – Why Self-driving Cars do not Need to Choose Whom to Kill*, January 2017.

[57] See: https://www.nhtsa.gov/manufacturers/automated-driving-systems.

The NTC considers that the crashworthiness criterion focuses on the vehicle rather than the ADS and is captured by vehicle standards (ADRs) made under the *Motor Vehicle Standards Act 1989* (Cwlth).[57] These ADRs specify vehicle crashworthiness requirements for full frontal crashes, side impacts and offset frontal impacts.

The crashworthiness ADRs will apply to automated vehicles, as they do to conventional vehicles. Therefore, the NTC considers it is not necessary for the ADSE to meet a separate crashworthiness criterion. ADSEs may seek exemptions to use vehicles that do not comply with ADRs. In that case, any decision on an exemption may need to consider the vehicle's crashworthiness.

C.3 Other obligations on ADSEs

C.3.1 Data recording and sharing

Description of criterion

The automated vehicle must record data relevant to enforcement of road traffic laws and the general safe operation of the ADS (including data relating to crashes and near-misses). Recorded data must be provided by the ADSE to relevant parties (such as police, insurers, road agencies and consumers) as necessary. The data provided must be standardised, readable and accessible to ensure its useability and relevance.

To assist with enforcing road traffic laws, automated vehicles should record whether the human driver or the ADS was in control at a particular time, and the level of automation engaged. The vehicle should also record crash or near-miss data to assist insurers and road agencies. Consumers may also want access to automated vehicle data for the purpose of disputing liability, and ADSEs should facilitate access.

The NTC welcomes feedback on whether we have identified appropriate data recording requirements and parties who should receive the data.

Requirements for the Statement of Compliance

The applicant must outline the data it will record and how it will provide the data to relevant parties. Without limiting the data to be recorded and shared, the applicant must explain how it will ensure:

- the vehicle has real-time monitoring of driving performance and incidents, including event data records in the lead-up to any crash or near-miss that identifies which party was in control of the vehicle at the relevant time
- the vehicle can provide road agencies with crash and near-miss data
- relevant parties (including police) receive information about the level of automation engaged at a point in time
- individuals receive data to dispute liability (for example, data showing which party was in control for the purposes of defending road traffic infringements) when the individual makes a reasonable request and the provision of information aligns with privacy regulation
- data is provided in a standardised, readable and accessible format when relevant

[57] Vehicle Standard (Australian Design Rule 69/00 – Full Frontal Impact Occupant Protection) 2006
Vehicle Standard (Australian Design Rule 72/00 – Dynamic Side Impact Occupant Protection) 2005
Vehicle Standard (Australian Design Rule 73/00 – Offset Frontal Impact Occupant Protection) 2005.

- data is retained to the extent necessary to provide it to relevant parties (the amount of time data is retained for may depend on the purpose(s) the information could be used for – for example, law enforcement, insurance)
- data is stored in Australia.

Comparison with other relevant regulatory systems

A number of relevant regulatory systems include an automated vehicle data recording and sharing requirement.

- The NHTSA's *Automated Driving Systems 2.0* focuses on crash data. It provides that vehicles should record all information relevant to a crash and whether the human driver or the ADS was in control of the vehicle leading up to, during and immediately following a crash. The NHTSA's policy also notes that such data should be available for crash reconstruction purposes.

  The earlier version of the NHTSA's policy, *Federal Automated Vehicles Policy* discussed a broader range of data. The earlier policy refers to recording event, incident and crash data, and states that vehicles should record all information relevant to an event and performance of the system. The policy also provided that vehicles should record the status of the ADS and who was in control of the vehicle, and manufacturers or other entities should have the capability to share the relevant recorded information. Such recording and sharing was not limited to crash-related purposes.

  It is not clear why the current version of the policy focuses on crash data.
- The California DMV's regulations require the manufacturer to certify that the vehicle is equipped with an autonomous technology data recorder capable of being accessed and retrieved by a commercially available tool.
- The WP.1 March 2018 document outlines principles for recording and sharing data. These cover automated vehicles recording and sharing data relating to control of the ADS, especially in events that affect road safety such as a collision or violation of traffic rules. This data should be recorded, secured and made available as necessary in accordance with privacy regulations.
- The German *Road Traffic Act* requires automated vehicles to record time and location information when control of the vehicle changes between the human driver and the ADS. Time and location information must also be stored when the driver is prompted by the system to take control of the vehicle or a system failure occurs. The Act allows the data to be transmitted to law enforcement at their request for the purpose of enforcing road traffic laws. The Act also requires the data to be provided to third parties if it is required to assert, satisfy or defend against legal claims relating to death or personal injury.

C.3.2 Corporate presence in Australia

Description of criterion

The ADSE must have a corporate presence in Australia that can be criminally and civilly liable under Australian law. We welcome feedback about whether the ADSE must be a 'corporate entity' (a corporation).

This will assist parties to bring legal action against the ADSE where necessary.

Requirements for the Statement of Compliance

The applicant must provide evidence of its corporate presence in Australia.

Comparison with other relevant regulatory systems

Having a corporate presence in the country where approval is sought is not specifically included in other relevant regulatory systems that the NTC has reviewed.

C.3.3 Minimum financial requirements

Description of criterion

The ADSE must not be insolvent or in liquidation, and must have sufficient grounds for claiming it will not become insolvent in the future. At this stage, the NTC is not seeking to prescribe a minimum annual turnover or other numerical financial measure. This is to ensure financial requirements do not prevent safe ADSs from entering Australia. However, we welcome feedback on this approach.

The ADSE must also hold an appropriate level of insurance to cover personal injury, death and property damage caused by the ADS when it is properly engaged. Insurance requirements must be considered in light of the NTC's changing compulsory third party insurance to support automated vehicles project.

These financial requirements will assist in ensuring financial risk and liability is appropriately distributed and managed. The onus is on the applicant to explain how they will remain solvent and why the level of insurance held is appropriate in the circumstances.

The NTC recognises that the ADSE may nonetheless become insolvent. Where this occurs, the ADS is likely to become unsafe over time (if not immediately) because it is not maintained. This may be covered by the Australian Consumer Law, which provides a regulatory mechanism to mandate product recalls, but such coverage may be insufficient. The NTC considers relevant parties could be required to ensure the ADS is disabled in circumstances where the ADSE becomes insolvent. We welcome feedback on this approach, including who the relevant parties should be, noting that enforcing obligations against an insolvent ADSE would be difficult.

Requirements for the Statement of Compliance

The applicant must provide evidence of its current financial position, its grounds for claiming it will have a strong financial position in the future and the level of insurance held.

Comparison with other relevant regulatory systems

The California DMV's regulations contain financial responsibility and insurance requirements.

C.4 Obligations that have not been included

The following obligation, which relates to privacy, has been raised by stakeholders. For the reasons outlined below, the NTC does not consider the applicant's Statement of Compliance needs to address privacy.

C.4.1 Privacy

Description

In the earlier version of its policy, *Federal Automated Vehicles Policy*, the NHTSA noted that manufacturers and other entities should take steps to protect consumer privacy. These steps include ensuring transparency, choice, respect for context, minimisation, de-identification and retention, data security, integrity and access and accountability.

Some stakeholders also raised concerns about the privacy of information collected by automated vehicle technology.

Reasons for exclusion

The privacy protection regulations in Australia already cover consumer privacy. The Commonwealth *Privacy Act 1988* covers Commonwealth public sector agencies and organisations with an annual turnover of greater than $3 million. The definition of an organisation is quite broad and includes individuals, corporations, partnerships,

unincorporated associations and trusts. The Act requires compliance with 13 Australian Privacy Principles (APPs) covering the collection, use and disclosure, security, accuracy and ability of an individual to correct, personal information held by the agency or organisation.

The NTC therefore considers the privacy of personal information collected and held by ADSEs is already be broadly covered by the APPs and a separate privacy criterion is not required. Privacy is also not specifically a safety issue, and private sector access to and use of data is a significant societal issue that is much broader than automated vehicle policy and regulation.

Automated Driving Systems 2.0, the current version of the NHTSA's policy, no longer includes a privacy criterion. The NHTSA notes that 'privacy is not directly relevant to motor vehicle safety and, generally, it is the Federal Trade Commission (FTC) and not the US Department of Transportation or NHTSA that is charged with protecting consumer privacy'.[58]

C.5 Provisions that could be captured in legislation

The following criterion, which relates to reporting obligations, has been raised by stakeholders and has been included in other relevant regulatory systems.

The NTC considers that reporting obligations are not relevant to the Statement of Compliance because they are specific obligations on ADSEs while the ADS is in-service. As such, the NTC considers reporting obligations would sit better in legislation.

C.5.1 Reporting obligations

Provisions requiring the ADSE to report breaches of the road rules, crash data, near-miss data, cybersecurity vulnerabilities and other safety-critical events to the agency responsible for the safety assurance system are likely to be included.

Reporting will assist the agency responsible for the safety assurance system to assess the ongoing safety of the ADS while it is in-service and ensure ADS issues are dealt with consistently rather than on a case-by-case basis.

The California DMV's regulations require entities to submit to the DMV, within specific timeframes, any identified safety-related defects in the autonomous technology that create an unreasonable safety risk.

[58] See: https://www.nhtsa.gov/manufacturers/automated-driving-systems.

Appendix D Existing road safety laws and regulations

D.1 The Motor Vehicle Standards Act and the Road Vehicle Standards Act

The *Motor Vehicle Standards Act 1989* (the MVSA) requires all road vehicles imported as new or second hand to comply with the relevant Australian Design Rules (ADRs) at the time of manufacture and supply to the Australian market. When a vehicle is first used on Australian roads the relevant state or territory government's legislation generally requires that it continue to comply with the relevant ADRs as at the time of manufacture (Department of Infrastructure, Regional Development and Cities, 2017b).

The MVSA is expected to be replaced by the Road Vehicle Standards Act (RVSA);[59] however, the technical requirements are not anticipated to significantly change beyond the use of different terminology for standard and nonstandard vehicles. The RVSA will maintain the ADRs as the mechanism for implementing vehicle standards in Australia (Department of Infrastructure and Regional Development, 2017a, p. 5).

The MVSA is the legal instrument for Australia's pre-market type-approval process for new and imported vehicles. The process allows self-testing by manufacturers against the technical standards in the ADRs.

Type-approved new vehicles that fully comply with the national standards are standard vehicles[60] and must be fitted with an identification plate.[61] These vehicles are approved for unrestricted supply to the Australian market.

As long as a vehicle meets the ADRs, it must be approved as a standard vehicle irrespective of any safety issues related to the automated driving system (ADS) itself.

ADRs and the type-approval process only apply when vehicles are first supplied to the market. State and territory governments (and the National Heavy Vehicle Regulator) are responsible for licensing, registration and in-service vehicle compliance.

Penalties and sanctions under the MVSA are imposed on the approval holder, who is likely to be the vehicle manufacturer. Given that the automated driving system entity (ADSE) may not be the vehicle manufacturer, sanctions and penalties may not be targeted to the most appropriate body. There is a possibility that the ADSE could be recognised as the manufacturer of a separate component and therefore be the holder of the approval for the ADS under the MVSA.

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[59] The Australian Government will introduce the Road Vehicle Standards Bill into parliament early in 2018. It is expected to be debated and passed by parliament in 2018 (although both the timing and the decision are ultimately a matter for tparliament to decide). The reforms will commence 12 months after the passage of legislation as the *Road Vehicle Standards Act (RVSA)*.

[60] Refer to subsection 10A(1) and the definition of ***standard vehicle*** in section 5 of the MVSA.

[61] Upon the commencement of the *Road Vehicle Standards Act (RVSA)*, 'identification plates' will be replaced by providing the vehicle information, currently shown on the identification plate, on an online Register of Approved Vehicles (RAV) containing information currently shown on the identification plate, refer to: https://infrastructure.gov.au/vehicles/mv_standards_act/files/Overview_Brochure.pdf.

The sanctions and penalties for noncompliance with the MVSA regulations include the following:

- Contravening a condition of approval under the MVSA is an offence with a maximum fine of 60 penalty units (or $12,600). Failure to comply with a condition of approval may also lead to the cancellation, suspension or variation of the approval to place identification plates on road vehicles of that type.
- The cancellation, suspension or variation of the approval to place identification plates on road vehicles of a particular type may affect the registered owner/operator rather than the party who failed to get approval under the safety assurance system.
- Potential refusal to register a vehicle – again, it is not clear whether this would affect the responsible party (the party who failed to get approval under the safety assurance system). It may affect the responsible party indirectly because new vehicles are generally registered in bulk by dealers, not purchasers. A dealer's inability to register vehicles is likely to be transferred back to the manufacturer.

D.2 Australian Design Rules

The ADRs are national standards for vehicle safety, anti-theft and emissions. They are generally performance-based and cover occupant protection, structures, lighting, noise, engine exhaust emissions, braking and a range of miscellaneous items (Department of Infrastructure, Regional Development and Cities, 2017b).

The standards are administered by the Australian Government under the MVSA.

D.3 Registration and roadworthiness

Vehicle registration permits a vehicle to operate on public roads and regulates the in-service safety performance. States and territories have registration powers to prevent the registration of unsafe vehicles.

While vehicles are being used on public roads, they must continue to comply with Australian Light Vehicle Standards Rules (ALVSRs), as implemented in each state and territory, and Heavy Vehicle (Vehicle Standards) National Regulation.

Light and heavy vehicle standards are primarily based on ADRs, however, they have certain gaps in their application. These are covered by the ALVSRs and heavy vehicle in-service standards, including vehicle combinations and ongoing maintenance requirements.

Unlike light vehicles, which are regulated on a state-by-state basis, heavy vehicles are regulated under the Heavy Vehicle National Law, which is administered by the National Heavy Vehicle Regulator. The Heavy Vehicle National Law established a single national system of laws for heavy vehicles over 4.5 tonnes gross vehicle mass and prescribes requirements related to:

- vehicle standards that heavy vehicles must meet before they can use our roads
- maximum permissible mass and dimensions of heavy vehicles
- securing and restraining loads on heavy vehicles
- ensuring parties in the chain of responsibility are held responsible for drivers of heavy vehicles exceeding speed limits
- preventing drivers of heavy vehicles from driving while impaired by fatigue (National Heavy Vehicle Regulator, n.d.)

State and territory road transport agencies currently rely on a mix of self-regulation and roadside enforcement to ensure compliance with vehicle standards. In most jurisdictions,

vehicle roadworthy checks are also required on an annual basis or when the vehicle is sold or reregistered.

The in-service vehicles standards are set out in the ALVSRs and the Heavy Vehicle (Vehicle Standards) National Regulation. Both sets of standards are based on the ADRs that are developed and administered by the Commonwealth.

For nonstandard vehicles, road managers may attach certain conditions to the registration of these vehicles. These conditions may relate to safety performance or access to parts of the road network.

Sanctions and penalties applied if a vehicle fails to meet relevant vehicle standards once it is in-service include:

- vehicle recalls to rectify a systemic problem (for example, faulty airbags)
- registration withdrawal for vehicle specific problems (for example, unsafe modifications or inadequate maintenance leading to safety standards not being met).

D.4 Licensing

Driver licensing is used to regulate drivers' understanding of road laws and competency in operating specific vehicle types. It is administered by state and territory road authorities, and state-based licenses are mutually recognised in all jurisdictions.

There is currently no licensing system for ADSs.

Sanction and penalties that could be applied if a vehicle failed to meet relevant vehicle standards once in-service are:

- road traffic infringements, including financial penalties and demerit points
- licence suspension or cancellation.

D.5 Australian Consumer Law

The Australian Consumer Law, corporate social responsibility and commercial imperatives already provide a framework for manufacturers and operators where safe operation of automated vehicles is incentivised.

Product safety regulation in Australia for general consumer products is a shared responsibility between the Australian Competition and Consumer Commission (ACCC) and the states and territories.

Consumer law will continue to provide consumers with statutory guarantees that products will be safe, free from defects and fit for purpose. It establishes manufacturer liability for products with safety defects and provides for consumer compensation claims for loss or damage and provides a regulatory mechanism to mandate product recalls.

A recall may be undertaken if there is:

- a risk that a product will or may cause injury
- awareness of a death, serious injury or illness associated with a product.

The system for vehicle recalls is well established through the ACCC and is in regular use, with around 200 recalls in 2016 alone. The Commonwealth Department of Infrastructure and Regional Development assesses complaints about vehicles with safety issues, carries out safety investigations and monitors vehicle recalls on behalf of the ACCC. Under the current approach option, this framework would continue to apply to automated vehicles and provide an important safeguard for automated vehicle safety.

D.6 International regulations on automatically commanded steering function

The United Nations Economic Commission for Europe (UNECE) contributes to enabling automated driving functionalities by hosting the Multilateral Agreements and Conventions ruling for the requirements and use of these technologies.

The UNECE Sustainable Transport Division provides the secretariat services to the World Forum for the Harmonization of Vehicle Regulations (WP.29). WP.29 is the UN World Forum dedicated to technical regulations applied to the broad automotive sector, addressing the safety and environmental performance of wheeled vehicles. This forum aims to ensure that the benefits of new technologies, such as automated driving, can be captured without compromising safety and other policy objectives (United Nations Economic Commission for Europe, n.d.).

As a United Nations member state, Australia has committed to harmonising its regulations, including the ADRs, with these international standards. The proposed ADR90 series will reflect the current regulation. If and when UN Regulation No. 79 (UN R79) is amended, the ADR90 series will subsequently be updated.

Currently UN R79 provides provisions concerning the approval of vehicles in regard to steering equipment. This regulation limits the use of automated systems to functions that operate at speeds at or below 10 km/hr (such as ‘traffic jam assist’ or ‘parking assist’) and lane-keeping functions. The regulation does not allow ADSs capable at operating at full automation.

An informal working group on Automatically Commanded Steering Functions is working on an amendment to UN R79 that would enable the approval of automated systems for use at speeds above 10 km/h.

Appendix E Testing the materiality of the key benefits

The options assessment did not specifically weight the different impact categories; however, consideration was given to the relative potential magnitude, or materiality, of some of the key benefits. This consideration is described below.

E.1 Results of materiality tests

The two tests in this appendix show that, under a range of plausible assumptions, an effective safety assurance approach will provide:

- significant road safety benefits in terms of reducing the number and severity of road crashes
- significant economic benefits resulting from earlier and higher uptake of automated vehicles.

These benefits should be considered against the quantum of regulatory costs and the costs to governments imposed by the reform options. Based on current information, the assessment below shows that these costs are highly uncertain, but they do appear to be of an order that would be a fraction of the value of the benefits that could be realised.

If we accept the relative strength of the possible road safety benefits, the overall assessment of options should be viewed with a heavier weighting towards those options that deliver the greatest road safety benefits. Conversely, the relative strengths of options with lower regulatory costs and costs to governments may be viewed as a somewhat less important consideration.

While the uptake benefits appear to be significant, there is currently limited information available to differentiate the options relative to this impact category. As such, no general weighting need be applied.

E.2 Materiality of road safety outcomes

Theoretically, road safety impacts are a function of the change in the number of crashes and the average cost of those crashes. This could be represented in a model as a function of change in a baseline safety indicator, such as the annual social costs of road fatalities, with the following variables:

1. **Generalised safety benefits of automated vehicles** – the degree that automated vehicles are safer than comparable human-driven vehicles, expressed as a percentage. This would be expected to be in the range of 0–94 per cent (where 0 is automated vehicles are equally as safe as the average human-driven vehicle and 94 is the complete elimination of the proportion of crashes in which human error is a *contributing* factor).
2. **Market penetration of automated driving systems** – the percentage of the total vehicle fleet that is automated.
3. **Effectiveness of the safety assurance system** (or alternative approach) – the degree to which regulation prevents unacceptable safety risks, improves safety outcomes and increases automated vehicle uptake, expressed as a percentage. This is a measure of the option's effect on safety above the safety outcome of the baseline option.

This model could be expressed as:

Road safety benefit = change in safety indicators

= BSI x GSBAV x MPAV x ESAS

Where:
BSI = baseline safety indicators (number, $)
GSBAV = generalised safety benefit of automated vehicles (%)
MPAV = market penetration of automated vehicles (%)
ESAS = effectiveness of the safety assurance system (%)

All percentages are defined within a range of 0–100%.

For example, if:

- BSI =
  - $4 billion social cost of road fatalities in 2020 (1,141, the predicted number of fatalities in 2020[62] × $3.452 million,[63] the cost of fatal crashes in 2017 dollars)
  - $13.58 billion social cost of road injuries in 2020[64]
  - $9.38 billion social cost of property damage in 2020[65]
- GSBAV = 50 per cent (estimate reflecting some but not all of the potential benefit of eliminating human error);
- MPAV = 6.45 per cent (mid-point between US uptake rates of level 3 and 4 automated vehicle for 2020); and
- ESAS = 70 per cent (assuming a fairly effective safety assurance system, compared with the base case); then
- Road safety benefit = ($4 billion + $13.58 billion + $9.38 billion) × 0.5 x 0.0645 × 0.7 = $607.2 million cost benefit.

Table 15 outlines the estimated single-year road safety benefits based on the preceding assumptions.

Table 15. Estimated road safety benefits under 70 per cent ESAS ($m)

	Fatalities	Injuries	Property damage	Total
Road safety benefit	88.9 (26 fatalities averted)	306.6 (729 serious injuries averted)	211.8 (10,239 property damage crashes averted)	607.2

[62] Road crash forecasts are detailed in Appendix G.

[63] The social cost of road crashes in outlined in Appendix G.

[64] Figure is an estimate for 2016, based on a recent paper (Litchfield, 2017).

[65] Figure is an estimate for 2016, based on a recent paper (Litchfield, 2017).

These road safety benefits need to be compared with the compliance, administration and other costs in order to assess the policy merits.

The expected road safety benefit of an option is influenced by both:

- the effectiveness of the safety assurance system to improve safety of automated vehicles
- the uptake of automated vehicles that comply with the safety assurance system.

This shows the intrinsic trade-off considered in this RIS, and that it is undesirable to set policy requirements for improved safety so high that they become barriers to the introduction and uptake of automated driving systems.

There is significant uncertainty both within and outside of the assessment. As a result, there is insufficient information to populate this model with a satisfactory degree of confidence. However, using the formula as described above, we can see the effectiveness of different levels of the safety assurance system. This is a useful test because regulatory responses are not always 100 per cent effective at achieving their stated objectives. As each assessed option differs in the extent of regulatory scope, they are likely to differ in effectiveness to address specific automated vehicle safety risks.

As new regulatory systems mature, their effectiveness can improve as governments and industry better understand their roles, obligations and requirements; that is, the effectiveness of a regulatory system is not static.

For this test, the NTC has identified two 'high' effectiveness values (ESAS values in the formula), and two 'low' effectiveness values:

- high 1 – 90 per cent effective (ESAS90)
- high 2 – 80 per cent effective (ESAS80)
- low 1 – 30 per cent effective (ESAS30)
- low 2 – 20 per cent effective (ESAS20).

These effectiveness values also show the sensitivity of a 10 percentage point difference in effectiveness on safety outcomes from relatively high and low effectiveness starting points.

Using the formula and keeping other variables (BSI, GSBAV and MPAV) static, we can also examine the material impact of varying the effectiveness of the regulatory response, using the above ESAS values. Table 16 shows the results of the model under different levels of effectiveness in the regulatory responses.

Table 16. Estimate of road safety benefits under different ESASs ($m)

	Fatalities	Injuries	Property damage	Total
Road safety benefit under ESAS90	114.3 (33 fatalities averted)	394.2 (938 serious injuries averted)	272.3 (13,164 property damage crashes averted)	780.7
Road safety benefit under ESAS80	101.6 (29 fatalities averted)	350.4 (833 serious injuries averted)	242.0 (11,702 property damage crashes averted)	694.0
Road safety benefit under ESAS30	38.1 (11 fatalities averted)	131.4 (313 serious injuries averted)	90.8 (4,388 property damage crashes averted)	260.2

	Fatalities	Injuries	Property damage	Total
Road safety benefit under ESAS20	25.4 (7 fatalities averted)	87.6 (208 serious injuries averted)	60.5 (2,925 property damage crashes averted)	173.5

This analysis shows the potential of the safety assurance system to avert fatalities. It also shows that a 10 percentage point improvement in effectiveness could generate additional safety outcomes of approximately $86.7 million per year, not including the benefits from reductions in non-fatal accidents.

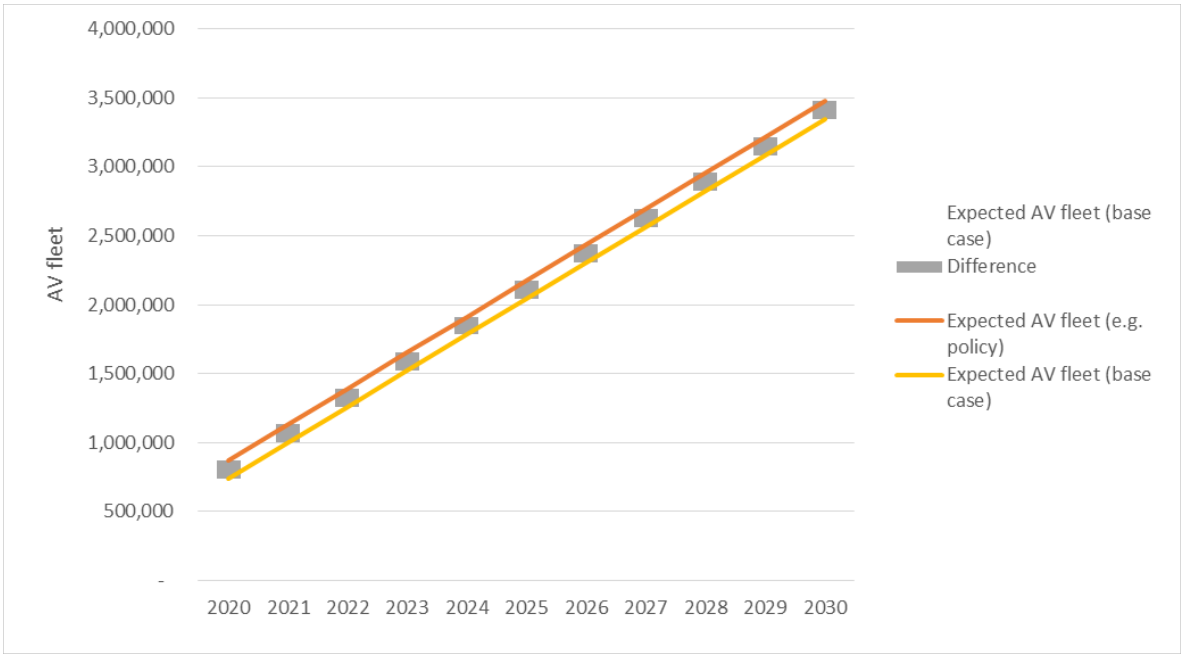
Other qualitative factors that influence the generalised safety benefits and the uptake of automated driving systems will largely be driven by the development and supply of the technologies and consumer demand.

E.3 Materiality of automated vehicle uptake outcomes

The following test considers the potential magnitude of the benefits of supporting automated vehicle uptake. These benefits are considered in the context that there are potential benefits from having additional automated vehicles in the Australian vehicle fleet that are expected to have better than average safety outcomes. This test centres on a policy that supports automated vehicle uptake equivalent to fast-tracking automated vehicle take-up by six months (namely consumer confidence, supplier clarity or similar) (Figure 4).

Using a low automated vehicle uptake scenario (where automated vehicles on the road go from 741,305 in 2020 to 3,343,942 in 2030), the effect of the policy intervention leads to approximately 130,000 more automated vehicles in use. Given that it is assumed that automated vehicle uptake proceeds at the same rate with or without the policy intervention, this difference of 130,000 persists in every year.

Figure 4. Impact of fast-tracking automated vehicle take-up by six months



An advantage is gained from the difference in automated vehicle fleet only if there is an intrinsic benefit in having automated vehicles on the road (for example, safety improvements, reduced congestion, more efficient journeys, mobility). The magnitude of this is unknown, but it may be broadly estimated using assumptions around crash performance.

Given the full social costs attributable to road crashes (from road fatalities, road injuries and property damage) are approximately $27 billion, then this corresponds to $1,418 per vehicle (if unitised across the predicted vehicle fleet of 19 million). Given human error is a contributing factor in up to 94 per cent of crashes, then if an automated vehicle can avoid 10 per cent of crashes by reducing the scope for human error, the safety benefits of an additional automated vehicle on the road (as opposed to a human-driven vehicle) may be approximately $142 per automated vehicle.

Under these assumptions, the benefits of the additional 130,000 automated vehicle on the road annually are equal to $18 million per year. Making the net present benefit of a policy intervention that fast-tracks automated vehicle take-up by six months over the period 2020 to 2030 is in the order of $154 million.

If the policy change is considered in the context of a high automated vehicle uptake (of 1,710,704 in 2020 to 9,534,754 in 2030), then the net present benefit is approximately $464 million. The estimated benefit is higher since an additional 390,000 automated vehicles are expected to be on the road each year as a result of the example policy.

This suggests that if automated vehicles can avoid 10 per cent of crashes, then a policy that can promote automated vehicle uptake and fast-track uptake by six months may provide a net present benefit in the order of $154–464 million. This finding demonstrates that, even under a set of conservative assumptions, the potential uptake impacts are significant over the proposed regulatory period.

Appendix F Costs to government

F.1 Assessment of options against the costs to government assessment criteria

Upfront structural, organisational and regulatory change costs

Table 17 outlines the expected once-off structural, organisational and regulatory change costs to the Commonwealth government and/or national agency administering the safety assurance system for each option.

Once-off administrative costs to the Commonwealth government and/or national body administering the safety assurance system are expected to be highest for option 4, followed by option 3 and then option 2. These costs are not applicable for option 1 because this option does not involve any changes to administrative systems.

The existing vehicle certification process, including developing and implementing legislation and systems changes, cost around $2 million to establish.[66] Similar once-off administrative costs could be incurred for developing and implementing the legislative and administrative systems necessary for a legislated safety assurance system (options 3 and 4). Costs are likely to be lower if a safety assurance system is introduced without legislative change (option 2).

Table 17. Once-off administrative costs to the Commonwealth government or a national agency administering the safety assurance system

Once-off administrative costs	Option 1	Option 2	Option 3	Option 4
Upfront investments into administrative systems	Costs not applicable[67]	Developing systems to assess Statements of Compliance and recording outcomes	The same costs as option 2 and additional costs to develop an enforcement system for new sanctions and penalties	The same costs as option 3 and additional costs to develop systems to investigate and enforce breaches of primary safety duties
Employee training	Costs not applicable	Training costs (may be significant)		
Developing a national advisory panel	Costs not applicable	Yes (insignificant)		
Regulatory change	Costs not applicable[68]	No additional costs	Costs associated with amending or developing new legislation	

[66] This information was provided by DIRDAC's Vehicles Safety Standards Branch.

[67] For context, DIRDAC advised that the existing certification process cost $2 million to establish.

[68] For context, DIRDAC has advised that establishing new ADR(s) for automated vehicles may cost up to $100,000 upfront and maintaining the ADR(s) would incur costs of around $100,000 annually.

Table 18 outlines the expected once-off costs to state and territory road managers and the National Heavy Vehicle Regulator for each option.

Option 2 is likely to require similar upfront investments for road managers as option 1.

Options 3 and 4 require regulatory change that may impose costs on state and territory road managers. However, regulatory change under options 3 and 4 would also remove the need for upfront investments to develop rules for conditional registration of ADSs.

Table 18. Costs to road managers (state and territory governments and National Heavy Vehicle Regulator)

Once-off administrative costs	Option 1	Option 2	Option 3	Option 4
Upfront investments into administrative systems	Expanding registration systems to record ADS details, and developing rules for conditional registration of ADSs		Expanding registration systems to record ADS details Removes costs associated with options 1 and 2 for developing rules for conditional registration of ADSs	
Employee training	Training costs expected for all options			
Developing a national advisory panel	Costs not applicable	Yes (insignificant)		
Regulatory change	Costs not applicable	Potentially (TBC)		

Ongoing administrative costs to government[69]

The Vehicle Safety Standards Branch of the Department of Infrastructure, Regional Development and Cities (DIRDAC) made some preliminary cost estimates for administering a safety assurance system. These estimates were developed as indicative estimates for the purposes of this consultation RIS.[70]

Table 19 shows potential costs for administering a safety assurance system.[71]

Some of the costs described in Table 19 may be offset by fees or charges for those seeking certification under the type approvals regime and/or approval under the safety assurance system. Such fees and charges have not yet been considered.

[69] See Table 27, Appendix F for a summary of ongoing cost estimates for existing administrative processes.

[70] They are premised on the broad automated vehicle uptake assumptions as described in Appendix G, and the assumption that administrative costs will be significantly lower once automated vehicles become 'mainstream'.

[71] This is based on the estimates and assumptions provided by DIRDAC's Vehicle Safety Standards Branch.

Table 19. Potential ongoing costs for administering a safety assurance system

Process	Cost per unit	Unit range	Estimated cost per year
Administering a safety assurance system, including assessing an applicant's Statement of Compliance	Niche – around $10,000 per assessment Mainstream – around $2,500 per assessment	Niche – 10 per year Mainstream (plausible peak) – 200 per year Mainstream (upper frontier) – 400 per year	Niche around $100,000 Mainstream (plausible peak) – $500,000 Mainstream (upper frontier) – $1,000,000
Notifying road agencies of safety assurances system assessment outcomes	Negligible	Niche – 10 per year Mainstream (plausible peak) – 200 per year Mainstream (upper frontier) – 400 per year	n/a
Monitoring in-service safety-related incidents relating to ADSs	Nil additional cost to business as usual Process is the same as for the general case of safety recalls	Quantity unknown	n/a
Investigating in-service safety-related incidents relating to ADSs	Variable	Quantity unknown	Unquantifiable

Table 20 outlines the expected ongoing administrative costs to the Commonwealth government and/or a national agency responsible for administering the safety assurance system.

Table 20. Ongoing administrative costs to the Commonwealth government or a national agency responsible for administering the safety assurance system

Ongoing administrative costs to government	Option 1	Option 2	Option 3	Option 4
Administering the current certification exemption or safety assurance system	No additional costs to administer the exemption process (unless additional assessments were required)[72] The annual variable cost of assessing automated vehicles under the ADRs may be somewhere between $1,000 and $80,000 based on a cost of $100 per ADR per application, and	The variable cost of assessing a Statement of Compliance may be between $100,000 and $1 million per year based on having an advisory panel, although this may decrease significantly if automated vehicles requirements were absorbed within ADRs or new legislation[73]		

[72] Advice from DIRDAC. The existing certification process has $5.5 million overhead costs per year.

[73] Advice from DIRDAC.

Ongoing administrative costs to government	Option 1	Option 2	Option 3	Option 4
	depending on the number of approvals sought			
National advisory panel	No applicable costs	Incorporated into the costs of 'administering the safety assurance system'		
Notifying state and territory road agencies of certification outcomes	No additional costs	No significant additional costs to business as usual[74]		
Monitoring in-service safety-related incidents relating to ADSs	No applicable costs		Uncertain, but there is potential for some government costs	Likely to be some significant government costs, but insufficient information available to quantify
Investigating in-service safety-related incidents relating to ADSs	No applicable costs		Uncertain, but there is potential for some government costs	Likely to be some significant government costs, but insufficient information available to quantify
Applying sanctions and penalties	No applicable costs		Likely to be some significant government costs, but insufficient information available to quantify	
Record-keeping costs	No applicable costs	Ensuring Statement of Compliance is maintained and up to date		The same costs as option 2 and 3 plus costs associated with maintaining records for primary safety duty investigations and enforcement

DIRDAC advised that there are no additional costs associated with current certification exemption processes compared with the standard certification process.

[74] Advice from DIRDAC.

On this basis, option 1 (the baseline option) could have the lowest regulatory costs for government and applicants but also the least safety assurance. This is true if there are no additional safety assessment requirements for a vehicle with an ADS under the exemption process.

Alternatively, the exemption process under option 1 could include additional assessment requirements, similar to those of the safety assurance system. This means regulatory costs to government of option 1 might be equivalent to the estimated costs of administering a safety assurance system. These alternate scenarios illustrate the regulatory uncertainty of option 1.

The most significant cost component is likely to be for administering the current certification exemption (options 1 and 2) and/or administering the safety assurance system (options 2 to 4).

Under the current certification system, the applicant pays fees and charges so that overall administrative costs are recovered. The NTC assumes that a similar cost recovery model would be adopted under a safety assurance system.

It unclear whether administration costs to government would be significantly different for a safety assurance system compared with the current certification exemption processes. Assuming a comparable safety standard and assessment scope, administrative costs should be broadly similar across all options.

However, option 4 potentially provides a greater level of regulatory oversight than options 2 and 3. The administrative costs of the Commonwealth government or the national agency administering the safety assurance system may be highest for option 4.

Table 21 outlines the expected ongoing costs to road managers (including the National Heavy Vehicle Regulator) for each option.

Table 21. Ongoing administrative costs to road managers (state and territory governments and National Heavy Vehicle Regulator)

<table>
<tr><th>Ongoing administrative costs to road managers</th><th>Option 1</th><th>Option 2</th><th>Option 3</th><th>Option 4</th></tr>
<tr><td>Registering a nonstandard vehicle with conditional registration</td><td colspan="2">Costs would be incurred
Uncertain of these costs</td><td colspan="2">No costs – conditional registration not required</td></tr>
<tr><td>Notifying national body of identified ADS incidents</td><td colspan="2">No applicable costs</td><td colspan="2">There are likely to be significant costs of providing dedicated analysts to interrogate and share the data</td></tr>
<tr><td>Assessing statements of compliance (as a member of the national advisory panel)</td><td>No applicable costs</td><td colspan="3">There are likely to be some costs to road managers, but the bulk of costs likely to be incurred by the Commonwealth or the national agency administrating the safety assurance system</td></tr>
<tr><td>Record-keeping costs</td><td colspan="4">There may be minimal additional costs in maintaining registration data</td></tr>
</table>

The costs to road managers for registering automated vehicles as standard vehicles (options 3 and 4) compared with registering them as nonstandard vehicles (options 1 and 2) are likely to differ significantly. We do not currently have sufficient information to assess the relative costs.

The costs for road managers to provide a national agency with intelligence about automated vehicle technical errors or safety performance issues (options 3 and 4) are expected to be significant.[75]

Under options 2, 3 and 4, state and territory road managers would have a role in assessing statements of compliance as members of the national advisory panel. The NTC expects that the bulk of these assessment costs would be incurred by the Commonwealth or the national agency administering the safety assurance system.

[75] The NTC's cost benefit analysis relating to the *National Heavy Vehicle Enforcement Strategy* suggested that, 'the costs of providing dedicated analysts to interrogate and share the data was identified by the agencies as the main area of cost of implementing the Strategy' (National Transport Commission, 2009, p. 5).

Appendix G Research on the expected benefits of automated vehicles

G.1 Safety benefits

Improvements to road safety are expected to be key benefits of automated vehicles (Austroads, 2017b, pp. 19, 20). A large literature has emerged investigating this topic (see summary in Melakis, et al., 2017 (pp. 327, 328)).

A recent Austroads paper investigated if lower levels of automation, or driver assistance, could reduce the number of road crashes in Australia (Austroads, 2017b). Using a dataset of actual crashes, the paper analysed (probabilistically) whether certain technologies[76] could have prevented the crashes if they had been available in the vehicles when the accident occurred. Because of the uncertainties involved and the probabilistic approach used, the paper provides lower and upper bounds for the number of crashes that could have been prevented by the technologies.

Table 22 shows crashes that could potentially be avoided if the technologies provided a signal when human intervention is required (columns 3 and 4).[77] Columns 5 and 6 show the hypothetical crash reduction (based on the authors' judgment) if the vehicle control was automated across all of the technologies, rather than relying on human intervention after a warning. Column 6 (42 per cent of crashes avoided) is roughly comparable to a figure cited in a US study, which suggested that there could be at least a 40 per cent reduction in fatal crashes following the introduction of automated vehicles (Fagnant & Kockelman, 2015, p. 3).[78] The final column assumes 94 per cent of crashes are avoided based on findings in the literature that human drivers cause this percentage of crashes (NHTSA, 2015, p. 1).

Note that all estimates in Table 22 are likely to over-estimate the potential reduction in crashes. Estimates assume 100 per cent deployment of vehicles in the fleet with the relevant technologies, which is unlikely over the time period of the current analysis. Second, as a result of the combination of human-controlled and automated vehicles – as well as the potential for vehicles with conditional automation – there are several human factors that may offset the effectiveness of automation.[79] Last, there may be vehicle automation risks such as system failure or the potential for hacking of the automated driving system (Litman, 2017, p. 12).

[76] Namely: Cooperative Forward Collision Warning, Curve Speed Warning, Intersection Movement Assist, Right Turn Assist, Lane Keeping Assist, Auto Emergency Braking.

[77] Except for Lane Keep Assist and Auto Emergency Braking, which are automated.

[78] The basis for this figure is that over 40 per cent of fatal crashes involve some combination of alcohol, distraction, drug involvement and/or fatigue.

[79] The Austroads paper cites the following: Driver Overreliance (Automation Complacency); Adoption of Risky Driving Behaviours; Driver Workload; Driver Distraction; Driver Acceptance; Driver Trust; Loss of Skill; Regaining Manual Control; human-machine interface issues (Austroads, 2017b).

Table 22. Road crashes, deaths and injuries in Australia

Statistic	Annual statistics in Australia	Austroads paper – ower bound (21% of crashes avoided)	Austroads paper – upper bound (33% of crashes avoided)	Austroads paper – hypothetical lower bound (27% of crashes avoided)	Austroads paper – hypothetical upper bound (42% of crashes avoided)	Assuming 94% of crashes are avoided
Crashes	19,874	15,724	13,389	14,526	11,496	1,192
Deaths*	1,227	971	827	897	710	74
Injuries*	34,901	27,613	23,513	25,509	20,189	2,094

* Data in columns 3–7 of the table are estimates based on scaling down the total number of deaths/injuries by the same percentage as the reduction in crashes.

Data sources for the 'Annual statistics in Australia' column. 'Crashes' is average fatal and serious injury crashes in Australia over the period 2009–2013 (Austroads, 2017b, p. 39). 'Deaths' is an average over the five years to 2016, and 'Injuries' is hospitalised injuries averaged over the three years to 2014 (BITRE, 2016, pp. 2, 16).

The data in the third and fourth columns of Table 22 provides a range for the potential for certain vehicle technologies/automation – which can be deployed without the safety assurance system – to reduce crashes. However, other factors such as increased driving distances may potentially offset this reduction.

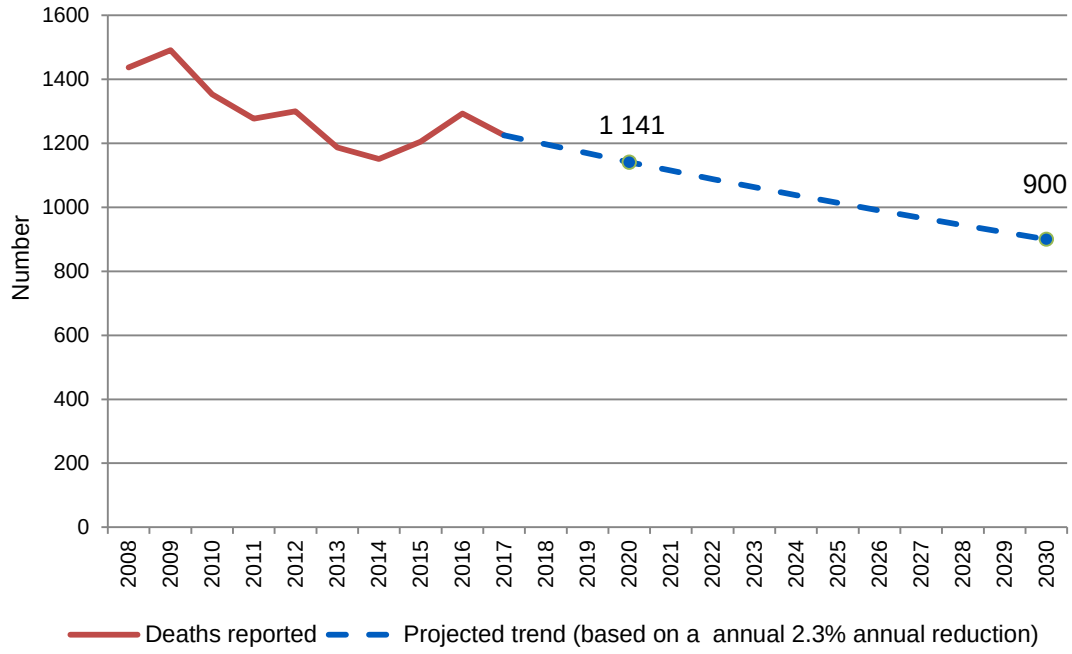
G.2 Projected road safety baseline

The NTC has estimated a baseline level of road safety outcome that could be achieved through the uptake of automated vehicles. Projecting road safety as the underlying rate of accidents would likely change from current levels irrespective of the regulatory approach taken for automated vehicles. Therefore, the potential rate of crashes is uncertain.

Historical numbers serve as a guide for the future, but actual outcomes in the future will be influenced by various other factors, for example, an increase in number of kilometres travelled by vehicles on the road, increased penetration of connected and automated vehicle technology, increased penetration of other vehicle safety features such as electronic stability control ESC, and the removal of 'black spots' on roads.

For the purposes of comparative analysis, the NTC has projected a baseline for annual road fatalities. This projection, as presented in Figure 5, uses a straight-line trend based on the average annual reduction between the National Road Safety Strategy's 2008–2010 baseline and 2017 of 2.3 per cent extended from 2017 to 2030.

Figure 5. Projected annual road fatalities to 2030



Under this baseline projection, the annual road toll would fall from 1,141 in 2020 to around 900 by 2030.

The NTC emphasises that the projections are only theoretical baselines to assess impacts against. Such projections need to be credible as far as it is practical, but absolute accuracy is not necessary, nor possible.

G.3 Costs of crashes

There are a variety of estimates of the costs of different crash severities. For this assessment we have used the Bureau of Infrastructure, Transport and Regional Economics (BITRE) estimates for the costs of different types of crashes (BITRE, 2009, p. 85), adjusted from 2006 to 2017 dollars (presented in Table 23).

Table 23. Estimated average costs of road crashes in Australia by crash outcome ($, 2017)

Fatal crash	Hospitalised injury crash	Non-hospitalised injury crash	Property damage only crash
3,451,685	344,028	19,065	12,869

Original data from Table T7.4 of BITRE's report (BITRE, 2009, p. 85). Values have been indexed using the ABS All groups CPI (Series ID: A2325846C) using the December 2006 and December 2017 data points.

Estimates of road crash costs can be used to quantify the expected benefits of the different reform options and allow for consistent comparisons between them.

G.4 Other benefits

Automated vehicles offer many additional benefits (for example, improved mobility, transport options, road network efficiencies, reduced travel costs and alternate uses of travel time)

that will be realised as automated vehicles are adopted and as they penetrate the vehicle fleet.

The literature on the potential wider benefits of automated vehicles is large and diverse, however, several papers contain good reviews of this literature (Milakis, et al., 2017; Litman, 2017). The evidence presented for many of the benefits is mixed and will depend on how automated vehicles are used in the future.

To illustrate the degree of uncertainty, we have selected research findings that highlight one benefit of automated vehicles that is quite likely to materialise and another that's outcome is highly uncertain.

It is likely that wide uptake of automated vehicles will increase access to mobility for currently unserved or underserved groups of society. These groups include those who may currently rely on transportation by relatives, government assistance or public transport due to their age or medical conditions that prevent them from driving. A US study found there could potentially be a 14 per cent increase in total annual distance travelled by light vehicles if automated vehicles were available for use by these groups (Harper, et al., 2016, p. 14). Although this travel is beneficial to the individuals concerned, it is difficult to quantify the overall value of this potential benefit.

As a contrasting example, the probable energy consumption of automated vehicles is far more uncertain. The US Energy Information Administration (EIA, 2017, p. 43) has noted that automated vehicles could potentially:

- reduce energy consumption – due to factors such as 'light-weighting' (reductions in vehicle weight due to the removal of certain safety features, the steering wheel, pedals, etc.), 'rightsizing' (where, in a situation of an automated vehicle fleet, a size-optimised vehicle is used for every journey depending on the number of passengers), and the potential for platooning, or
- increase energy consumption – due to factors such as increased vehicle travel (because of a fall in the generalised cost of travel,[80] increased mobility for user groups that were previously unserved, or vehicles driving empty between destinations), increased weight because of additional features in the vehicle (for example, if a vehicle was a 'mobile office') or higher highway speeds.

Other potential benefits, such as reduced congestion and improvements in travel comfort and use of time, also have somewhat mixed evidence in the literature, and may depend on how the market develops in the future (Milakis, et al., 2017, p. 327). Table 24 outlines a summary of the literature, as reported by Milakis et al (2017).

Table 24. Summary of automated vehicle impacts

Automated vehicle impacts	Impact direction	Description
Travel costs		
Fixed costs of automated vehicles	+	Current automated vehicle applications cost several times the price of a conventional vehicle in the US, but the price could be gradually reduced to $3000 or even lower with mass production and the technological advances of automated vehicles.
Travel comfort	?	Comfort has been incorporated in trajectory planning and adaptive cruise control algorithms as the optimising metric. Motion sickness,

[80] The generalised cost of travel includes both monetary and non-monetary costs (such as the time taken and what the journey time can be used for).

Automated vehicle impacts	Impact direction	Description
		apparent safety and natural human-like paths could be included in path planning systems. Time headway between vehicles below 1.5–2.0 seconds can influence comfort.
Travel time	–	Vehicle automation can reduce delays on highways, at intersections and in contexts involving shared automated vehicles.
Value of time	?	Automated vehicles (level 3 and higher) could reduce the value of time. Yet, the value of time could increase for users of automated vehicles as an egress mode to train trips. The ability to work on the move is not perceived as a major advantage of an automated vehicle.
Road capacity		
Highway capacity	+	The higher the level of automation, cooperation and penetration rate, the higher the positive impact on road capacity. A 40 per cent penetration rate of cooperative adaptive cruise control appears to be a critical threshold for realising significant benefits on capacity (>10 per cent), while a 100 per cent penetration rate of cooperative adaptive cruise control could theoretically double capacity. Capacity impacts at level 3 or higher levels of vehicle automation and more advanced levels of cooperation among vehicles, but also between vehicles and infrastructure, could well exceed this theoretical threshold. Capacity might be affected by vehicle heterogeneity. Capacity could decrease in entrance/exit of automated highway systems.
Intersection capacity	+	Significant capacity benefits (more than 100 per cent under certain conditions) are expected from automated intersection control systems.
Travel choices		
Vehicle kilometres travelled	+	Automated vehicles could induce an increase in travel demand of 3–27 per cent due to changes in destination choice (longer trips), mode choice (modal shift from public transport and walking to car) and mobility (more trips, especially from people currently experiencing travel restrictions such as the elderly). Shared automated vehicles could result in additional kilometres travelled because of their need to move or relocate with no one in them to serve the next traveller. Extra kilometres travelled are expected to be lower for dynamic ride-sharing systems.
Vehicle ownership	–	Shared automated vehicles could replace from about 67 per cent up to over 90 per cent of conventional vehicles delivering equal mobility levels. The overall reduction of the conventional vehicle fleet could vary according to the automated mode (vehicle-sharing, ride-sharing, shared electric vehicle), the penetration rate of shared automated vehicles and the presence or absence of public transport.
Local choices and land use	?	Automated vehicles could enhance accessibility citywide, especially in remote rural areas, triggering further urban expansion. Automated vehicles could also have a positive impact on the density of economic activity at the centre of the cities. Parking

Automated vehicle impacts	Impact direction	Description
		demand for automated vehicles could be shifted to peripheral zones. Parking demand for shared automated vehicles can be high in city centres, if empty cruising is not allowed.
Transport infrastructure	–	Shared automated vehicles could significantly reduce parking space requirements up to over 90 per cent. The overall reduction of parking spaces could vary according to the automated mode (vehicle-sharing, ride-sharing, shared electric vehicle), the penetration rate of shared automated vehicles and the presence or absence of public transport. Less wheel wander and increased capacity because of automated vehicles could accelerate pavement-rutting damage. Increase in speed of automated vehicles could compensate for such negative effect by decreasing rut depth.
Energy consumption and air pollution		
Fuel efficiency	+	Significant fuel savings can be achieved by various longitudinal, lateral (up to 31 per cent), and intersection control (up to 45 per cent) algorithms and optimisation systems for automated vehicles. Higher level of automation, cooperation and penetration rate could lead to higher fuel savings.
Energy consumption	?	Battery electric shared automated vehicles are associated with significant energy savings (90–100 per cent) in the long term. The energy gains are attributed to more efficient travel and electrification. Several factors could lead to increased energy use (for example, longer travel distances and increased travel by underserved populations such as youth, people with disabilities and the elderly). Thus, the net effect of vehicle automation on energy consumption remains uncertain.
Emissions	–	Vehicle automation can lead to lower emissions of NOx, CO, and CO_2. Higher level of automation, cooperation and penetration rates could lead to even lower emissions. Shared use of automated vehicles could further reduce emissions (VOC and CO in particular) because of lower number of times vehicles start.
Air pollution	?	Long-term impacts of battery electric shared automated vehicles are associated with up to 94% less GHG. Yet, the net effect of vehicle automation on GHG emissions remains uncertain.
Social equity	?	In-vehicle technologies can have positive effects (i.e. avoiding crashes, enhancing easiness and comfort of driving, increasing place, and temporal accessibility) for the elderly. Automated vehicles could induce up to 14 per cent additional travel demand from the non-driving, elderly and people with travel-restrictive medical conditions. Automated vehicles offer the opportunity to incorporate social justice aspects in future traffic control systems.
Economy	?	Social benefits per automated vehicle per year could reach $3,900 when there's a 90 per cent market share of automated vehicles. Jobs in the transportation and logistics sectors have a high probability of being replaced by computer automation within the next two decades.

Automated vehicle impacts	Impact direction	Description
Public health	?	No systematic studies were found about the implications of automated vehicles for public health. However, public health outcomes could be negative if automated vehicle use reduces active transport (walking, cycling) and hence health benefits gained from these activities.

Appendix H Automated vehicle uptake

H.1 Increasing automation in vehicles

Vehicle manufacturers are progressively introducing higher levels of automation in their vehicles. In the near future, automated driving systems (ADS) will be capable of controlling the driving task of a vehicle for defined periods of time.

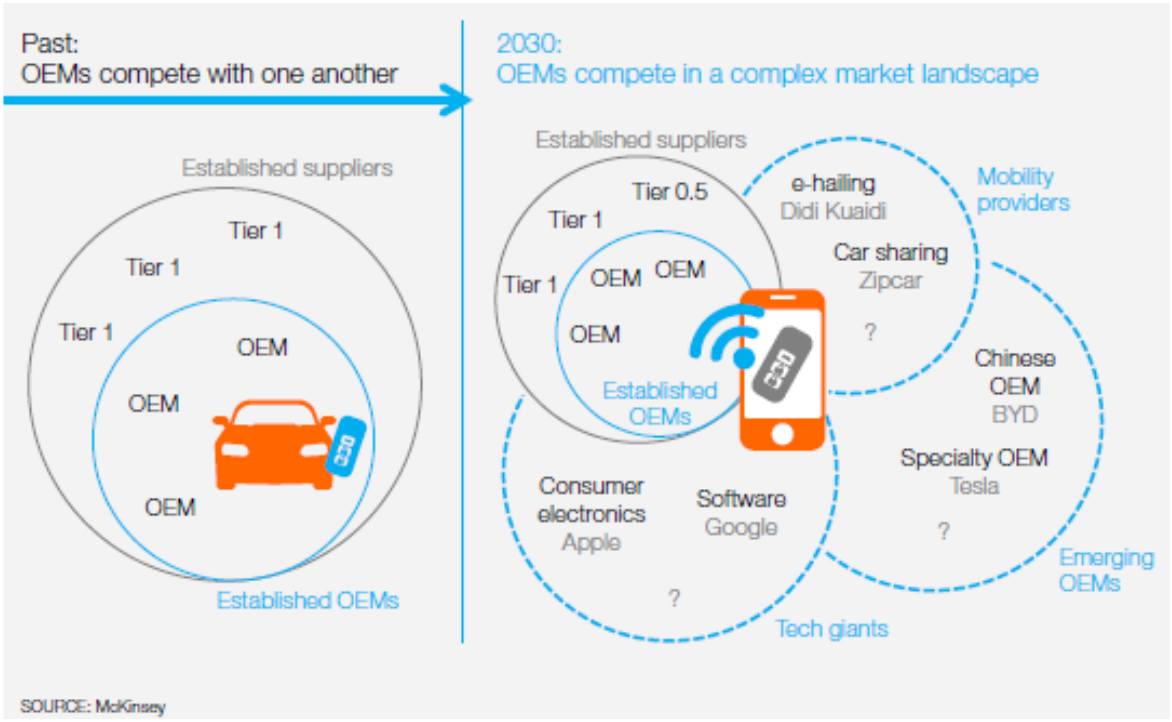
An increasing number of advanced driver assistance systems (ADAS) have been introduced into the Australian vehicle market. Systems such as autonomous emergency braking, lane-keeping assistance and parking assistance help the driver to complete the driving task but do not perform the entire dynamic driving task autonomously. The Federal Chamber of Automotive Industries stated in their submission to the NTC (2017, p. 4) that these systems 'are part of an evolution' progressively being developed and becoming readily available in new vehicles. It is uncertain how automated vehicles will be developed and commercialised in the future because vehicle manufacturers are all taking different approaches. Some manufacturers are focusing on vehicles that require a human driver to monitor the environment and intervene if required (conditional automation/SAE level 3). Other manufacturers want to skip this level, developing vehicles that do not require a human driver (high automation/SAE level 4). These vehicles can only operate in defined low-speed zones with limited interaction with other vehicles, such as in a university campus or airport precinct. It is not expected that manufacturers will progress from vehicles that require a human to monitor the environment to vehicles that do not.

H.2 Complexity of the automated vehicle market

The automated vehicle market is likely to consist of new and mature technology manufacturers. A large group of companies are developing components for and complete ADSs. These companies include traditional automotive manufacturers and suppliers, technology companies and start-ups (Navigant Research, 2017, p. 12). Many of the traditional automotive manufacturers have been developing automated driving technologies for a number of years. Some other companies who have entered the market more recently have progressed rapidly through acquisitions, investments and strategic hiring of key personnel.

Figure 6 shows the growing complexity of the market.

Figure 6. Complex automated vehicle market



Source: (McKinsey&Company, 2016)

The NTC also notes that increasing autonomy in the transport sector will also support consumer-side disruptions (for example, increasing ride-sharing and mobility as a service), leading to further complexity of the broader transport sector.

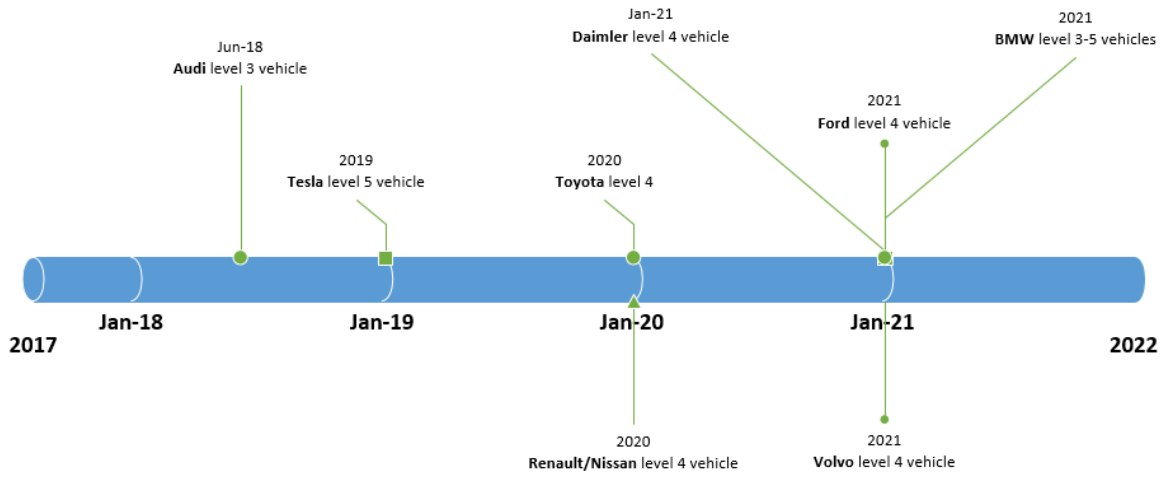
H.3 Commercial availability of automated vehicles

Major vehicle manufacturers and newer technology companies expect initial ADS models (SAE level 3 or above) to be commercially available to overseas markets between 2018 and 2021. It is not known when ADS models will be made available in the Australian market. There is even less certainty about when ADS will become a mainstream product offering, or even a standard feature in new vehicle models.

Figure 7 shows a timeline of predicted international release dates of ADS models as announced by the respective manufacturers.[81]

[81] Manufacturer predicted release timeframes are subject to change and are accurate at the time of writing.

Figure 7. Timeline of manufacturers predicted release of automated vehicles



Traditional automobile makers such as General Motors expect to have vehicles capable of operating at high levels of automation in 2019 in big cities (CNBC, 2018). Volvo has announced it aims to have 'fully autonomous' vehicles commercially available in 2021 (Volvo, 2017). BMW has also announced it aims to deploy a vehicle capable of operating at high levels of automation in 2021 (The Verge , 2018). As shown above in Figure 7, most traditional automobile makers are aiming to commercialise vehicles equipped with high automation by 2021.

H.4 Effect of cost on uptake of automated vehicles

It is uncertain what the uptake rates of automated vehicles will be and what proportion of new vehicles sales or the total vehicle fleet they will make up.

Automated driving functionality is likely to be released in new vehicle models, starting with high-end luxury models and eventually in mainstream models over time.

It is possible that a marginal number of operators may fit ADSs to conventional vehicles; however, it is not expected to be widespread because very few consumers would have added airbags or ABS to existing vehicles, despite their clear value.

The speed and extent of ADS uptake will be dependent on the cost of the systems (up-front purchase and operating) as well as the perceived benefit of the ADS functionality (value).

The advanced technology components required for vehicles with high levels of automation are expensive. LIDARs (light detection and ranging) alone currently cost approximately $75,000, making the full cost of the required technology $150,000. These high upfront costs could be a potentially limiting factor in the take-up of vehicles with high automation.

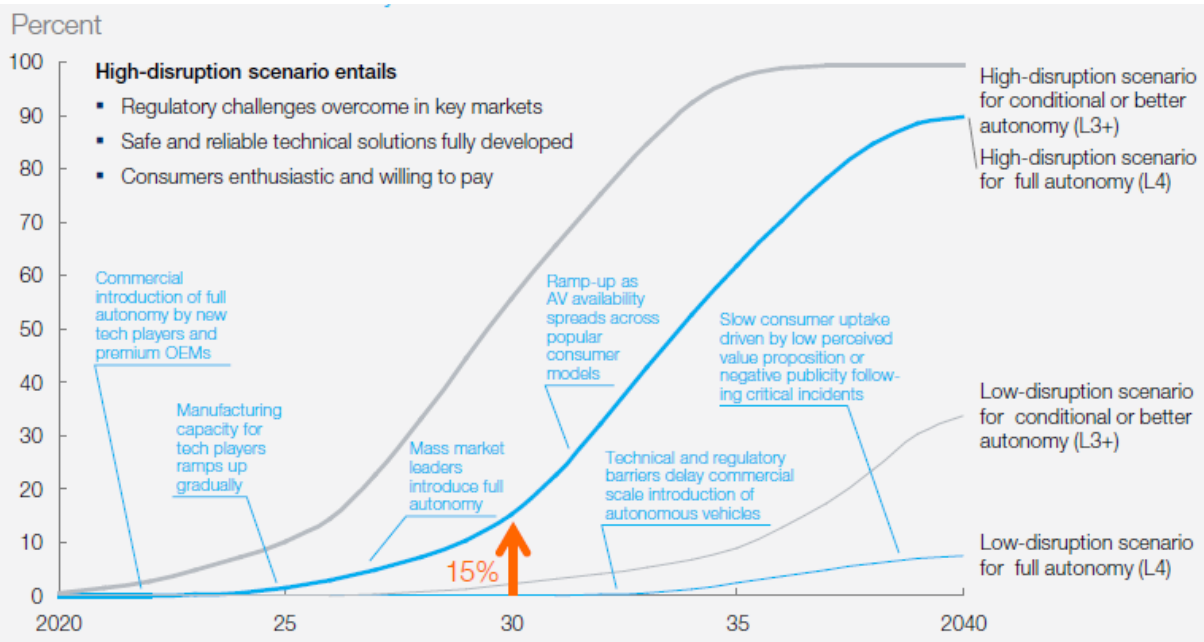
As advanced technology costs fall, high levels of automation will become more affordable and their uptake should increase. Experts predict that vehicles with high levels of automation will become affordable by 2025–2030.

H.5 Predicted automated vehicle uptake

McKinsey & Company developed predictions of new vehicle market shares for conditional automation and high automation[82] for low-disruption and high-disruption scenarios between 2020 and 2040. These predictions generate four uptake curves of market penetration as shown in Figure 8.

[82] McKinsey predictions are based on National Highway Traffic Safety Administration (NHTSA) levels of automation.

Figure 8. New vehicle market share of conditional and Level 3 and 4 automated vehicles



Source: (McKinsey&Company, 2016)

Under the high disruption scenarios,[83] vehicles with conditional and higher levels of automation would reach 60 per cent market share by 2030, and up to 15 per cent of all new vehicles would high/full automation. Under the low-disruption scenarios,[84] vehicles with conditional automation would make up less than 5 per cent of new vehicle sales while sales of vehicles with high/full automation would be negligible.

A paper by Bansal and Kockelman (2017) forecasts the uptake rate of connected and automated vehicles in the US under different levels of automation (Bansal & Kockelman, 2017, p. 18). The study uses simulations and takes into account developments in demand and supply within the market. Across the various scenarios, the study suggests minimum and maximum uptake rates in 2020 and 2030 as presented in Table 25. The 'levels' used in the paper are as defined by the NHTSA, ranging from level 0 to level 4, with levels 3 and 4 corresponding to those used in the McKinsey paper (McKinsey&Company, 2016, p. 11).

Table 25. Forecasted connected and automated vehicle uptake in the US, 2020 and 2030

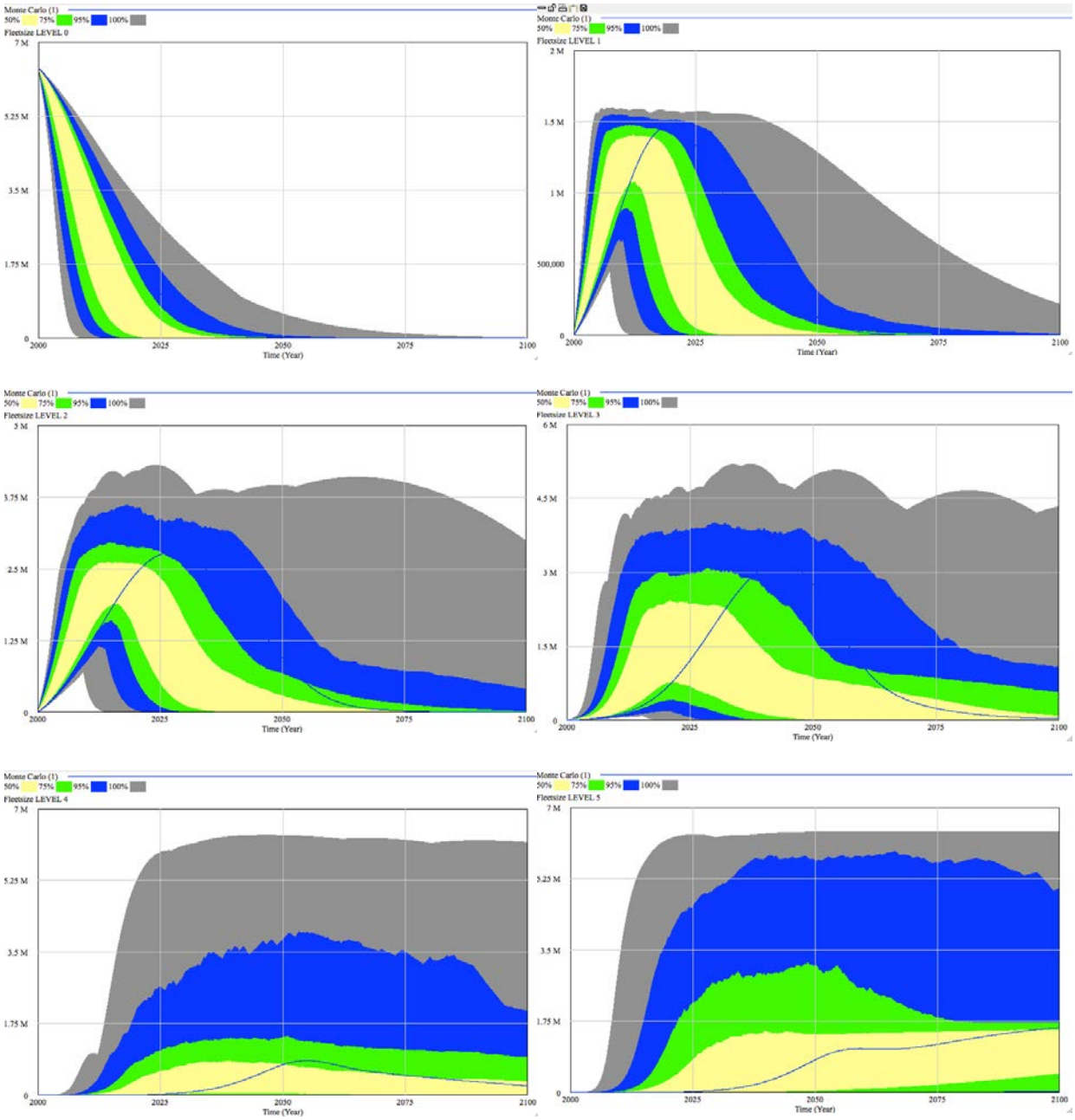
Level of automation	Estimated uptake rates			
	2020		2030	
	Minimum	Maximum	Minimum	Maximum
Level 3	1.9%	3.5%	4.5%	8.4%
Level 4	2.0%	5.5%	10.3%	33.8%

[83] The high-disruption scenarios entail: regulatory challenges being overcome; safe and reliable technical solutions being fully developed, and consumers being enthusiastic and willing to pay.

[84] The low-disruption scenarios entail: gradual resolution of regulatory challenges, incomplete development of safety and reliable technical solutions, and limited consumer acceptance and willingness to pay.

A study in the Netherlands conducted simulations showing considerable uncertainty about the potential fleet size for different levels of automated vehicles (Nieuwenhuijsen, 2015, p. 316). The simulations for levels 0 to 5 are shown in Figure 9, from top-left to bottom-right. The graphs show that the fleet size of level 0 and level 1 vehicles – which is currently around 8 million vehicles in total in the Netherlands – is expected to fall relatively rapidly. By contrast, take-up of levels 4 and 5 is expected to be relatively slow, with the 75 per cent confidence interval suggesting that the fleet size in 2025 could be between 1.1 million and 2.2 million for levels 4 and 5, respectively (or as low as zero).

Figure 9. Figures showing potential fleet size at different automation levels



Source: (Nieuwenhuijsen, 2015, p. 316)

Lavasani, Jin and Du (2016, p. 12) also run simulations of the uptake of automated vehicles. In their model, sales of automated vehicles are assumed to begin in 2025, with relatively limited uptake occurring by 2030. The results of the authors' prediction model show that

uptake is far more sensitive to variations in the market size than variations in the costs of the automated vehicles.

The broad range of predictions demonstrates the high level of uncertainty for future uptake. In addition, the previous studies have focused on foreign (developed) countries, meaning the results may not be transferable to the Australian context. However, the results can potentially be treated as indicative of what may occur in Australia.

The Vehicle Safety Standards Branch of the Department of Infrastructure, Regional Development and Cities suggested some preliminary assumptions on the uptake of automated vehicles:

- Within the first five years (2020–2025), automated vehicle models are likely to be **'niche'**, with around 10 new automated vehicle applications per year.
- Beyond 2025, automated vehicles may start to become '**mainstream**'. If all new vehicle models were automated vehicles, there could be an **'upper frontier'** of around 400 applications per year under a safety assurance system; however, the Department suggests a more **plausible 'peak'** within the regulatory timeframes under consideration (until 2030) could be around 50 per cent of new vehicle models being automated vehicles.

For the purposes of this analysis, the NTC has used the estimates contained in Table 25 as a guide to develop two baselines for the penetration of vehicles with conditional and high automation. These market penetration rates are shown in Figure 10 and Figure 11 using a linear projection to interpolate values between the 2020 and 2030 data points. Notably, the forecasts predict that:

- Vehicles with conditional automation (level 3) would make up between 1.9 and 3.5 per cent of the vehicle fleet by 2020 and between 4.5 and 8.4 per cent by 2030.
- Vehicles with high automation (level 4) would make up between 2.0 and 5.5 per cent of the vehicle fleet by 2020 and between 10.3 and 33.8 per cent by 2030.

Figure 10. Forecasted market penetration rates of vehicles with level 3 automation

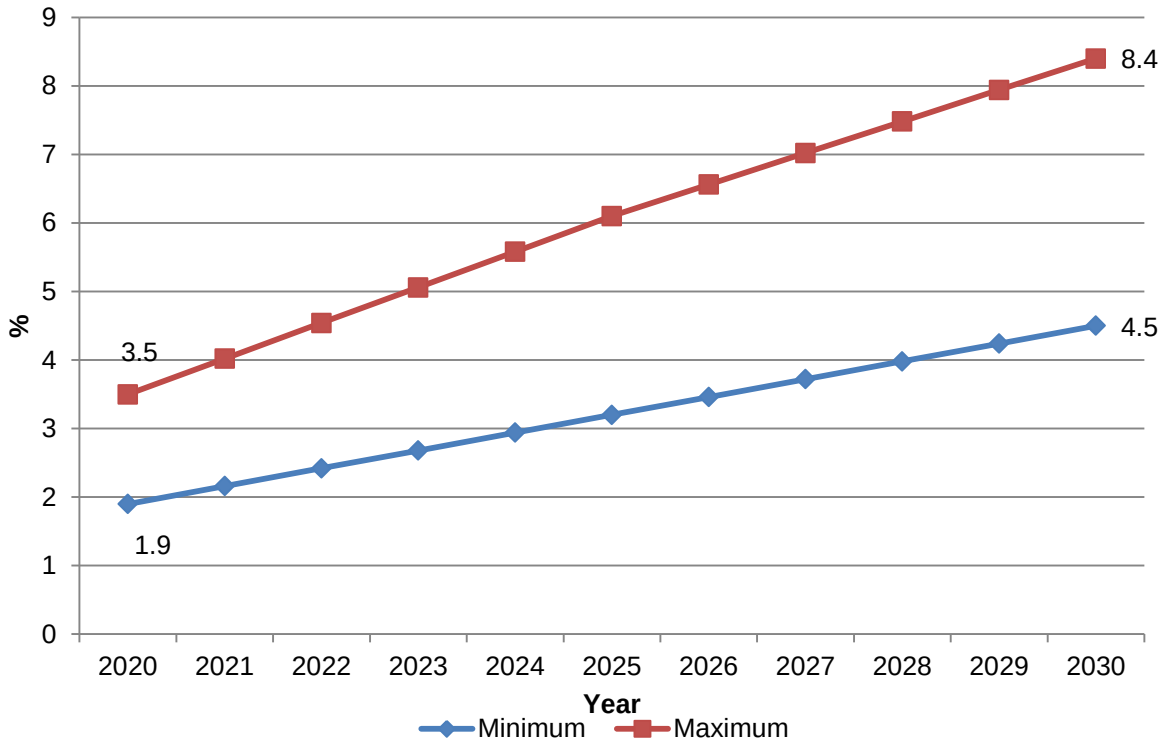


Figure 11. Forecasted market penetration rates of vehicles with level 4 automation

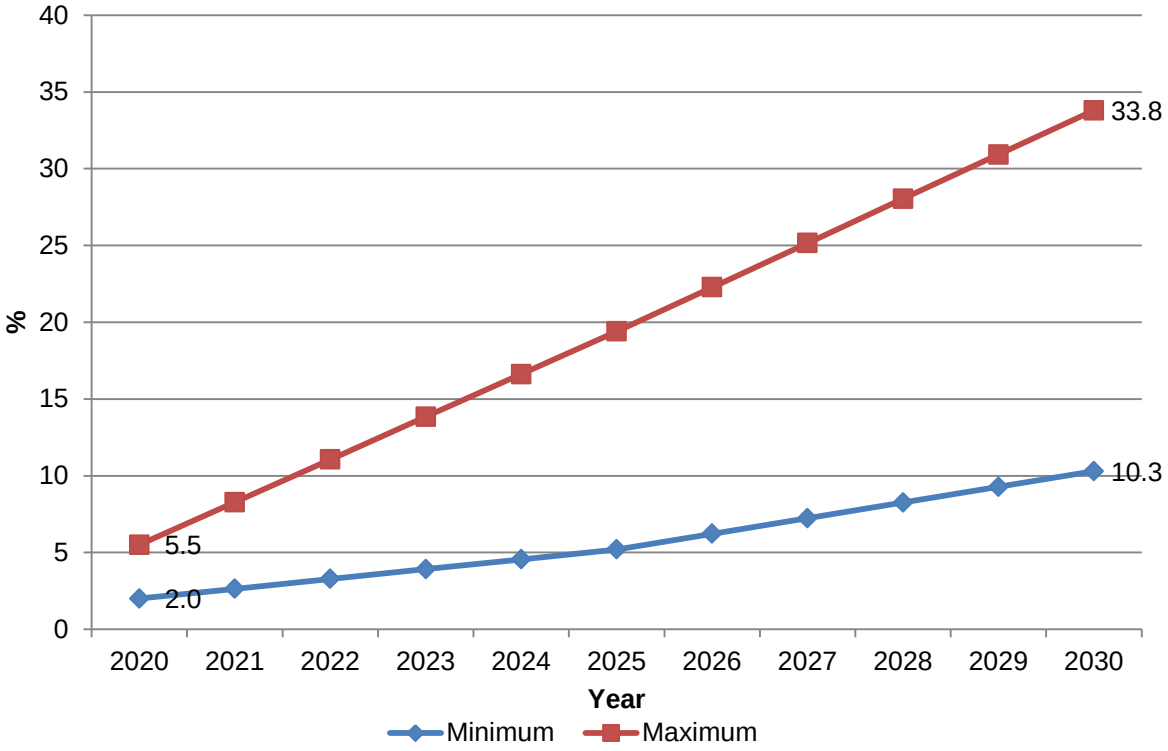


Table 26 applies the forecasted US uptake rates to the Australian context showing maximum and minimum market penetration numbers. It also shows Australian passenger vehicle and all vehicle (excluding motor cycles) population estimates for 2020 and 2030[85]. The results suggest there could be up to 1.7 million highly automated vehicles in the Australian fleet by 2020 and almost 9 million by 2030.

Table 26. Forecasted Australian market penetration of highly automated vehicles

	2020		2030	
	Minimum	Maximum	Minimum	Maximum
Predicted passenger vehicle fleet size	14,923,322		17,739,043	
Predicted all vehicle fleet (excluding motorcycles)	19,007,822		22,594,204	
Level 3 – passenger vehicles	283,543	522,316	798,257	1,490,080
Level 3 – all vehicle types (excluding motorcycles)	361,149	665,274	1,016,739	1,897,913
Level 4 – passenger vehicles	298,466	820,783	1,827,121	5,995,797
Level 4 – all vehicle types (excluding motorcycles)	380,156	1,045,430	2,327,203	7,636,841

[85] Vehicle population estimated use Australian Bureau of Statistics 2017 vehicle population estimates and a 2 per cent per annum growth rate.

Combined levels 3 and 4 – passenger vehicles	582,009	1,343,099	2,625,378	7,485,877
Combined levels 3 and 4 – all vehicle types (excluding motor cycles)	741,305	1,710,704	3,343,942	9,534,754

On face value, these estimates appear optimistic in terms of the penetration rates and/or the timing. However, as there is no specific research of automated vehicle uptake or penetration in the Australian market, the NTC has assumed that automated vehicle uptake in Australia could occur along similar projections to those presented in the international research. The NTC recognises there may be a slight delay as some manufacturers may choose to initially focus their product offerings in the larger markets such as the US, Europe and China. The NTC emphasises that the projections and estimates are only theoretical baselines to assess impacts against. Such projections need to be credible as far as it is practical, but absolute accuracy is not necessary, nor possible.

Appendix I Ongoing cost estimates for existing administrative processes

The Commonwealth government's existing on-going administrative costs include:

- assessing new and imported vehicle compliance against the Australian Design Rules (ADRs)
- administering the existing ADR certification process (including costs of issuing an identification plate and/or revised costs associated with the anticipated amendments to the Motor Vehicle Standards Act)
- administering the current certification exemption processes for non-standard new and imported vehicle types
- notifying state and territory road agencies of new and imported vehicle-type certification outcomes
- notifying state and territory road agencies of nonstandard new and imported vehicle-type exemption outcomes.

The Vehicle Safety Standards Branch of the Commonwealth Department of Infrastructure, Regional Development and Cities advises that there are around 400 new vehicle model applications per year and around 1,000,000 new vehicle sales per year.

Table 27 shows cost estimates for existing administrative processes provided by the Vehicle Safety Standards Branch.

Table 27. Cost estimates for existing on-going administrative processes

Process	Cost per unit	Unit range	Estimated cost per year
Assessing new and imported vehicle compliance against the ADRs	$100 per application	400 per year	$40,000 per year
Administering the existing ADR certification process, including compliance and enforcement, administration and maintenance of legislation	$5.5 million per year	1 per year	$5.5 million per year (~$55 million over 10 years)
Administering the current certification exemption processes for nonstandard new and imported vehicle types	Nil additional (assuming no additional assessment requirements)	1 per year	n/a
Notifying state and territory road agencies of new and imported vehicle-type certification outcomes	No applicable costs	400 per year	n/a
Notifying state and territory road agencies of nonstandard new and imported vehicle-type exemption outcomes	No applicable costs	Unknown	n/a
Fees or charges that are applied to industry bodies that are seeking ADR certification	$6 per vehicle	1,000,000 new vehicle sales per year	$6 million per year (cost offset)

Glossary

Term[86]	Definition
Australian Design Rules (ADRs)	National standards for safety, anti-theft and emissions in vehicle design.
Australian Road Rules	National model law intended to provide the basis for nationally consistent road rules in each jurisdiction. These rules do not, by themselves, have any legal effect.
Austroads	The association of Australasian road transport and traffic agencies.
automated driving system (ADS)	In-vehicle operating system that controls a vehicle's automated functions.
automated driving system entity (ADSE)	The legal entity responsible for the automated driving system.
conditional automation	An automated vehicle where the system drives the vehicle for sustained periods of time, but the human driver must be receptive to system errors and be the fallback for the dynamic driving task.
dynamic driving task*	All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints, and including without limitation: 1. Lateral vehicle motion control via steering (operational); 2. Longitudinal vehicle motion control via acceleration and deceleration (operational); 3. Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical); 4. Object and event response execution (operational and tactical); 5. Manoeuvre planning (tactical); and 6. Enhancing conspicuity via lighting, signaling and gesturing, etc. (tactical).
full automation	An automated vehicle where all aspects of the driving task and monitoring of the driving environment and the dynamic driving task are undertaken by the vehicle system. The vehicle can operate on all roads at all times.
Heavy Vehicle National Law (HVNL)	National laws related to the regulation of heavy vehicles over 4.5 tonnes. Operational in all Australia states and territories except Western Australia and the Northern Territory.
Heavy Vehicle (Vehicle Standards) National Regulation	Heavy vehicle regulation made by the Queensland Governor with approval from state and territory transport ministers and commenced at the same time as the HVNL in 2014.
high automation	An automated vehicle where the system drives the vehicle for sustained periods of time in some situations, or all of the time in defined places, and no human driver is required to monitor the driving environment and the driving task, or intervene, when

[86] Terms marked with an asterisk are quoted from SAE International Standard J3016.

Term[86]	Definition
	the system is driving the vehicle.
human–machine interface	Interface between a human operator and a machine. Includes functional and ergonomic design of the interface (human factors).
Motor Vehicle Standards Act 1989 (MVSA)	Commonwealth legislation to control the safety, environmental and anti-theft performance of all new and used vehicles entering the Australian market for the first time.
National Heavy Vehicle Regulator (NHVR)	The NHVR administers one set of laws for heavy vehicles under the HVNL, delivering a comprehensive range of services under a consistent regulatory framework.
National Highway Traffic Safety Administration (NHTSA)	An agency of the Executive Branch of the United States Government and part of the Department of Transportation.
National Transport Commission (NTC)	Independent statutory body that contributes to the achievement of national transport policy objectives by developing regulatory and operational reform of road, rail and intermodal transport.
operational design domain* (ODD)	The specific conditions under which a driving automation system or feature is designed to function (e.g. locations, weather conditions, driving modes).
partial automation	An automated vehicle where the automated driving system may take control of steering, acceleration and braking in defined circumstances, but the human driver must continue to monitor the driving environment and the driving task, and intervene if required.
National Exchange of Vehicle and Driver Information System	A national system that exchanges information about vehicles and driver licences, managed by Austroads.
Department of Infrastructure, Regional Development and Cities (DIRDAC)	Department of the Australian Government responsible for administering the MVSA.
system failure*	A malfunction in a driving automation system and/or other vehicle system that prevents the driving automation system from reliably sustaining dynamic driving task performance (partial or complete).
Transport and Infrastructure Council	Group comprising Commonwealth, state, territory and New Zealand ministers with responsibility for transport and infrastructure issues, as well as the Australian Local Government Association.
United Nations Working Party 29	International regulatory forum within the institutional framework of the UNECE Inland Transport Committee.

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