Automated Vehicles: Are we ready?

INTERNAL REPORT ON POTENTIAL IMPLICATIONS FOR MAIN ROADS WA
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AUTOMATED VEHICLES: ARE WE READY?
Internal report on potential implications for Main Roads WA

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Automated Vehicles: Are We Ready?

Technology appears to be developing so rapidly that we may see highly Automated Vehicles on our roads sooner than expected. Driverless trucks have been operating in some Western Australian mine sites for some time now, albeit with real-time control from the control centres in Perth.

Automated Vehicles have the potential to fundamentally change the transport landscape. As a road agency, we need to be prepared to identify and implement the changes and improvements that may be required to our infrastructure to enable safe operation of Automated Vehicles. Managing the transition period, with Automated Vehicles and current generation vehicles in co-existing is likely to be particularly challenging for road operators. Eventually, Automated Vehicles with new vehicle designs and different operational characteristics will require new standards and practices in road planning and design, traffic engineering, transport modelling and road construction, maintenance and operation. This requires significant transformation in road agencies.

I want Main Roads to be well prepared for a future with Automated Vehicles. In collaboration with our portfolio agencies and other stakeholders, we should take a leading role to facilitate and adopt Automated Vehicles on our road network so that the Western Australian community can derive early benefits from this technology.

I asked our Road Network Operations branch to produce this report, primarily to raise awareness within the organisation of the current state of play in regard to Automated Vehicles and what it means for us as a road agency. Our recently released ITS Master Plan has some high level actions concerning Automated and Connected Vehicles. This report will also inform the implementation of these actions.

I hope you will find this report interesting, and it stimulates your thinking. I expect it will generate some momentum and early action in our journey towards an exciting future with Automated Vehicles. I invite you to provide feedback and comments on this report so that we can further improve its value.

Steve Troughton
Managing Director of Main Roads
The purpose of this report is to highlight the potential implications for Main Roads of the introduction and wider use of Automated Vehicles (AVs) on Western Australian roads. It will inform Main Roads’ strategic decision-making process and position the organisation to appropriately respond to a potentially disruptive innovation, which could fundamentally change the transport landscape and society, and have profound implications for those agencies involved.

As railways transformed the way we travelled in the 19th century, and the internal combustion engine or the motor car in the 20th, AVs will revolutionise transport in the 21st century. The impacts of automation on the transport system will be far reaching and felt well in advance of the arrival of the fully ‘driverless car’.

Convergence of Automated Vehicles and Connected Vehicles

In the context of smart vehicles, there are two main areas in which rapid technological developments are occurring, defined as Automated Vehicles (AVs) and Connected Vehicles (CVs).

AVs are vehicles where some aspects of a safety-critical control function such as steering, throttle control or braking occurs without direct driver input. They use on-board sensors, cameras, GPS and telecommunications to obtain and analyse information using complex computer algorithms, and respond appropriately by effectuating control in safety-critical situations.

CVs are capable of communicating with each other (Vehicle-to-Vehicle or V2V), with roadside infrastructure, such as traffic control signals (Vehicle-to-Infrastructure or V2I and vice versa), or with other devices, such as mobile phones carried by road users (V2X).

Cooperative Intelligent Transport Systems or C-ITS, mainly focus on V2V and V2I, using wireless communication to share real-time information about the road environment (such as potential incidents, threats and hazards) with an increased time horizon and awareness distance that is beyond both what in-vehicle technologies (radars or cameras) and the driver can visualise. In addition, CVs also include traveller information and navigation, infotainment, remote diagnostics, maintenance and software updates, and safety alerts and warnings.

The developments in CVs and AVs are occurring largely independently, although convergence of the two areas will be required for full automation of vehicles. The main focus of this report is AVs. CVs are only covered to the extent required for AVs.

Executive Summary

Cooperative ITS to be deployed in 2016-2020

C-ITS can be considered a subset of CVs. Substantial work has been undertaken internationally in this area, particularly in the regions of Europe, USA, Japan and South Korea. Japan has already begun deploying vehicles with basic C-ITS functionality, while the other regions are looking at deploying C-ITS between 2016 and 2020. With 85 percent of Australia’s new vehicles now imported, vehicles with C-ITS functionality can be expected in Australia within the same timeframe.

Austroads has established a C-ITS Steering Committee and appointed a Project Director for the Austroads’ C-ITS Project. There is a significant body of work being undertaken through these channels to ensure an appropriate policy and regulatory framework is in place to enable successful deployment of C-ITS in both Australia and New Zealand.

Likely timelines for Automated Vehicles

Almost all major car manufacturers are working on Fully Automated Vehicles (FAVs). Some manufacturers are claiming their FAVs will be ready as early as 2020, however most are expected to be released into the market on the 2020-2030 timeframe.

The adoption of most new technologies follows an S-curve, and it’s reasonable to assume that AVs will follow a similar trajectory. However, the rate of adoption depends on many factors. In the case of AVs, we expect these factors to be maturity of technology, resolution of human factor (human-machine interface) issues, regulatory framework, consumer acceptance, critical mass for network effects (connectivity) and production cycles.

The Institution of Electrical and Electronics Engineers (IEEE) believes that by 2025, 60 percent of the cars on the road will be internet connected. The increased dependence on CVs will increase consumers’ trust and reliance on automated systems. IEEE predicts that 75 percent of the cars on the road will be AVs by 2040.
Managing the transition period

The imminent introduction of vehicles with C-ITS capability and AVs of increasing levels of automation, which is likely to occur in the next three to five years, will mark the beginning of the journey towards FAVs for road agencies. Depending on the market readiness and adoption rates of FAVs, the transition period, which is likely to begin in the next decade, may last until 2040-2050. Full saturation may occur sooner if the safety and mobility benefits of FAVs inspire governments to mandate their use or consumer take-up is faster than expected. Pressure is likely to increase over the next 15 to 20 years to restrict the operation of current generation vehicles to realise the full benefits of vehicle automation. Managing the transition period with a mix of FAVs, or high level AVs and current generation vehicles with no AV capabilities, will create challenges for road agencies.

Emerging issues and implications for Main Roads

There are many emerging issues that need to be resolved before AVs can be deployed. These issues include maturity of technology (electronic control system safety), human factors (human-machine interface issues), liability and regulation, privacy, security (vulnerability to hacking), public acceptance and accuracy of vehicle positioning.

Other implications for Main Roads include the need to roll out more roadside units, future proofing of new ITS, higher standards in road signs and markings, common standard formats for traffic and incident data, and changes in fundamentals in traffic engineering, transport modelling, road design and pavement engineering.

Full automation will also result in infrastructure changes such as the removal of traffic control. Static and digital signs may become redundant, although there will still be challenges in providing a controlled environment for vulnerable road users to cross the road.

A sensible approach for Main Roads in making long-term (over 20 years) planning and investment decisions would be consideration of robust sensitivity testing to explore ‘what-if’ scenarios around the implications of AVs.

While there will be a need for a coordinated national approach, Main Roads needs to build its own momentum and lay the groundwork for Western Australia to support the national work and to minimise the risks of late action.

It is recommended that Main Roads’ strategic direction should:

- prepare and develop capabilities to thrive in the future by undertaking targeted initiatives in areas most relevant to Western Australia and laying the groundwork for AVs within the State; and
- use this work to assist the national approach to achieve the necessary rate of progress.

Main Roads needs to be prepared to transition to a future, with AVs. Enabling this change requires leadership with a vision and building capability within the organisation.

Building up the organisational capability will be critical for a successful transition. A core group of experts, strongly linked with the relevant national and international committees that set the required standards, policy and regulatory frameworks, and ITS architecture aligned with national initiatives, will be required to identify the potential implications and to guide the organisation through this major change to the transport landscape.
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1. Introduction

1.1 Purpose
The purpose of this report is to highlight the potential implications for Main Roads from the introduction and wider use of Automated Vehicles (AVs) of various levels of automation on Western Australian roads. In doing so, the report seeks to inform Main Roads’ strategic decision making process and position the organisation to respond to a potentially disruptive innovation, which could fundamentally change the transport landscape and society and have profound implications for those agencies involved.

1.2 What are Automated Vehicles?
In the context of smart vehicles, there are two main areas in which rapid technological developments are occurring, defined as Automated Vehicles (AVs) and Connected Vehicles (CVs) as indicated in Figure 1.1. The developments in CVs and AVs are occurring largely independently, although convergence of the two areas will be required for full automation of vehicles.

AVs are vehicles where some aspects of a safety-critical control function such as steering, throttle control or braking occurs without direct driver input (NHTSA, 2013). Vehicles that provide safety warnings to drivers (for example forward crash warning) but do not perform a control function are, in this context, not considered automated, even though the technology necessary to provide that warning involves varying degrees of automation (e.g. the necessary data is received and processed, and the warning is provided without any driver input). AVs use on-board sensors, cameras, GPS and telecommunications to obtain and analyse information using complex computer algorithms, and respond appropriately by effectuating control in safety-critical situations. The widely known ‘Google self-driving car’, is an example of an AV.
1.2.1 Levels of automation

NHTSA levels of automation

The US National Highway Traffic Safety Administration (NHTSA) has defined different levels of vehicle automation, ranging from vehicles that do not have any vehicle systems automated (Level 0) to Fully Automated Vehicles (FAVs) (Level 4) as outlined in Table 1.1.

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Examples</th>
<th>Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Warning but no automation</td>
<td>Lane departure warning, blind spot warning</td>
<td>The driver is in full control but supported by systems</td>
</tr>
<tr>
<td>1</td>
<td>Function-specific automation</td>
<td>Electronic Stability Control (ESC),</td>
<td>The driver is always in control but safety systems take</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adaptive Cruise Control (ACC), Auto Emergency</td>
<td>some corrective action if needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Braking (AEB)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Combined function automation</td>
<td>ACC and lane keeping assistance, self-parking</td>
<td>The vehicle can operate without driver input in some</td>
</tr>
<tr>
<td>3</td>
<td>Limited self-driving automation</td>
<td>In normal conditions vehicle can operate</td>
<td>driver at short notice in some conditions</td>
</tr>
<tr>
<td>4</td>
<td>Full self-driving automation</td>
<td>Vehicles operate without requiring driver</td>
<td>vehicles may or may not have a driver present</td>
</tr>
</tbody>
</table>

Table 1.1 - NHTSA levels of automation
Following several years of work by road safety practitioners, new cars in Australia already require the Level-1 automation of Electronic Stability Control (ESC), and an advocacy campaign has commenced for Autonomous Emergency Braking (AEB). There are some vehicles on the market in Australia with Level-2 automation, for example the Honda CR-VS is available with a combination of Collision Mitigation Braking System (CMBS), Lane Keep Assist System (LKAS) and Adaptive Cruise Control (ACC) (Honda Australia, 2013). Another common form of Level-2 automation, albeit at low speeds, is automatic parking, available in an increasing number of cars. In Level-1 automation, the vehicle cannot operate without driver input. In Level 2, in some conditions, driver input is not required.

Vehicles with Level-2 automation are commercially available, with enhancements to advanced driver assistance systems for use on controlled access highways. For example, the 2014 Mercedes-Benz S class features Intelligent Drive, and its most advanced automated function is the ‘traffic jam assist’, which lets the car steer, brake and accelerate itself in congested conditions at speeds lower than 37 mph (60 km/h) (Kurylko, 2014). Audi’s self-parking system is also a similar Level-2 automation function.

A video about Audi’s ‘self-parking car’ is available at: http://www.youtube.com/watch?v=vt20UnkmkUJ&feature=player_detailpage#t=17

Automated truck platoon systems with driver supervision, especially in truck lanes, have also been trialled in Europe (refer section 4.3.2).

Figure 1.4 Audi ‘self-parking car’ (Level-2 automation) (Source: Audi)
1.3 What are Connected Vehicles?

Connected Vehicles (CVs) are capable of communicating with each other (Vehicle-to-Vehicle or V2V), with roadside infrastructure, such as traffic control signals (Vehicle-to-Infrastructure or V2I and vice versa), or with other devices, such as mobile phones carried by road users (V2X).

Cooperative Intelligent Transport Systems or C-ITS, which can be considered a subset of CVs, mainly focus on V2V and V2I using wireless communication to share real-time information about the road environment (such as potential incidents, threats and hazards) with an increased time horizon and awareness distance that is beyond what in-vehicle technologies (radars or cameras) and the driver can visualise (Austroads, 2012).

In addition, CVs also include traveller information and navigation, infotainment, remote diagnostics, maintenance and software updates, and safety alerts and warnings. Substantial work has been undertaken internationally in this area, particularly in the regions of Europe, USA, Japan and South Korea. Japan has already begun deploying vehicles with basic C-ITS functionality, while the other regions are looking at deploying C-ITS between 2016 and 2020 (Austroads, 2012). With 85 percent of Australia’s new vehicles now imported, vehicles with C-ITS functionality can be expected to be in Australia within the same timeframe.

1.4 Automated or autonomous?

The terms ‘autonomous cars’ and ‘driverless cars’ are often used to describe automated vehicle systems. However, leading ITS research engineer Steven Shladover, who also delivered recommendations to the California Department of Motor Vehicles on regulating the testing and operations of AVs, says those are serious misnomers (ITS Berkeley, 2014). In most cases, these vehicles will have a driver but the role of that driver may be significantly reduced compared to today’s drivers.

The word ‘autonomous’ is often used by those in robotics engineering to signify complete automation. It means independent or self-sufficient. Therefore, it refers to a vehicle that obtains information by itself, using only its own on-board sensors, and it operates independently of all other vehicles and infrastructure.

By contrast, cooperative vehicles also obtain information by communication with other vehicles and the roadway infrastructure, and can negotiate with those other entities to coordinate their actions.

The existing collision warning and control assistance systems on the market are autonomous but they have very low levels of automation.

Shladover says that in the future we are likely to see fully automated systems that are cooperative but less likely to be autonomous, since that would severely limit their ability to collect and exchange vital information.
1.5 Automated Vehicles in the context of Main Roads’ ITS Master Plan

Main Roads released an ITS Master Plan in September 2014 as part of its 2020 Strategy. The Master Plan identified that the vision of Smart Roads, Safe Journeys in 2020, would include:

- reduced crashes through smarter vehicles and roads; and
- improved connectivity and cooperation between vehicles, roads and travellers.

Part of achieving this vision was to accelerate adoption of increasingly automated and connected vehicles that can substantially reduce crashes and increase network capacity. As a result, one of the three external focus areas in the Master Plan is to encourage and facilitate adoption of smarter, safer vehicle and road technologies (MRWA, 2014).

The Master Plan included the following action:

“...in collaboration with the Department of Transport and other stakeholders, develop a strategy to facilitate the adoption of automated and connected vehicles. A strategy is required to identify and address any barriers to wider adoption of automated and connected vehicle technologies that can deliver safety and efficiency benefits. The strategy should also consider requirements for monitoring of any impacts of such technologies.”

This report is the first step towards this action, examining the implications of AVs for Main Roads as a necessary prerequisite to developing a strategy that facilitates wider adoption of smarter vehicles.

1.6 Report structure

The remainder of this report is structured as follows:

- Section 2 reviews the transportation and societal impacts of AVs;
- Section 3 considers the emerging issues associated with AVs that need to be resolved before deployment;
- Section 4 examines the current state of play in Australia and internationally, including the USA, Europe and the Asia Pacific countries;
- Section 5 discusses the likely adoption rates and timelines for AVs; and
- Section 6 considers the potential implications for Main Roads.
There is little doubt that AVs have the potential to transform the way we use transport and therefore our society, with profound implications for those agencies involved in transport. Le Vine and Polak (2014) state that as railways transformed the way we travelled in the 19th century, and the internal combustion engine or the motor car in the 20th, AVs will revolutionise transport in the 21st century. The impacts of automation on the transport system will be far reaching and felt well in advance of the arrival of the fully ‘driverless car’ (Le Vine and Polak, 2014).

In theory, an entire vehicle fleet comprising FAVs (full saturation) has the potential to virtually eliminate almost all of the main intractable negative impacts of transport, such as crashes, congestion, emissions and (to a lesser degree) noise. Traffic flows will be self-optimised with vehicles that cannot crash. The road network will not require traffic signals, road signs, variable message signs, overhead lane control signs or other roadside furniture such as safety barriers. However, this ultimate transformation is likely to be some time away.

Some benefits, particularly those related to safety, will come with lower level automation and are likely to increase with the level of automation and the adoption rate (uptake) of AVs. The key transportation and societal impacts resulting from AVs are briefly discussed below.

2.1 Impacts on vehicle ownership

FAVs have the potential to profoundly change the current vehicle ownership model and expand opportunities for vehicle sharing. If vehicles can drive themselves, they can be summoned when needed and returned to other duties when the trip is over (KPMG, 2012). Travellers would no longer need to own vehicles and could purchase mobility service on demand.

FAVs could be used more efficiently instead of being parked most of the time. This would require new models for vehicle insurance and maintenance but will also open up new business opportunities. With passengers having the option to share their journey with others if they want and lower fares, there is likely to be a big shift away from car ownership to car clubs, shared vehicles or new forms of personalised public transport (Begg, 2014).

This is likely to cause a significant decline in vehicle ownership, creating new challenges for traditional auto manufacturers, equipment suppliers and others involved in the automotive supply chain. Using analytical and simulation models, Columbia University’s Earth Institute forecasts a significant reduction of the vehicle fleet, although the time span over which this reduction would occur is not explicit. For example, 120,000 privately owned vehicles could be replaced by 18,000 shared AVs in Ann Arbor (The Earth Institute, 2013).

2.2 Mobility freedom

In the US, the current legislation in some states, such as California, Florida and Nevada, mandates that all drivers pursuing AV testing on public roadways be licensed and prepared to take over vehicle operation if required. However, as experience with AVs increases, this requirement could be relaxed and AVs may be permitted to legally chauffeur children and persons that otherwise would be unable to safely drive. FAVs could eventually provide ‘mobility freedom’ for the elderly, children, people with disabilities and others who don’t drive or are unlicensed to drive (KPMG, 2012).

FAVs could eventually provide ‘mobility freedom’ for the elderly, children, people with disabilities and those who don’t drive or are unlicensed to drive (KPMG, 2012).

Such mobility freedom will be increasingly beneficial as the population ages. The overall demand for travel is likely to increase as a result, but will also depend on other factors, such as pricing.

Vehicle automation provides opportunities for significant reductions in operational costs of public transport and for improved service levels (e.g. reliability), with the possibility of on-demand services on low-patronage routes. However, the attraction of public transport, when people have access to on-demand, door-to-door transport, with near perfect reliability and safety, is unclear.
2.3 Safety benefits

AVs have the potential to dramatically reduce crashes (KPMG, 2012), and these benefits are seen at the lowest levels of automation. Driver error is believed to be the primary factor behind over 90 percent of all crashes. As vehicles become increasingly automated, the sources of driver error will disappear subject to resolving any new human factor complications introduced by AVs in terms of driver ‘under-load’ and re-engagement if they need to take back the control of the vehicle.

Level-1 AV functions, such as ESC, have already demonstrated safety improvements. Further benefits can be expected as other Level-1 AV functions become more widely used. The US Insurance Institute for Highway Safety (IIHS) found that some models of Volvo, Mercedes-Benz and Honda with crash avoidance technology had 14 to 16 percent fewer accident insurance claims, than the same vehicles without this technology (Collins, 2014).

The safety benefits of Level 2 and Level 3 automation will depend to a large degree on the balance between crash reductions from the AV technology and any crash increases associated with human factors. This is discussed in more detail in Section 3.2.

The primary benefits of CVs also include safety. According to NHTSA, if V2V technologies are widely deployed, they have the potential to address 76 percent of multi-vehicle crashes involving at least one light vehicle by providing warnings to drivers (US GO, 2013). V2I technologies could offer additional safety features that V2V technologies cannot, such as providing drivers with additional warnings when traffic signals are about to change and warnings that could help reduce collisions at intersections.

The safety of other vulnerable road users (VRUs), such as pedestrians and cyclists, is also likely to significantly increase, as AVs will be able to detect their presence and take evasive action automatically. Any redundant road space due to narrower and fewer lanes could potentially be transformed to provide a safer and friendlier environment for VRUs.

Full automation (and connectivity) will eventually lead to vehicles that cannot crash or at least cannot crash under normal operation (KPMG, 2012). System failure remains a possibility, but convergence of automation and connectivity will include a number of redundant systems that can substitute for one another and yield safe operations even in failure.

AVs that cannot crash will no longer require a significant amount of structural steel, roll cages or air bags, among other safety features, and therefore could be much lighter. Cabins can be redesigned to support activities other than driving and crash survival. Possibilities include a rolling office or a reconfigurable space to suit the occupant’s changing needs.

With such significant safety benefits, the pressure is likely to grow over the next 15-25 years to restrict the operation of current generation vehicles to help realise the full potential of vehicle automation.

2.4 Reduced congestion

AVs, which can operate as connected vehicles, will have the potential to significantly reduce congestion (through increased throughput per lane). This is primarily due to a reduction in headways in vehicle platoons, as they are able to travel closer together.

Smaller and lighter AVs will not require the same lane widths as current generation vehicles. This is likely to result in the ability to accommodate more lanes on the same carriageway, which will help increase throughput per unit length.

With FAVs, time-distance-location pricing would be a real possibility. This will play a significant role in reducing congestion, with road users making conscious decisions to time their trips to minimise costs. Also, some commentators argue that this may lead to airline type booking system for roads, where people will be able to book their trips (road use) in advance to take advantage of discounted prices (Begg, 2014).

With AVs, the ITS of the future will be able to provide each vehicle with a reliable and predictable path from origin to destination (KPMG, 2012). This will virtually eliminate the need to allocate extra time for trips to account for variability of travel times, enabling more efficient travel for both people and freight.
2.5 Productivity benefits

Improved travel-time reliability with AVs will decrease transport costs and improve supply-chain productivity. Industries dependent on just-in-time delivery will be able to reduce inventories even further (KPMG, 2012).

FAVs could not only eliminate most urban congestion, but will also enable travellers to make productive use of their travel time. Vehicles may be customised to serve the needs of the traveller (e.g. mobile offices, sleep pods or entertainment centres). Through connected services, former drivers will now be capable, at no loss of safety or risk of violation, of undertaking work or having social time with their family or friends while in transit.

2.6 Air quality and environmental benefits

A transportation system composed of AVs would decrease energy consumption in at least three primary ways (KPMG, 2012): more efficient driving; lighter, more fuel efficient vehicles; and efficient infrastructure.

Vehicle platooning alone, which could reduce the effective drag coefficient on following vehicles, could reduce fuel use by up to 20 percent. In addition, reduced congestion and efficient vehicle operation and navigation (compared to vehicles operated by humans) could also reduce fuel consumption significantly.

Lighter and smaller AVs will also require less fuel to operate. NHTSA, EPA and CARB (2010) estimate that a 10 percent reduction in vehicle mass leads to a six to seven percent reduction in fuel consumption.

In addition to reduced emissions due to less fuel consumption by AVs, there may also be environmental benefits from infrastructure modifications for AVs. There may not be a need for the same levels of lighting, electric VMS and other signs, reducing energy use.

AVs, which can operate as connected vehicles, will have the potential to significantly reduce congestion (through increased throughput per lane). This is primarily due to a reduction in headways in vehicle platoons, as they are able to travel closer together.
2.7 Impacts on transport infrastructure

Today’s road networks are designed with a higher margin of safety for imprecise and sometimes unpredictable movement patterns of human-driven vehicles with wide lanes, shoulders, guardrails, road signs (static and electronic), traffic signals, rumble strips and other safety features. Most, if not all, of these features will not be required for FAVs.

With platooning, decreased size and the ability to track more precisely within lanes, AVs will enable more throughput per lane and reduced lane widths. This will increase road capacity exponentially (KPMG, 2012). Eno (2013) states that unless new travel from AVs is significantly underestimated, existing infrastructure capacity should be adequate to accommodate the new and induced demand.

Figure 2.2 Smaller AVs will dramatically increase road capacity – General Motors’ Chevrolet EN-V concept vehicle, which can be driven in manual or automated modes (© General Motors)

2.8 Impacts on freight transportation

AVs are already being used in some warehousing operations and at least one harbour container terminal in Germany (DHL, 2014). Freight transportation is likely to be one of the early adopters of AVs in line-haul transportation. Increased fuel economy, improved travel times and reliability, improved safety, time-distance-location pricing, driverless operations and platooning will all significantly benefit freight transportation. It is estimated that a four metre headway between trucks could reduce fuel consumption by 10 to 15 percent. Platooning will also facilitate adaptive braking, which could further reduce fuel consumption (Eno, 2013).

Another possibility with FAVs is that they could enable automatic pick-up and delivery – both in the form of automated delivery vehicles and by AVs being sent to pick up goods (Begg, 2014).

However, the implications of this for travel demand are difficult to predict. Begg postulates that this is likely to lead to an increase in household deliveries, but on the basis that one delivery vehicle can replace up to 30 car trips on average, this could be viewed as beneficial in reducing trips. This will not be the case if households use their AVs to pick up goods for them.

Figure 2.3 A truck platoon in KONVOI project in Germany (Source: RWTH Aachen University)
2.9 Impacts on public transport

AVs have the potential to either complement or replace public transport. With their improved service levels, AVs may attract public transport patrons back to cars. Buses with fixed timetables and routes will find it difficult to survive with on-demand AVs that can provide a door-to-door service.

Today at Heathrow airport, an on-demand fully-automated transport service is operating between remote car parks and Terminal 5, replacing buses. Commonly known as ‘pods’, they operate on a protected guide-way with a waiting time of under a minute. (Le Vine and Polak, 2014).

However, in larger, denser cites, it’s difficult to imagine that AVs, even with a doubling of the existing road capacity, could replace the capacity of large metro systems, which can carry over 70,000 passengers per hour in one direction (Jacobs, 2013b). In such a scenario, AVs could provide a feeder service to mass public transport systems. Traditional taxis could be the first mode of transport to disappear with AVs.
2.10 Surplus transport land

The average car only turns its wheels 4 percent of its life; the rest of the time it is lying idle. This results in too many cars, leading to pressure on parking (Begg, 2014). With AVs, parking will be revolutionised with vehicles parking themselves. After dropping off their passengers, vehicles could drive themselves to a multi-storey car park, where an automated mechanical system would stack vehicles close together as there is no need to open doors. This will eliminate any increase in congestion caused by drivers cruising around looking for parking. Vehicles could also drop off passengers and park away from the city, where space is not so scarce.

The potential reduction in the total vehicle fleet, coupled with limited parking requirements for vehicles, will release valuable land currently occupied for parking, particularly in inner city areas, to be used for other purposes.

There may also be surplus land due to a reduction in lane widths and the number of lanes, which could be transformed to provide better amenity for other road users such as cyclists and pedestrians.

With FAVs, there will also be no need for park-and-ride at public transport terminals.

2.11 Urban sprawl

AVs have the potential to increase trip lengths, due to improved travel times and reliability of travel. People will also be able to use their travel time more productively. Therefore, unless carefully managed through pricing and other measures, urban sprawl could be a potential adverse impact of AVs, as people will have an option to live further away from cities without a corresponding increase in costs in travelling to the city.
3. Emerging issues with Automated Vehicles

As the technology for AVs becomes more advanced, the focus is increasingly shifting towards the emerging issues and potential barriers for their implementation.

The major Australian policy work completed in this area is the National Transport Commission’s (NTC) paper on Cooperative ITS Regulatory Policy Issues released in December 2013 (NTC, 2013), after approval by the Standing Council on Transport and Infrastructure in November 2013. Although this policy paper covers C-ITS, many of the aspects of privacy, liability and driver distraction are also relevant to AVs.

The NHTSA is actively working through some of the issues associated with the greater use of AVs and its 2013 policy statement sets out a program of research covering human factors, the safety of electronic control systems and performance requirements for the systems. Many of the trials and demonstrations highlighted in Section 4 are focused on working through these general issues as well as further developing the technology itself.

3.1 Electronic control system safety

Google reported in April 2014 that its cars had covered nearly 70,000 miles (112,000 km) of ‘autonomous driving’ without any incident. The only time a Google car was involved in a crash was when it was driven by a human near its headquarters (Begg, 2014).

RAND (2014) identifies that AVs employ a “sense-plan-act” approach as per many robotic systems. A suite of sensors on the vehicle, and any external sensors accessed via V2X communications, gather raw data about the road environment and the vehicle’s relationship to its environment. This sensor data is complemented by detailed maps. Software algorithms interpret the sensor data, such as lane markings from images of the road, GPS positional data and behaviour of other vehicles from radar and Lidar data. Sophisticated algorithms use this data to make plans about the vehicle’s projected trajectory, acceleration/deceleration and change in direction. These plans are converted into actionable commands for steering, throttle and brakes.

There are several types of technology failure that can occur in an AV:

- Sensors and/or processing algorithms fail to perceive and respond to a hazard (false negative),
- Sensors and/or processing algorithms perceive and respond to a non-existent hazard (false positive),
- System performance is degraded due to some inoperable sensors or algorithms, and
- AV systems are completely inoperable.

Given the potential for disastrous consequences, AVs will have built-in fail-safe mechanisms and redundancy to achieve a defined near-zero benchmark. It is unlikely that FAVs will be allowed on to the road networks until any concerns around technology robustness are fully resolved.

A common element in all levels of automation is safety-critical electronic control systems. There are voluntary industry standards, such as ISO 26262, which establish uniform practices for specific levels of safety integrity in complex embedded systems. In the United States, NHTSA has the regulatory responsibility for performance standards for vehicle systems or sub-systems that address a specific type of safety risk. For AVs, NHTSA is focusing on developing functional safety requirements as well as potential liability requirements in the areas of diagnostics, prognostics and failure response (fail safe) mechanisms (NHTSA, 2014).

NHTSA has identified the following topics that need to be addressed in the areas of safe reliability:

- Failure modes – Evaluating failure modes and associated severities.
- Failure probability – Evaluating the likelihood of a failure to occur.
- Diagnostics/prognostics – Evaluating the need and feasibility of enhanced capabilities that can self-detect or predict failures and investigating how to communicate potential system degradation to the driver.
- Redundancy – Investigating what additional hardware, software, data communications, infrastructure etc. that may be needed to ensure the safety of highly automated vehicles.
- Availability - Ability to perform even at a degraded level in case of failure.
- Certification – requirements and processes to validate that the system is safe at deployment and remains safe in operation, including vehicle software.
3.2 Human factors

The time when humans must take back control of the vehicle is emerging as one of the greatest challenges associated with AVs. If the driver cannot provide assistance when it’s most needed, it could make the situation worse and have potentially catastrophic consequences.

Google’s ‘self-driving’ Lexus SUV offers one current template for this handover (Bosker, 2013). When the car knows it needs human help – perhaps when approaching a construction zone or merging into a freeway – an icon or message will flash on a custom-made screen mounted on the car’s dash. The driver usually has 30 seconds notice to take control of the car.

One of the open questions is how much time is needed for the driver to re-engage, which is considered to be in the range of five to ten seconds (Berkley, 2014). Besides the limited time, the handover must happen seamlessly and safely, and the driver must be thoroughly comfortable with the process in any vehicle they use (KPMG, 2012).

NTC (2013) identified a number of areas where human factors must be considered as part of the greater adoption of AV style technology:

• Behavioural adaptation (over-reliance on technology);
• Awareness of capabilities and limitations;
• Risk compensation (greater risk taking);
• Distraction;
• Skill loss;
• Risk exposure change through changed travel patterns; and
• Driver acceptance.

The first five of these risk areas relate to the role of the driver in an increasingly automated vehicle. In Levels 1 to 3 of automation, the driver has a critical role in the safe operation of the vehicle as summarised below:

• A vehicle with Level-1 automation will only move if controlled by a driver, with the technology only intervening in limited circumstances;
• A vehicle with Level-2 automation will drive itself in limited circumstances, but a driver is required to control the vehicle as conditions change and at other times; and
• A vehicle with Level-3 automation will drive itself in most circumstances, but requires driver input when conditions are outside those circumstances.

In Level-4 automation the vehicle can operate without the driver. However, in NHTSA’s opinion there are very few true Level-4 AVs currently in existence, even in testing, with most current “self-driving” cars operating at Level 3 (NHTSA, 2013).

Driver awareness is a critical requirement of the safe operation of all but Level-4 AVs. However, there is the potential for increased driver distraction as their role in the driving task reduces. Some marketing efforts for AVs focus on the ability of the vehicle to take a load off the driver. This means driver distraction - both in terms of the driver’s ability to disengage from non-driving tasks and re-engage in driving at short notice when needed - needs careful consideration.

Some vehicle manufacturers have recognised the risk associated with driver ‘under-load’ and driver re-engagement. The Level-2 self-driving functions in the Mercedes (for inter-urban motorways) requires driver pressure on the steering wheel to continue operation and Volvo’s Lane Keeping Assistance deactivates after the third intervention. These approaches are similar to the vigilance monitoring used for train drivers.

NTC (2013) identified that the assessment of safety benefits from increased automation must consider both the ability and limitations of the technology in preventing and/or reducing the severity of crashes, as well as the changes in crash risk from the changed human behaviour. Crashes are rare events, so a crash in an AV reflects a simultaneous failure of both the automated system and the driver (Verweij et al, 2010). A safety benefit is still achieved, provided that the increased risk of driver failure is more than offset by the reduced risk in cases where the system prevented driver error.

NHTSA is undertaking research on human factors to develop requirements for the driver-vehicle interface (DVI), so that drivers can safely transition between automated and non-automated vehicle operation, and any additional information relevant to the safe operation of the vehicle is effectively communicated to the driver. The research will primarily focus on Level 2 and 3 systems.
The main topics to be addressed as part of this human factors research include the following:

- **Driver/vehicle interaction** – Evaluating communication methods between driver and vehicle to ensure safe vehicle operation.
- **Ensuring proper allocation of vehicle control functions between the driver and the vehicle:**
  - Division of labour and control authority – assuring that either the driver and/or vehicle are in control all the time;
  - Transitions – investigating appropriate means of transferring control from driver to vehicle and vice versa; and
  - Override - evaluating override requirements so the driver can always, or when appropriate, override the automated system and regain control.
- **Driver acceptance** – Factors leading to driver acceptance (false alarm rates, nuisance warnings, automation system availability and reliability).
- **Driver training** – Evaluating training requirements that may be needed for Level 2 and 3 systems.
- **Developing human factor research tools** – Developing the appropriate test and evaluation tools (e.g. simulators, test vehicles) to evaluate driver and system performance for various automated vehicle concepts.

As a first step toward completing research on these issues, the NHTSA has initiated an evaluation of emerging Level 2 and Level 3 system concepts to answer fundamental human factor questions. The evaluation will examine how drivers react and perform in these types of automated vehicles. In addition, it will consider DVI concepts that may be needed to ensure that drivers safely transition between automated driving and manual operation of the vehicle. The initial research will address the following human factor questions:

- What is the driver performance profile in sustained (longer term) and short-cycle (shorter term) automation?
- What are the risks from interrupting the driver’s involvement with secondary tasks when operating a Level 3 type automated vehicle?
- What are the most effective handover strategies between the system and the driver, including response to faults and failures?
- What are the most effective human-machine interface concepts, guided by human factor best practices, which optimise safe operation?

One of the main outcomes of this initial research program will be the recommended requirements for the driver-vehicle interface to allow safe operation and transition between automated and non-automated vehicle operation.

### 3.3 Liability and insurance

The transition from current vehicles to FAVs is likely to shift the focus of liability for crashes from drivers to the vehicle manufacturers (Karla, Anderson and Wachs, 2009). A legal framework will be necessary to deal with the potentially complex liability issues that may come with AVs (KPMG, 2012). While this will raise complex new liability questions, Scott Pendry, Policy Specialist – Road Safety, at the Association of British Insurers, says there is no reason to expect that the legal system will be unable to resolve them (Local Transport Today, 31 October – 13 November 2014, p. 4).

The work by Karla et al (2009) suggests that for technologies that share vehicle control (and thus responsibility) with a driver, a manufacturer may be held liable under the claim that a driver was misinformed about the true capabilities of the system. It also indicates that warnings, consumer education and driver monitoring will play a crucial role in managing manufacturer liability for these systems.

However, Karla et al (2009) argue that increasing manufacturer liability may significantly slow the introduction of highly complex systems such as FAVs, for which it is difficult to prove absolute safety and reliability.

Government regulations are likely to play an important role in AV technologies, by setting standards for how they perform and also by requiring them to be included in future vehicles (Karla, Anderson and Wachs, 2009). The US standards development organisations SAE, IEEE and NCTIP, and the European standards development organisations ETSI and CEN/ISO, have already published a number of standards in relation to CV and AV technologies (refer section 4.9 for further details). Insurance underwriting will be another related issue, and a greater proportion of the liability could transfer to manufacturers and infrastructure providers (KPMG, 2012).

AVs are capable of providing large amounts of data that could assist investigation in case of a crash. By recording the actions and forces involved in the minutes before and after a crash, they may help determine the cause of the crash and assist in resolving any liability dispute.

Liability may not be such a critical issue for CVs. The NTC (2013) recommends that no changes are made to the current approach. However, it recognises that further research may be required on human factor issues and the implications of increasingly automated vehicles.
3.4 Legislation

In regard to road rules, the NTC (2013) identifies that rule 297 in the Australian Road Rules states that “a driver must not drive a vehicle unless the driver has proper control of the vehicle”. There are some differences in implementation of these road rules by the various states.

There is no equivalent rule 297 in the WA Road Traffic Code 2000; however, of some relevance is rule 263 which states that a person shall not drive a vehicle, unless he or she is in such a position behind the steering wheel that he or she has full control over the vehicle.

There is a need to review rule 297 in the Australian Road Rules in light of highly automated systems.

Although Australia is not a signatory, internationally the UN Vienna Convention on Road Traffic has been raised as a barrier to self-driving due to its requirement for drivers to be in control of vehicles. Proposed amendments to the convention (UNECE, 2014) would allow increased intervention by AV systems, perhaps up to Level-3 automation, but would still require a driver to be present and able to override the system, excluding Level-4 operation.

Changes to the Vienna Convention and US state legislation to permit wider use of AVs indicate a potential willingness to update legislation and regulations as required. Nevertheless, it is likely that legislation and regulations will trail behind technological development in vehicle automation.

Particularly notable is the requirement by the California Department of Motor Vehicles that self-driving cars have a steering wheel so a driver can take control if necessary. When considered together with the limitations in the proposed alteration to the Vienna Convention, it appears that there is currently much greater acceptance in legislation of Level-3 than Level-4 self-driving, due to the ability for a driver to intervene.

3.5 Privacy

The NTC policy paper on Cooperative ITS Regulatory Issues (NTC, 2013) considers the question of privacy at some length, albeit in the context of C-ITS only.

Although the security system being developed for CVs is designed to ensure data privacy is through a structure that prevents the association of a vehicle’s communication security certificates with any unique identifier of its driver, the perceived lack of privacy is a challenge (GAO, 2013). The communication security system would contain multiple technical, physical and organisational controls to minimise privacy risks, including the risk of vehicle tracking by individuals, government or commercial entities.

There may still be concerns around data ownership and sharing, particularly in the case of a crash. It is likely that crash data will be owned or shared by AV technology suppliers, since they will likely to be responsible for damages in the event of a crash. In the US, 96 percent of new passenger vehicles sold have event data recorders (although less detailed) that describe vehicle actions taken in the seconds prior to and following a crash. The NHTSA is also considering mandating event data recorders on all new vehicles under 8,500 lbs (Eno, 2013). California law concerning AVs requires 30 seconds of sensor data storage prior to a collision to help establish fault.

While security measures for personal computers and internet communications were implemented largely as an afterthought and in an ad-hoc manner, V2V and V2I protocols have been developed with security embedded in the initial development phase.

There is already widespread collection and use of personal information through ITS generally, through navigation systems and apps on smartphones as well as for vehicle maintenance. Many of these current uses of personal information are on an opt-in basis.

A key question is the extent to which AVs create additional privacy implications compared to business as usual. There is a possibility that new information, new access to information or mandating of functionality may prevent the opt-in approach.

3.6 Cybersecurity (vulnerability to hacking)

Involves the vehicle being in control of its actions, there is the possibility that malicious use of this functionality causes loss of life or serious injuries. The question of adequate security against hacking is therefore relevant with respect to vehicle automation for on-board systems, and data acquired from other vehicles and the road infrastructure. By intercepting and tampering with mobile communications, there is the potential for cyber-criminals to interfere with or override the operating systems of vehicles.

The security risks of AVs relate mostly to connectivity. While security measures for personal computers and internet communications were implemented largely as an afterthought and in an ad-hoc manner, V2V and V2I protocols have been developed with security embedded in the initial development phase. This and other security measures, such as separation of mission critical and communication systems, should make large-scale attacks on AVs and related infrastructure more difficult (ENO, 2013).
The Security Credential Management System (SCMS) is a central part of the Connected Vehicle security environment, and Austroads is currently exploring how this will operate in Australia.

As currently envisioned, the SCMS for CVs will be a complex Public Key Infrastructure (PKI) that creates, manages, stores, distributes and revokes digital certificates that accompany and validate each message (known as BSM or Basic Security Message) (FHWA, 2014). It is this PKI that will allow users of the CV environment’s unsecure public network to securely and privately exchange BSM data through the use of a public and private cryptographic key pair that is obtained and shared through a trusted authority.

The US Department of Transport (DOT) has determined that the KPI for the CV environment should be organised so that no single organisation within the KPI holds enough information about a participant to link a BSM transmitted by a vehicle to a specific driver or identified vehicle.

NHTSA has identified the following topics that need to be addressed in the area of cybersecurity (NHSTA, n.d.):

- Security – Capability of the system to resist cyber attacks
- Risks – Potential gaps in the system that can be compromised by cyber attacks
- Performance – Effectiveness of security systems
- Unintended consequences – Impacts of cybersecurity on performance of the system
- Certification – Methods to assure that critical vehicle subsystems such as communications are secure

3.7 Public acceptance

Regardless of how safe AVs eventually become, there is likely to be an initial perception that they are potentially unsafe because of the lack of a human driver. Perception issues have often been known to drive policy and delay implementation (Eno, 2013).

The University of Michigan Transportation Research Institute (UMTRI)’s survey of public opinion on “self-driving vehicles” provides some insight into how the public rate the issues related to vehicle automation, although this data is limited to the Level 4 full self-driving applications (Schoettle and Sivak, 2014). Figure 3.1 below illustrates the levels of concern about different issues.

![Figure 3.1](source:Schoettle and Sivak (2014))
In general, the results show that the public is not yet convinced that the issues have been addressed to allow full general use of Level-4 automation. The most confident response was in the ability to learn how to use self-driving vehicles, where 20 percent of respondents expressed no concern. In most other cases, around 90 percent of respondents expressed some level of concern, with 96 percent having some concern about the safety consequences of equipment/system failure and 94 percent having some concern about how self-driving vehicles would deal with unexpected situations.

However, acceptance of AVs is likely to increase when the public experiences the benefits of them. A recurring customer satisfaction survey about the automated pods at Heathrow airport indicates high customer satisfaction levels (Jacobs, 2013c).

Another dimension of public acceptance is that some demographics of the population, such as car enthusiasts and those who equate their cars with personal freedom and identity (e.g. baby boomers), may be reluctant to give up their wheel (KPMG, 2012). On the other hand, younger generations – those within the Digital Natives and Gen Now cohorts, who value their time on social networks, may be more receptive to AVs.

The lack of where-in-lane level accuracy (0.7 to 1.0 m) from GNSS positioning is a barrier to widespread use of AVs in Australia and to the use of many Cooperative ITS functions. There is no committed pathway for how Australia will achieve the required positional accuracy. However, there are a number of options currently being considered including:

- drawing on multiple GNSS signals (e.g. GPS, GLONASS, GALILEO);
- upgrading Australian capabilities to provide the ionospheric correction necessary for real time correction from existing augmentation systems; and
- accessing new augmentation as offered by initiatives such as the Japanese QZSS (quasi-zenith satellite system).

3.8 Vehicle positioning accuracy

The safety critical C-ITS applications require a high standard Global Navigation Satellite System (GNSS) in terms of accuracy, timeliness, availability and reliability that is not always available in mass-market systems. The accuracy requirements for emerging C-ITS safety applications are classified into three levels (Austroads, 2013):

- Road level (on which road the vehicle is placed)
- Lane level (in which lane the vehicle is in)
- Where-in-lane level (where the vehicle is in the lane)

At present, GNSS in vehicles in Australia is sufficiently accurate for the road level (accuracy better than 5 m in a relative or absolute sense). In the US and Europe, GNSS augmentation enables positioning to the lane level accuracy (1.5 m or better). Current self-driving vehicles rely on information from their on-vehicle sensors that identify road elements such as kerbs and lane lines to determine the where-in-lane information.

Geoscience Australia is the lead agency for positioning in Australia. However, Austroads is maintaining a keen interest on behalf of the transport sector due to the critical role that more accurate positioning plays in accessing benefits from smarter vehicles.
4. Current state of play

4.1 Australia

Australia has mandated some Level-1 automated functions, with Australian Design Rule (ADR) 31/02 requiring Electronic Stability Control (ESC) on all light vehicles from 2011. Similarly, government road safety groups have commenced an advocacy campaign encouraging use of Auto Emergency Braking (AEB).

Level-2 combined function automation is starting to become more common in new vehicles. As an example, the Honda CR-V includes the combination of Adaptive Cruise Control (ACC), Collision Mitigation & Breaking System (CMBS) and Lane Keep Assist System (LKAS) in a model available ‘on road’ for less than $50,000. Many other new vehicles lack the lane keeping assistance required to complement ACC for Level-2 operation. It is unclear whether this is due to the quality of line marking on Australian roads or manufacturer responses to (perceived) buyer preferences.

Some partial automation is available in Australian-built cars, including parking assistance on even the base models of new Holden Commodores.

No Australian government is understood to have commenced work to allow trials of self-driving on public roads. This in contrast to New Zealand, where the Ministry of Transport’s ITS Action Plan includes actions to establish New Zealand as a potential regional test bed.

4.1.1 Driverless vehicles at mines

Australia has been a world leader in using driverless vehicles in mining. However, a fundamental difference between ‘driverless trucks’ being used in mining operations and AVs is that the former are remotely controlled and operated from a control room.

Rio Tinto currently operates 53 driverless trucks as part of its ‘Mine of the Future’ program and expects to increase this fleet to 150 (Rio Tinto, 2014 and IT News, 2014) as part of the Autonomous Haulage System. These trucks are remotely controlled and supervised from a control room in Perth. They share the mine site with traditional manned vehicles (McGagh, 2014).

Rio Tinto has also successfully operated a driverless train in the Pilbara region. It expects to introduce driverless trains into its operations in the near future.

BHP Billiton is trialling driverless trucks for its mining operations, but is apparently taking a more cautious approach (The Australian, 2014).

Hancock Prospecting plans to deploy autonomous trucks and trains at its Roy Hill mine to keep the mine operation costs low (IT News for Australian Business, 2013).

4.1.2 Cooperative ITS

The SCOTI (Standing Council on Transport and Infrastructure)’s Policy Framework for Intelligent Transport Systems in Australia (DoIT, 2012) identifies that to maximise the benefits and penetration of C-ITS, a consistent national approach is required that addresses the complexities involved in deploying C-ITS. In particular, clear direction from governments is needed on the types of messages sent and received by C-ITS systems, and their technical requirements, such as data frequency and accuracy. The development of a national ITS architecture and consideration of the management and use of the 5.9GHz band are two specific issues being addressed in the context of the broader strategy.

Supported by TISOC, Austroads has an on-going C-ITS project, which has started developing a regulatory and operational framework that will enable C-ITS to be effectively deployed in Australia and New Zealand. So far, it has achieved the following key milestones (Austroads, 2013):

- A submission to the Australian Communications and Media Authority (ACMA) on the allocation of the 5.9 GHz band for use in C-ITS
- The establishment of a C-ITS Steering Committee and C-ITS Industry Reference Group
- The publication of an Austroads report on the potential safety benefits of vehicle-to-vehicle (V2V) collision avoidance (Austroads 2011a)
• Formal and informal representation on various international standards committees
• Trials of various C-ITS type applications and testing of technologies by universities, research centres, road agencies and industry
• The identification of key challenge areas, through consultation with the C-ITS Industry Reference Group, with respect to the deployment of C-ITS as outlined in Austroads (2011b)
• Preparation of a strategic plan and roadmap outlining the key tasks that need to be completed to deploy C-ITS in Australia
• Progress towards officially having C-ITS share the 5.9 GHz spectrum with limited existing users of the spectrum
• The agreement to nominate Austroads as the body to manage C-ITS until 2014 to 2015, while a permanent body is established.

4.2 The United States

Many of the greatest efforts to develop AVs have taken place in the US, with both technology companies and vehicle manufacturers progressing vehicle automation. They are arguably ahead in road testing and legislation of AVs (Jacobs, 2013). The North American efforts appear to focus almost exclusively on cars, which is in contrast to European developments that also include Personal Rapid Transit (PRT) and truck platooning.

4.2.1 Legislation and policy

In the United States, the regulation of vehicles and drivers is a state issue. Four US states (Nevada, Florida, Michigan and California) and the District of Columbia have legislated to permit testing of self-driving vehicles. These regulations do not permit use beyond testing and include restrictions such as a driver needing to be present.

NHTSA has announced a policy concerning vehicle automation, including its plans for research on related safety issues and recommendations for states related to the testing, licensing and regulation of AVs (NHTSA, 2013). Historically, the US federal agencies have been more active in CVs than AVs. In August 2014, the NHTSA gave advance notice that it intends to require future light vehicles to have DSRC V2V capabilities. This V2V capability would assist vehicle automation by providing additional information on the presence and trajectory of surrounding vehicles.

4.2.2 Google ‘self-driving car’ project

The highest profile AV development in the US has been the Google ‘self-driving car’. They have retrofitted prototypes of Toyota Prius and Lexus RX, which are reported to have completed over 1 million km of test driving on limited access highways. However, Google has also developed a custom-built pod car with emphasis on low speed urban driving, which does not have a steering wheel, gear shift or pedals.

Figure 4.2a (top) Google’s retrofitted prototype Toyota Prius self-driving car; and Figure 4.2b (bottom) Google’s self-driving pod car, which does not have a steering wheel, gear shift or pedals. Google’s current prediction is that many or all of these technology performance issues will be resolved over the next five years (Source: Google)
Although they have undergone extensive testing on public roads, the Google cars are a long way from ready for general public use. Some of the limitations being identified in a news interview with Google are listed below:

- Reliance on special high resolution mapping; an area has to be mapped multiple times by a sensor vehicle to record details such as driveways. This is followed by intensive processing by humans and computers. These maps currently exist only for testing routes.
- Unable to operate in snow or heavy rain, which reduces sensor performance, and
- Unable to understand some contextual information, such as the difference between a normal pedestrian and a police officer waving the car over (Griffiths, 2014).

Google’s current prediction is that many or all of these technology performance issues will be resolved over the next five years.

### 4.2.3 Connected Vehicle Safety Pilot

The US DOT, in collaboration with the University of Michigan Transportation Research Centre, has launched a large-scale research program called Connected Vehicle Safety Pilot that demonstrates the readiness of DSRC-based connected vehicle safety applications for nationwide deployment. The vision of this program is to test CV safety applications in real-world driving scenarios to determine their effectiveness at reducing crashes and to ensure that the devices are safe (US DOT, 2014).

Under this pilot, approximately 3,000 vehicles equipped with wireless CV devices have been operating on public roads, in an area highly concentrated with equipped vehicles. The deployment model includes a mix of cars, trucks and transit vehicles and is the first test of this magnitude of CV technology deployment in a real world, multi-modal operating environment.
DOT has also been working with Crash Avoidance Metric Partnership (CAMP), a pre-competitive research consortium consisting of nine Original Equipment Manufacturers (OEMs), to build integrated cars for testing during the safety pilot.

It is understood this trial is to be extended for another three years and will include up to 9,000 vehicles, 60 intersections and 500 roadside units.

4.2.4 CVRIA

The US DOT’s ITS Joint Program Office is leading a research effort to develop a Connected Vehicle Reference Implementation Architecture (CVRIA) as the basis to develop a Standards Development Plan to identify and prioritise the standards needed to support CV implementation.

4.2.5 California PATH

Founded in 1986, California Partners for Advanced Transportation Technology (PATH) is a research and development program of Berkeley’s University of California (UC) in ITS including Automated and Connected Vehicles. In collaboration with the California Department of Transportation (Caltrans), administered by the university’s Institute of Transportation Studies (ITS), PATH is a multi-disciplinary program with staff, faculty, and students from universities worldwide and cooperative projects with private industry, state and local agencies, and nonprofit institutions.

In 2011, the current incarnation of PATH emerged through the consolidation of two UC Berkeley programs; the California Partners for Advanced Transit and Highways and the California Center for Innovative Transportation. The new organisation has brought together expertise in both research and deployment and is redefining the concept of “Intelligent Transportation Systems” to meet the realities of the Information Age (Berkeley, n.d.).

4.2.6 FDOT Connected Vehicles test bed

The Florida Department of Transportation (FDOT) has developed a CV test bed as part of the 18th ITS World Congress, which includes 26 roadside units installed on a 25 miles stretch of Interstate 4 and 42 specially-equipped vehicles (FDOT).

Figure 4.4 Florida DOT Connected Vehicles test bed [Source: Florida DOT and Atkins (North America)]
4.2.7 University of Virginia CVI-UTC

The University of Virginia has established the Connected Vehicle/Infrastructure-University Transportation Centre (CVI-UTC) to conduct research that will advance surface transportation through the application of innovative research and by using connected vehicle and infrastructure technologies to improve safety, state of repair, economic competitiveness, livable communities and environmental sustainability (cvi-utc). It has awarded the following advanced research projects:

- Safety and Human Factors of Adaptive Stop/Yield Signs Using Connected Vehicle Infrastructure
- Connected Vehicle Applications for Adaptive Lighting
- Intersection Management Using In-Vehicle Speed Advisory/Adaptation
- Field Testing of Eco-Speed Control Using V2I Communication
- Innovative “Intelligent” Awareness System for Roadway Workers Using Dedicated Short-Range Communications
- Emergency Vehicle-to-Vehicle Communication
- Connected Vehicle Enabled Freeway Merge Management - Field Test
- Infrastructure Safety Assessment Using Connected Vehicle Data
- Infrastructure Pavement Assessment and Management Applications Enabled by the Connected Vehicles Environment Research Program - Phase I: Proof-of-Concept
- Connected Vehicle-Infrastructure Application Development for Addressing Safety and Congestion Issues Related to Public Transportation, Pedestrians, and Bicyclists
- Connected Motorcycle Crash Warning Interfaces
- Connected Motorcycle System Performance
- Developing and Evaluating a Smartphone Application Aimed at Reducing Crashes Involving Motorcycles and Bicycles
- Develop and Test Connected Vehicle Freeway Speed Harmonization Systems
- Reducing School Bus/Light-Vehicle Conflicts Through Connected Vehicle Communications
- Next Generation Transit Signal Priority with Connected Vehicle Technology
- Prototyping and Evaluating a Smart Phone Dynamic Message Sign Application in the CVI-UTC Test Bed
- Measuring User Acceptance of and Willingness to Pay for CVI Technology
- Field Demonstration of Cumulative Travel-time Responsive Intersection Control Algorithm under Connected Vehicle Technology
- Effect of In-Vehicle ATDM on Traffic Management, Distraction and Desirability

4.3 Europe

Although Europe has seen a lesser focus on driverless cars than in the USA, there have been some areas where European developments have been notable:

- Truck platoons;
- Automated public transport, including personal rapid transit; and
- Lower level automation, such as ESC, AEB and ACC.

4.3.1 Driverless car trials in the UK

The UK government is actively encouraging the increasing automation of vehicles, starting with an announcement by the Department for Transport (DfT) in July 2013 that it would “work to encourage the development and introduction of autonomous vehicles” (UK Parliament, 2013). This was followed by an announcement in July 2014 that autonomous vehicle testing could commence from January 2015 and would be supported by a £10m competition (UK Government, 2014).

The Transport Systems Catapult (TSC) is supporting the LUTZ Pathfinder programme that includes three electric-powered two-seater pods built by Coventry-based firm RDM. These pods are equipped with sensor and navigation technology provided by the University of Oxford and feature an open platform capability that will allow other autonomous control system suppliers to use the pods for test purposes (TSC, 2014). From 2015, the pods will be tested in Milton Keynes.

Starting in early 2015, the TSC will test the pods in an “urban laboratory” using a pavement route agreed with partners at Milton Keynes Council.

Figure 4.5 Personal Rapid Transit (PRT) pods will be tested in Milton Keynes from 2015 (Source: RDM Group, UK)
4.3.2 Automated truck platoons in Europe

There have been a number of European projects demonstrating the potential for platoons of trucks on motorways, such as KONVOI and SARTRE, seeking fuel efficiency and emissions improvements. As part of a push to accelerate the adoption of self-driving cars, the Dutch government has announced that it will seek to amend regulations during 2015 (Government of the Netherlands, 2014). The Minister stated: “I want us as the Netherlands not only to be ready, but also to be at the vanguard of this innovative development internationally”. The first application for testing under this initiative is for autonomous trucks that drive in convoys.

4.3.3 SCOOP@F

The Ministry of Sustainable Development, France, has implemented the SCOOP@F project for test deployment of C-ITS in 2014. It is a nationwide project including up to 3,000 vehicles and 2,000 km of arterial and intercity roads (France Ministry of Ecology, Sustainable Development and Energy, 2014).

For each test site, vehicles and roads will communicate with each other through wireless networks using wi-fi routers along the road and receptors in the vehicles, and public GSM networks. The information exchanged will include vehicle position, speed, traffic conditions, road works, speed limits and incidents.

The timelines for the project are as follows:

- February 2014 – Launch of SCOOP@F
- 2014 – Technical specifications and developments
- 2015 – First connected infrastructures and vehicles plus tests
- 2016 – Full scale experimentation
- 2017 – If the outcomes are positive, nationwide deployment
4.3.4 Compass4D

Compass4D is a three-year EU co-funded pilot project to deploy C-ITS in a corridor connecting seven cities (Bordeaux, Copenhagen, Helmond, Newcastle, Thessaloniki, Verona and Vigo) spreading across Europe (EU, n.d.). It will provide three services: Red Light Violating Warning (RLW), Road Hazard Warning (RHW) and Energy Efficient Intersection (EEI) to demonstrate the benefits of C-ITS. Over 300 buses, taxis, emergency vehicles and private cars will be equipped with on-board units that will communicate with roadside units.

4.3.5 Completed EU projects

The following EU projects were completed around 2010/11 but are reported because of their significance.

COOPERS

Cooperative Systems for Intelligent Roads Safety (COOPERS) was an EU-funded INTRO (‘Intelligent roads’) project to address the dual problems of road safety and increasing road capacity, bringing together information from the latest sensing and real-time networking technologies (EC, 2012).

INTRO called for increased co-operation between road authorities, national road research institutes, private engineering companies and the road industry. Specific INTRO aims included the following:

- Assessing current road safety and road capacity technologies, strategies and knowledge;
- Data fusion - bringing together in situ sensor data and vehicle sensor data within common data bases;
- Evaluation of in situ and vehicle-based sensors and development of ‘smarter’ roads and intelligent vehicles for monitoring pavement conditions;
- Development and validation of novel concepts and systems for monitoring and predicting road friction and skid resistance;
- Development of other new and improved methods for traffic and safety monitoring; and
- Structured clustering activities with other FEHRL projects and targeted activities to disseminate project results.

CVIS

CVIS (Cooperative Vehicle-Infrastructure Systems) was a major European research and development project to design, develop and test the technologies needed to allow cars to communicate with each other and with the nearby roadside infrastructure (ERTICO, n.d.). The project’s ambition was to begin a revolution in mobility for travellers and goods, completely re-engineering how drivers, their vehicles, the goods they carry and the transport infrastructure interact.

Information shown on road signs was available wirelessly and shown on a display in the vehicle. Such displays also warned drivers of approaching emergency vehicles, allowing emergency personnel to reach accidents faster with less danger for themselves and for cars along their path. In the same way, hazardous goods shipments could be tracked at all times and have priority along a pre-selected safe route. Other key innovations included high-precision positioning and local dynamic maps, a secure and open application framework for access to online services and a system for gathering, integrating and monitoring data from moving vehicles and roadside detectors and sensors.
CVIS developed a mobile router using a wide range of communication media, including mobile cellular and wireless local area networks, short-range microwave (DSRC) or infra-red, to link vehicles continuously with roadside equipment and servers. The project applied and validated the ISO “CALM” standards for continuous mobile communication and provided input to standards development in European and global standardisation bodies.

To validate the project’s results, all CVIS technologies and applications were tested at one or more test sites in six European countries: France, Germany, Italy, Netherlands/Belgium, Sweden and the UK.

The CVIS project also created a toolkit to address key “deployment enablers”, such as user acceptance, data privacy and security, system openness and interoperability, risk and liability, public policy needs, cost/benefit and business models, and roll-out plans for implementation.

SAFESPOT

SAFESPOT was an integrated research project co-funded by the European Commission Information Society Technologies as an initiative of the sixth Framework Program. The objective was to understand how intelligent vehicles and intelligent roads could cooperate to produce a breakthrough for road safety (ERTICO, n.d.).

The aim was to prevent road accidents, developing a Safety Margin Assistant that would provide advance detection of potentially dangerous situations and extend drivers’ awareness of the surrounding environment in terms of space and time.

4.4 Japan

Japan has already deployed vehicles with basic C-ITS functionality (Austroads, 2012). Japan implemented the SmartWay project using DSRC in 2007, which is a cooperative vehicle-highway system primarily using V2I (or Vehicle to Road or V2R as referred to in Japan). It provides wide area travel time information, safety information, miscellaneous information and fee collection (Austroads, 2012).

The Japanese government has indicated that it expects to have AVs operating on public roads in the early 2020s. The Nissan LEAF with Advanced Driver Assist System (ADAS) was the first to get a licence for testing on public roads in Japan (Nissan, 2013). The license for this test car includes the number 2020, which reflects Nissan’s goal to be ready with commercially available AVs by 2020. Nissan claims LEAF’s ADAS is capable of automatic lane keeping, exit (from freeway), overtaking slower or stopped vehicles, deceleration behind congestion on freeways and stopping at red lights.

Japan is also driving research and innovation in automated vehicle technologies under the Cross Ministerial Innovation Program (SIP) (sip-adus, n.d.). The roadmap for SIP Automated Driving Systems Project aims to deploy fully automated driving systems between 2020 and 2030, with significantly advanced next generation traffic systems expected to be deployed for the Tokyo Olympic/Paralympic Games in 2020.

Figure 4.8a (left) Japanese Prime Minister Shinzo Abe on Nissan LEAF AV on 9 November 2013 (He also took test rides on AVs from Toyota and Honda on the same day); and Figure 4.8b (right) Nissan LEAF AV test car has 2020 in its numberplate to signify the company’s ambition to have commercially available AVs by 2020 (Source: Nissan)
4.5 South Korea

South Korea has been heavily investing in ITS in the order of US$230 million per year to 2020 (CNN, 2010). It has been laying the foundation for advanced ITS by including fibre optic cables on over 3,500 km of expressways.

Considerable work and development has been undertaken in South Korea with the development of the Green Intelli Travel Society (G-ITS) model. The G-ITS model somewhat mirrors other C-ITS international business directions. However, it has a strong focus on the need to maintain multimodal connectivity and identifies the use of personal (wireless) devices as being the key to the future (Austroads, 2012).

The Advanced Institute of Convergence Information Technology, a research organisation jointly established by Seoul National University and the Gyeonggi provincial government, has developed a driverless single seater electric vehicle mainly for the benefit of people with physical disabilities and the elderly (Safe Car News, 2014).

South Korea has a long history of research & development relating to AVs, with KATECH (Korea Automotive Technology Institute) demonstrating the world’s fourth platoon with four cars at the speed of 80 km/h during the 4th ITS World Congress in 1998. It also has a National Autonomous Vehicle Competition supported by the Ministry of Trade, Industry and Energy (MOTIE). In 2013, MOTIE released a seven-year Automated Vehicle development plan and technology roadmap.

4.6 Singapore

In August 2014, Singapore’s Ministry of Transport announced a 17-member Committee on Autonomous Road Transport for Singapore (CARTS) to provide leadership and guidance on the research, development and deployment of AV technology for the city-state and study the associated opportunities and challenges (Channel NewsAsia, 2014). From January 2015, a network of roads in the north of the country will be used as test routes for AVs operating amongst non-automated vehicles. The Agency for Science, Technology and Research (A*STAR) also expects to carry out trials in 2016.

There will be two working groups supporting CARTS’ work. One group will consider what AV-enabled towns in Singapore in the future could look like, recommend AV-enabled mobility concept plans for such towns, and chart a roadmap for implementation. The other group, chaired by the CEO of Land Transport Authority, will focus on regulation and implementation.

Singapore-MIT Alliance for Research and Technology (SMART) and the National University of Singapore, in a collaborative Project, have developed a driverless car dubbed SCOT (Shared Computer Operated Transport), which they claim is operationally ready for public roads. It aims to primarily resolve the ‘first and last mile problem’, which is particularly relevant for the ageing population.
4.7 China

The focus of China’s ITS Industry Alliance is to develop standards for four aspects of C-ITS, including collaborative intelligent transportation, telematics services and security, intelligent public transportation, and portable mobile terminal supporting traffic information services (International telecommunication Union, 2014).

There are four technical working groups looking at e-Call, autonomous driving, V2X and Vehicle IQ. The Vehicle IQ working group focuses on a ‘vehicle informatisation (sic) index’ or ‘Vehicle IQ’. Technical specifications for Vehicle IQ were drafted in 2013, and the working group is planning to promote the Vehicle IQ evaluation system to OEMs and consumers.

Since 2008, China has also been holding the ‘Telematics @ China’ annual international summit, focusing on ‘informatisation’ of vehicles (telematics).

4.8 New Zealand


The Ministry of Transport, in conjunction with transport agencies, will scan all transport legislation to identify barriers to the continued deployment of ITS technologies in New Zealand. It will also consider the need to review legislation in light of the increasing introduction of advanced driver assistance systems (ADAS) and semi-autonomous vehicles.

4.9 Standards development

The countries/regions mainly involved in developing standards for AVs and CVs are the USA, Europe, Japan and South Korea. Austroads (2014) states that there are in excess of 160 standards emerging from the US and European standards development organisations (such as SAE, IEE and NCTIP in the US, and ESTI and CEN/ISO in Europe) that relate to C-ITS, for possible adoption by Australia and New Zealand.

Of the 157 European standards, 55 were identified as being high priority for adoption. Of the 11 US standards, seven were identified as high priority (Austroads, 2014). This Austroads report has identified that it may not be feasible to mix and match the US and European standards. Therefore, a decision on which scenario to align with is needed. This report is intended to provide input and guidance to the Standards Australia IT-023 Committee on the adoption of C-ITS standards and, in particular, the adoption of a minimum set of standards to enable early local deployment.
5. Likely adoption rates and timelines

Most major car manufacturers are working on FAVs. Some are claiming their FAVs will be ready as early as 2020; however, most are expected to be released into the market in the 2020 - 2030 timeframe.

The adoption of most new technologies follows an S-curve, and it’s reasonable to assume that AVs will follow a similar trajectory. However, the rate of adoption will depend on many factors, including, maturity of technology, resolution of human factor (human-machine interface) issues, regulatory framework, consumer acceptance, critical mass for network effects (connectivity) and production cycles.

KPMG (2012) identifies consumer acceptance, achieving critical mass, legal and regulatory framework, and incentives for investors as the four major requirements for the adoption of AVs. Timelines for adoption could vary, depending on how the pieces of the puzzle come together.

KPMG in their research also identifies three possible adoption scenarios: Aggressive, base case and Conservative. It believes each scenario is likely to go through four stages as indicated in Figure 5.2 on page 29.

Public acceptance will depend on many factors, but ‘trust in technology’ will be critical in the early stages of adoption. There is no margin for error in safety critical technologies, and they must work perfectly every time. Consumers will not embrace AVs until they are absolutely convinced of their safety and reliability (KPMG, 2012).

Another factor in public acceptance is the cohort of drivers, who are reluctant to relinquish the personal freedom and identity that comes with owning and driving a car. Baby boomers are identified in this cohort and therefore could be less likely to embrace AVs. On the contrary, ‘Digital Native’ and ‘Gen Now’ generations, who value digital connectivity and are less likely to be attached to the ‘driving experience’, are likely to be the most receptive to AVs (KPMG, 2012).

To achieve the full benefits, there needs to be a critical mass of Connected Vehicles operating on the network. Consumers may not want to buy vehicles if they are unable to derive the full benefits due to lack of interoperable CVs.
Figure 5.2 Scenarios and stages of adoption of AVs (Source: KPMG, 2012)

**AGGRESSIVE SCENARIO**
- Early applications “sell” the promise of self-driving
- Consumers embrace tangible benefits
- NHTSA issues NRI followed by immediate V2V mandate that includes aftermarket component
- Technology breakthroughs lead to even greater value for V2X solutions

**BASE CASE SCENARIO**
- Early applications “sell” the promise of self-driving vehicles
- Consumers excited by tangible benefits
- NHTSA issues NRI
- Assist systems provide greater value proposition to consumers
- Early adopters flock to new offerings
- NHTSA issues V2V mandate but without aftermarket component
- Adoption plateaus due to lack of V2X functionality in aftermarket
- Private enterprise introduces aftermarket solutions
- Aftermarket retrofit reaches required density for “control” apps
- Adoption eventually levels off (not necessarily at 100 percent participation)

**CONSERVATIVE SCENARIO**
- Initial adoption slow due to lack of consumer enthusiasm for early assist and information systems
- NHTSA issues NRI unfavorable because DSRC not seen as viable for V2V
- Unfavorable NRI causes adoption to plateau due to lack of consumer interest in available sensor-based solutions
- Slow rise in adoption as sensor technology improves
- Adoption levels never reach critical mass for self-driving due to lack of V2X capability
The timeline in Table 5.1, setting out a likely deployment timeline for increased automation, has been adapted from Ernst and Young (2014) based on other data reviewed for this report. This timeline is a forecast and does not indicate the intent of the Government of Western Australia. Jacobs (2013a) has developed the potential 30-year AV implementation scenario in Figure 5.3, assuming AV technology continues to develop at the same pace and without barriers such as legislation issues.

<table>
<thead>
<tr>
<th>5-10 years (2020-2025)</th>
<th>10-20 years (2025-2035)</th>
<th>20+ years (2035+)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Early days for self-driving</strong></td>
<td><strong>Transition</strong></td>
<td><strong>Mobility transformed</strong></td>
</tr>
<tr>
<td>• Continued growth in Level 1-2 automation</td>
<td>• Less restriction on self-driving environments</td>
<td>• Large, connected AV networks allow multiple mobility scenarios</td>
</tr>
<tr>
<td>• Self-driving limited to low complexity environments</td>
<td>• High level of self-driving (Levels 2-3)</td>
<td>• On demand mobility and fleet services</td>
</tr>
<tr>
<td>• Moderate level of self-driving (Levels 2-3)</td>
<td>• Level 4 vehicles become more common and more affordable</td>
<td></td>
</tr>
<tr>
<td>• First Level 4 vehicles may become commercially available, but are expensive</td>
<td></td>
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</tbody>
</table>

**Table 5.1** Forecast timeline for increased automation

The Institution of Electrical and Electronics Engineers (IEEE) believes that by 2025, 60 percent of the cars on the road will be internet connected. The increased dependence on CVs will increase consumers’ trust and reliance on automated systems. IEEE predicts that 75 percent of the cars on the road will be AVs by 2040 (IEEE, 2013).

IEEE predicts that 75 percent of the cars on the road will be AVs by 2040.
**Figure 5.3 Potential 30-year implementation scenario for AVs (adapted from Jacobs, 2013a)**

<table>
<thead>
<tr>
<th>Timescale</th>
<th>Potential Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Now - 2025</strong></td>
<td>• Increasing automation of driving functions, even on affordable cars</td>
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<td></td>
<td>• Vehicles park themselves</td>
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<tr>
<td></td>
<td>• Vehicle to vehicle communication</td>
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<tr>
<td></td>
<td>• Vehicles drive themselves in traffic jams or highways (adaptive cruise control)</td>
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<td></td>
<td>• Early adopter entrepreneurs start to hire out AVs</td>
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<tr>
<td></td>
<td>• Taxi industry disruption</td>
</tr>
<tr>
<td></td>
<td>• Standardisation of communication and technology protocols</td>
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<tr>
<td><strong>2025 - 2035</strong></td>
<td>• Car ownership declines - car sharing increases. Demand for parking starts to decline</td>
</tr>
<tr>
<td></td>
<td>• Bus service disruption - segregated or guided busways become fully driverless, bringing costs down</td>
</tr>
<tr>
<td></td>
<td>• Logistics industry disruption</td>
</tr>
<tr>
<td></td>
<td>• Vehicle to vehicle and vehicle to infrastructure communication technology matures</td>
</tr>
<tr>
<td></td>
<td>• Accidents/collisions significantly reduce</td>
</tr>
<tr>
<td><strong>2035 - 2045</strong></td>
<td>• Vehicle size/weight/emissions reduce. New vehicle platforms</td>
</tr>
<tr>
<td></td>
<td>• Catalyst for alternative mass produced propulsion systems - electric</td>
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<td></td>
<td>• Catalyst for fiscal incentives (road charging, pay as you go)</td>
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<td></td>
<td>• Urban road-space optimisation - narrower lanes, tighter intersections etc</td>
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<td></td>
<td>• Reduced need for urban parking - re-inventing/relocating car parks, on-street parking space reclaimed for other road uses (walking, cycling, market stalls)</td>
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<tr>
<td></td>
<td>• Vehicles on demand - no reduction in availability or quality of services</td>
</tr>
<tr>
<td><strong>2045 onwards</strong></td>
<td>• Maturing technology, convergence and standardisation. Artificial intelligence in vehicles “learns to read” the road</td>
</tr>
<tr>
<td></td>
<td>• Eradication of congestion on highways</td>
</tr>
<tr>
<td></td>
<td>• Elimination of accidents/collisions</td>
</tr>
<tr>
<td></td>
<td>• Significant reduction in urban congestion</td>
</tr>
<tr>
<td></td>
<td>• Ubiquitous autonomous door-to-door travel</td>
</tr>
<tr>
<td></td>
<td>• Increased urban sprawl</td>
</tr>
</tbody>
</table>

*Figure 5.3 Potential 30-year implementation scenario for AVs (adapted from Jacobs, 2013a)*
6. Potential implications for Main Roads

The benefits of AVs are likely to arrive well within the standard 40-year planning horizon for roads. Therefore, a key challenge for Main Roads is to be able to quantify these benefits and consider them in the planning and investment decisions we make today.

It is likely that the returns on investment realised from the safety benefits of CVs and increasing automation will overtake the diminishing returns on traditional road safety investments. Therefore, there may be a compelling business case to facilitate faster adoption rates of CVs and AVs.

It is important not to passively wait until the full extent of the impacts of these new technologies is revealed (NZIER, 2014). As policy-makers, we must be aware of the rapid changes about to occur and think about how we can harness new technologies to improve social outcomes. Transport planning needs to reflect the likely risks, opportunities and transition issues these new technologies may bring in reshaping cities and transport networks.

The implications for Main Roads (or any road agency for that matter) from AV technologies need to be considered in the context of how rapidly the fleet will change over to FAVs (adoption rate). The adoption rate will depend on the many factors discussed in the previous chapter. With a mixed vehicle fleet featuring current generation vehicles and vehicles with different levels of automation, this transition period will have different implications compared to full saturation of AVs.

For the purpose of this report, these two periods with distinctly different implications for road agencies are identified as the transition period and full saturation and are considered separately. The impending introduction of CVs (likely to be 2016-2020) would be considered as part of the transition period. A prolonged transition period (conservative scenario) may see a more controlled, evolutionary change to full saturation, while a shorter transition period may result in a disruptive change if road and transport agencies are not adequately prepared.

6.1 Transition period

During this period, CVs with V2I, V2V and V2X communications are likely to increase. Vehicles with increasing levels of automation will also begin operations, initially in isolation but later in platoons, particularly trucks. These smart vehicles will operate alongside current generation vehicles.

CVs with V2I capability will be communicating with traffic signals, other roadside digital infrastructure, and the freeway control system. The SAE J2735 standard outlines the message structure for V2I interactions with traffic signals:

- MAP: the map of the intersection including lane configuration sent by the infrastructure
- SPaT: signal phase and timing information sent by the infrastructure
- SRM: a signal request message sent by the vehicle to request action from the traffic signals
- SSM: a signal status message sent by the infrastructure in confirmation of the signal request message
- BSM: the basic safety message sent by vehicles with their position and trajectory

The V2I interaction with the freeway control system will give vehicles information about what the road management systems plan to do. This is because AV operation is assisted by access to information about the planned and real-time operation of the road network, including lane closures, road work speed limits and traffic signal information. Increasingly, vehicles will also start to inform the road management systems of their intentions and make requests from the road management systems.

During the transition period, it may be possible that pedestrians and cyclists can be connected to the CV environment via their mobile devices.

With increasing connectivity, vehicles will be receiving more real-time road and traffic condition information via in-vehicle telematics. However, as there will still be current generation vehicles on the network, both digital and static road signs will need to be provided on roadsides.

During this period, the benefits from AVs and CVs will largely be safety related. However, there may be some marginal benefits in improving capacity and reliability, particularly when some vehicles are able to travel in platoons and due to flow improvements through connectivity with traffic control signals.

We may also start to see some significant changes in vehicle designs as advanced crash avoidance systems lead to reduced vehicle size and weight.

During the transition period, a key challenge will be managing the mix of AVs of different levels of automation with current generation vehicles on the road network. One way to manage this is to provide dedicated infrastructure such as dedicated lanes on certain roads or even some areas exclusively for AVs. This is seen as desirable by some parts of the automotive sector. It may enable...
realisation of full benefits of AVs and encourage adoption. However, obviously it involves additional cost.

The following are likely implications for Main Roads during the transition period:

- Roadside units need to be in place to enable V2I communication. Road agencies are likely to come under increasing pressure to develop corridors and precincts that enable vehicles to communicate with infrastructure, which will need to include sensors, transmitters and cabling to enable a connected network. New roads will need to be future proofed in this regard (Jacobs, 2013d).

- New ITS devices such as VMS, VSL and other warning systems will need to be able to directly communicate with vehicles through V2I.

- Road signs and markings need to be conspicuous and legible to the AV sensors as well as to human eyes.

- All traffic and incident information will need to be in an acceptable standard and format for digital transmission, such as RDS-TMC.

- Road mapping and databases may need to be maintained to a higher standard with up-to-date information (this could be facilitated through private sector providers).

- Traffic signals will need to be able to directly communicate with vehicles through V2I.

- Dedicated lanes for AVs in freeways and high volume arterial roads may be required as the proportion of AVs increases.

- Strategic transport models will need to consider changed lane/road capacity, perhaps on the basis of sensitivity tests, given the uncertainty about the impacts on capacity.

- Transport models will need to include a combination of traditional vehicles and AVs with updated car following and lane changing algorithms incorporating AV behaviour.

- Along with other road agencies, collaboration will be required with auto-makers and technology companies to understand the technical requirements and infrastructure modifications required for AVs, and timelines for implementation.

Main Roads will have an important role in facilitating the introduction of AVs and managing the transition risks. If the state is to derive early benefits from this new technology, we should embrace and encourage the benefits of AVs rather than regulate for their use afterwards.

### 6.2 Full saturation

This period is defined as the complete transition to FAVs, with the full implications of AVs felt across transport and society.

Transportation will be predominantly an on-demand service, with new vehicle sharing and public transport models in operation and reduced vehicle ownership. Mobility freedom coupled with improved service levels in terms of lack of congestion and high travel time reliability is likely to increase demand. Improved service and the ability to use travel time productively for other purposes, such as work (‘work from car’), may encourage commuters to live further away from cities, resulting in increased urban sprawl, unless it is managed through pricing or other measures.

There will be productivity benefits from driverless truck platoons as well as reduced operational costs. Also, there may be an increase in on-line purchasing as AVs will be able to pick-up or deliver goods.

There may be surplus transport land due to smaller compact car parks away from city centres, no demand for ‘park and ride’ and also reduced lane widths and improved throughput per lane on road networks.

Vehicle design will change as there will no longer be a need for heavy and strong safety protection; vehicles are likely to be lighter and smaller in terms of per passenger requirements. Vehicle cabins for personal vehicles could be redesigned for other purposes.

The changed nature of interactions between vehicles and the road environment may allow removal of many of the controlled devices used to assist humans in the road traffic system, including signs, signals, lane markings and kerbs. These could be replaced with new ways of guiding vehicles.

Many traditional functions undertaken by road agencies, such as road design, traffic management, network operations, pavement design, and transport modelling, will substantially change, reduce or may even disappear or be replaced with new functions. If AVs that cannot crash can drive in a road network operating at optimum capacity with no congestion and almost perfectly predictable travel times, and with no road signs, traffic signals or pavement markings, what would be the role of practitioners in traffic management, road safety or network operations?

Using new transport models, road planners will need to consider scenarios where AVs and increased capacity will create opportunities to delay or postpone new projects.
Changed vehicle design and operational characteristics will fundamentally change the principles and relationships in road design, traffic engineering, transport modelling and pavement engineering.

The smaller size of FAVs and their more accurate positioning within the lanes will reduce lane widths. The removal of the human factor in vehicle operations and increased sensing distance and faster reaction by FAVs will enable more compact road designs. The lighter weight of FAVs (per person) and their precision positioning will impact pavement designs.

6.3 Implications for today’s planning and investment decisions

The imminent introduction of vehicles with C-ITS capability and AVs of increasing levels of automation, which is likely to occur in the next three to five years, will mark the beginning of the journey towards FAVs for road agencies. Depending on the market readiness and adoption rates of FAVs, the transition period may start in the next decade and last until 2040-2050. The tipping point to full saturation may occur sooner if the safety and mobility benefits of FAVs inspire governments to mandate their use or consumer take-up is faster than expected.

Therefore, a sensible approach for Main Roads when making long-term (over 20 years) planning and investment decisions would be to consider robust sensitivity testing to explore ‘what-if’ scenarios around the implications of AVs. Using new transport models, road planners will need to consider scenarios where AVs and increased capacity will create opportunities to delay or postpone new projects. New infrastructure should include maximum future flexibility and the ability to be retrofitted with AV-related technologies (Jacobs, 2013d).

6.4 State strategy

WA’s ITS Master Plan identifies the need to develop a strategy to facilitate the adoption of AVs and CVs, in collaboration with the Department of Transport and other stakeholders. It is recommended that the scope of this strategy should include the following:

- Establish a shared vision of what on-demand transport with AVs will mean for Perth and Western Australia.
- Explore the feasibility of innovation in vehicle automation in areas most relevant to WA, that are not well catered for by national and international developments; examples may include remote area travel and movement of high/width loads.
- Work with industry partners to improve the delivery of value-added information to travellers while reducing reliance on roadside infrastructure to do so.
- Work with other Australian road authorities through Austroads to explore potential changes required in road and barrier design associated with any reduction in crash frequency from vehicle automation.
- Work with road authorities and industry partners to gain access to, and where necessary contribute to the development of, updated road management systems that cater for and benefit from the adoption of CVs and AVs.
- Develop an implementation plan to roll-out any required changes to roadside infrastructure to support the operation of CVs and AVs, including any roadside units.
- Request the NTC to accelerate its work on the liability impacts of vehicle automation and participate in this review, and
- With other Australian stakeholders, review transport and other legislation to identify barriers to the adoption of increased vehicle automation.

6.5 Opportunities and risks for Main Roads

There are three alternatives for Main Roads’ strategic direction in relation to the opportunities and risks arising from AVs:

- Aim to encourage rapid progression to full automation by positioning Western Australia as a leader,
- Aim to be part of a common national approach with other Australian road authorities, noting that this may not keep pace with the externally imposed changes in vehicle automation, or
- Seek to take a cautious and ‘follower’ approach, which may restrict access for Western Australian road users to vehicle automation until adequate risk management is in place for each application or use.

The selection of a strategic direction involves the trade-off between opportunity and risk. The risk aspect in this regard has two broad dimensions:

- The risk that Main Roads allows or encourages use of increasingly automated vehicle operations in a way that fails to adequately manage negative impacts to the community and government, and
- The risk that Main Roads fails to respond to the pace of change and loses the ability to influence that change in a way that manages negative impacts and increases benefit realisation.

These risk dimensions reflect the consequences of action and inaction due to the externally imposed nature of change.
The opportunity aspect has three dimensions:

• Realising the safety, congestion, air quality and environmental benefits of increased vehicle automation,
• Realising the economic benefit of being a national or international leader in any new paradigm for mobility, and
• Reducing whole-of-life costs through better targeted investment in road network infrastructure that meets future needs.

In many respects, this report marks the start of Main Roads’ journey towards a future with AVs. There is still much uncertainty about what the end point of full saturation will mean for a road authority.

However, it is clear that AVs will have significant implications for Main Roads. We will need to develop further maturity to be able to successfully manage the opportunities and risks. This may be applicable for many other road agencies.

While there will be a need for a coordinated national approach, Main Roads also needs to build its own momentum and lay the groundwork for Western Australia to support the national work and to minimise the risks of late action.

It would appear that the sensible strategic direction for Main Roads would be a combination (hybrid approach) of the first two choices of strategic directions outlined above. This would see Main Roads:

• prepare and develop capabilities to thrive in the future, by undertaking targeted initiatives in areas most relevant to Western Australia and laying the groundwork for AVs within the State; and
• use this work to assist the national approach to achieve the necessary rate of progress.

Once Main Roads has developed the necessary capability, and as the implications of AVs become clearer over the next couple of years, this hybrid approach will enable Main Roads to further strengthen its leadership position and rely on national collaboration as appropriate.

6.6 Leadership and capability development

Main Roads needs to be prepared to transition to a future with AVs, with an appreciation of their potential to radically change the transport landscape and society. Enabling this change requires leadership with a vision and building capability within the organisation.

Main Roads needs to be prepared to transition to a future with AVs, with an appreciation of their potential to radically change the transport landscape and society. Enabling this change requires leadership with a vision and building capability within the organisation (Jacobs, 2013d).

Building up the organisational capability will be critical for successful transitioning. A core group of experts, strongly linked with the relevant national and international committees that set the required standards, policy and regulatory frameworks, and ITS architecture aligned with national initiatives will be required to identify the potential implications and to guide the organisation through this transformation of the transport landscape.
References


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## Appendix – Glossary of Terms

<table>
<thead>
<tr>
<th>Acronym (if used)</th>
<th>Term</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>5.9 GHz band</td>
<td></td>
<td>Refers to the 75 MHz of spectrum between 5.850 – 5.925 GHz band of radio frequencies intended for use by DSRC for V2X communications involving specifically moving objects like vehicles.</td>
</tr>
<tr>
<td>ACC</td>
<td>Adaptive Cruise Control</td>
<td>An intelligent cruise control system that adapts the vehicle’s speed to the prevailing traffic environment, using radar and/or other sensors to detect any slower moving vehicles in the path.</td>
</tr>
<tr>
<td>ACMA</td>
<td>Australian Communication and Media Authority</td>
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<tr>
<td>ADAS</td>
<td>Advanced Driver Assistance System</td>
<td>A general term for technology developed to automate, adapt or enhance vehicle systems to improve safety and better driving, including features such as ACC and AEB.</td>
</tr>
<tr>
<td>Adoption rate</td>
<td></td>
<td>The changeover rate from current generation vehicles to AVs.</td>
</tr>
<tr>
<td>ADR</td>
<td>Australian Design Rules</td>
<td>Australian national design standards for vehicle safety, anti-theft and emissions, which are generally performance based and covering issues such as occupant protection, structure, lighting, noise, engine exhaust emissions, braking and a range of miscellaneous items.</td>
</tr>
<tr>
<td>AEB</td>
<td>Autonomous Emergency Braking or Auto Emergency Braking</td>
<td>A system designed to intervene in critical situations by identifying potential hazards ahead of the vehicle by, in most cases, using sensors such as radar or lidar, and in combination with information about the vehicle’s own speed and trajectory, to avoid the impact by warning the driver or applying brakes if no action is taken by the driver.</td>
</tr>
<tr>
<td>Austroads</td>
<td></td>
<td>Association of Australian and New Zealand road transport and traffic authorities. Comprises the six state and two territory road transport and traffic authorities, Commonwealth Department of Infrastructure and Transport, Australian Local Government Association and New Zealand Transport Agency.</td>
</tr>
<tr>
<td>ATDM</td>
<td>Active Transportation Demand Management</td>
<td>Dynamic management, control and influence of travel demand, traffic demand and traffic flow on transportation facilities.</td>
</tr>
<tr>
<td>AV</td>
<td>Automated Vehicle</td>
<td>A vehicle where some aspects of a safety-critical control function such as steering, throttle control or braking occurs without direct driver input.</td>
</tr>
<tr>
<td>Autonomous Vehicles</td>
<td></td>
<td>Often confused with Automated Vehicles, Autonomous Vehicle is a narrower term applicable only to an entirely self-sufficient vehicle being able to operate on its own without any external input similar to a robot.</td>
</tr>
<tr>
<td>BSM</td>
<td>Basic Safety Message</td>
<td>The core dataset transmitted by the Connected Vehicle (vehicle size, position, speed, acceleration, brake system status) and transmitted approximately 10x per second. A secondary set is available depending upon events (e.g. ABS activated) transmitted less frequently.</td>
</tr>
<tr>
<td>CALM</td>
<td>Communication Access for Land Mobiles</td>
<td>Usually used in relation to ISO CALM standards or architecture.</td>
</tr>
<tr>
<td>CAMP</td>
<td>Crash Voidance Metric Partnership</td>
<td>A precompetitive research consortium in the US consisting of nine OEMs.</td>
</tr>
<tr>
<td>Acronym (if used)</td>
<td>Term</td>
<td>Description</td>
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<tr>
<td>CARB</td>
<td>California Air Resources Board</td>
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<tr>
<td>CEN</td>
<td>French: Comité Européen de Normalisation</td>
<td>European Committee for Standardisation.</td>
</tr>
<tr>
<td>CITI</td>
<td>Cooperative Intelligent Transport Initiative</td>
<td>A trial of C-ITS technology along a section of freight corridor connecting Hume Hwy to Port Kembla south of Sydney.</td>
</tr>
<tr>
<td>C-ITS</td>
<td>Cooperative ITS</td>
<td>Cooperative ITS is an ITS platform that can be applied to vehicles and roadside infrastructure to enable direct two-way communication. For AVs, this has the effect of increasing the available information beyond that collected by the vehicle’s own sensors.</td>
</tr>
<tr>
<td>CMBS</td>
<td>Collision Mitigation Braking System</td>
<td>Manufacturer specific term for AEB.</td>
</tr>
<tr>
<td>COOPERS</td>
<td>Cooperative Systems for Intelligent Road Safety</td>
<td>EU funded project aiming to address safety and road capacity using sensing and real-time networking technologies.</td>
</tr>
<tr>
<td>CV</td>
<td>Connected Vehicle</td>
<td>Connected Vehicles are those capable of communicating with each other (Vehicle to Vehicle or V2V), with roadside infrastructure (Vehicle-to-Infrastructure or V2I, and vice versa), or with other devices, such as mobile phones carried by road users (V2X).</td>
</tr>
<tr>
<td>CVIRA</td>
<td>Connected Vehicles Reference Implementation Architecture</td>
<td>A set of system architecture views that describe the functions, physical and logical interfaces, enterprise/institutional relationships, and communication protocol dependencies with the connected vehicle environment. It defines functionality and information exchanges needed to provide Connected Vehicle applications.</td>
</tr>
<tr>
<td>CVIS</td>
<td>Cooperative Vehicle-Infrastructure Systems</td>
<td>European research &amp; development project aiming to design, develop and test the technologies needed for V2V and V2I communications.</td>
</tr>
<tr>
<td>CVI-UTC</td>
<td>Connected Vehicle/Infrastructure – University Transportation Centre at University of Virginia</td>
<td></td>
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<tr>
<td>DOT (or US DOT)</td>
<td>United States Department of Transport</td>
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<tr>
<td>DSRC</td>
<td>Dedicated Short Range Communications</td>
<td>Wireless communication technology for transmission of information between moving vehicles (V2V) and transportation infrastructure (V2I).</td>
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<tr>
<td></td>
<td>Digital Natives</td>
<td>The generation of people born after the rise of digital technologies.</td>
</tr>
<tr>
<td>DVI</td>
<td>Driver-Vehicle Interface</td>
<td>The software and other elements of the presentation of information and/or warnings to the driver via visual, audible or haptic means about the status of a process, and to accept and implement the appropriate actions.</td>
</tr>
<tr>
<td>EPA</td>
<td>US Environmental Protection Agency</td>
<td></td>
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<tr>
<td>ERTICO</td>
<td>Europe’s ITS organisation with about 100 partners.</td>
<td></td>
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<tr>
<td>ESC</td>
<td>Electronic Stability Control</td>
<td>A system designed to help drivers avoid crashes by detecting skidding or loss of traction as a result of over-steering, using computer-controlled technology to apply individual brakes and increase stability.</td>
</tr>
<tr>
<td>ESTI</td>
<td>European Communications Standards Institute</td>
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<tr>
<td>Acronym (if used)</td>
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<tr>
<td>FAV</td>
<td>Fully Automated Vehicle</td>
<td>Vehicle with all control functions fully automated, so that it can operate without the need for a driver at any stage of its movement; they can also be labelled as ‘driverless cars’ or ‘self-driving cars’.</td>
</tr>
<tr>
<td></td>
<td>Full saturation</td>
<td>Period after the current generation of vehicles are almost entirely replaced by AVs.</td>
</tr>
<tr>
<td>GALILEO</td>
<td>Europe’s own Global Navigation Satellite System under civilian control, which is inter-operable with GPS and GLONASS, the US and Russian Global Navigation Satellite Systems.</td>
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<tr>
<td>Gen Now</td>
<td>Gen Now or Now Generation characterises people who want instant gratification, prevalent in the late 20th century and 21st century, with Baby Boomers considered as the first Gen Now.</td>
<td></td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
<td>Satellite-based radio navigation system developed by the US Defence, which provides geo-spatial positioning information including location, time and velocity in all weather conditions, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites.</td>
</tr>
<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
<td>Generic term for satellite navigation systems that provides autonomous geo-spatial positioning with global coverage and includes GPS, GLONASS, Galileo and Beidou.</td>
</tr>
<tr>
<td>GLONASS</td>
<td>Russian Global Navigation Satellite System.</td>
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<tr>
<td>IEEE</td>
<td>Institution of Electrical and Electronics Engineers.</td>
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<tr>
<td>Infotainment</td>
<td>Media content that includes a combination of information and entertainment.</td>
<td></td>
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<tr>
<td>Internal combustion engine</td>
<td>An engine which generates motive power by the burning of petrol, oil or other fuel with air inside the engine, and the hot gases produced being used to drive a piston or do other work.</td>
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<tr>
<td>ISO</td>
<td>International Standards Organisation</td>
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<tr>
<td>Interoperability</td>
<td>The ability of two or more systems or components to exchange information and to use that information.</td>
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<tr>
<td>ITS</td>
<td>Intelligent Transport Systems (ITS)</td>
<td>Comprise a range of communications, electronics and computer technologies used to improve transport services. These include: systems that collect real-time traffic data and transmit information to the public via variable message signs; ramp signals and dynamic lane control signs to improve traffic flows on freeways; and coordinated traffic signals that are dynamically adjusted in response to traffic conditions.</td>
</tr>
<tr>
<td>KATECH</td>
<td>Korea Automotive Technology Institute</td>
<td></td>
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<tr>
<td>KONVOI</td>
<td>Interdisciplinary project conducted at the RWTH University Aachen in Germany to research electronically coupled truck convoys.</td>
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<tr>
<td>Lidar or LiDAR</td>
<td>Light detection and ranging</td>
<td>Method of using a narrow beam to transmit infrared light pulses to a target, for the purpose of computing the distance to the target, by measuring the elapsed time of the light beam to reach the target and return.</td>
</tr>
<tr>
<td>LKAS</td>
<td>Lane Keeping Assistance System</td>
<td>A vehicle technology capable of applying corrective steering actions to return a vehicle to its position in a lane. Also known as Lane Keeping Assistance and Lane Assist. Differs from Lane Departure Warning (LDW), which only offers a warning but does not exert control.</td>
</tr>
<tr>
<td>Acronym (if used)</td>
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<tr>
<td>LUTZ</td>
<td>Low-carbon Urban Transport Zone</td>
<td>The potential newfound ability of those mobility-disadvantaged demographics such as the elderly, children, people with disabilities and those who do not drive or are unlicensed to drive, to enjoy high levels of mobility with AVs.</td>
</tr>
<tr>
<td>NCTIP</td>
<td>National Transportation Communications for Intelligent Transportation System Protocol</td>
<td>Family of standards designed to achieve interoperability and interchangeability between computers and electronic traffic control equipment from different manufacturers.</td>
</tr>
<tr>
<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
<td>A US federal executive agency focusing on safety in transport, including writing and enforcing Federal Motor Vehicle Safety Standards</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
<td>Entity that originally manufactures an item that may be branded and sold by others. In the CV environment it is commonly used to refer to automobile manufacturers.</td>
</tr>
<tr>
<td>PATH (or California PATH)</td>
<td>Partners for Advanced Transportation Technology</td>
<td>A research &amp; development program of the University of California in Berkeley in ITS including CVs and AVs, established in 1986.</td>
</tr>
<tr>
<td>Pricing (or road pricing)</td>
<td>Paying for use of roads, or parts of roads such as specific lanes, tunnels or bridges</td>
<td></td>
</tr>
<tr>
<td>PKI</td>
<td>Public Key Infrastructure</td>
<td>Set of hardware, software, people, policies and procedures needed to enable users of the Internet and other public networks to engage in secure communication, data exchange and money exchange through cryptographic key pairs provided by a certificate authority.</td>
</tr>
<tr>
<td>PRT</td>
<td>Personal Rapid Transit</td>
<td>Small vehicles available for direct origin-destination service, usually with no stops or transfer at intermediate stations.</td>
</tr>
<tr>
<td>QZSS</td>
<td>Quasi-Zenith Satellite System</td>
<td>Japanese satellite positioning system comprising mainly satellites in quasi-zenith orbits to support improved accuracy for GNSS positioning.</td>
</tr>
<tr>
<td>Radar</td>
<td>Radio detection and ranging</td>
<td>Method of detecting objects and determining their position, velocity or other characteristics by analysis of high frequency radio waves reflected from their surface.</td>
</tr>
<tr>
<td>RDS-TMC</td>
<td>Radio Data System – Traffic Message Channel</td>
<td>Technology for providing traffic information to drivers via digital FM radio waves.</td>
</tr>
<tr>
<td>RSE</td>
<td>Roadside Equipment</td>
<td>Equipment installed at the roadside that will prepare and transmit messages to vehicles and receive messages from vehicles to support V2I applications. Includes DSRC radio, a traffic signal controller where appropriate and the interface to backhaul communication network. Sometimes referred to as roadside ITS station; when speaking of the DSRC radio alone, the correct term is RSU.</td>
</tr>
<tr>
<td>RSU</td>
<td>Roadside Unit</td>
<td>Connected device operating from a fixed position (permanent installation or equipment brought on site temporarily) used to transmit or receive messages from another device on a vehicle or in the roadside.</td>
</tr>
<tr>
<td>SAE</td>
<td>Society of Automotive Engineers</td>
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<tr>
<td>Acronym (if used)</td>
<td>Term Description</td>
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<tr>
<td>SATRE</td>
<td>Safe Road Trains for the Environment</td>
<td>Project funded by the European Commission under the Framework 7 program to develop strategies and technologies to enable vehicle platoons on public roads.</td>
</tr>
<tr>
<td>SCMS</td>
<td>Security Credential Management System</td>
<td>A public key infrastructure approach to security involving the management of digital certificates that are used to sign and authenticate messages between vehicles, equipment and other points of connection.</td>
</tr>
<tr>
<td>SCOTI</td>
<td>Standing Council on Transport and Infrastructure</td>
<td>A Council of Australian Commonwealth, State and Territory and New Zealand Ministers with responsibility for transport and infrastructure, as well as the Australian Local Government Association, to focus on nationally significant reforms. In December 2013, this was replaced by the Transport and Infrastructure Council.</td>
</tr>
<tr>
<td>Smart vehicles</td>
<td>General term used to refer to vehicles with some wireless connectivity and/or automated functions.</td>
<td></td>
</tr>
<tr>
<td>SPaT</td>
<td>Signal Phase and Timing</td>
<td>Message type that describes the current state of a traffic signal system including phases and relates this to specific lanes/maneuvres at the intersection.</td>
</tr>
<tr>
<td>SRM</td>
<td>Signal Request Message</td>
<td>Message sent by a CV to request action from the traffic signals.</td>
</tr>
<tr>
<td>SSM</td>
<td>Signal Status Message</td>
<td>Message sent to the CV by the infrastructure (traffic signal) in confirmation of the SRM.</td>
</tr>
<tr>
<td>TISOC</td>
<td>Transport and Infrastructure Senior Officials’ Committee</td>
<td>Committee of senior officials providing advice, guidance and assistance to SCOTI (now Transport and Infrastructure Council).</td>
</tr>
<tr>
<td>Transition period</td>
<td>Period in which smart vehicles with increasing levels of automation and/or connectivity will co-exist and operate with current generation vehicles on the road network.</td>
<td></td>
</tr>
<tr>
<td>TSC</td>
<td>Transport Systems Catapult</td>
<td>The UK’s innovation centre for Intelligent Mobility.</td>
</tr>
<tr>
<td>UN Vienna Convention on Road Traffic</td>
<td>International treaty designed to facilitate international road traffic and to increase road safety by establishing standard traffic rules among the contracting parties, agreed upon at the UNESCO Conference on Road Traffic in November 1968 in Vienna and came into force on 21 May 1977.</td>
<td></td>
</tr>
<tr>
<td>V2I</td>
<td>Vehicle to Infrastructure communications</td>
<td>Transmission of information between vehicles and the road infrastructure to enable a variety of safety, mobility and environmental applications.</td>
</tr>
<tr>
<td>V2V</td>
<td>Vehicle to Vehicle communications</td>
<td>Transmission of basic safety and other information between vehicles to facilitate warnings to drivers concerning traffic conditions and impending crashes.</td>
</tr>
<tr>
<td>V2X</td>
<td>Vehicle to anything communications</td>
<td>Communications between a vehicle and any external entity, including V2I, V2V, Vehicle to Centre, Vehicle to Cloud (V2C) or Vehicle to any other device such as mobile phones.</td>
</tr>
<tr>
<td>Vehicle IQ</td>
<td>Vehicle IQ (Intelligent Quotient) is a concept used primarily in China to evaluate ‘intelligence’ of a vehicle.</td>
<td></td>
</tr>
<tr>
<td>VRU</td>
<td>Vulnerable Road User</td>
<td>A pedestrian, cyclist or similar road user, who is at a relatively high risk of harm if involved in crash.</td>
</tr>
</tbody>
</table>
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