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Impacts and Implications of Automated Vehicles for Australian and New Zealand Road Operators

Road vehicles that are 'highly' automated are expected to be introduced to our roads before the end of this decade. Austroads has commissioned WSP | Parsons Brinckerhoff to develop a report for road operators in Australia and New Zealand that identifies and assesses key issues impacting automated vehicles(AV). The end goal is a consistent approach to regulation across local, state and federal road organisations to allow AV vehicles to:

(a) be safely and effectively operated on our road networks, and;

(b) achieve an optimised level of safety and mobility benefits.

A key output of this Austroads report will be the identification of key issues that are anticipated to arise due to the pending introduction of a greater number of automated vehicles, and the provision of guidance on how to consistently address these issues. This report will be of interest to a wide range of road operators given the substantial change expected on our road networks in the near future.

The key deliverable from this report will be guidance to road agencies and other key stakeholders on how road networks can be managed to support and optimise the introduction and use of automated vehicles. This will include consideration of design, operation and maintenance of road side infrastructure.

This paper outlines some of the background and key considerations in developing the report which will be published later this year.

Biography of Primary Authors

Scott Benjamin

Scott Benjamin, Technical Executive, ITS, leads WSP | Parsons Brinckerhoff's ITS capability for the ANZ region. Originally a traffic engineer, he has over 20 years' experience in the development of policy, strategy and development of innovative transport solutions in Australia and the UK. Scott was an author of the first Australian ITS Strategy in 1999 "eTransport" and had lead numerous European studies and Australian policy, strategy and feasibility and development of unique

traffic management technology solutions. Scott is the project manager of the Austoads project to develop the above mentioned Austroads report.

Stuart Ballingall

Stuart Ballingall is Program Director for Austroads' Cooperative and Automated Vehicles program. As part of this role, Stuart is leading the establishment a national framework to support the deployment of Cooperative Intelligent Transport Systems, and he plays a key role in planning for the introduction of Automated Vehicles to Australian roads. With a background in automotive engineering, Stuart has previously held senior roles with VicRoads, General Motors Holden and the RACV. Stuart is also an active member of numerous national and international forums covering transport, automotive and ICT.

1. Introduction

It is anticipated that 'highly' automated road vehicles will be introduced to our roads before the end of this decade. The concept of self-sufficient vehicles that are capable of not only connecting with other vehicles but also being 'driverless' raises a number of key issues and concerns for road operators in how they should be regulated. Considerations such as safety, fault, reliability and efficiency require a common approach across all jurisdictions in order to facilitate the smooth introduction of the automated vehicle (AV).

Austroads has commissioned WSP | Parsons Brinckerhoff to develop a report for road operators in Australia and New Zealand that will take these considerations

into account. The end goal is to create a consistent approach to regulation across local, state and federal road organisations to allow AV's to:

(a) be safely and effectively operated on our road networks, and;
(b) achieve an optimised level of safety and mobility benefits.

The key deliverable from this report will be guidance to road agencies, road operators and other key stakeholders on what changes may be required to the way road networks are managed, so as to support and optimise the outcomes from the introduction and use of automated vehicles.

This paper outlines some of the background and key considerations which have been made in forming the Austroads report. In particular those that relate to the traffic engineering, transport and infrastructure planning and design and transport management at a state and local government level.

Key aspects to be considered as part of this paper are:

1. Background information about AV operation and needs
2. Frameworks to consider AV operation and interaction with the environment
3. Physical infrastructure (designs and maintenance of structures, pavements, line marking and signs)
4. Digital Infrastructure (Intelligent Transport Systems, Communication Systems, positioning and mapping systems)
5. Road Operation (considering mixed fleet operation and how to optimize vehicle throughput)

The final Austroads report will also consider wider societal consideration e.g. legal, enforcement and insurance issues that are directly relevant to road agencies.

2. Methodology

WSP | Parsons Brinckerhoff have involved a wide range of industry experts in their team to deliver the project, including technical experts from Telstra, Bosch, CIE legal and a range of international experts from our USA and Northern European offices.

Key data collection was focused on a wide ranging interview process with key government and industry groups to ensure AV's rapidly evolving issues are well understood. We also undertook an extensive literature study. These two inputs were used as the basis of the document.

3. Background

Automated Vehicle (AV) is a term used for a motor vehicle that automates part or all of the primary driving controls (i.e. steering, acceleration, braking). Systems such as power assisted steering and brakes, have gradually entered the realm of "standard inclusions" and there is a gap in the market for more 'highly' automated vehicles that continues to increase. The idea of vehicles with greater levels of automation has been explored countless times over the decades

including the 1964 World Fair General Motors Exhibition "Futurama", as well as later General Motors concept cars such as the Firebird.

From a consumer perspective, automation has been more overt in recent years with the advent of intelligent cruise control and automated emergency braking. These are lower forms of single application automation that support driver functions.

Advanced Driver Assistance Systems (ADAS) such as ABS and cruise control were considered significant technology advancements at the time of their introduction, but did not fundamentally change driving processes. In recent years, the demand for automation has surpassed these 'simpler' driver assistance capabilities, and has moved to a focus on more complex technologies that require little to no human input, allowing vehicles to effectively operate themselves in most or all circumstances.

Since AV's are relatively uncharted territory, their regulation greatly benefits from the input of a wide variety of organisations that can each consider the impacts and implications of this type of technology on the safety and management of our roads.

Vehicle regulation and driver licensing are both currently being reviewed, in separate projects, by the National Transport Commission and Austroads respectively in order to manage risks and plan for the introduction of AV technology.

AV's use a wide range of sensors to consider their environment. Figure 1 below (Texas instruments) outlines some of the sensors used by most (though not at all uniformly) by a range of AV Original Equipment Manufacturers (OEMs).

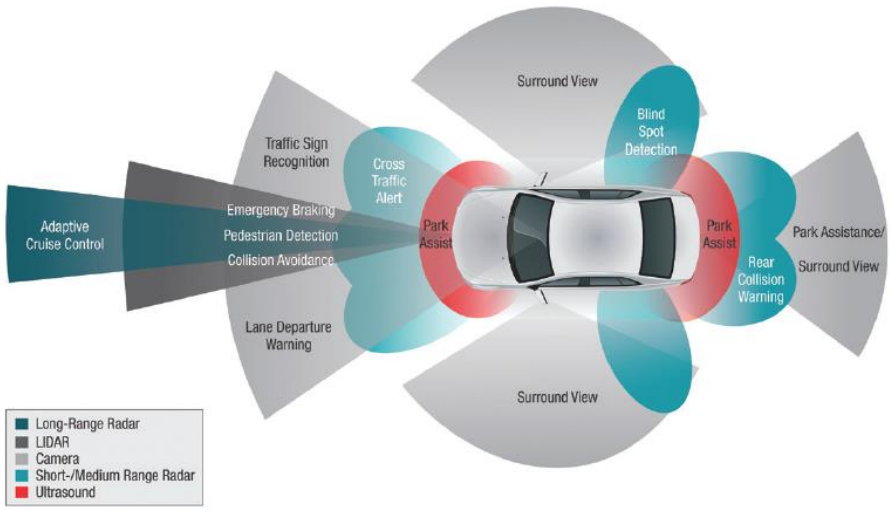

Figure 1: Typical AV sensor arrangement (Texas Instruments)

Understanding the exact way in which AV's "read" their environment is vital to understanding their needs. It is most appropriate to consider AVs as another

type of road user, which has some limitations. It is important road infrastructure providers and operators understand the nature of these limitations. This is discussed in Section 5, 6 and 7 below.

AV's are able to undertake a wide range of computation to allow consideration of the road environment and the necessary control to ensure the safe interaction with their road environment and other road users. Section 4 below outlines frameworks to consider this interaction.

4. Considering a Common Framework

Having common models or frameworks to reference the form and function of automation will allow road authorities to consider potential impacts, opportunities and implications of increasing vehicular automation. Ultimately, the potential for completely driverless vehicles to operate on our transport networks, will need to be considered – we need a common way of considering the localised impacts and network-wide implications of AV operation.

Government and industry bodies have collaborated on a wide range of frameworks to allow more meaningful consideration of what AV's are and the short and long term impacts of their implementation. We propose the adoption of a three-part framework:

1. **Vehicle Automation:** SAE AV Taxonomy (J3016) classifies/defines levels of 'driving automation' [REF] This is generically described as the SAE AV Taxonomy throughout this paper.
2. **Interaction with the Road Environment:** Using a model developed by the European AV program AdaptIVe as a base to consider AV interaction with the road environment [REF]
3. **Navigation and wider traffic network considerations:** considering the relevance of Link and Place and network Operating Plans

2.1 SAE Levels of Driving Automation (J3016)

The first model for consideration is the SAE AV Taxonomy. The SAE taxonomy outlines the level of automation as follows (REF):

Level 0: No Automation
Level 1: Driver Assistance
Level 2: Partial Automation
Level 3: Conditional Automation
Level 4: Highly Automated
Level 5: Fully Automated (Driverless Vehicle)

Australia has a regulatory framework for the market introduction and use of motor vehicles, however it does not currently specifically address differing levels of driver automation.

In Australia, the Commonwealth, State and Territory governments jointly maintain a federal system for regulating motor vehicles. The Commonwealth's Department of Infrastructure and Regional Development (DIRD) is responsible for regulating vehicles up to the point of first supply. Once in service, State/Territory governments oversee continuing vehicle regulation for road registered vehicles with the National Heavy Vehicle Regulator (NHVR)

increasingly taking a role overseeing vehicle regulation for heavy vehicles. The system is based on national design and performance standards for vehicles, known as the Australian Design Rules (ADR's), administered under the Motor Vehicle Standards Act 1989(Cth) by the Vehicle Standards Safety Branch of the DIRD.

The Commonwealth has a policy to increase the level of harmonisation of vehicle ADR's with the United Nations Economic Commission for Europe (UNECE) vehicle regulations. The Informal Group on ITS & Automated Driving (IG-ITS/AD), under UN Working Party 29, is currently working towards an agreed definition for automated driving. They currently refer to the SAE AV taxonomy at present, but it is important to note that it is not specifically referenced as such in any regulated standards. Despite this, SAE remains the most suitable framework we have at present to consider level of vehicle automations. Updates to the framework are currently occurring and will be of great interest to road operators and regulatory bodies both locally and internationally.

2.2 AdaptIVE Framework – Vehicle Interaction with the environment

The AdaptIVe Framework project references SAE taxonomy and has been able to build on this to present the consideration of the interaction between the vehicle and the environment. Most standards and frameworks relating to AV are written solely from the perspective of vehicle systems. The AdaptIVe model being proposed is developed with greater consideration given to the road operator and the need to test the functions of the vehicle in a structured gateway process to consider implementation.

The AdaptIVe project involved the development of a framework for assessing the implementation of a specific type of AV under certain environmental conditions (or use cases e.g. heavy vehicle platooning). Figure 2 outlines three key dimensions that need to be assessed when evaluating the operational safety of AV's:

1. Level of automation
2. Speed of the vehicle
3. Particular vehicle manoeuvres to be performed which we propose to consider more generically as road "complexity".

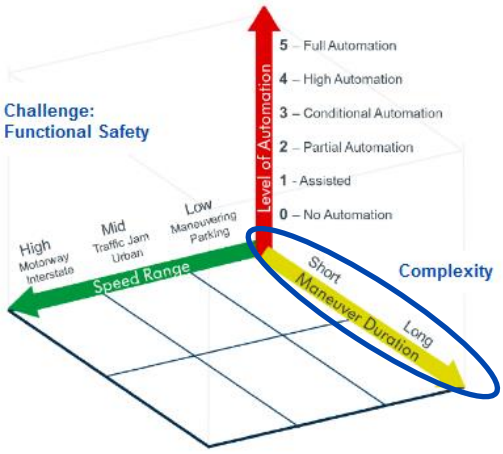

Figure 2: AdaptIVe Framework (https://www.adaptive-ip.eu/)

2.3 Consideration of Link and Place: Wider Network Implications

"Link and Place" or what is sometimes referred to as "Movement and Place" is a concept and framework which is being adopted by many government authorities internationally to consider and plan our road network and urban environment. It states that streets can be can be considered as having one of two primary functions as outlined in Figure 3 below.

Figure 3: Link and Place (http://atrf.info/papers/2009/2009_Jones_Boujenko.pdf)

While the model is simplistic, it is a useful instrument that facilitates stakeholder discussions about what outcomes we are seeking for our urban environments.

Network Operation Plan (NOP) is a process originally developed by VicRoads as part of the SmartRoads Framework, and later adopted by numerous authorities across Australia and New Zealand. The use of NOP is outlined in the Austroads Guide to Traffic Management Part 4: Network Management (Ref Austroads 2015). The development of a NOP allows development and integrated operation of our road transport network. It considers land use but only in terms of access to and impact on the transport network.

Given the different nature of operation of highly and fully automated AV's, it is important that we consider the impacts on "Place" as well as impacts on transport networks to ensure optimised outcomes from a whole of community perspective.

The next three sections of this paper summarise potential implications for the design and maintaining of physical and digital infrastructure and road operations for AV operation. These issues are discussed at length in the final Austroads report to be published later this year and guidance is provided outlining appropriate responses.

5. Physical Infrastructure

A careful balancing act will be required to create a consistent design and asset management regime that support AV vehicles operation. Consistency: nationally and ideally, internationally, while also accounting for situations where flexibility may be required i.e. road works will be a key focus for the infrastructure response.

Some of the areas to be considered in the Austroads report include:

- Line marking and delineation
- Road Signs (static and electronic)
- Pavements, structures and barriers
- Need for consistency in maintenance intervention levels

5.1 Line Marking and Delineation

Issues concerning line marking and delineation include:

- Design
  - → Need for minimum standards
  - → Need for national and preferably international consistency
  - → Machine prompts from other forms of delineation e.g. kerb lines needs to be understood – may be different from human needs and prompts
- Maintenance and Asset Management
  - → Removal of old line markings is problematic for machine reading
  - → Need for consistent maintenance treatments
  - → Particular emphasis in road works zones

5.2 Road Signs (Static and Electronic)

Key issues regarding road signs are noted as follows:

- Design
  - → Need for minimum standards
  - → Need for national and preferably international consistency
- Installation and Maintenance
  - → Timeliness to install and confirm signs, speed signs of particular concern
  - → Need for consistency in maintenance of signs (retro reflectivity / machine readability)
  - → Positioning of signs – particularly on service roads immediately adjacent to a road with another speed limit is very difficult for AV users
  - → Particular emphasis in road works zones
- Electronic Signs (VMS)
  - → Machine readability of VMS potentially impaired due to refresh rate and other optical issues

5.3 Pavements, Structures and Barriers

Key issues regarding other physical infrastructure is noted as possible:

- Road vehicle and User Interaction and Geometric Design (lane width, gradient, curvature, intersection design)
  - → National and where possible international consistency is required
  - → Need to consider issues for specific use cases (e.g. platooning – see Road Operations)
- Consider needs of AVs in highly automated mode of operation to bring vehicles to a safe resting state if they are not able to hand back control to the human operator at any given point in time

- Design assumptions for structures pavement, bridges, tunnels and barriers to protect critical infrastructure. Consider in terms of key use cases e.g. heavy vehicle platooning. This will change the base requirements for design and asset management of pavements, structures and barriers.

6. Digital Infrastructure

The proper management of digital infrastructure is fundamental to both the efficiency and safe operation of AV's, particularly as the reliability of digital infrastructure centres on providing accurate data and information.

There are three main considerations regarding potential impacts on digital infrastructure:

- Communications: Notably cellular coverage is like to be a minimum pre-requisite for some AV use cases
  - → Need to consider coverage versus accident exposure
  - → Coverage from multiple cellular operators using shared infrastructure is advantageous
- Consider the need to make key data available in real time:
  - → Speed zone data for permanent signs. There is a need to improve business processes to update this information
  - → Dynamic speed limit data – information could be provided in near real time
  - → Information about clearways, loading zones and parking restrictions to be provided in a timely manner – business process consideration for local governments
  - → Road closure and lane availability data (road works data) of key interest to be provided in real time
  - → Information about roads soon to be opened to be shared with industry as early as possible including the opportunity to drive through as early as possible (mapping providers)
- Vehicle positioning services for AV
  - → Satellite Based Augmented System (SBAS)- continue to work with key government agencies to get ensure satellite positioning services in Australia and New Zealand consider the emerging needs of AVs
  - → Consider positioning needs in tunnels and built up areas (urban canyons)

7. Road Operations

At an operational level, road operators need to consider the practical implications of introducing AV technologies, particularly how and where they will operate alongside other non-automated vehicles, their lifecycle and maintenance, as well as considering any issues with their operation along particular road networks or terrain. The issue of AV's and road operations spans a wide range of areas, with the Austroads report aiming to provide clarity on:

- Determining asset management and maintenance intervention levels needed for AV operation and optimal use of physical infrastructure. Also need to consider a framework for review and assessment e.g. ANRAM.

- Potential implications of road certification for different uses this should include kerb side use (i.e. parking and pick up/drop off or dedicated lanes). Consider concept of "certification" OR where AV use cases should "**not** operate" and legal issues related to this. One potential approach could be to consider movement and place that could be used to inform OEMs and service providers about where AV use cases could operate
- Consideration of unique AV operational requirements:
  - → How to manage AV breakdown and how to mitigate with infrastructure design (consider implications for emergency lanes and bringing vehicles to a safe resting state). This may be a shared consideration between road operators and motoring clubs
  - → Particular AV needs at road works or during incident conditions. This will including changes to lane widths, lane demarcation, signs and traffic interaction, and interaction with traffic management personnel (traffic control) and emergency services personnel

8. Conclusion

The introduction of AV's and the potential options and strategies support AV use cases will continue to be debated across the industry. This report anticipates some of the impacts and issues associated with the introduction of AV's and how they will be supported by physical and digital infrastructure, as well as the practical implications on road operations.

The Austroads report released later this year will build on the themes explored in this paper and will seek to clarify the issues in contention which will be of great interest and use to road operators both locally and internationally moving forward.