Connected and Autonomous Vehicles: Impact Assessment Model

Final Report (Part 2)

December 2020

Connected and Automated Vehicles: Impact Assessment Model

Prepared by

Subhadarsini Parida, Kerry Brown, Ferry Jie and

Hadrian G. Djajadikerta

Keywords

Connected and Autonomous Vehicles

Version control

Final

Project No

iMOVE Project 3-007, Milestone 3.3 Part 2

Project steering committee

Flori Mihai, Main Roads Western Australia

Graeme O'Neil, Department of Transport

Acknowledgments

This research is funded by iMOVE CRC and supported by the Cooperative Research Centres program, an Australian Government initiative, as well as PATREC core research funds.

About PATREC

The Planning and Transport Research Centre (PATREC) is a collaboration between the Government of Western Australia and local universities, constituted to conduct collaborative, applied research and teaching in support of policy in the connected spaces of transport and land use planning. The collaborating parties are: The University of Western Australia, Curtin University, Edith Cowan University, Department of Transport, Main Roads Western Australia, Western Australian Planning Commission
Australian Local Government Association.

Publisher

Planning and Transport Research Centre
The University of Western Australia (M087)
35 Stirling Highway, Crawley, WA 6009
+61 8 6488 3385
patrec@uwa.edu.au
https://patrec.org/

Executive Summary

Long term transport infrastructure planning and policy decisions are increasingly made in an environment that is volatile, uncertain, complex and ambiguous as technology development, consumer demand and transport service business models change. In the area of transport infrastructure, an array of disruptive transport technologies is changing the way business operates the nature of roles in the workforce, agile customer transactions and outcomes for users as to be more adaptable. The transportation environment is changing with the introduction of connected and automated vehicles (CAV). CAV refers to a range of vehicles including electric vehicles with some level of automation, to a high level of automation (self-driving) and equipped with interoperable cooperative ITS systems and cloud connectivity that may be used for services such as live traffic information, automated crash notification, concierge and booking services.

Considerable work has been undertaken overseas and in Australia about monitoring CAV technological developments and undergoing trials, and identifying and developing legislation and regulatory requirements, governance frameworks in order to facilitate and be ready for the uptake of CAV.

However, little or no work has been done in relation to how the uptake of CAV may impact the practice of asset management. CAV in many forms and ownership models, including individual vehicles, buses, commercial vehicles, or trains, will operate on the existing infrastructure assets. This project explores how CAV may affect the asset and the business of managing the asset, throughout its life cycle. More specifically, the impact of CAV on asset management is assessed according to:

- Two CAV uptake scenarios: less than 100% uptake and 100% uptake.
- Six key asset management areas: policy, strategy, planning, legislation and statutory requirements, customer and stakeholder expectations and risk management.

Asset management as applied to the roads sector represents "a systematic process of maintaining, upgrading and operating assets, combining engineering principles with sound business practice and economic rationale, and providing tools to facilitate a more organised and flexible approach to making the decisions necessary to achieve the public's expectations" (OECD 2002).

The Final Report of the study includes three parts as follows:

- **Part 1** is a comprehensive literature review of the relevant CAV developments overseas and in Australia and contains a summary of learnings for asset management in regard to each of the six areas outlined above.
- **Part 2** provides an assessment model for the impact of CAV uptake on the six key asset management areas, for the two uptake scenarios, less than 100% uptake and 100% uptake, and outlines and discusses the results of the assessment.

- **Part 3** provides recommendations for asset managers, and a summary of asset management opportunities and uncertainties resulting from CAV uptake.

This is the second part of the Final Report for this project.

The Impact assessment model and assessment methodology include:

a) Consideration of the findings from the literature review, vis-a-vis the six key asset management areas: policy, strategy, planning, legislation and statutory requirements, customer and stakeholder expectations and risk management;

b) Preparation of impact statements for the six focus areas and assessing via Delphi methodology the impact likelihood, for the two CAV adoption scenarios: partial uptake and 100% adoption;

c) Presentation of the results and conclusions; and

d) Identification of opportunities and potential benefits for asset management, as well as areas of uncertainty, where the future impact of CAV on asset management is difficult to evaluate.

A diagrammatic representation of the Impact Assessment model is outlined in Figure 1.

The findings from the Impact assessment and Delphi process, as well as a summary of opportunities and uncertainties for asset management (items c and d), are presented in part 3 of the final report for this project. The diagrammatic representation of the impact assessment model is set out in Figure 1 below.

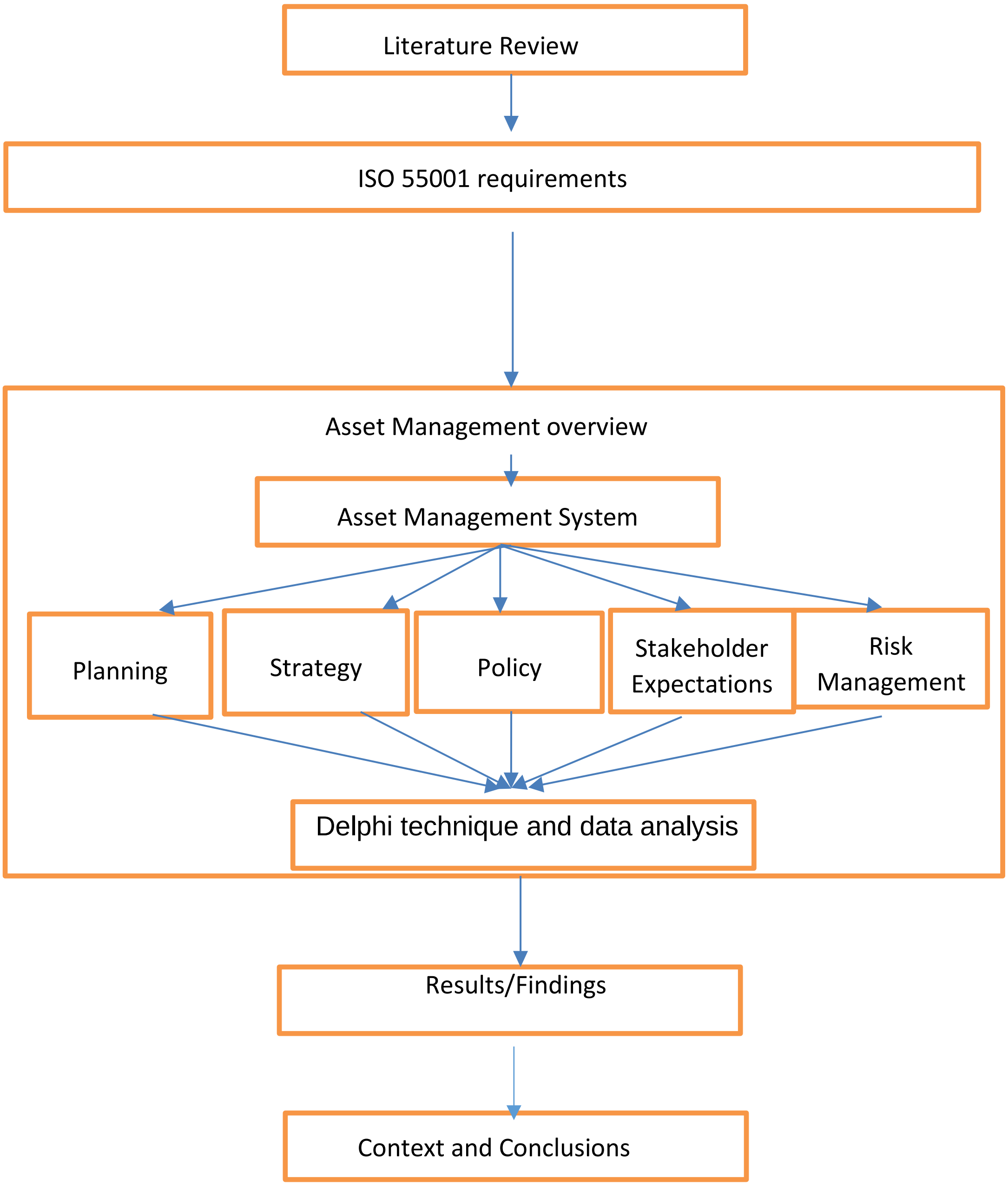

Figure 1: Impact assessment model

Key Findings

The impact assessment and Delphi process identified the key findings in the below section.

Most asset management functions will be impacted by CAV uptake for all uptake levels.

- The majority of participants (91%) agree (somewhat agree to strongly agree) that CAV uptake, particularly by freight operators, can result in *changes to freight policies and strategies* including areas of access, productivity, fatigue management, for both <100% and 100% uptake of CAV.

- The majority of participants agreed (74.9%) CAV can impact *real-time data collection* irrespective of the uptake level (<100% and 100%).

- Similarly, 91.6% and 91% participants agreed that CAV uptake (<100% and 100% uptake respectively) will improve *telematics* (for example, telecommunications, vehicular technologies), electrical engineering (sensors, instrumentation, wireless communications), and computer science (multimedia, Internet).

- The majority of participants agreed that CAV will impact a *railway crossing strategy* (66.6% for <100% uptake and 75% for 100% uptake of CAV).

- There was a high rate of agreement in both scenarios (74.9% for <100% uptake and 91.5% for 100% uptake) that CAV will ease *congestion and traffic delays* due to a reduction in crashes.

- Participants showed a high level of agreement on CAV impacting *road investment planning process,* particularly needs assessment, (91.6% for <100% uptake and 100% for 100% uptake of CAV).

- A similar pattern was observed for CAV affecting *road maintenance practices* (83.2% for <100% uptake and 91.6% for 100% uptake of CAV).

- The participants agreed the CAV uptake will result in creating infrastructure that considers the low carbon economy (particularly *EV and AV charging stations*), (66.6% for <100% uptake and 75.2% for 100% uptake of CAV).

- There was also a high level of agreement on CAV resulting in rethinking and adjusting the *conventional road management tools* (commercial vehicle usage, zoning, roadway classification systems, and street design standards) (83.3% for less than 100% uptake and 91.6% for 100% for CAV).

- Finally, 66.5% participants agree in relation to <100% uptake and 83.3% participants for 100% uptake agree that CAV uptake will reduce *urban* *congestion* if operated as a shared rather than exclusive privately owned vehicle.

- Almost all participants agreed that CAV uptake will facilitate *legislation for interactions between all types of road users*, autonomous and connected, or human-operated vehicles (91.6% for <100% uptake and 100% for 100% uptake of CAV).

- There was agreement that in both scenarios, there is a need to change the *definition of "licensed driver"* (58.2% for <100% and 83.2% for 100% uptake of CAV).

- Participants agreed that AV uptake will result in *comprehensive regulation for* future deployment of CAVs (91.5% for <100% uptake and 100% for 100% uptake).

- Participants agreed CAV will impact driver behaviour such as focusing on driving vs non-driving tasks in both scenarios (91.6% for <100% and 83.2% for 100%).

- 75% of participants agreed that CAV will also result in increased *road user expectations* regarding the level of service provided by the road irrespective of uptake scenarios.

In some areas, CAV uptake will impact on asset management practices, but more likely in the 100% uptake scenario.

- Regarding CAV facilitating the *provision of incentives to people who use shared CAV*; only 58.6% participants agree that CAV will have an impact for <100%. However, for 100% CAV uptake, 66.6% agreed (somewhat agree to strongly agree) that CAV can have an impact.

Areas in which CAV uptake will not impact asset management

- The *need to build new roads* due to AV uptake was generally disagreed by 50% participants irrespective of <100% or 100% uptake of AVs.

Areas of uncertainty regarding the potential impact of CAV uptake

- Participants were uncertain if CAV will improve car occupancy rate, with 41.66 % of responses being in the “neither agree or disagree’ category.

- The results from the Delphi highlighted that the policy around AV uptake to f*acilitate peak usage through penalties* suggested that 41.63% participants disagreed for <100% uptake of AV while 33.3% respondents were uncertain for 100% AV uptake.

Table of Contents

1. Introduction

“Disruptive technology” as defined by Bower and Christensen (1995) refers to a technology that causes a change or paradigm shift and is set to revolutionise an existing system or process. This technology may result in lower cost and performance as measured by traditional criteria but having higher ancillary performance (Alessandrini, Campagna, Delle Site, Filippi, & Persia, 2015). Disruptive technologies may enter and expand emerging market niches, improving with time and ultimately challenging or replacing established products in their traditional markets. Rapid advances in technology, combined with increasing interest in improving transport efficiency, enhancing productivity, efficiency, safety and security have led to the emergence of a wide range of disruptive transport technologies (Garrison, 2000).

In the area of transport infrastructure, an array of disruptive transport technologies is changing the way a business operates, the nature of roles in the workforce, agile customer transactions and more adaptable outcomes for transport users. The transportation environment is changing with the introduction of electric automated and connected vehicles (CAV).

CAV referred to a range of vehicles including electric vehicles with some level of automation, to a high level of automation (self-driving) and equipped with interoperable cooperative ITS systems and cloud connectivity that may be used for services such as live traffic information, automated crash notification, concierge and booking services.

This project explores how the uptake of CAV may influence the business of asset management, and identifies what opportunities, if any, CAV can facilitate in regard to asset management practice.

Asset management as applied to the roads sector represents “a systematic process of maintaining, upgrading and operating assets, combining engineering principles with sound business practice and economic rationale, and providing tools to facilitate a more organised and flexible approach to making the decisions necessary to achieve the public’s expectations” (OECD 2002).

The impact of CAV on asset management is assessed according to six key asset management areas.

- Policy
- Strategy
- Planning
- Legislation and Statutory Requirements
- Customer and Stakeholder Expectations
- Risk Management.

Two CAV uptake scenarios are considered n this project: 1) less than 100% uptake and 2) 100% uptake.

The Final Report of the study includes three parts as follows:

- Part 1 is a comprehensive literature review of the relevant CAV developments overseas and in Australia and a summary of learnings for asset management.

- Part 2 provides an assessment model for the impact of CAV uptake on the six key asset management areas, for the two uptake scenarios, partial and 100% uptake, and presents the results of the Delphi process.

- Part 3 provides recommendations for asset managers and a summary of key asset management opportunities and uncertainties resulting from CAV uptake.

This is the second part of the Final Report.

2. Asset Management - Areas of Focus

Asset management as applied to the roads sector represents "a systematic process of maintaining, upgrading and operating assets, combining engineering principles with sound business practice and economic rationale, and providing tools to facilitate a more organised and flexible approach to making the decisions necessary to achieve the public's expectations" (OECD 2002).

Asset management practice is informed by international standards such as ISO 55000 (2014), PAS 55 (2008) and in Australia by Austroads Guide to Asset Management, GAM (2018) and the International Infrastructure Management Manual (2015), to name most relevant.

The six asset management areas that form the focus of this project (policy, strategy, planning, customer/stakeholder expectations, risk management and legislation/ statutory requirements), are identified in all asset management guidance documents internationally and in Australia.

An Asset Management Policy allows the organisation to apply asset management to specific objectives. It provides a statement of intent/commitment towards applying asset management principles (e.g. being proactive in changing environment; deliver value for customers) and key objectives (e.g. prioritise investment based on balancing customer outcomes, cost and risk; capture the right data to enable well-informed decisions). An Asset Management Strategy outlines the implementation and documentation of asset management practices, plans, processes and procedures within an organisation. Asset management strategies can address specific activities such as Maintenance Strategy. Asset management strategies cascade down from the asset management policy, then translate into planning processes and specific plans for implementation.

Planning in asset management fundamentals is a part of ISO 55001:2014. Clause 6 ISO 55000 defines an Asset Management Plan as "documented information that specifies the activities, resources and timescales required for an individual asset, or a grouping of assets, to achieve the organisation's asset management objectives". The planning processes and plans can be in regard to any of the asset life cycle (e.g.

maintenance, operations, replacement, disposal), and relate to any asset (e.g. pavements, bridges, vehicle fleet). Plans can be operational, tactical or strategic. Legislation and statutory requirements ensure the asset management activities are compliant with relevant standards and procedures (IAM, 2015).

Under the broad requirement of ISO 55001:2014, stakeholder needs, and expectations should be considered when developing the Asset Management System. An organisation should identify its stakeholders and customers and understand their needs and expectations, translate them into organisational outcomes and measurable levels of service parameters, reflect in asset management strategies and integrate with the planning processes including investment planning.

Risk management is the identification, evaluation, and prioritisation of risks in the context of managing assets. ISO 31000 defines risk as the effect of uncertainty on objectives, followed by coordinated and economical application of resources to minimise, monitor, and control the probability or impact of unfortunate events or to maximise the realisation of opportunities. Asset management aims to balance risk, costs and asset performance/customer level of service.

3. Impact Model

The purpose of this report is to develop a model to assess the impact of CAV uptake on asset management, under two scenarios: 100% uptake and partial uptake (<100%). The CAV impact model, presented in Figure 1, considers the learnings from the literature review. These are further analysed in the context of the six-asset management areas and considering the two scenarios for CAV uptake.

The model was used in conjunction with a Delphi methodology to gain a better understanding of the impact of CAV on asset management practice.

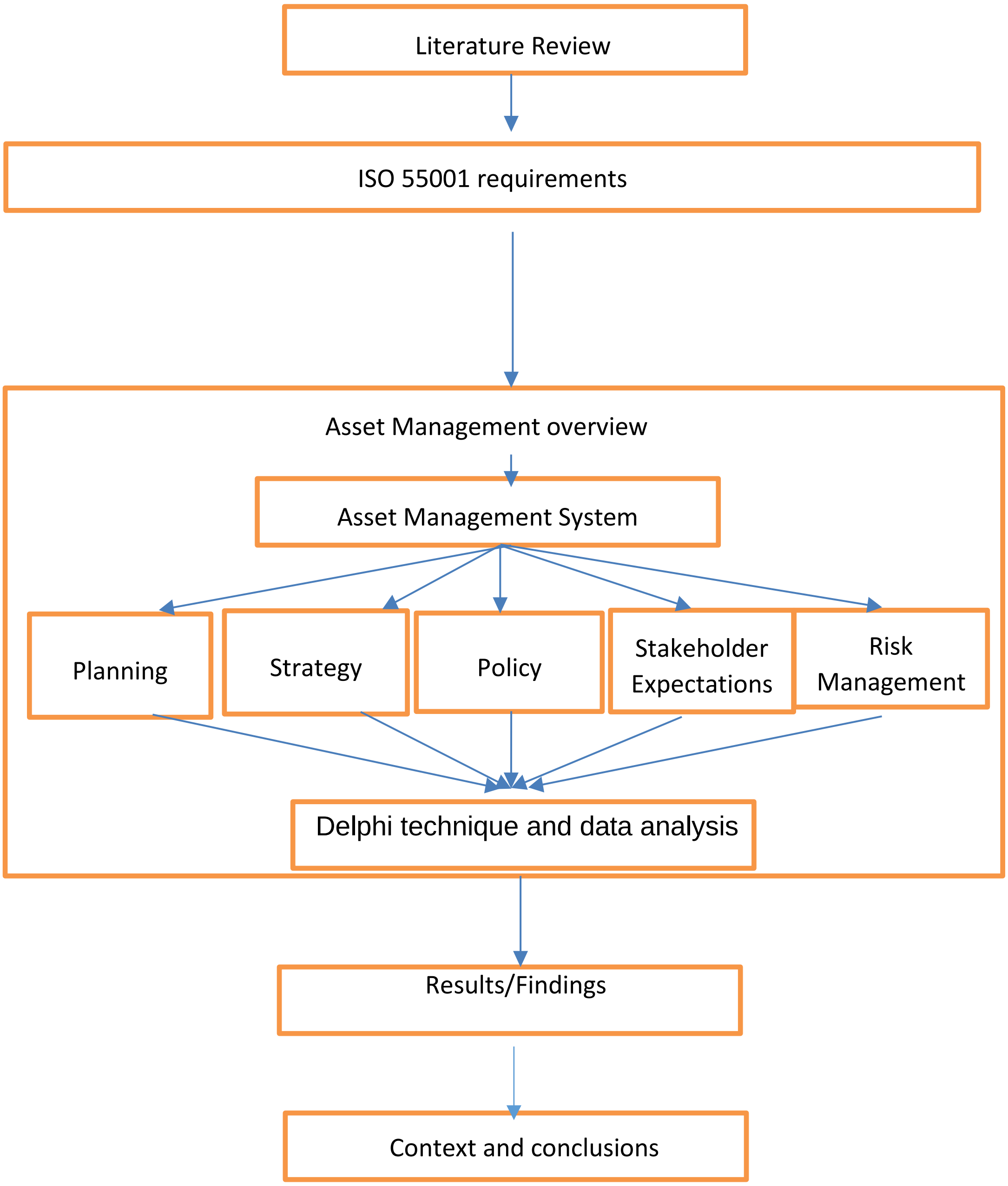

Figure 1: Impact assessment model (Source: Authors own work)

3.1. Methodology

Policy Delphi techniques are typically used to systematically build consensus among a panel of relevant participants, especially when scenarios are not well defined, and the issues are complex (Rayens & Hahn, 2000). Policy Delphi typically targets experts with diverse backgrounds, rather than using a homogeneous group of experts, and seeks to generate the strongest possible opposing views from experts on the potential resolutions of a major policy issue (Wiewiora et al., 2015). This result is achieved by a series of intensive questionnaires interspersed with controlled opinion feedback. The Policy Delphi method provides a useful means to inform asset management policy and strategy development within the context of complex asset organisations (McGeoch et al., 2014).

The key steps of the Delphi process are:

- Selection of experts
- Survey development
- Experts undertaking the Survey (round 1)
- Focus group discussion to gain greater depth of understanding of the topic and build consensus about the topic responses from the survey (round 2)
- Preparing the results.

3.1.1. Expert Selection

Expert selection is essential for the quality of the outcomes as inappropriate participant selection can cause results bias, thereby adversely impacting the method's validity (Merfield et al., 2019). This study adopted an expert selection process outlined by Wechsler (1978) including:

- Compiling a list of potential experts from different fields within AVs
- Increasing participation motivation to take part in this study by providing a briefing paper of the project, two weeks prior to the Policy Delphi round, allowing participants to reflect and add to the list of issues.

The experts for the Delphi process were contacted from around Australia (Perth, Adelaide, Sydney, and Melbourne). The experts were drawn from diverse backgrounds such as engineering and technology, industry experts, project management, working in a strategic organisational level, in intermediate roles and government transport.

Participants were contacted through email, zoom (video conference) and via phone to participate in this research. A total of twelve experts participated in both the rounds in the Delphi process. Table 1 presented the age of the survey participants.

Age	
40-44	25%
45-49	33.33%
50-54	16.66%
55-59	16.66%
Older than 60 years	8.33%

Table 1: Demographics of the data collected

The participants were provided with the participant consent form (Appendix 1) and Delphi Panel Briefing Document (Appendix 2).

3.1.2. Survey Development

The survey comprised a series of statements developed based on the learnings from the literature review and with consideration of opportunities and uncertainties presented by CAV uptake, less than 100% and 100%. The statements were grouped by the six asset management areas, as follows:

- Policy aspects comprised six statements,
- Strategy comprised six statements,
- Planning comprised five statements,
- Legislation/statutory requirements included three statements,
- Customer/ stakeholder expectations included five statements, and finally,
- Risk management included seven statements.

3.1.3. Undertaking the Survey (round 1)

The participants assessed the extent to which they agreed or disagreed with each statement. The questionnaire scored the statements according to a seven-point Likert scale where 1 = strongly disagree, 2 = disagree 3 = somewhat disagree, 4 = neither agree nor disagree, 5= somewhat agree, 6= agree and 7= strongly agree. The questionnaire aimed to take no longer than 30 minutes to complete.

3.1.4. Focus Group Discussion (round 2)

The focus group discussion allowed participants to clarify the survey responses, expand upon their contributions to the discussion and come to a consensus in regard to the results from round 1.

The focus group was conducted via a Zoom Meeting. Additional probing questions were raised by facilitators when there was a need to obtain a further explanation or provide additional information on the ideas raised. The session lasted for over an hour. The session was recorded and later transcribed. The questionnaire responses are strictly confidential and anonymous. The Delphi process was led by two facilitators. One was responsible for conducting the discussion, asking questions and maintaining the focus of the discussion. The second facilitator took notes and ensured the timeframe is maintained.

3.1.5. Data Analysis

The data analysis comprised data reduction, categorisation and recombination (Wiewiora et al. 2015). The categories were created according to themes identified as part of the requirements of the project, and more categories emerged from the analysis phase. Data was examined from different perspectives, to avoid oversimplification and to report on subjective views, looking for the most plausible explanation, identifying overall agreements and capturing opposing views.

3.2. Survey Results

The below Table 2 highlights the percentage share of responses from the questionnaire.

	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Neither agree or disagree (4)	Somewhat agree (5)	Agree (6)	Strongly agree (7)
POLICY							
1. Connected and autonomous vehicles uptake, particularly by freight operators, can result in changes re freight policies and strategies (e.g., access, productivity, fatigue management)							
Uptake <100%	0%	0%	8.3%	0%	8.3%	33.3%	50%
Uptake 100%	0%	0%	0%	0%	8.3%	16.6%	75%
2. Connected and autonomous vehicles uptake will improve car occupancy rate							
Uptake <100%	16.6%	8.3%	0%	33.3%	33.3%	8.3%	0%
Uptake 100%	16.6%	0%	0%	41.6%	0%	25%	16.6%
3. Autonomous vehicles will result in changes to road design and construction standards, perhaps less stringent/more relaxed road standards (e.g., geometry requirements, minimum lane width, overtaking opportunities)							
Uptake <100%	16.6%	8.3%	33.3%	8.3%	16.6%	16.6%	0%
Uptake 100%	0%	25%	8.3%	0%	8.3%	8.3%	50%
4. Autonomous vehicles uptake will result in creating national standards							
Uptake <100%	8.3%	0%	0%	16.6%	16.6%	16.6%	41.6%

Uptake 100%	0%	8.3%	0%	8.3%	0%	16.6%	66.6%

5. Autonomous vehicles uptake can facilitate the provision of incentives to people who use shared (rather than individuals who use private AVs) to minimise traffic congestion

Uptake <100%	8.3%	0%	8.3%	25%	33.3%	16.6%	8.3%
Uptake 100%	8.3%	0%	0%	25%	16.6%	25%	25%

6. Autonomous vehicles uptake can facilitate more peak usage through penalties for peak usage

Uptake <100%	8.3%	25%	8.33%	33.3%	16.6%	8.3%	0%
Uptake 100%	8.3%	25%	0%	33.3%	16.6%	0%	16.6%

STRATEGY

1. Connected and autonomous vehicles uptake impact real time data collection

Uptake <100%	0%	0%	8.3%	16.6%	16.6%	33.3%	25%
Uptake 100%	0%	0%	8.3%	16.6%	8.3%	8.3%	58.3%

2. Connected and autonomous vehicles uptake improve telematics (telematics is an interdisciplinary field that encompasses telecommunications, vehicular technologies, road safety, electrical engineering and computer science)

Uptake <100%	0%	0%	0%	8.3%	8.3%	50%	33.3%
Uptake 100%	0%	0%	0%	8.3%	0%	25%	66.6%

3. Connected and autonomous vehicles impact railway crossing strategy

Uptake <100%	0%	8.3%	8.3%	16.6%	33.3%	25%	8.3%
Uptake 100%	0%	8.3%	8.3%	8.3%	0%	25%	50%

4. Autonomous vehicles uptake eases congestion and traffic delays due to reduction in vehicles crashes

	Uptake <100%	0%	0%	0%	25%	66.6%	8.3%	0%
	Uptake 100%	0%	0%	8.3%	0%	16.6%	41.6%	33.3%

5. Autonomous vehicles usage can impact the use of active transport such as walking, cycling or public transport

Uptake <100%	0%	16.6%	8.3%	16.6%	33.3%	8.3%	16.6%
Uptake 100%	0%	16.6%	0%	8.3%	16.66	25%	33.3%

6. Autonomous vehicle usage results in building new roads

Uptake <100%	16.6%	25%	8.3%	41.6%	0%	8.3%	0%
Uptake 100%	16.6%	16.6%	16.6%	33.3%	0%	8.3%	8.3%

PLANNING

1. Connected and autonomous vehicle uptake impacts road investment planning process, particularly needs assessment

Uptake <100%	0%	0%	0%	8.3%	25%	33.3%	33.3%
Uptake 100%	0%	0%	0%	0%	8.3%	41.6%	50%

2. Connected and autonomous vehicles affect road maintenance practice

Uptake <100%	0%	8.3%	0%	8.3%	16.6%	41.6%	25%
Uptake 100%	0%	8.3%	0%	0%	8.3%	25%	58.3%

3. Autonomous vehicles uptake results in creating infrastructure considering low carbon economy (combination of EV and AV requires EV charging stations)

Uptake <100%	0%	8.3%	0%	25%	25%	41.6%	0%
Uptake 100%	0%	8.3%	0%	16.6%	0%	58.3%	16.6%

4. Autonomous vehicles uptake results in rethinking and adjusting the conventional tools (commercial vehicles usage, zoning, roadway classification systems, and street design standards) to take into account AVs

Uptake <100%	0%	8.3%	0%	8.3%	50%	25%	8.3%
Uptake 100%	0%	8.3%	0%	0%	33.3%	8.3%	50%

5. Autonomous vehicles uptake results in reduction of urban congestion if operated as shared rather than exclusive private ownership vehicle

Uptake <100%	0%	8.3%	0%	25%	41.6%	8.3%	16.6%
Uptake 100%	0%	8.3%	0%	8.3%	25%	8.3%	50%

LEGISLATION/STATUTORY REQUIREMENTS

1. Autonomous vehicle uptake facilitates legislation for interactions between all types of road users (autonomous and connected or manual operated vehicles, as well as other types of users)

Uptake <100%	0%	0%	0%	8.3%	25%	25%	41.6%
Uptake 100%	0%	0%	0%	8.3%	8.3%	33.3%	50%

2. Autonomous vehicles uptake results in changing the definition of "licensed driver"

Uptake <100%	0%	8.3%	8.3%	25%	8.3%	16.6%	33.3%
Uptake 100%	0%	8.3%	0%	8.3%	8.3%	16.6%	58.3%

3. Autonomous vehicles uptake will result in comprehensive regulation for future deployment of autonomous vehicles

Uptake <100%	0%	0%	0%	8.3%	33.3%	16.6%	41.6%
Uptake 100%	0%	0%	0%	8.3%	16.6%	16.6%	58.3%

CUSTOMER/STAKEHOLDERS EXPECTATIONS							
1. Connected and autonomous vehicles uptake results in changes in driver behaviour							
Uptake <100%	0%	0%	0%	8.3%	33.3%	33.3%	25%
Uptake 100%	8.3%	0%	0%	8.3%	8.3%	8.3%	66.6%
2. Connected and autonomous vehicles result in increased road user expectations regarding the level of service provided by the road (e.g., potentially increased posted speed, reduced delays, better road safety, access, but also Connected and autonomous vehicle amenities such as recharging stations)							
Uptake <100%	8.3%	0%	0%	16.6%	33.3%	25%	16.6%
Uptake 100%	8.3%	0%	0%	16.6%	16.6%	25%	33.3%
3. Connected and autonomous vehicles uptake results in changes to road design and construction standards, perhaps less stringent/more relaxed road standards (e.g., re geometry requirements, minimum lane width, overtaking opportunities)							
Uptake <100%	8.3%	33.3%	16.6%	8.3%	8.3%	25%	0%
Uptake 100%	16.6%	33.3%	0%	0%	0%	16.6%	33.3%
4. Autonomous vehicles uptake results in upskilling the workforce in road asset management							
Uptake <100%	8.3%	0%	0%	33.3%	33.3%	8.3%	16.6%
Uptake 100%	8.3%	0%	0%	25%	16.6%	16.6%	33.3%
5. Autonomous vehicles uptake results in interaction with electric micro-mobility such as scooters							
Uptake <100%	8.3%	0%	0%	25%	16.6%	33.3%	16.6%
Uptake 100%	8.3%	0%	0%	25%	0%	25%	41.6%

RISK MANAGEMENT

1. Connected and autonomous vehicles uptake affect road safety strategy

Uptake <100%	0%	0%	0%	0%	25%	50%	25%
Uptake 100%	0%	0%	0%	0%	16.6%	16.6%	66.6%

2. Autonomous vehicles uptake results in better programs to ensure saving lives (taking artificial intelligence as well as emotional intelligence) as compared to human drivers

Uptake <100%	0%	8.3%	0%	25%	25%	33.3%	8.3%
Uptake 100%	0%	0%	0%	33.3%	16.6%	25%	25%

3. Autonomous vehicle uptake results in more non-driving tasks for the primary occupant (for example, system failure, health and medical emergencies, monitoring travel routes)

Uptake <100%	0%	0%	0%	33.3%	41.6%	25%	0%
Uptake 100%	0%	0%	8.3%	16.6%	8.3%	41.6%	25%

4. Autonomous vehicles uptake results in determining warning system based on the differences in reaction times due to abilities, age etc.

Uptake <100%	8.3%	0%	8.3%	33.3%	16.6%	33.3%	0%
Uptake 100%	8.3%	0%	0%	33.3%	0%	25%	33.3%

5. Autonomous vehicles uptake results in the need for better protection of Autonomous vehicles related information from cyber threats

Uptake <100%	0%	0%	0%	0%	16.6%	33.3%	5%
Uptake 100%	0%	0%	0%	0%	0%	16.66	83.33

6. Autonomous vehicles uptake results in facilitating open data sharing for public acceptance of autonomous vehicles

Uptake <100%	8.3%	8.3%	8.3%	25%	25%	16.6%	8.3%
Uptake 100%	8.3%	8.3%	8.3%	16.6%	8.3%	16.6%	33.3%

7. Autonomous vehicle uptake results in creating a common database for a 'lessons learned' repository for automated vehicle technologies

Uptake <100%	0%	25%	0%	8.33%	33.33 %	8.33%	25%
Uptake 100%	0%	25%	0%	8.33%	25%	16.66 %	25%

Table 2: Delphi process, phase 1 results

4. Findings

This section describes the findings from phases 1 and 2 of the Delphi process.
An average of the level of agreement for each statement with policy, strategy, planning, legislation/statutory requirements, customer/stakeholder expectations and risk management is displayed.

The results for this section provide responses for both <100% and 100% uptake of AV. The findings from phase 1 are provided through a visual tool called a *spider diagram*. The spider diagram organises the responses from the survey and showcases the differences in the responses for <100% and 100% uptake AV within the seven scale 1-7 with 1 being strongly disagree and 7-strongly agree. It is followed by the key findings from the focus group (phase 2).

4.1.1. Policy

The asset management *policy* allows an organisation to apply asset management to specific objectives, it provides a statement of intent/commitment towards applying asset management principles (e.g. being proactive in changing environment; deliver value for customers) and key objectives (e.g. prioritise investment based on balancing customer outcomes, cost and risk; capture the right data to enable well informed decisions).

Phase 1 findings

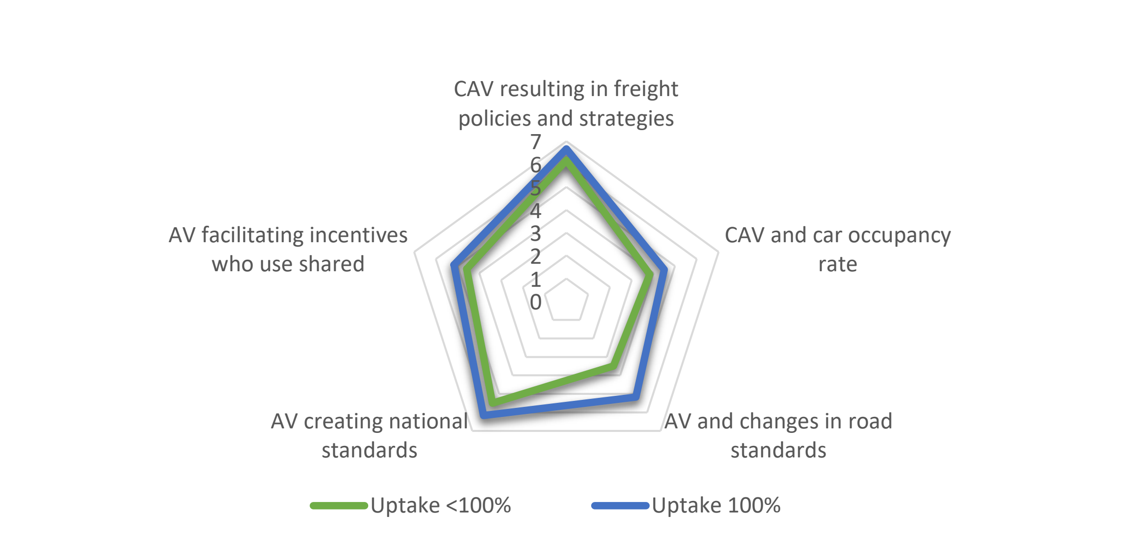

Figure 2: Spider diagram in relation to participants' response to *Policy* related questions (Source: Authors own work)

The majority of participants (91.66% for <100% and 100 for 100% uptake) agree (somewhat agree to strongly agree) that CAV uptake, particularly by freight operators, can result in *changes re freight policies and strategies (*e.g., access, productivity, fatigue management), for both scenarios (<100% and 100%) CAV uptake.

- Most of the participants were uncertain if CAV will improve *car occupancy rate*, with 41.66% being in the "neither agree or disagree category, and the rest split between agree and disagree.

- 58.2% of participants agreed that <100% uptake will not result in a change to *road design and construction standards;* however, for the 100% uptake, 67% agreed there is possible road construction and design standards may change.

- Regarding CAV facilitating the *provision of incentives to people who use shared CAV*; only 58.2% participants agreed that CAV will have impact <100%; however, for full CAV uptake, 66.6% had agreed (somewhat agree to strongly agree) that CAV can have an impact.

- Regarding CAV uptake impacting peak usage through penalties, participants disagreed from 41.63% for <100% uptake of AV while 33% respondents were uncertain for 100% AV uptake.

Phase 2 findings

- Policy requirements for CAV lack predictability due to the uncertainty of the CAV technology.
- The acceptance of new technologies such as CAV is dependent on policy changes.
- Standardisation in policy in certain areas is a requirement — for example, areas such as signage, speed limits, current technology, cameras.
- Considering the middle path to include national standards that can assist in achieving a compliance with the specifications such as road design, speed limits etc within individual jurisdictions.
- Regulating bodies and legal instruments would require differentiating binding and non-binding regulations for CAV implementations for the future.
- Policy around commuting might impact travel behaviour. For example, pricing single trips rather than round trips will encourage people to use shared vehicles.
- As there is a lot of uncertainty of 100% CAV uptake and rapid technological advancement on current CAV, the policy levers around implementing CAV on roads is a priority rather than changing road infrastructure.

4.1.2. Strategy

Asset management *strategy* outlines the implementation and documentation of asset management practices, plans, processes and procedures within an organisation. Asset management strategies can address specific activities, e.g. Maintenance Strategy. Asset management strategies cascade down from the asset management policy, then translate into planning processes and specific plans for implementation.

Phase 1 findings

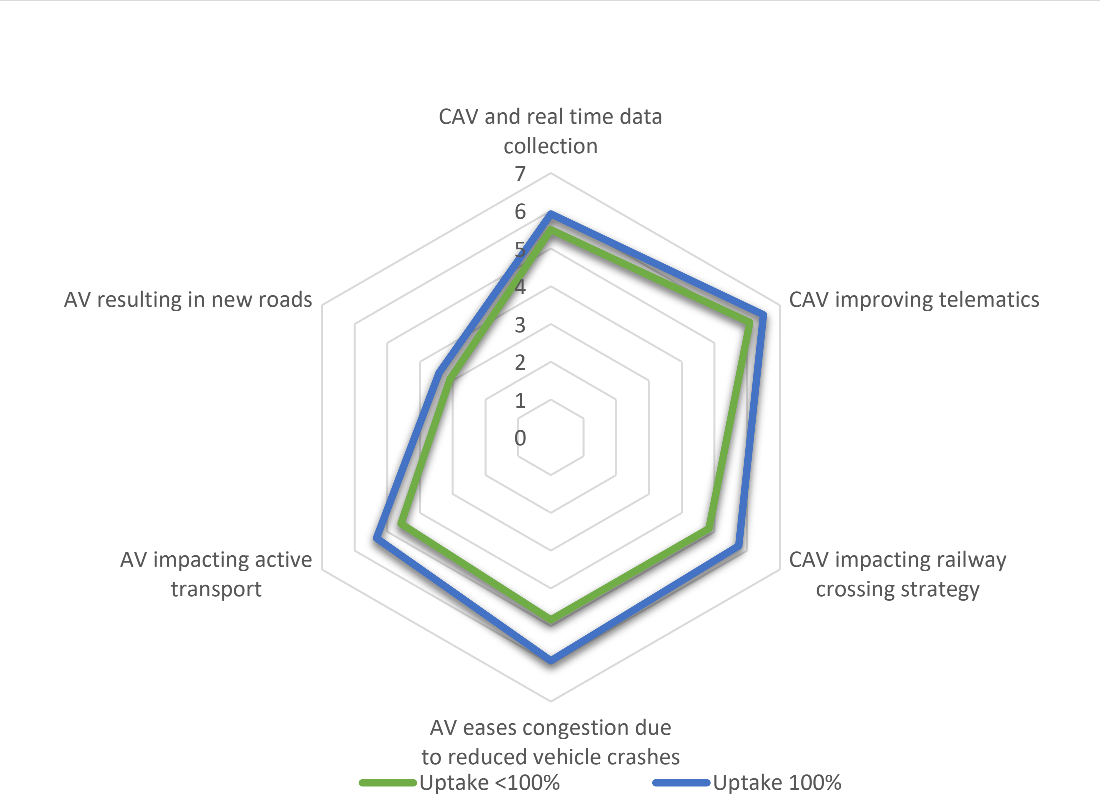

Figure 3: Spider diagram in relation to participants' response to S*trategy* related questions (Source: Authors own work)

- The majority of participants agreed (74.9%) that CAV can impact real-time data collection for both <100% and 100% uptake of CAV.
- Similarly, participants agreed (91.6% for <100% and 91% for 100% uptake) CAV uptake will improve telematics (telecommunications, vehicular technologies, etc), electrical engineering (sensors, instrumentation, wireless communications, etc.), and computer science (multimedia, Internet, etc.).
- The majority of participants agreed that CAV would impact railway crossing strategy (66.6% for <100% and 75% for 100%).
- There was a high rate of agreement in both scenarios (74.9% for <100% uptake and 91.5% for 100% uptake) that CAV will ease congestion and traffic delays due to a reduction in crashes.
- There was less agreement that CAV usage can impact active transport (e.g., walking, cycling, and public transport). A total of 58.2% agreed for <100% uptake and 75% agreed for 100% uptake.

- The need to build new roads due to CAV uptake was generally disagreed by 50% participants for <100% and 100% uptake of AVs.

Phase 2 findings

- As the regulations around CAV are not fully developed, the road agencies should be provided with guidance on operating and implementing CAVs by the government (at federal and state levels).
- Collecting data needs to follow common protocols in each jurisdiction in Australia to provide relevant and comparable information regarding the uptake of CAV to the agencies to check the readiness of CAVs in future. For example, the differences in the treatment, policy levers around incentives, and vehicle specifications of CAVs within different jurisdictions will impact the design of a national standard for CAV adoption in Australia.
- There is an opportunity for collecting data to improve CAV for future transport; however, there is no capacity for the government currently to analyse the data.
- The adoption of CAV is a gradual process and changing road design in the current scenario for <100% uptake for CAV might be irrelevant for road agencies.
- The change in road related infrastructure and amenities will have to include provision for other types of vehicles such as electric vehicles. For example, installing charging stations or signage specifically for EV might require road agencies to develop strategy for including EV exist with AV.

4.1.3. Planning

Planning in asset management fundamentals is a part of ISO 55001:2014. Clause 6, ISO 55000 defines an Asset Management Plan as “documented information that specifies the activities, resources and timescales required for an individual asset, or a grouping of assets, to achieve the organisation’s asset management objectives”. The planning process and plans can be in regard to any of the asset life cycles (e.g. maintenance, operations, replacement, disposal), and in regard to any asset (e.g. pavements, bridges, vehicle fleet). Plans can be operational, tactical or strategic.

Phase 1 findings

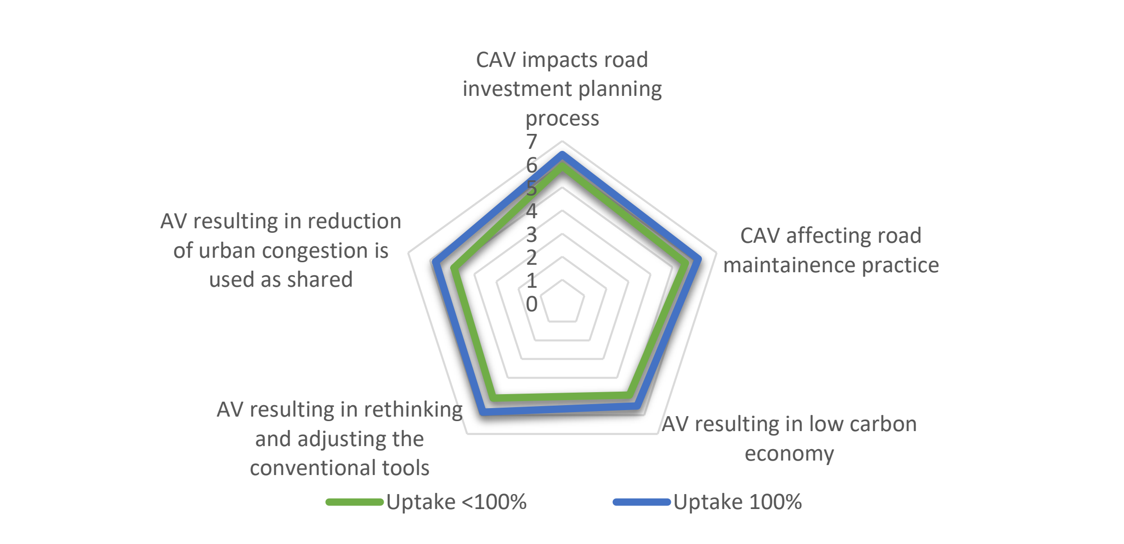

Figure 4: Spider diagram in relation to participants' response to *Planning* related questions (Source: Authors own work)

- Participants showed a high level of agreement on CAV impacting road investment planning process, particularly needs assessment (91.6% for <100% and 100% for 100% uptake).

- Participants also showed a high level of agreement that CAV can affect road maintenance practices (83.2% for <100% uptake and 91.6% for 100% uptake).

- The participants agreed (66.6% for <100% and 75.2% for 100% uptake scenarios) that the CAV uptake would consider planning for a low carbon economy (particularly planning for provision of EV and CAV charging stations).

- There was also a high level of agreement on AV resulting in rethinking and adjusting the conventional road management tools (commercial vehicles usage, zoning, roadway classification systems, and street design standards) (83.3% for <100% to 91.6% for 100%).

- Finally, 66.5% participants for <100% uptake and 83.3% participants for 100% agree that AV uptake will reduce urban congestion if operated as a shared rather than private vehicle.

Phase 2 findings

- The reliability of CAV depends on how the CAV reads speed signs and negotiates the road infrastructure.

- Privately operated shared CAVs and Mobility as Service (MaaS) vehicles should be integrated into a state-controlled public transport system with regulation of market entry, pricing, and service levels.
- The introduction of CAV will lead to a mixture of both automated and manually operated vehicles on the roads. Further, a vehicle may also have a manual mode and a fully automated mode which can be activated on different sections of the road.
- It is difficult to move directly from the current situation to 100% uptake without making changes to road infrastructure. Until the requirements of CAVs and AVs and level of acceptance of the general public is understood, it is difficult to make any changes in road infrastructure.
- The planning for the change in road infrastructure is dependent on demand. For example, Western Australia is in a unique position to incorporate AV on public roads as many mining companies have extensive experience in operating this technology. The spillover effects from the mining industry will encourage the use of AV technology to accelerate into public roads in Western Australia.

4.1.4. Legislation/Statutory Requirements

The *legislation and statutory* requirements comprise processes used by the organisation to ensure its asset management activities are compliant with relevant regulations (IAM, 2015).

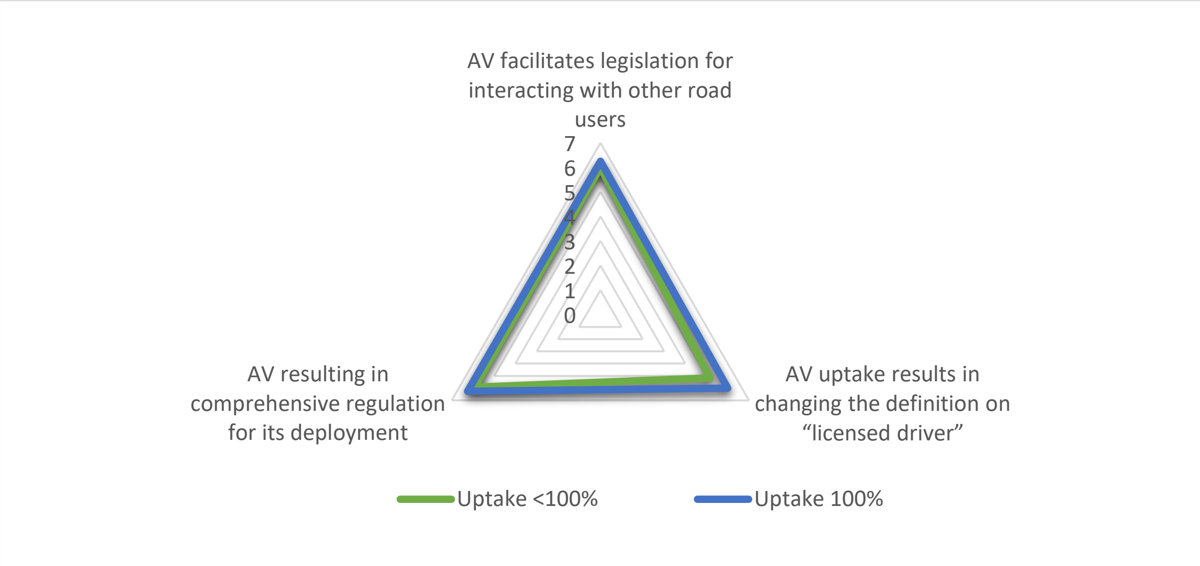

Figure 5: Spider diagram in relation to participants' response to Legislation/Statutory related questions (Source: Authors own work)

Phase 1 findings

- Majority of participants agreed that CAV uptake would require common types of legislations for interactions between all types of road users, autonomous and connected, or human-operated vehicles, as well as other types of users, (91.6% for <100% uptake and 100% for 100% uptake).

- There was agreement that in both scenarios, there is a need to change the definition of “licensed driver” (58.2% for <100% and 83.2% for 100%).

- Participants agreed that AV uptake would require comprehensive regulation for future deployment of CAVs (91.5% for <100% and 100% for 100%).

Phase 2 findings

- The 100% and <100% uptake of CAV will impact the existence of other vehicles. Legislation on restricting the purchase of non-CAV vehicles will encourage people to buy CAV.
- Advancement of technology will create a requirement to change policies. As we move towards 100% uptake of AV, the existence of other automated vehicles such as motorbikes along with AV cars will be prevalent.
- Asset managers and planners can rethink spaces to improve liveability. For example, a policy decision by the government to increase parking fees could encourage the use of public transport and in turn could facilitate CAVs. This approach will allow innovation, collaboration and generate new business models.
- Legislation may be required to ensure CAV’s are programmed to behave ethically. For example, the programs in CAVs may have to choose between harming several humans and harming one person.

4.1.5. Customer/Stakeholder Expectations

Customer and stakeholder expectations exert strong influences on an organisation’s ability to adopt and embed asset management policies successfully. It is essential that adequate time and efforts are invested to produce the performance and behaviours that will support the successful delivery of the asset management strategy and objectives (IAM, 2015).

Phase 1 findings

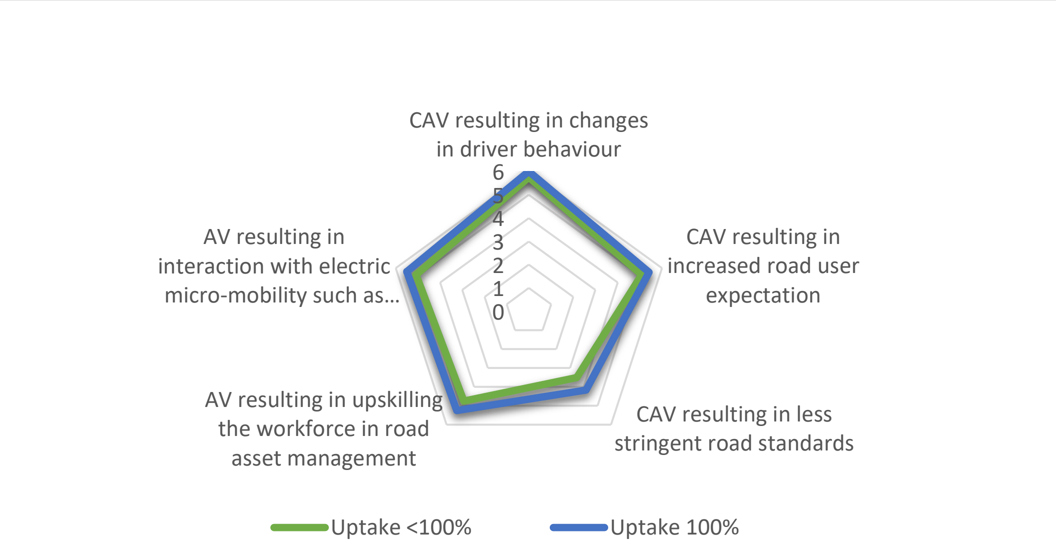

Figure 6: Spider diagram in relation to participants' response to *Customer/Stakeholders' Expectations* related questions (Source: Authors own work)

- Participants agreed CAV would impact driver behaviours in both scenarios (91.6% for <100% and 83.2% for 100%).

- 75% of participants agreed that CAV would also result in increased road user expectations regarding the level of service provided by the road for <100% and 100% uptake.

- Participants also agreed that CAV would require upskilling the workforce in road asset management (58.2% for <100% and 66.5% for 100%).

- There was a reasonable level of agreement (66.5% for <100% at 66% for 100% uptake) among the participants that AV uptake results in interaction with electric micro-mobility such as scooters.

- Participants disagreed CAV uptake will result in a change to road design and construction standards (58.2% for <100% and 50% for 100%).

Phase 2 findings

- CAV uptake will encourage ride sharing such as shared electric AV.
- Decision-makers need to encourage public transport as well as include infrastructure for charging in case of electric vehicles. Further, they could enable other business models such as uber, uber share and MaaS, to integrate into the public and private transport network.

4.1.6. Risk Management

The risk management aspects consist of the policies and processes for identifying, quantifying and mitigating risks and exploiting opportunities (IAM, 2015).

Phase 1 findings

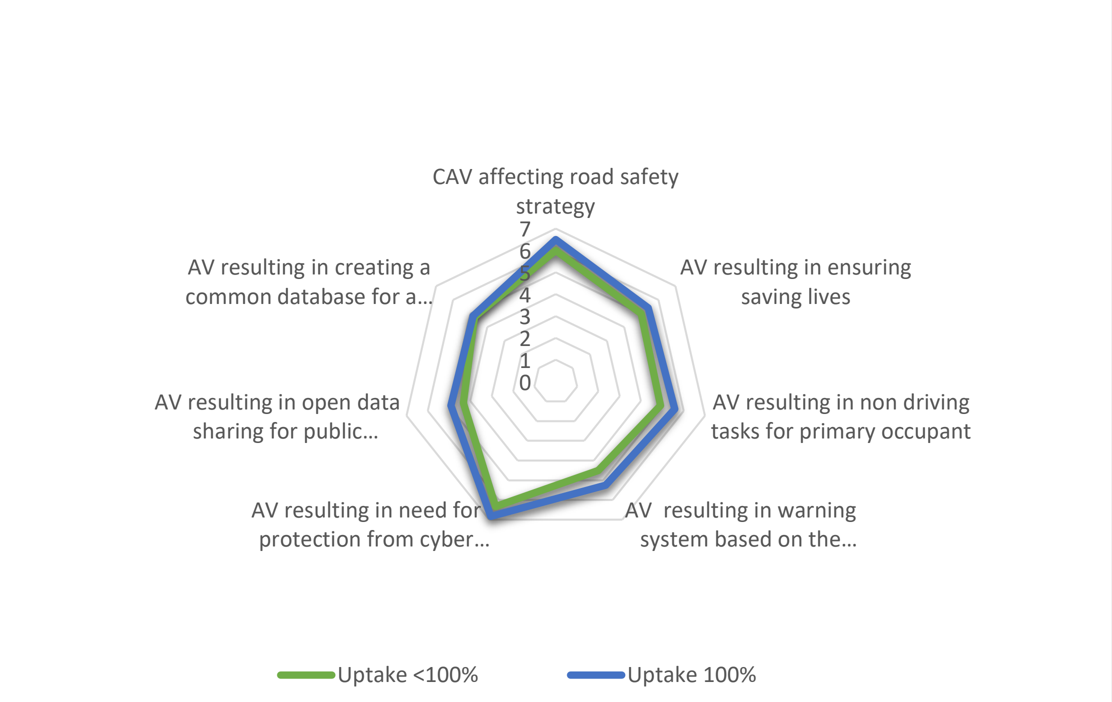

Figure 7: Spider diagram in relation to participants' response to *Risk management* related questions (Source: Authors own work)

- 100% participants agreed that CAV uptake will improve road safety.
- Participants also agreed that CAV uptake will result in better programs to save lives compared to human drivers. (66.6% for <100% uptake and 100%)
- There was agreement that CAV uptake results in more non-driving tasks for primary occupants (66.6% for <100% uptake and 75% for 100%)
- 55% for <100% and 55.3% for 100% agreed that CAV uptake will result in a in-built warning system taking into account how riders react to the technology due to abilities and age.
- There was 100% agreement for CAV uptake results in the need for better protection of CAV-related information from cyber threat.
- 50% for <100% and 58.2% for 100% had agreed that there is a need for open data sharing for public acceptance of AVs.
- 66.6% participants agreed that there are opportunities of creating a common database for a 'lessons learned' data repository for CAV technologies, irrespective of <100% or 100% uptake of CAV.

Phase 2 findings

- Artificial intelligence can assist CAV to increase safety. Including artificial intelligence into CAV will enable the scale of investment in addition to changing infrastructure of roads.
- There are risks about data being utilised for consumer products and advertising which can impact the future business model for AV sales.

A summary of the responses by the level of uptake and level of acceptance is presented in Figure 8, which shows the majority of responses indicate agreement CAV uptake will impact most asset management areas, for <100% and 100% uptake of CAV.

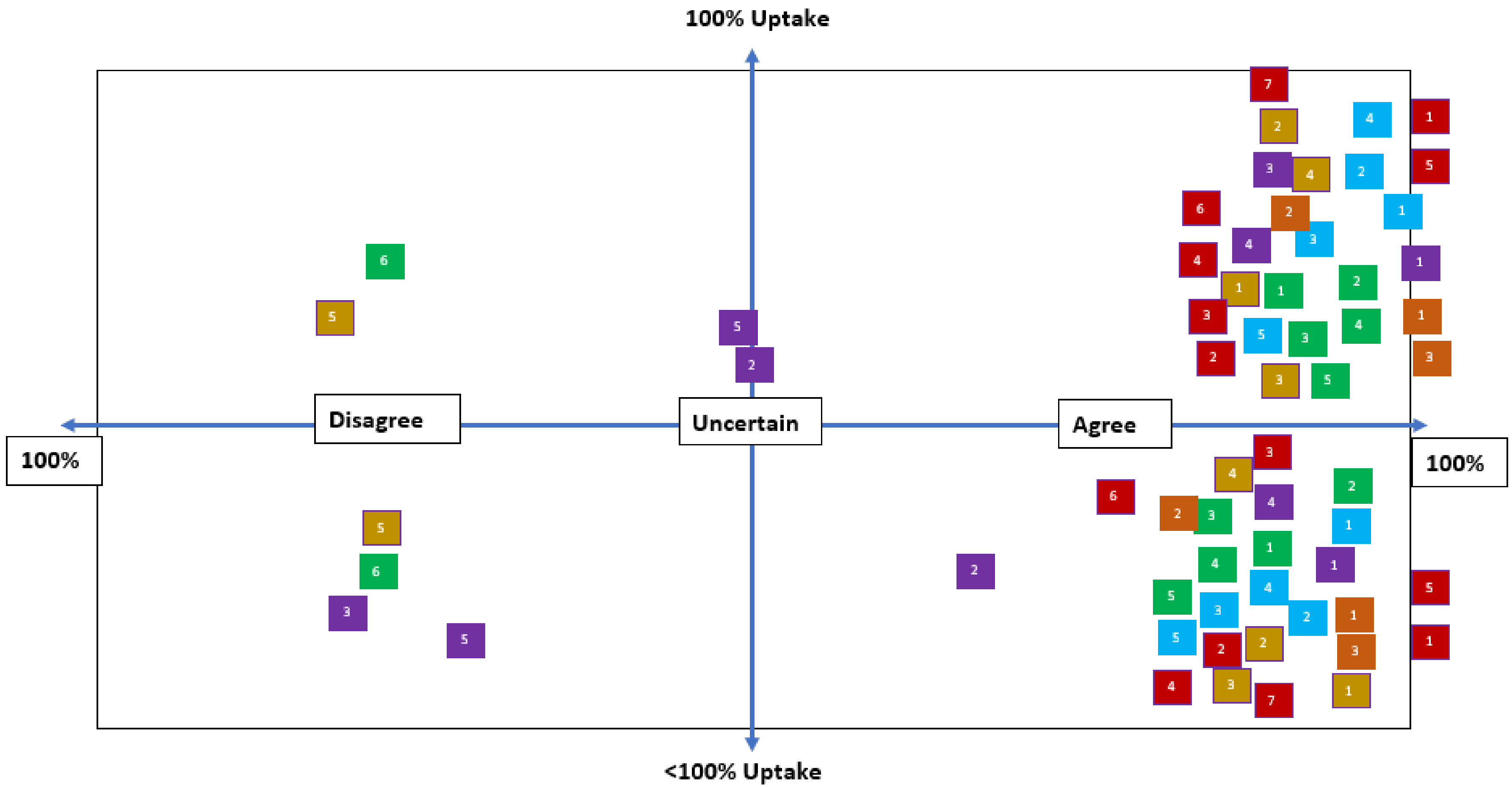

Figure 8: Policy: Purple; Strategy: Green; Planning: Blue; Legislation/Statutory: Orange; Customers/Stakeholders expectations: Yellow; Risk Management: Red: X-axis refers to level of agreement. Y-axis refers to uptake scenarios.

The number indicates statement number as follows:

Policy

1. Connected and autonomous vehicles uptake, particularly by freight operators, can result in changes re freight policies and strategies (e.g., access, productivity, fatigue management)
2. Connected and autonomous vehicles uptake will improve car occupancy rate
3. Autonomous vehicles will result in changes to road design and construction standards, perhaps less stringent/more relaxed road standards (e.g., geometry requirements, minimum lane width, overtaking opportunities)
4. Autonomous vehicles uptake will result in creating national standards
5. Autonomous vehicles uptake can facilitate the provision of incentives to people who use shared (rather than individuals who use private AVs) to minimise traffic congestion
6. Autonomous vehicles uptake can facilitate more peak usage through penalties for peak usage

Strategy

1. Connected and autonomous vehicles uptake impact real time data collection
2. Connected and autonomous vehicles uptake improve telematics (telematics is an interdisciplinary field that encompasses telecommunications, vehicular technologies, road safety, electrical engineering and computer science)
3. Connected and autonomous vehicles impact railway crossing strategy
4. Autonomous vehicles uptake eases congestion and traffic delays due to reduction in vehicles crashes
5. Autonomous vehicles usage can impact the use of active transport such as walking, cycling or public transport
6. Autonomous vehicles usage results in building new roads

Planning

1. Connected and autonomous vehicle uptake impacts road investment planning process, particularly needs assessment
2. Connected and autonomous vehicles affect road maintenance practice
3. Autonomous vehicles uptake results in creating infrastructure considering low carbon economy (combination of EV and AV requires EV charging stations)
4. Autonomous vehicles uptake results in rethinking and adjusting the conventional tools (commercial vehicles usage, zoning, roadway classification systems, and street design standards) to take into account AVs
5. Autonomous vehicles uptake results in reduction of urban congestion if operated as shared rather than exclusive private ownership vehicle

Legislation/statutory requirements

1. Autonomous vehicle uptake facilitates legislation for interactions between all types of road users (autonomous and connected or manual operated vehicles, as well as other types of users)

2. Autonomous vehicles uptake results in changing the definition of “licensed driver”
3. Autonomous vehicles uptake will result in comprehensive regulation for future deployment of autonomous vehicles

Customers/stakeholders expectations

1. Connected and autonomous vehicles uptake results in changes in driver behaviour
2. Connected and autonomous vehicles result in increased road user expectations regarding the level of service provided by the road (e.g., potentially increased posted speed, reduced delays, better road safety, access, but also Connected and autonomous vehicles amenities such as recharging stations)
3. Connected and autonomous vehicles uptake results in changes to road design and construction standards, perhaps less stringent/more relaxed road standards (e.g., re geometry requirements, minimum lane width, overtaking opportunities)
4. Autonomous vehicles uptake results in upskilling the workforce in road asset management
5. Autonomous vehicles uptake results in interaction with electric micro-mobility such as scooters

Risk Management

1. Connected and autonomous vehicles uptake affect road safety strategy
2. Autonomous vehicles uptake results in better programs to ensure saving lives (taking artificial intelligence as well as emotional intelligence) as compared to human drivers
3. Autonomous vehicle uptake results in more nondriving tasks for the primary occupant (for example, system failure, health and medical emergencies, monitoring travel routes)
4. Autonomous vehicles uptake results in determining warning system based on the differences in reaction times due to abilities, age etc.
5. Autonomous vehicles uptake results in the need for better protection of Autonomous vehicles related information from cyber threats
6. Autonomous vehicles uptake results in facilitating open data sharing for public acceptance of autonomous vehicles
7. Autonomous vehicle uptake results in creating a common database for a ‘lessons learned’ repository for automated vehicle technologies

5. Recommendations

The following section highlights some key recommendations arising from the impact assessment.

5.1.1. Provide a framework for digital infrastructure

- Apart from sensors that capture data about an AV's physical environment, the use of data from other sources external to the vehicle must be included to support a comprehensive understanding of the data.

- The provisions for collecting, sharing, storing and owning data require interventions from the government to introduce protocols to control the data related to CAV.

- The introduction of legislation and associated regulations should align with the global technology to ensure Australia as a key player in the global market for CAV.

- Data could provide key insights for manufacturers and consumers. This approach could include the availability of data in real-time and post real-time for specific platforms such as CAV and AVs. This approach will help the asset managers to better plan infrastructure for <100% and 100% uptake of CAV.

- The current advancement of CAV is technology agnostic. Rather than asset managers adapting the road infrastructure to the dynamic technological needs to accommodate CAV, the CAV had to adapt to the current road infrastructure to make progress as a future mobility solution

5.1.2. Develop and adapt standards in Australia

- It is essential that Australia does not miss out on the benefits of CAVs.
- The Commonwealth and state governments should establish competitive grants programs that encourage the trial of CAV technologies that can be adapted to the geographical or climatic conditions that are unique to Australia. This will further ensure that a standard is maintained unique to Australia.
- State, territory and local governments should plan for and adapt to future changes to Australia's AV fleet by undertaking consistent policies across all jurisdictions.

5.1.3. Provide mechanisms to improve safety

- Eliminating humans from driving would result in less or nil concentration lapses, road rage incidents, misjudgements, sensory limitations, drink and drug-affected driving and other causes of crashes. Further, there are issues related to safety incidents caused by the technology – e.g. Tesla fatalities caused by automated driving systems. These situations provide a case for policies designed to encourage 100% uptake of CAV. Sufficient evidence on a safe, efficient and equitable transport system by the introduction of CAVs will help government commit to spending funds on CAV infrastructure.

- As computer hacking and terrorism by malicious hackers of both CAV and smart infrastructure are serious concerns, data safety related to these issues must be taken seriously by policy makers

- The existence of other policy options such as pricing could ensure people are discouraged from using non-AVs or non-shared private travel.

References

Alessandrini, A., Campagna, A., Delle Site, P., Filippi, F., & Persia, L. (2015). Automated vehicles and the rethinking of mobility and cities. *Transportation Research Procedia, 5*, 145-160.

Anderson, J. M., Nidhi, K., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2014). *Autonomous vehicle technology: A guide for policymakers*: Rand Corporation.

Bagloee, S., Tavana, M., Asadi, M., & Oliver, T. (2016). Autonomous vehicles: challenges, opportunities, and future implications for transportation policies. *Journal of Modern Transportation, 24*(4), 284-303. doi:10.1007/s40534-016-0117-3

Bissell, D., Birtchnell, T., Elliott, A., & Hsu, E. L. (2020). Autonomous automobilities: The social impacts of driverless vehicles. *Current Sociology, 68*(1), 116-134. doi:10.1177/0011392118816743

Bolsin, N. (2018). Designing national guidelines for automated vehicle trials in Australia. *International Journal of Transport Development and Integration, 2*(2), 176-188. doi:10.2495/TDI-V2-N2-176188

Booth, L., Norman, R., & Pettigrew, S. (2019). The potential implications of autonomous vehicles for active transport. *Journal of Transport & Health, 15*. doi:10.1016/j.jth.2019.100623

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal, 9*(2), 27-40.

Bower, J. L., & Christensen, C. M. (1995). Disruptive technologies: catching the wave. *Harvard business review, 73*(1), 43–53.

Cervero, R. (2003). The built environment and travel: Evidence from the United States. *European Journal of Transport and Infrastructure Research, 3*(2), 119-137.

Chen, T. D., Kockelman, K. M., & Hanna, J. P. (2016). Operations of a shared, autonomous, electric vehicle fleet: Implications of vehicle & charging infrastructure decisions. *Transportation Research Part A: Policy and Practice, 94*, 243-254.

Curtis, C., Stone, J., Legacy, C., & Ashmore, D. (2019). Governance of Future Urban Mobility: A Research Agenda. *Urban Policy and Research, 37*(3), 393-404. doi:10.1080/08111146.2019.1626711

Daziano, R. A., Sarrias, M., & Leard, B. (2017). Are consumers willing to pay to let cars drive for them? Analyzing response to autonomous vehicles. *Transportation Research Part C: Emerging Technologies, 78*, 150-164.

Dent, C. (2018). Taking the human out of the regulation of road behaviour. *Sydney Law Review, The, 40*(1), 39-62.

El Zarwi, F., Vij, A., & Walker, J. L. (2017). A discrete choice framework for modeling and forecasting the adoption and diffusion of new transportation services. *Transportation Research Part C, 79*(C), 207-223. doi:10.1016/j.trc.2017.03.004

Faisal, A., Yigitcanlar, T., Kamruzzaman, M., & Currie, G. (2019). Understanding autonomous vehicles: A systematic literature review on capability, impact, planning and policy. *Journal of Transport and Land Use, 12*(1), 45-72. doi:10.5198/jtlu.2019.1405

Favarò, F., Eurich, S., & Nader, N. (2018). Autonomous vehicles' disengagements: trends, triggers, and regulatory limitations. *Accident Analysis & Prevention, 110*, 136-148.

Firnkorn, J., & Müller, M. (2015). Free-floating electric carsharing-fleets in smart cities: The dawning of a post-private car era in urban environments? *Environmental Science & Policy, 45*, 30-40.

Garrison, W. L. (2000). Innovation and transportation's technologies. *Journal of Advanced Transportation, 34*(1), 31-63.

Hietanen, S. (2014). Mobility as a Service. *the new transport model*, 2-4.

Higgins, J. P., & Green, S. (2006). Cochrane handbook for systematic reviews of interventions.

IAM. (2015). Asset Management-an anatomy. The Institute of Asset Management. https://theiam.org/knowledge/asset-management-an-anatomy/

International Organization for Standardization 2014, Asset management: overview, principles and terminology, ISO 55000:2014, Geneva, Switzerland.

Kane, M., & Whitehead, J. (2017). How to ride transport disruption -a sustainable framework for future urban mobility. *Australian Planner, 54*(3), 177-185. doi:10.1080/07293682.2018.1424002

Kaur, K., & Rampersad, G. (2018). Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars. *Journal of Engineering and Technology Management, 48*, 87-96.

Krueger, R., Rashidi, T. H., & Rose, J. M. (2016). Preferences for shared autonomous vehicles. *Transportation research part C: emerging technologies, 69*, 343-355.

Legacy, C., Ashmore, D., Scheurer, J., Stone, J., & Curtis, C. (2019). Planning the driverless city. *Transport Reviews, 39*(1), 84-102. doi:10.1080/01441647.2018.1466835

Lyon, B., Hudson, N., Twycross, M., Finn, D., Porter, S., Maklary, Z. and Waller, T., 2017. Automated vehicles do we know which road to take. I*nfrastructure Partnerships Australia.* https://infrastructure.org.au/wp-content/uploads/2017/09/AV-paper-FINAL.pdf

Mackie, T. (2018). Proving liability for highly and fully automated vehicle accidents in Australia. *Computer Law & Security Review: The International Journal of Technology Law and Practice, 34*(6), 1314-1332. doi:10.1016/j.clsr.2018.09.002

McGeoch, M., Brunetto, Y., & Brown, K. (2014). The policy delphi method: contribution to policy and strategy within energy organisations: a 2013 Malaysian case study with global implications. *Quality & Quantity, 48*(6), 3195-3208.

Merfeld, K., Wilhelms, M.P., Henkel, S. and Kreutzer, K., (2019). Carsharing with shared autonomous vehicles: uncovering drivers, barriers and future developments–a four-stage Delphi study. *Technological Forecasting and Social Change*, *144*, pp.66-81.

OECD. 2002. Asset Management for the Roads Sector. OECD https://www.itf-oecd.org/sites/default/files/docs/01assete.pdf

Pettigrew, S., Dana, L. M., & Norman, R. (2019). Clusters of potential autonomous vehicles users according to propensity to use individual versus shared vehicles. *Transport Policy, 76*, 13-20. doi:10.1016/j.tranpol.2019.01.010

Pettigrew, S., Fritschi, L., & Norman, R. (2018a). The Potential Implications of Autonomous Vehicles in and around the Workplace. *International journal of environmental research and public health, 15*(9). doi:10.3390/ijerph15091876

Pettigrew, S., Fritschi, L., & Norman, R. (2018b). The potential implications of autonomous vehicles in and around the workplace. *International journal of environmental research and public health, 15*(9), 1876.

Prideaux, B., & Yin, P. (2019). The disruptive potential of autonomous vehicles (AVs) on future lowcarbon tourism mobility. *Asia Pacific Journal of Tourism Research, 24*(5), 459-467. doi:10.1080/10941665.2019.1588138

Rayens, M. K., & Hahn, E. J. (2000). Building consensus using the policy Delphi method. Policy, *Politics, and Nursing Practice*, 1(4), 308-315.

Rowthorn, M. (2019). How Should Autonomous Vehicles Make Moral Decisions? Machine Ethics, Artificial Driving Intelligence, and Crash Algorithms. *Contemporary Readings in Law and Social Justice, 11*(1), 9-14. doi:10.22381/CRLSJ11120191

Shay, E., & Khattak, A. J. (2010). Toward sustainable transport: Conventional and disruptive approaches in the US context. *International Journal of Sustainable Transportation, 4*(1), 14-40.

Shin, K. J., Tada, N., & Managi, S. (2019). Consumer demand for fully automated driving technology. *Economic Analysis and Policy, 61*, 16-28. doi:10.1016/j.eap.2018.10.002

Standing, C., Standing, S., & Biermann, S. (2019). The implications of the sharing economy for transport. *Transport Reviews, 39*(2), 226-242. doi:10.1080/01441647.2018.1450307

Sun, Y., Olaru, D., Smith, B., Greaves, S., & Collins, A. (2016). *Road to autonomous vehicles in Australia: A comparative literature review.* Paper presented at the Australasian Transport Research Forum.

Sun, Y., Olaru, D., Smith, B., Greaves, S., & Collins, A. (2017). Road to autonomous vehicles in Australia: an exploratory literature review. *Road Transp. Res., 26*(1), 34-47.

Tan, Y., Mark, W., & Md, K. (2019). Disruptive Impacts of Automated Driving Systems on the Built Environment and Land Use: An Urban Planner's Perspective. *Journal of Open Innovation: Technology, Market and Complexity, 5*(2), 24. doi:10.3390/joitmc5020024

Tranter, K. (2016). The challenges of autonomous motor vehicles for Queensland road and criminal laws. *QUT Law Review, 16*(2), 59-81. doi:10.5204/qutlr.v16i2.626

Wechsler, W., 1978. Delphi-Methode: Gestaltung und Potential für betriebliche Prognoseprozesse. Florentz, München. https://www.abebooks.de/9783921491980/Delphi-Methode-Gestaltung-Potential-betriebliche-Prognoseprozesse-3921491983/plp

Wiewiora, A., Keast, R., & Brown, K. (2015). Opportunities and Challenges in Engaging Citizens in the Co-Production of Infrastructure-based Services in Australia. *Public Management Review*, 18(4), pp.483-507

Zhang, X., Liu, W., & Waller, S. T. (2019). A network traffic assignment model for autonomous vehicles with parking choices. *Computer-Aided Civil and Infrastructure Engineering, 34*(12), 1100-1118. doi:10.1111/mice.12486

Appendices

Appendix 1: Participant Consent Form

Chief Investigator: Professor Kerry Brown
School of Business and Law
Edith Cowan University
270 Joondalup Drive
JOONDALUP WA 6027
Phone: +61 8 6304 2157
Email: k.brown@ecu.edu.au

Participant Consent Form

Project title: Adapting portfolio-wide strategic infrastructure investment planning and asset management tools, guidelines and frameworks in the context of disruptive technologies
Approval Number: 2019-00902-BROWN
Principal Investigator: Professor Kerry Brown

I, ________________________________ have read the Participant Information Sheet. By signing this consent form, I acknowledge that I:

- have been provided with a copy of the Information Letter for Participants, explaining the research study
- have read and understood the information provided
- have been given the opportunity to ask questions and have had any questions answered to my satisfaction
- am aware that if I have any additional questions, I can contact the research team
- understand that participation in the research project will involve:
    - Participating in a Policy Delphi (as outlined in the Information Letter for Participants)
- understand that the information provided will be kept confidential, and that my identity will not be disclosed without consent
- understand that I am free to withdraw from further participation at any time, without explanation or penalty
- freely agree to participate in the project
- The data and/or samples collected may be used only for the purposes of this research project.

Yes ☐ *No* ☐ *I agree to have my conversations audiotaped*

Yes ☐ *No* ☐ *I agree to be photographed or videotaped*

Participant name: ________________________________

Signature: ________________________ Date ______________

Approval to conduct this research has been provided by the Edith Cowan University's Human Research Ethics Committee, approval number 2019-00902-BROWN, in accordance with its ethics review and approval procedures.

Appendix 2: Delphi Panel Briefing Document

Introduction: Disruptive technology and AVs

"Disruptive technology" as defined by Bower and Christensen (1995) refers to a technology that causes a change or paradigm shift and is set to revolutionise an existing system or process. This technology may result in lower cost and performance as measured by traditional criteria but having higher ancillary performance (Alessandrini et al., 2015). Disruptive technologies may enter and expand emerging market niches, improving with time and ultimately challenging or replacing established products in their traditional markets. Rapid advances in technology, combined with increasing interest in improving transport efficiency, enhancing productivity, efficiency, safety and security have led to the emergence of a wide range of disruptive transport technologies (Garrison, 2000).

In the area of transport infrastructure, an array of disruptive transport technologies is changing the way business operates, the nature of roles in the workforce, agile customer transactions and outcomes for users as to be more adaptable. The transportation environment is changing with the introduction of automated public transports on roads and on rails. More traditional passenger vehicles with increasingly greater automation will gradually hit our roads over the next 10–15 years. For example, and in Australia, it is anticipated that highly automated private vehicles (AVs) will be on the roads from 2020 to 2025, with fully AVs introduced sometime after this date (Kaye et al., 2019). Shared Autonomous Electric Vehicles (SAEVs) includes synergies between shared autonomous vehicle (AV) fleets and electric vehicle (EV) technology focusing on traveller range anxiety, access to charging infrastructure, and charging time management (Chen et al., 2016). There are transport planning implications for car sharing, including new trends in one-way car sharing, ride-hailing, and peer-2-peer options (Cervero, 2003). Mobility as a Service (MaaS) business models predicts that most AVs will be not owned by the public but rather be used as a service that will impact in our cities (Hietanen, 2014). Some examples of services include intelligent transport systems such as real-time traffic flow, allowing for monitoring of individual vehicle movements, enhance safety by allowing certain safety-critical control functions, traveller information services (Shay & Khattak, 2010) and multi-modal journey planning strategies. Options for AVs includes incorporating applications and smartphone payment options for transport services of all modes (Firnkorn & Müller, 2015).

Types of AVs and level of automation

While the terms autonomous and automated are closely related, they have been loosely used in the AV context. The US National Highway Traffic Safety Administration (NHTSA) defines automated vehicles as those capable of actuating at least some mission-critical controls with no human intervention (Yc Sun et al., 2017). AV technology exists in many distinct forms and with different levels of automation including "connected" vehicles, shared vehicles, driverless vehicles, electric vehicles and tailored vehicles (Legacy et al., 2019). There are three primary ways in which AVs are being introduced around the world (Pettigrew et al., 2018a):

1. the implementation of autonomous forms of public transport (e.g., trains and buses),
2. ride-share companies are developing autonomous fleets, and
3. individuals are purchasing personal vehicles with autonomous features (e.g., lane keeping systems, adaptive cruise control, parking assistance, automatic braking while skidding, and blind spot and collision warning systems

In line with the automation concept, a taxonomy of vehicle automation was developed by the Federal Highway Research Institute as four levels, developed by National Highway Traffic Safety Administration (NHTSA) as four levels, and by Society of Automotive Engineers (SAE) as five levels (Curtis et al., 2019; Tan, et al, 2019). The details are shown in Table 1:

	LEVEL OF AUTOMATION				
SOURCE	**0**	**1**	**2**	**3**	**4**
FEDERAL HIGHWAY RESEARCH INSTITUTE	Driver Only (Level 0)	Assisted (Level 1)	Partly automated (Level 2)	Highly automated (Level 3)	
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION (NHTSA)	No automation (Level 0)	Function specific automation (Level 1)	Combined function automation (Level 2)	Limited self-driving automation (Level3)	
SOCIETY OF AUTOMATIVE ENGINEERS (SAE)	No automation (Level 0)	Driver assistance (Level 1)	Partial automation (Level 2)	Conditional automation (Level 3)	Full automation (Level 5)

Table 1: Automation Level of AVs **(Curtis et al., 2019; Tan et al., 2019)**

Scope of this research

As a response to uncertainties for AVs, this study aims to explore Strategic Asset Management Planning for transport infrastructure and service delivery in the future that requires offering a strategic perspective to rethink the way transport assets facilitate the delivery of services into the future. It establishes a conceptual framework for setting business development objectives and contributing to desired strategic outcomes in the next generation transport context.

To respond to this aim, the research questions are:

- What are the uncertainties from emerging technologies that may shape the future of transport and infrastructure?
- What are the strategies to advance autonomous vehicles intended for state, regional, and local agency and political decision makers to frame public policy around these transformational technologies?
- What are the critical issues that transport-related departments and agencies will face regarding autonomous vehicles?

The scope of the work to be undertaken by the study are as follows:

- Examining the impact of AVs as disruptive technologies in transport including rail and road
- Two scenarios: Stage 1-Transition for less than 100% and Stage 2-100% CAV
- Advancing asset management in terms of innovation that impacts AVs and service delivery

ASSET MANAGEMENT POLICY CONTEXT

Section 5.2. Policy (ISO 55002 2014) The asset management policy provides the organization’s vision, values, intentions and directions about asset management. This policy should align with organizational objectives. The asset management policy is a short statement that sets out the principles by which the organization intends to apply asset management to achieve its organizational objectives. Asset management policy should support a principles-based approach. Eg. the asset management policy should relate to top management’s overarching intentions for assets, asset management and asset management systems and not relate to specific assets. The policy should set out the organization's commitments and expectations for continual improvement of assets, asset management and the asset management system. It should be aligned to, and demonstrate support for, the organizational objectives.

The asset management policy should align to the purpose of the organization and be consistent with the organizational plan and other relevant organizational policies. The asset management policy should provide guiding principles for asset management, and asset management objectives and include commitments for: a) adhering to applicable legal and regulatory requirements; b) providing resources to realise the asset management objectives; c) reporting on and evaluating asset management performance; d) supporting long-term objectives, sustainable outcomes and stakeholder requirements; e) abiding by any relevant contractual obligations; f) continual improvement of asset management and the asset management system.

Asset Management Policy - the translation of the Corporate Strategy for the process area of Asset Management; as such it is based on the Corporate Policy and Corporate Objectives. It has to be consistent with the Government Policy Framework and the Government Objectives and has to help to satisfy community needs and expectations. An Asset Management Policy is the overall basis of all Asset Management decisions and activities and, like the Corporate Policy, it includes a Vision and a Vision Statement, a Mission and a Mission Statement, and Principles for the area of Asset Management.

(Integrated Strategic Asset Management Guide, Australian Asset Management Collaborative Group, 2012)

Context

The uncertainty of AVs and planning for asset management is categorised under six groups; Planning, policy, strategy, customer/stakeholders expectations. Risk management, legislation/statutory requirements.

Planning

1. The state and local transportation agencies can use autonomous vehicles to cooperate with other travel modes (as well as broader community goals) (Alessandrini et al., 2015).
2. The implementation of AVs should consider uncertainty regarding how the technology will be implemented (Daziano, Sarrias, & Leard, 2017).
3. Planners need to rethink conventional tools and develop new tools and practices to meet future challenges (Anderson et al., 2014).
4. Many of the benefits claimed for the new technologies in safety and more efficient use of contested urban space are expected to be realised only when the transition to full autonomy is reached, and when these vehicles operate as “robo-taxis” rather than in exclusive private ownership (Curtis et al., 2019).
5. It is important to understand sharing economy developments in order to assess their potential impact on public transport demand and road use (Standing, Standing, & Biermann, 2019).
6. There is a need to proactively manage the transition to AVs to minimise the disruptive effects of inevitable job losses in driving and related occupations (Pettigrew, Fritschi, & Norman, 2018b).

Policy

1. Autonomous vehicles will affect infrastructure planning decisions and will impact the design and costs of infrastructure. National standards are particularly important when considering smart infrastructure and vehicle communications (Yuchao Sun, Olaru, Smith, Greaves, & Collins, 2016).
2. Governments will need to establish regulations for the systems, and regular testing regimes (Pettigrew et al., 2018a).
3. The peculiarities of Australian urban politics and patterns of urban development mean that local AV futures will be influenced but not determined by European and North American practice(Legacy et al., 2019).
4. Policy debates on the adoption of AVs are likely to involve more than their direct impact on mobility and will be caught up in the wider discussion on responses to climate change and a shift to a low-carbon economy (Prideaux & Yin, 2019).
5. The AV technology will also dramatically lower the likelihood of accidents so that the insurance primes contained in current carsharing rates could be reduced (Krueger et al., 2016).
6. Policymakers could potentially consider offering incentives to people who use shared AVs (rather than individuals who use private AVs) to encourage vehicle sharing and limit the potential negative effects of the introduction of these vehicles (Kaye et al., 2019).
7. Privacy issues with personal data sharing may be another constraint with public acceptance of fully AVs. Thus, it is important that future policies take into consideration the privacy issues

involved in the use of sharing data and respect the privacy of AV owners/operators (Kaye et al., 2019).

Strategy

1. Three main factors related to AVs that affect congestion positively and sometimes negatively: (i) reducing traffic delay due to a reduction in vehicle crashes; (ii) enhancing vehicle throughput; and (iii) changes in the total vehicle-kilometre travelled (Bagloee, Tavana, Asadi, & Oliver, 2016).
2. Optimize the parking planning and parking pricing strategy depending on different socioeconomic objectives (Zhang, Liu, & Waller, 2019).
3. The results highlight the need to proactively develop strategies to optimize the use of active transport before, during, and after the wide-scale introduction of AVs (Booth, Norman, & Pettigrew, 2019).

Customer/Stakeholder Expectation

1. Fully AVs have the ability to transport a number of people. Drones could also be used in some cases in order to monitor traffic flow. Other technological advancements in electric micro-mobility industry (e.g., electrical bikes and scooters) may assist with reducing traffic congestion (Kaye et al., 2019).
2. Major technological and infrastructural changes over the next decades, such as the introduction of autonomous vehicles.
3. Implementation of mileage-based fees, carsharing and ridesharing are expected to have a profound impact on lifestyles and travel behaviour (El Zarwi, Vij, & Walker, 2017).
4. The levels of awareness and cultural differences, have led to a wide range of attitudes around the globe for AVs (Yc Sun et al., 2017).
5. Considering that people who do not have cars or drivers' licenses are more willing to accept automated driving than people who do have cars and drivers' licenses, and thus resulting in the expansion of usage for people without cars (Shin, Tada, & Managi, 2019).
6. The acceptability of fully autonomous vehicles in future transportation systems will depend on how intelligent it appears to the other road users. A socially acceptable behaviour would be adapting the social rules of the road and understand the intentions of different road users to take critical traffic decisions(Gupta et al., 2019).
7. Males, younger people, and those living in urban areas tending to be more positively oriented to AVs (Pettigrew, Dana, & Norman, 2019).

Risk Management

1. As fully driverless cars have not been advanced, their efficiency is hard to forecast (Rowthorn, 2019).
2. An obvious impact will be that congestion should improve due to the decrease in human-error road accidents and because of the improved efficiency of autonomous driving. AVs, by having the ability to constantly monitor traffic (Kane & Whitehead, 2017).
3. AVs should be able to prevent an appreciable number of the crashes, in turn eliminating the vast majority of all traffic delays (Bagloee et al., 2016).

Legislation/Statutory Requirements

1. There is a requirement for legislation that either promotes global mitigation strategies to reduce GHG emissions (Prideaux & Yin, 2019).
2. Designated as independent contractors, these workers have no rights to sick leave, annual leave, or maternity pay, and from a legal perspective have little protection from the organizations that they provide their labour for. It is vital, therefore, in the transition to autonomous mobilities that the kinds of employment that are created are scrutinized for their labour standards(Bissell, Birtchnell, Elliott, & Hsu, 2020).
3. Another Australian-specific issue was compulsory third-party (CTP) insurance which is required for all vehicles in all states in Australia (Bolsin, 2018).
4. To avoid regulatory error, a safety management plan is required from each trialling organization that reflects the technology being tested (Bolsin, 2018).
5. It also suggests that as fully AVs become more widespread and accepted, there might need to be further reforms to the licensing and the registration regimes (Tranter, 2016).

6. Standards of behaviour that road users are expected to abide by. Some of these relate to behaviour that may be seen as ‘common courtesy’, such as letting a driver on a side street into traffic when stopped at a set of traffic lights (Dent, 2018).
7. The regulation of road behaviour can be extended to include those processes that are available to seek redress for any harm suffered as a result of a breach of the rules (Dent, 2018).
8. According to National Transport Commission (NTC), it is recommended that “whether human monitoring of an automated vehicle constitutes legal control of the vehicle requires clarification”, and for the purposes of road rules and insurance schemes, the legal definition of a ‘driver’ should be clarified on the same basis (Mackie, 2018).

What we would like you to do, how and when

The task is to produce consensus statements on criteria provided above for planning, policy, strategy, customer/stakeholders expectations, risk management, legislation/statutory requirements. We are inviting you to be a member of our Delphi panel; if you agree, please return the attached form stating your agreement.

A Delphi panel is a way of working towards consensus on a topic or question. It consists of a number of rounds (usually two or more), in which you will be asked to do a task which involves *scoring* a draft set of statements. There will be a deadline for this, because we can’t analyse the responses until everyone has replied. We anticipate it will take between 30 and 60 minutes to complete the scoring for each round. This is done in your own time, and we will give you about 4 weeks to do it. You will be requested to provide your opinion through an online questionnaire (30-60 minutes).

After each scoring round, you will be sent your own scores *and* the distribution of scores for everyone in the group. If you find you are an ‘outlier’, you have two choices: amend your score (after reflecting on the statement and why you scored it as you did) – or stand your ground and argue your case to the group (they won’t know how you scored the statement). Based on the results, another round will take place to collect your opinion in the second stage through Zoom (45-55 minutes). Even if you scored a statement similarly to the group average, you may be swayed to change your score by arguments put subsequently.

Participation Instructions

Statements are scored on the dimension below:

- Relevance (should we include this topic/theme at planning, policy, strategy, customer/stakeholders expectations, risk management and legislation/statutory requirements) and
    - Identify and rate -1-5
    - (On a scale 1-5, where 1 = highly critical importance, 2 = strong importance 3 =moderate importance, 4 = weak importance and 5= unimportant)
- In view of the information above (Briefing Paper)
    - What are the key actions? What needs to be done to get there?
    - Please prioritise these – list and rate.

Here’s what we’d like you to do now:

- Read this background paper
- Either complete the form giving your consent or let us know if you do not wish to take part.

If you would like to take part, you will receive a ROUND 1 email. You should then:

- Respond to the ROUND 1 email within 4 weeks by looking at the statements and entering your scores for each (we’ll give you a link to an online questionnaire)
- Wait while we analyse the data and send you back your scores
- Join in an online discussion on how we might amend the statements
- Repeat the last three steps for ROUND 2 (expected in around one-month time)