Adapting Strategic Asset Management Practice for CAV

Final Report (Part 3): Recommendation for Asset Managers

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PART 3: Recommendations for Asset Managers

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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 and the Western Australian Local Government Association.

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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 so far about monitoring CAV technological developments and trials, and identifying and developing legislation and regulatory requirements, governance frameworks, harmonisation of certain parameters etc. 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, as individual vehicles, buses, commercial vehicles, or trains will operate on the existing infrastructure assets. This project explores how they 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 a summary of learnings for asset management in regard to each of the six areas.
- 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 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 Part 3 of the Final Report of the project.

The findings of the project are that CAV uptake will:

- Affect asset management in many areas including policy, strategy planning, customer and stakeholder expectation, statute and legislation and risk management.
- Provide several opportunities for improving asset management outcomes including improved road safety, decreased carbon emission, reduced traffic congestion, improve mobility, intermodal integration, optimised supply chains and reduced transport cost.
- Present also some challenges, particularly in relation to managing a rapidly changing transport market with a transition to Mobility as a Service (MaaS) and the rapid increase in micro-mobility, fueled by technology changes and increased customer expectations re improved mobility.

In terms of the big picture for CAV uptake, asset managers need to be proactively engaged with three key areas:

- development of a framework for digital infrastructure to support safe, cybercrime protected vehicle-to-vehicle and vehicle-infrastructure communication,
- national policies, standards, governance and regulation for CAV uptake, and
- CAV infrastructure decisions.

Overall, it is difficult to predict with a high degree of confidence all the implications for asset management resulting from the uptake of CAV especially at the 100% uptake point. Asset managers need to constantly monitor CAV technology progression, capture results of trials and any relevant information available, be involved and contribute to national policies and be ready to adapt their practice as required.

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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 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 electric automated and connected 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 so far about monitoring CAV technological developments and 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 about how the uptake of CAV may impact the practice of asset management. CAV in any form, as individual vehicles, buses, trains or commercial vehicles will operate on existing infrastructure assets. This project explores how CAV may influence the business of asset management, and what opportunities, if any, CAV can facilitate. More specifically, the impact of CAV on asset management is assessed in relation 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 stakeholders' expectations and risk management.

The Final Report of the project 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 the findings from the assessment.

- Part 3 summarises asset management considerations for the six areas of focus identified through the literature review and the impact assessment and identifies opportunities and uncertainties for asset management.

This is Part 3 of the Final Report of the project.

1.1. Terminology

Mobility
Mobility is the ability and level of ease of moving goods and services.

Mobility as a Service (MaaS)
Mobility-as-a-Service is considered the biggest transport revolution of the 21st century. The key concept behind MaaS is to put the users at the core of transport services, offering them tailor-made mobility solutions based on their individual needs. Mobility-as-a-Service (MaaS) is a type of service that through a joint digital channel enables users to plan, book, and pay for multiple types of mobility services. The concept describes a shift away from personally owned modes of transportation and towards mobility provided as a service.

Micromobility
Micromobility refers to a range of small, lightweight vehicles operating at speeds typically below 25 km/h (15 mph) and driven by users personally (unlike rickshaws). Micromobility devices include bicycles, Ebikes, electric scooters, electric skateboards, shared bicycles, and electric pedal-assisted (pedelec) bicycles.

Shared Economy
Sharing economy is a term for a way of distributing goods and services, a way that differs from the traditional model of corporations hiring employees and selling products to consumers. In the sharing economy, individuals are said to rent or "share" things like their cars.

2. Asset management, a brief description

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 *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).

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 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 category (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 to 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

In order to assess the impact of CAV uptake on asset management, a model and methodology were developed, as outlined in the Part 2 report. The diagrammatic representation of the impact assessment framework is set out in Figure 1 below.

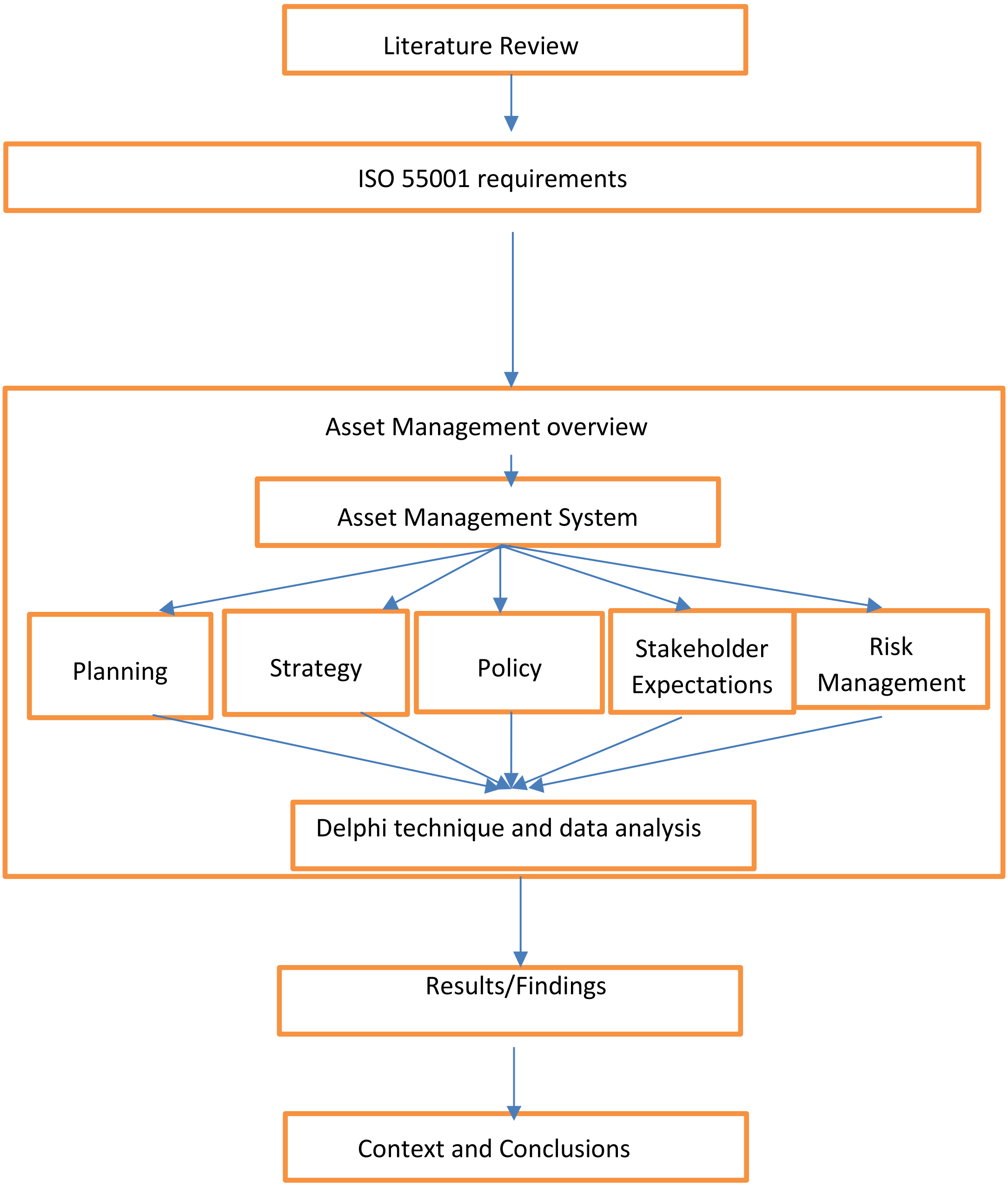

Figure 1: Impact assessment framework

In essence, the model considers the learnings from the literature review (Part 1 Report) to establish the context for asset management, and these are further analysed for each of the six asset management areas and considering the two scenarios of less than 100% and 100% for CAV uptake. The model was used in conjunction with a Delphi methodology, which involves participants undertaking a structured survey, followed by a focus group discussion to gain a greater depth of understanding of the topic and build consensus about the topic responses from the survey.

The results from the impact assessment and Delphi process are presented in the Part 2 report.

4. Considerations for Asset Management

4.1. CAV Context

This section outlines briefly the categories of CAV being introduced around the world, and CAV technology and levels of automation. A comprehensive description of CAV developments in Australia and overseas is presented in the Part 1 report.

There are three primary ways in which CAV are being introduced globally (Pettigrew, Fritschi, & Norman, 2018):

- the implementation of autonomous forms of public transport (e.g., trains and buses),
- ride-share companies are developing autonomous fleets, and
- 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).

CAVs are required to adapt to the driving environment to complete a range of tasks from simple through to very complex, relying on internal sensors and systems such as LIDAR and cameras; and other external inputs such as data packets from other connected vehicles or cloud services. These inputs allow the machine to develop a model of its environment and continually interpret the model to control the vehicle appropriately. There is a significant trend towards higher levels of automation in new vehicles as well as connectivity achieved through interoperable cooperative ITS systems and cloud connectivity.

'Partial' CAVs that can drive themselves in limited scenarios are already on the roads. However, the driver is still responsible for monitoring the driving environment and must be ready to take back control (e.g., highway driving assist, traffic jam assist). Some automakers, including GM and Ford, proposed automation would occur in a progression of steps featuring increasing autonomy. Other automakers, and the technology companies such as Google are taking to the path of AVs.

Table 1 describes the different levels of automation and the possible timeline of implementation.

Timeline	2010>	2015>	2020>	2025>	2030>
Level 1-Driver Assistance	< Park Steering Assist-low Speed				
	< Adaptive Cruise Control (ACC)-high-mid speed				
	Lan Keep Assist (LKA)-active lane centring, high mid speed				
Level 2-Partial Automation	Low speed-Auto Parking Assist				
	High-to-mid speed-Highway Driving Assist (eg ACC+ LKA+ (Automatic Emergency Braking (AEB))				
	Mid-to-low speed-Traffic Jam Assist (eg ACC + LKA +AEB + Stop&Go)				
Level 3-Conditional Automation		Low speed-Auto Valet Parking			
		High-mid speed, low-mid complex roads-Auto Hwy Chauffeur			
			Truck Platooning-only on specific roads		
			Hi-mid-low speed, highly complex urban and rural roads		
Level 4-High Automation			Low speed-Auto Parking Pilot		
				L4 on specific roads	
			Driverless (always in auto pilot), but road access limited		
Level 5-Full Automation					Driverless, all roads

Source: Developed by Austroads following discussions with vehicle manufacturers and wider industry (Huggins. et. al 2017).

5. Asset Management Considerations

The following section outlines findings from the literature review relevant for asset managers regarding the adoption of CAV, covering the six areas of asset management: planning, policy, strategy, customer/stakeholder expectation, risk management, and legislation/statutory requirements.

5.1. Policy

- Vehicle Safety & Cyber Security Frameworks may need to be developed to assess the robustness of in-vehicle software. These can help also redefine and re-assess vehicle licencing registration requirements.

- Policy debates on the adoption of CAVs 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 (Preideaux and Yin, 2019).

- CAV technology can potentially lower accidents in the AV uptake scenarios so that the insurance premiums will emphasise losses that are not caused by crashes (Krueger et al., 2017).

- Policymakers could potentially consider offering incentives for ridesharing to encourage reduced vehicle ownership, and in turn, lower the number of vehicles on the road, resulting in reduced traffic congestion (Kaye et al., 2019).

- Privacy issues with personal data sharing may be another constraint with public acceptance of fully CAVs. It is essential that future policies take into consideration the privacy issues involved in the use of sharing data and ensure the privacy of CAV owners/operators.

- The Guidelines for Trials of Automated Vehicles in Australia in 2017 have opened the way for larger-scale trials with a view to commercial deployments. Governments will need to monitor and review the regulations for the CAV systems operating on different levels, and regular testing regimes to monitor their performance.

- Autonomous vehicles can 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.

5.2. Strategy

- CAV uptake with its full range of safety features will enhance the benefits of the Safe System approach advocated by the road safety strategy, by minimising or possibly eliminating the impact of driver behaviour and by increased safety resilience from the vehicle perspective. CAV technology can communicate directly with traffic lights and integrate with pedestrian pathways, hence potentially reducing the incidence of road crashes.

- It is expected CAV uptake will improve mobility and can have a significant impact on travel demand management and sustainable transport, with flow-on effects into broader areas such as climate change and digitisation, if managed in conjunction with the sharing economy and increasing urban density.

- CAV can further improve the performance of smart infrastructures, such as Smart Freeways/ramp metering, and will need to be captured in asset management strategies.

- Maintenance strategies can consider the use of driverless cars as utility vehicles for rubbish collection and road sweeping on urban roads at night, therefore not impeding traffic during the day (e.g. as in the example of Singapore).

- CAV adoption can drive the optimisation of parking planning and parking pricing strategy, following the expansion of the sharing economy.

- There is a need to proactively develop strategies to optimise the use of active transport such as walking, cycling or public transport before, during, and after the wide-scale introduction of CAVs (Booth et al., 2019).

- There is a potential to establish a **'lessons learned' repository** for Australian trials of automated vehicle technologies, connected vehicle technologies and zero and low-emission vehicle technologies. If established, the repository could enable asset managers to periodically revise their strategies, policies, and planning in order to take into consideration, where appropriate, any significant advances in technology and overall CAV functionality, particularly in regard to the vehicle to vehicle and vehicle to infrastructure communication.

5.3. Planning

- CAV-enabled mobility could be a central feature in Australia's future town-planning by enabling commuters to change transport modes effortlessly and by improving supply chains offering better first- and last-mile connectivity.

- CAV can revolutionise future public transport in urban and suburban environments, by making timetables and fixed bus stops obsolete, and by offering a service that will allow passengers to call and hop on and off a ride at any time. It has the potential to free up road space which can be repurposed for other activities.

- CAV, either cars, buses, freight trucks or light rail present the opportunity for transport planners to achieve better intermodal integration.

- Planning processes, including project assessment and prioritisation, need to be adapted to include uncertainties arising from the uptake of CAV (Daziano et al.,2017). Planners need to rethink conventional tools and practices to meet future challenges. Road user cost models such as tolls, vehicle registration will need to be modified to account for CAV.

- CAV uptake and CAV data have the potential to support governments in improving network efficiency and safety and inform investment decision making. There is a need to develop learnings, potentially drawing from trials, to inform the approach to data that would help guide governments developing policies and plans for data usage while protecting data privacy. Any CAV data projects should align with other data projects and national data consistency guidelines[107].

- Many automotive and transport sector leaders have indicated that connectivity in vehicles will help solve complex problems in emerging technology. National and international initiatives are underway on connectivity solutions, including short-range communications and cellular technologies. A greater understanding of business and assurance models for deployment in Australia and their costbenefit for industry and government will support effective regulatory and investment decision-making (TAIC, 2020).

- Identification of any gaps in the standards of CAV needs to be in-line with national developments on connectivity solutions, including short-range communications and cellular technologies.

- It is essential to understand the developments in the sharing economy to assess their potential impact on public transport demand and road use. Without careful consideration of the impacts in interrelationships between CAV, electrification of vehicles, sharing economy and increased urban density, the likely outcome can be a sub-optimal urban mobility system; possibly with negative characteristics worse than those present in existing transport systems. There is scope for considering multi-area impact scenarios and analysis were relevant when developing asset management strategies and planning processes.

- There is a need to develop guidance about how infrastructure can be future-ready for CAV technology within an integrated transport and land use planning framework. The guidance developed will support policy and investment decisions on technology in the road transport sector. The guidance will consider strategic priorities for governments to harness the safety, productivity, sustainability and accessibility benefits of transport technology (TAIC, 2020).

5.4. Customer/Stakeholder Expectations

- "Future of mobility" network(s) can combine CAV and ITS. This combination can be established to support urban communities. These can consist of working groups to cover a range of topics relating to sustainable transport, impact on, and of, climate change, digitisation, alternative fuels and industry standardisation.

- The issue of CAV data security needs to be addressed to ensure privacy is protected while data can be utilised to improve network efficiency.

- Potential deployment scenarios for CAV may influence commercial issues such as eCommerce platforms and access to data. Research into this aspect of the technology will guide future regulatory decision making and identify future analysis needed (TAIC, 2020).

- If governments and their transport agencies are willing to incentivise sharing economy models, it may be realistic to foresee public-private agreements in this space, which may lead to such commercial agencies becoming stakeholders and/or partners.

- Customer expectations potentially could increase in terms of seeking reduced congestion, emissions reduction, improved mobility, delivered by a variety of choices, including CAV individual ownership, CAV public transport, and other micromobility options such as electric bikes ad scooters, and possibly air taxis, as well as walking. This approach will encourage customers to choose CAV over other vehicle options.

- Implementation of kilometre-based fees, carsharing and ridesharing are expected to have a profound impact on lifestyles and travel behaviours such as different commuting patterns or reduce active transport (El Zarwi et al., 2020).

- Customer expectations may be influenced by their opinion regarding CAV, their trust in the technology and the willingness to relinquish control of the vehicle. Males, younger people, and those living in urban areas tend to be more positively oriented toward CAVs and more capable of accepting CAVs. During the period of partial CAV uptake, asset managers will need to manage the various expectations arising from these differences.

5.5. Risk Management

- CAVs should be able to prevent an appreciable number of crashes. International and Australian trials and research have shown that new technologies in CAVs can increase network efficiency, decrease risk to transport users, reduce fuel usage and emissions, and enhance traceability of supply chains. There is a need to develop evidence-based studies to validate such claims and inform the development of a risk management framework.

- As fully driverless cars have not been introduced, their efficiency is hard to forecast. An obvious potential impact of advanced CAVs will be that traffic congestion should be reduced due to the decrease in human-error road accidents and because of the improved efficiency of autonomous driving which has the ability to constantly monitor traffic (Kane and Whitehead, 2017). For example, the smart technology of fully connected and autonomous trucks to detect objects in their path in the mining sector is a valuable contribution to transferable knowledge to implement fully autonomous CAVs on public roads.

5.6. Legislation/Statutory Requirements

- There is scope to create a common repository for Australian mobility data space and to regulate the handling of data critical to the CAV space. This repository can be monitored centrally by government and data related to CAV can be stored.

- There is a need for end-to-end regulation for the commercial deployment of CAV. The National Transport Commission is working with the Commonwealth, states and territories to develop a regulatory system that supports the safe deployment and operation of CAV in Australia. Key actions related to this work include implementing regulatory arrangements so fully CAVs are safe to operate and deploy at the point of first supply in Australia.

- There is a requirement for legislation that promotes global mitigation strategies to reduce GHG emissions (Prideaux and Yin, 2019). CAVs are able to support such legislation by their focus on low carbon vehicles.

- According to the National Transport Commission (NTC), it is recommended that "whether human monitoring of an automated vehicle constitutes legal control of the vehicle requires clarification". Hence for the purposes of road rules and insurance schemes, the legal definition of a 'driver' should be clarified on the same basis (Mackie, 2018).

6. Findings from the Impact Assessment and Delphi Process

The key findings from the impact assessment and Delphi process are presented below. The following paragraphs highlight the key results from the statements used in the Delphi process.

1. **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 *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.

2. 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.

3. 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.

4. 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 nor disagree' category.

- The results from the Delphi highlighted that the policy around AV uptake to facilitate 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.

7. Opportunities for Asset Management

The uptake of CAV has the potential to improve asset management outcomes. Figure 2 highlights some benefits of CAVs.

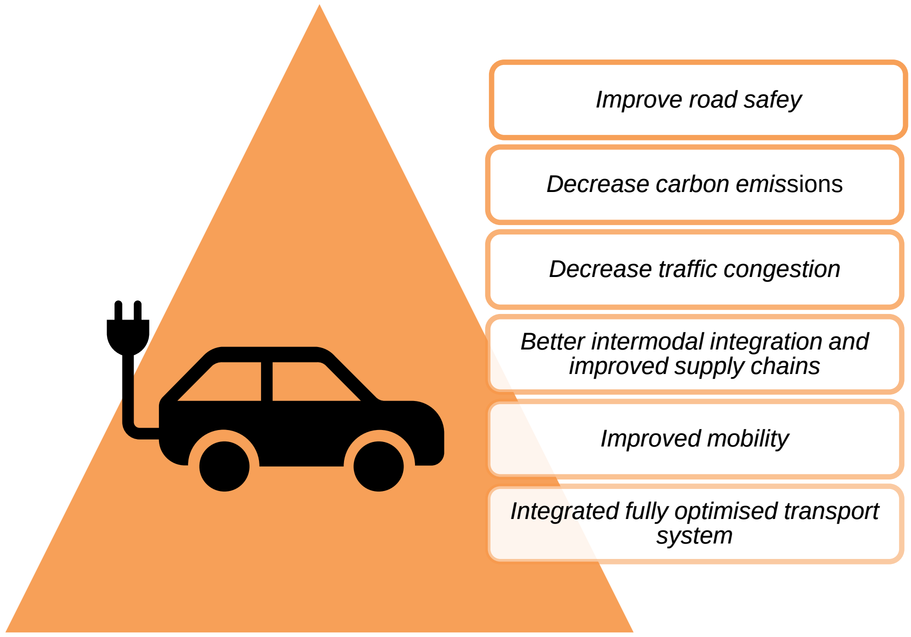

Figure 2: Benefits of AVs

- *Improved road safety*, through initially reducing, then eliminating human driver error, potentially fewer cars as a result of shifting from private ownership to sharing economy.

- *Decreased carbon emissions* from replacing fuel with electricity, and potentially less cars due to sharing economy.

- *Decreased traffic congestion*, by eliminating human driver limitations; more efficient traffic management via in-car communication, car-to-car and car-infrastructure communication; decreased private car ownership, and increased public transport uptake.

- *Better intermodal integration and improved supply chains* can be facilitated by vehicle to vehicle and vehicle-infrastructure communication. In a dense urban environment, the utilisation of parking space can be optimised by integrating parking sensors and via infrastructure to vehicle communication, to book parking space.

- *Improved mobility* and mobility choices when CAV uptake, in all forms, cars, busses, taxis, trains, is supported and incentivised through policies and regulations to include a full range of models from private to public ownership, individual and shared use, and integrated with other transport options such as micromobility.

- An *integrated fully optimised transport system* with reduced transport costs, traffic congestion and travel time, road trauma, and emissions, as a result of the CAV uptake, in conjunction with shared economy policies, particularly in high density urban environments.

8. Challenges

MaaS is an emerging concept which is already supported by governments and provided by private and public companies. Micromobility is a rapidly expanding market, particularly exploding though the COVID 19 period, and supported in many countries by government policies (e.g in Paris where during COVID 19 traffic lanes were repurposed for micromobility, mostly bicycles (Lagadic, 2020). COVID 19 has tested, among other things, the resilience of the transport system, which was required to accommodate a sudden and disruptive change in transport behaviour. The resilience of the transport system is ensured by having multiple, well-connected transport options. CAV uptake, MaaS and micromobility and their interaction will lead to the need to reconsider the utilisation of the transport space. Asset managers, particularly policy makers, will have to make sense of this complex environment, where CAV uptake is only one element, and develop policies and strategies to reflect the reutilisation of the transport space and intermodal connectivity. This situation may also need a new approach in relation to transport integration. Policy development and planning processes need to adapt to a more complex environment with a potentially higher level of uncertainty than in the past.

Many of the opportunities claimed for the new technologies in safety, traffic congestion, and more efficient use of contested urban space are expected to be realised only when the transition to full autonomy is reached.

9. Recommendations

In terms of the high-level strategy for CAV uptake, asset managers need to be proactively engaged with three key areas:

- development of a framework for digital infrastructure to support safe, cybercrime-protected vehicle-to-vehicle and vehicle-infrastructure communication.

- national policies, standards, governance and regulation for CAV uptake, and
- CAV infrastructure decisions.

10. Conclusions

The project has drawn from a review of CAV development in Australia and overseas and developed an impact model to identify if and how asset management practice will be influenced by the uptake of these vehicles.

The findings of the project were that CAV uptake will:

- Affect asset management in many areas including policy, strategy planning, customer and stakeholder expectations, statute and legislation and risk management.
- Provide several opportunities such as rethinking existing road infrastructure to coexist with other travel modes as well as improving road design to accommodate 100% CAV uptake in future for improving asset management outcomes, and
- Present also some challenges, particularly in regard to managing a rapidly changing transport market with a transition to MaaS and the rapid increase in micromobility, fueled by technology changes and increased customer expectations re improved mobility.

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