FUTURE-DRIVEN AUTONOBUS PILOT PROJECT AT LA TROBE UNIVERSITY

future driven
autonobus

THINK LIKE A PASSENGER

"I believe Autonomous shuttles will provide a revolution in transport. My elderly parents will be able to maintain their autonomy after being unable to drive. I also think that it will provide opportunity for better transport schemes."
Comment from a Pilot Project participant

Disclaimer: The partners involved in the Autonobus project provide no warranties and make no representations in relation to the information provided in this paper. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken.

EXECUTIVE SUMMARY

In March 2016, VicRoads announced the Victorian $4.5 million Intelligent Transport System (ITS) Transport Technology Grants Program, offering funding to trial projects that support innovation and the development of transport technologies and products that benefit Victoria and the wider Australian community.

It was the intention of the Program that VicRoads would work with industry to develop technologies to help reduce traffic congestion and improve traffic flow, reduce road crashes, improve the integration between transport modes, improve environmental sustainability, and improve traveller information to enable travellers to choose alternative transport modes.

A partnership led by Keolis Downer submitted a proposal in April 2017 to undertake an Autonomous Vehicle (AV) pilot – offering a sustainable transport solution in response to the ITS transport technology grants program – at the Bundoora Campus of La Trobe University, with the focus on first and last mile transport.

The proposal was accepted; and in June 2017, the Project was announced by the Victorian Government, receiving $395,438 in grant funding out of the project's total cost.

Keolis Downer and its partners, La Trobe University, RACV, HMI Technologies and ARRB have extensive, diverse experience developing similar projects in Australia and overseas. Leveraging from the AV deployments by Keolis in Lyon and Las Vegas and linked with RAC's Intellibus in Perth and HMI's Christchurch airport and Olympic Park deployment in NZ and NSW respectively, our innovation driven objectives for the pilot project were:

1. To demonstrate the interaction between Autonomous Vehicles, pedestrians and other road users such as buses, motorcyclists and cyclists;
2. To increase awareness of Autonomous Vehicles by providing an opportunity for the public to interact with the technology in an urban environment;
3. To develop an understanding of Autonomous Vehicles to support future deployments regarding the potential use of AV shuttles in the provision of integrated mobility services;
4. To develop knowledge and expertise relating to the development and operation of Autonomous Vehicles and all associated technologies;
5. To establish a commercial, legal and technical framework for AV deployment and assess the readiness of the AV for commercial operations;
6. To test the deployment of an Autonomous Vehicle in Victoria as a potential means to address 'first and last mile access' and integration; and
7. To develop a commercially viable transport solution, which if deployed long-term, would provide significant benefits to the community including increased connectivity with other modes of transport, more frequent services, higher safety (personal and on the road), reduced costs, and increased accessibility.

Making Autonomous Shuttles a reality is a multi-faceted challenge requiring a collaborative approach. Below is a brief update on each of these key factors (as at August 2018):

Factor	Outcome
Practical regulation	The project has informed Victorian legislation allowing Autonomous Vehicles to be trialled across the state. Additional state and federal legislation and regulations urgently need to be modified, with further areas of regulatory development identified.
Reliable technology platform and sustainable operations	The National Transport Commission (NTC) guideline for AV trials was adopted across all project activities and full compliance was demonstrated (where applicable). Appropriate exemption was obtained from VicRoads. Transport Safety Victoria provided the required certification for non-commercial operations of the AV shuttle. Insurance covering all relevant liabilities was provided by the operator. Applicable road rules were programmed into the vehicle and demonstrated successfully in operation, including passing through a roundabout, pedestrian crossing, parking at bus stops and give-way scenarios. Interaction with other traffic was also demonstrated including pedestrian crossing, parking at bus stops and give-way scenarios. A GNSS base-station was required to provide accurate GPS correction. Programming the trial route and vehicle took a few days, which included route mapping and sensor configurations for the operational environment. To facilitate widespread AV deployments, suitable infrastructure is needed as well as adapted charging stations for electric vehicles. Reliable telecommunications connectivity for precise GPS positioning and optimisation of other functionalities such as vehicle-to-vehicle and vehicle-to-infrastructure communications are also essential.
Safety	The vehicle was proven to be safe through 450 public rides and hundreds of test rides. Cohesive safety use cases were developed and demonstrated in a live environment.
The right use case, value proposition and user experience	The Autonobus travelled between the Southern and Northern ends of the University, along Science Drive. This use case was well received, as it helps pedestrians access car parks, trams and bus lines. Use cases that solved more pressing issues, such as connecting to a nearby train station, indicated an even stronger preference. The value proposition of the Autonobus lies primarily in its ability to cater for groups and situations not captured through traditional means, as well as its potential to reduce congestion, accidents and environmental impact. Representing diverse demographics, over 1,100 people shared their opinions about Autonomous Vehicles, with 517 participants who took an actual ride in the Autonobus, stating their perception of AVs had changed for the positive, and significantly reduced their level of concern.

Factor	Outcome
Clear legal and insurance responsibilities	Clear responsibility was established; the owner/operator of the vehicle is responsible for any (unforeseen) operational incidents but the precinct owner and other stakeholders in the community need assurance that all due care has been taken in the planning and implementation of the deployment. While a few insurance companies will accommodate AVs, more insurance companies need to modify their policies to provide for the operation of AVs on both private and public roads.
Viable commercial framework	Passengers indicated that they would be willing to pay a fair price for the service, and they could see this mode of transport becoming an integral part of their 21st century life. Furthermore, if the shuttle service was to be extended to a nearby train station (offering a first and last mile transport service), this would increase the service's appeal significantly. Initial indications are that AVs can provide services on a commercial basis, but further testing is required to establish conclusively whether On-Demand Transport services using AV technology are viable. Commercial indications are positive but need to be contested to establish a sustainable commercial framework for On-Demand Transportation using AV technology being modified to facilitate the operation of these new services.
Public education	Stakeholder engagement are key for increasing community awareness. A range of digital and physical channels, including TV, radio, print media, direct marketing and speaking opportunities were used to reach over four million people – to educate the public and help recruit a demographically diverse group of participants for the trial project.

In summary, there is strong evidence to suggest Autonomous Vehicles present a significant opportunity to meet existing transport needs in a new way. This pilot project has demonstrated that a high standard of safety, technical, operational and community acceptance requirements can be met for successful deployments in similar environments. The learnings from the pilot can be applied to future deployments and assist in making the roll out of AVs a reality in the short term.

Governments at the federal, state and local level, combined with statutory bodies, need to prepare further for the introduction of this innovative transport technology – by amending regulations to facilitate the deployment of AVs and by ensuring infrastructure that supports the implementation of AVs is fully integrated into the planning process for transport and urban developments.

INTRODUCTION

This report details the primary objectives and project outcomes associated with the La Trobe Autonobus Pilot Project, including recommendations for the future to enable the successful deployment of Autonomous Vehicles across suitably controlled environments and fit-for-purpose applications, with the ambition that they are shared and fully integrated into the range of transport solutions available to residents and businesses within Victoria, and in the longer term, nationwide.

The project focused on showcasing and testing a Level 4 autonomous shuttle (a NAVYA Arma) in a real traffic environment; demonstrating the long-term operations and commercial benefits, the safety challenges and the customers' uptake from the new transport solution. It also accelerated and informed legislation announced in February 2018 from the Victorian Parliament that allows Autonomous Vehicles to be trialled across the state.

PROJECT PARTNERS

Six key partners were involved in the La Trobe Autonomous Pilot Project, each with specific responsibilities and highly complementary areas of expertise:

Partner	Project Role
VicRoads	Client leadership, support and facilitation.
Keolis Downer	Project lead, governance, mobility solutions, report delivery. Design passenger experience research.
La Trobe University	Project implementation, precinct partner, legal and risk management advisor (or reviewer) and lead the customer experience research.
RACV	Marketing. Community and stakeholder engagement.
HMI Technologies	Project management, design technical assessment with shuttle provider 'NAVYA', operation and owner of the AV shuttle.
ARRB	Safety advisor and development of the safety case.

vicroads

VicRoads

VicRoads plans, develops and manages the arterial road network and delivers road safety initiatives and customer focused registration and licensing services in the State of Victoria. Their key role is to help provide Victorians with safe and easy connections to the people and places that matter most to them, and to regularly review and adapt Victoria's Road Rules and relevant Regulations (both the language used and concepts) to modern behaviours, demands and technological advancements. VicRoads is the Roads Corporation of Victoria and this project's direct client.

Keolis Downer

Keolis Downer is a joint venture between Keolis, the international public transport operator and integrator of shared mobility services, and Downer, a leading provider of integrated services in Australia and New Zealand.

Keolis Downer, as a leading multimodal operator, works closely with transport authorities and governments to develop shared mobility solutions that are adapted to local needs and are innovative. As such, Keolis Downer is committed to developing and conducting a series of AV pilots to accelerate the introduction of AVs, with a focus on commercial viability, customer experience and operational costs, as well as unfolding the benefits that AVs can provide to give a better access to public transport and help communities with 'first and last mile' transport solutions. Keolis Downer has been previously involved in the testing and commercial rollout of similar solutions in France, the Netherlands, Canada and the USA.

Keolis Downer is the project leader of this pilot, meaning they have a direct responsibility to VicRoads to deliver the report, outline how the grant is being spent as well as meeting regular reporting requirements; and was responsible for the governance and regulatory components of the pilot to enable the AV to be tested along the Science Drive route at La Trobe University, as well as the mobility solutions design and planning of the customer experience research.

La Trobe University

La Trobe University (LTU) is an Australian, multi-campus, public research university with its flagship campus located in Bundoora, Melbourne. They have been ranked in the world's top 2% of global universities and one of the world's best young universities; and have a strong interest in increasing connectivity and decreasing the dependence on cars to travel to their main campus, which is approximately 1.5 times the size of Melbourne's CBD. In addition, since their Centre for Technology Infusion (CTI) was established over 10 years ago, it has been involved in multiple transport-related trial projects, and has built a robust track record in technology R&D, delivering award-winning innovative solutions and services.

LTU hosted the trial. The precinct was ideal for the pilot as it has: (i) an extensive network of roads which are both public and private, (ii) over 20,000 students and staff and a high level of activity which is close to mirroring a real-life urban environment, (iii) shared roads with pedestrians, cyclists, cars and buses; and (iv) is specialised in live field deployment. As the precinct partner and road manager, the LTU legal, OH&S and insurance team laid the contractual foundations for operation of the shuttle on a shared road, which covered all legal, liability, safety and regulatory aspects of the project. CTI coordinated all Autonobus activities at La Trobe University; and worked with the Technical team to ensure the required infrastructure such as signal repeaters, safe storage and charging stations were in place. CTI also ensured that the safety testing was conducted in a framework and to the standards acceptable by the university's OH&S and risk management teams. This included a severe accident drill training over the span of two days.

Given that the trial involved humans, CTI also engaged with the Ethics Committee to ensure the privacy and ethical aspects were dealt with according to National Ethics University Standards. As the host of the project at its Bundoora campus, with the Science Drive bus route as the nominated testing platform, the Infrastructure and Operations (I&O) team negotiated and confirmed the road status with neighbouring council Darebin and VicRoads expediting the required exemption status. CTI also managed all customer-facing interactions; creating a dedicated microsite, booking tools and direct communications (SMS and email), email responses, induction and survey follow-up. CTI's proprietary techadoption methodology was successfully applied to the survey design and adoption analysis - both of which are included in this report.

RACV

Royal Automobile Club of Victoria (RACV) is a leading motoring club and mutual organisation which provides its members with a range of products and services in the areas of motoring, home, leisure, financial services and general insurance. RACV is also the prime transport advocate in Victoria to improve road safety, road network and public transport performance, and customer experience.

RACV led the marketing and community and stakeholder engagement (including customer acquisition) for this pilot. It is also anticipated they will help with influencing customer acceptance of the technology, as a new and alternate mode of transport, once the deployment of AVs is approved.

HMI Technologies

Established in 2002, HMI Technologies (HMI) is a world leader in the Intelligent Transport Systems (ITS) industry, offering proven and trusted solutions to support diverse traffic management applications.

In recent years, HMI has been developing more innovative cutting-edge products and services focused on enhancing technologies for safer journeys. Key innovations of HMI products and services include communication technology, sensor technology, integration and automation; all of which are key functional areas underpinning disruption in the wider ITS industry.

In recognising the substantial safety, efficiency, economic and other benefits that Automated Vehicle technologies will provide, HMI started developing and manufacturing their own AV shuttles 'Ohmio' in 2015, including technology development and delivery; and is the owner/operator of the Autonomous Vehicle (AV) used in this trial (a NAVYA Arma), known as the Autonobus. Appointed project manager for this project, HMI led all aspects of the project including: (i) project planning and risk management in accordance with NTC guideline; (ii) AV service design and technical assessment; (iii) concept of operations development; (iv) traffic management plans and cohesive safety risk assessment (eg. the shuttle, participants' and road users' safety) ; (v) Autonomous Vehicle configuration and operations; and (vi) obtaining the required exemptions and certification. In addition, they oversee all technical, safety, regulatory and operational aspects of the vehicle, the planning of the customer experience, commercial possibilities, as well as determining the readiness of the AV.

The National Transport Commission's (NTC) *Guidelines for trials of automated vehicles in Australia* were adopted for this Pilot Project; a comprehensive analysis of the NTC guideline requirements and the relevant international guidelines was conducted and full compliance was demonstrated across all streams.

HMI has expertise and experience in the development and operation of Autonomous Shuttle and considers itself a leading expert in this field. HMI is involved in the establishment of International Standards in the field of Connected and Automated Vehicles, as Heads of Delegation and Working Group Convenors in ISO's Technical Committee TC204.

ARRB

Australian Road Research Board (ARRB) is the not-for-profit national road research agency. ARRB is the source of independent expert transport knowledge, supporting and delivering high quality applied research for Australian and New Zealand state road agencies and for the community. Recent ARRB research and operational projects have focused on connected and automated vehicles to support National and State Road Agencies in policy and operational outcomes for a future of smart connected roads.

ARE AV SHUTTLES READY TO BE DEPLOYED NOW?

Autonomous Vehicles hold a significant promise of providing a green, smart and affordable mode of transportation; for instance, to or from public transport stations – the so called 'first and last mile' - but are they really ready to be deployed now?

There are a wide range of Autonomous Vehicles being developed, including military vehicles and private cars with increasing levels of autonomous functionality. For example, the Audi A8 was launched in Australia this year, and is the first mass production car capable of Level 3 automation.

This specific trial project focused on the small AV shuttle, a Level 4 automation model of which there are several now available in Australia. With many benefits, they can decrease congestion on the roads (by reducing a reliance on private cars) through ride-sharing, provide greater mobility for the elderly and mobility impaired, and provide a safer and better option for people who would usually walk to their destination in the dark or in inclement weather.

- ✓ Increase connectivity with other modes
- ✓ Higher safety (personal and on-road)
- ✓ Cost reduction
- ✓ Improve social inclusion
- ✓ Improve accessibility and increase mobility
- ✓ Reduce carbon emission (environmentally friendly)

This finding means that AV shuttles may now also be of practical interest to:

- State Road and Transport Authorities;
- Public Transport Providers;
- Local Government Agencies;
- Private Land Developers;
- Private Residential Providers (including retirement villages); and
- Large activity precincts such as airport, universities, conference centres and shopping centres.

> **"I am older and retired. Autonomous shuttles could be a tremendous help to maintain independence and mobility in the future."**
> *Comment from a Pilot Project participant*

The Project also confirmed other trends observed in the Australian transport market:

- Participant and stakeholder feedback reflected an increasing demand for sustainable and truly integrated transport networks, providing genuine 'door to door' alternatives to a private car;
- Cost effective technological solutions such as AVs are developing rapidly – and as such, transportation solutions should be reviewed regularly to ensure the community is benefiting from these advancements;
- AV shuttles present an opportunity for greater safety and mobility;
- Increasing consumer tolerance and even preference for shared economic models, including in the transport sector;
- AV shuttles will work well in the emerging space of shared 'on-demand' micro-transit environments, such as those being trialled in NSW and in most Australian cities;
- AVs will complement rather than replace mass transit systems, and are necessary for increased economies of scale; and
- To achieve the full benefits of electric and Autonomous Vehicles, as well as 'on-demand' transport, governments will need to implement a substantial shift in transport policy (including developing new economic models for vehicle registration, fuel excise, road use, parking, urban planning and land development).

Although it was beyond the scope of the trial, we note that Autonomous Vehicles also offer suitable opportunities beyond passenger transport, such as for military (eg. land-based weapons deployment), freight applications (eg. airport "airside" luggage transport), and potentially as first responders or search and rescue support, in natural disaster situations.

TRIALLING THE NAVYA STATE-OF-THE-ART AV SHUTTLE

Used in the trial was the 'NAVYA Arma-4' AV shuttle; selected for its availability and established credentials in technological functionality. Developed by NAVYA, a French company that has over 10 years' experience in designing and producing driverless vehicles, the NAVYA Arama-4 is designed to meet SAE Level-4 High Automation Vehicle standards.

As outlined in the Figure below, the AV shuttle can operate in full autonomous mode on mapped routes, or have an operator intervene and stop the vehicle, if needed.

SAE Level	Name	Steering, acceleration, deceleration	Monitoring driving environment	Fallback performance of dynamic driving back	Virtual testing in PTV Vissim
0	NO AUTOMATION the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems.				✓
1	DRIVER ASSISTANCE the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.				✓
2	PARTIAL AUTOMATION the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.				✓
3	CONDITIONAL AUTOMATION the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene.				✓
4	HIGH AUTOMATION the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.				✓
5	FULL AUTOMATION the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver.				✓

Figure – SAE level of Autonomous driving

Note – A comparative analysis of the technologies and vehicles released during the trial period was not undertaken. Since the start of the project (in April 2017), the technology of NAVYA and other AV shuttle manufacturers has continued to advance at a rapid pace, with other AV shuttles being deployed in Australia, such as the Easy Mile and Olli.

THE AUTONOBUS PILOT PROJECT

future driven
autonobus

100% Autonomous | Electric
Driverless | Available

15 Passengers	**11 seats**	**4 standing**
Dimensions	**length** 4,75m / **width** 2,11m / **height** 2,65m	
Average Autonomy	**7-12 hours**	

The NAVYA Arma-4, the unregistered AV shuttle which received approval from the various road and transport authorities to operate during this project, has a range of safety and security features and technical specifications including seat belts for fixed and folding seats, GNSS/GPS antennas, and an interactive on-board touch screen. It is also equipped with robust industrial sensors for its autonomous operation as well as an internal security camera and VoIP intercom.

The shuttles practice on the programmed circuit. Accurate to within 2cm they detect any changes to the surroundings (obstacles, pedestrians etc.) thanks to multiple technologies.

The NAVYA ARMA-4 Autonobus used at La Trobe University during this pilot project.

PROJECT IMPLEMENTATION

La Trobe University's Bundoora campus, in Melbourne's North, was the nominated site for the trial with the Science Drive bus route as the specific testing platform.

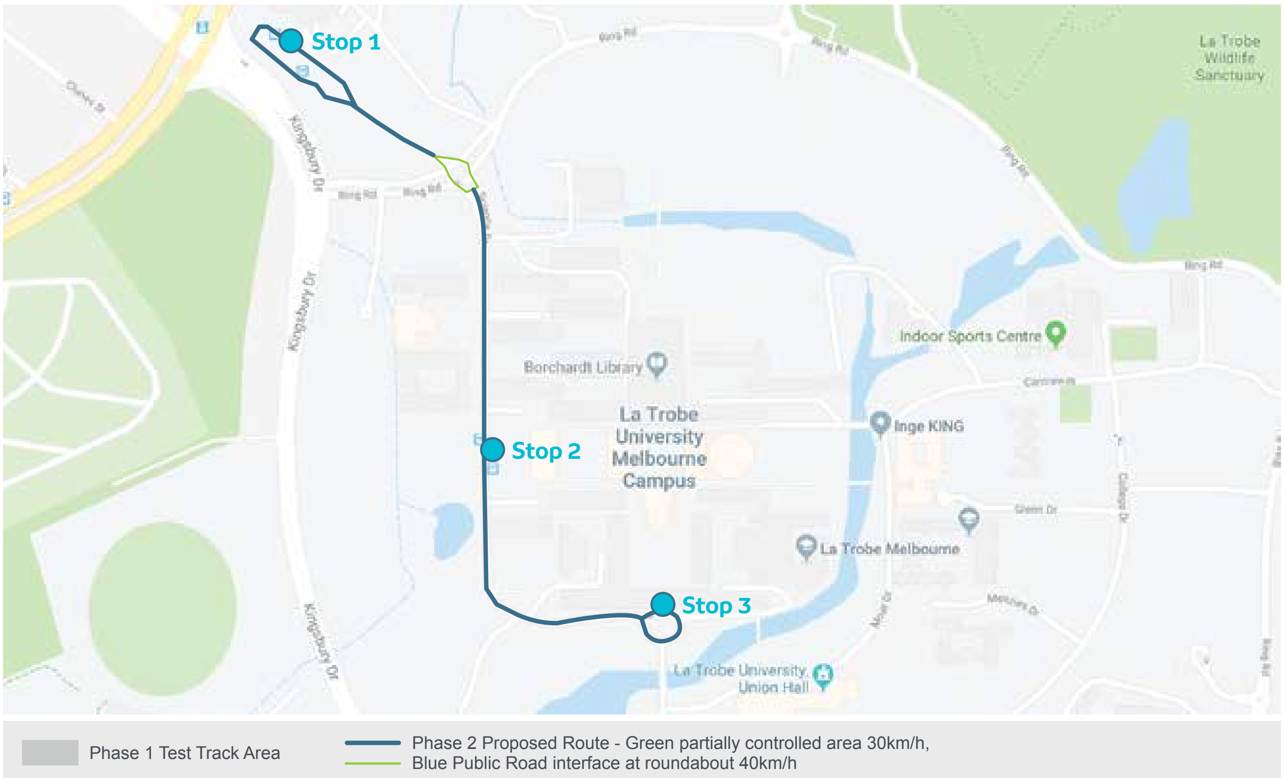
Unique in many ways, the precinct at LTU served as the perfect space for testing an Autonomous Vehicle for the first time in Australia in such a complex environment complex environment, with features including:

- an extensive network of both public and private roads, approximately 1.5 times the size of Melbourne's CBD;
- over 20,000 students and staff producing a high level of activity;
- shared roads with pedestrians, cyclists, cars and buses; and
- being specialised in field deployment.

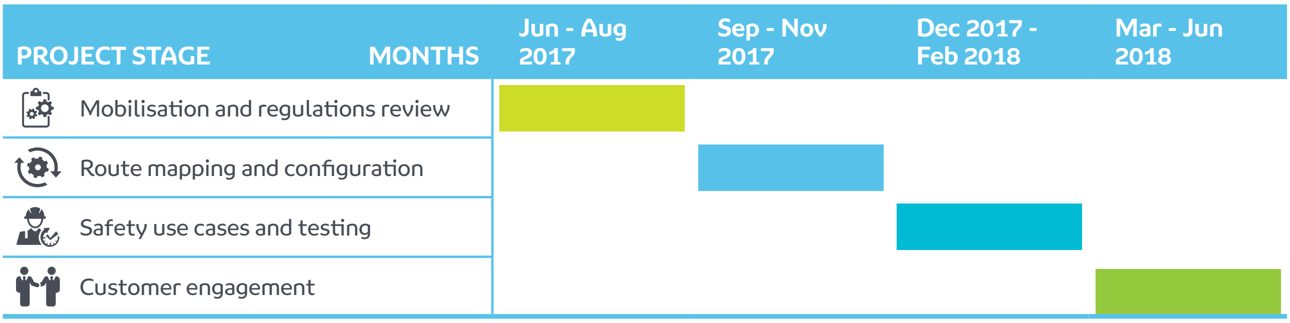
LTU also offered the following facilities:

- the Centre for Technology Infusion – which is located on-site, has many years' experience with multiple transport-related trial projects, and undertakes cohesive research on the AV shuttle operations and safety requirements;
- live bus services (including Public Transport Victoria (PTV) and Glider services) along the Science Drive route which are connected to the tram services at Plenty Road - enabling the project team to offer the last mile transport services using the AV shuttle complementing the existing bus services; and
- adequate GPS coverage and 3G/4G mobile coverage by the major telecommunication providers (eg. Telstra and Optus).

As illustrated in the Figure below, the Bundoora site closely mirrors a typical urban environment; the vehicle was following an itinerary that was approximately 2.5km long, providing an excellent example for the project team to assess the interaction of the AV shuttle (Autonobus) with other traffic modes.



With four major operational phases of the project each comprising three months, the (i) Mobilisation, (ii) Mapping and Configuration, (iii) Testing, and (iv) Customer trials were conducted between June 2017 and June 2018.



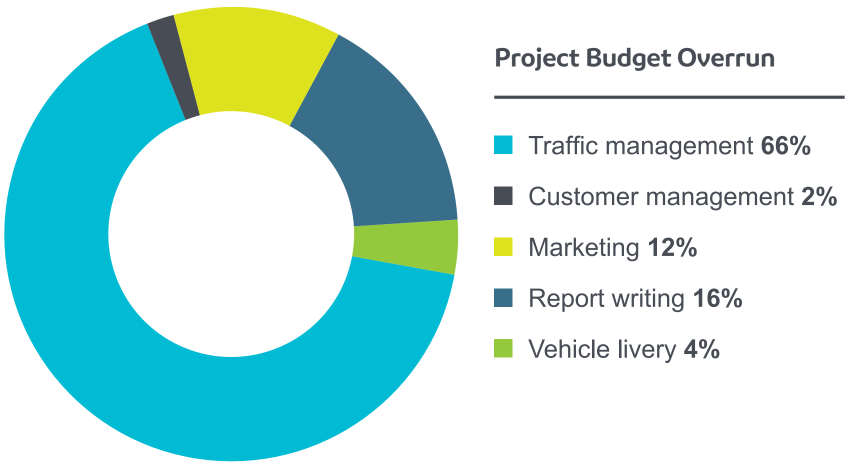
Key Learnings

The Project provided a challenging and productive forum for learning about the effective implementation of new technology in a public operating environment. The project team, including VicRoads, comprised six organisations each with their own strategic reasons for participating in the project. In many cases, project members also had to manage the interests of other stakeholders to ensure the project outcomes were achieved.

Given the complexity of the project scope, areas of work/expertise and organisational touch points, good governance practices required the project members to respect and allow for different organisational styles, cultures and responsibilities. Ensuring strong alignment on project fundamentals at the start of the project was critical to the long-term success. Being prepared to be flexible to accommodate "best-for-project" outcomes at the expense of some initial individual aspirations or expectations was also important. Strong project management, open consultation and regular steering committee meetings were required to ensure all parties remained focused on the shared priorities and timelines.

Most importantly, the participants had to accommodate some budget flexibility from the initial estimates. In areas of new technology and operation, it is not always possible to predict all the costs which will be incurred. The parties needed to recognise this and manage cost pressures pragmatically – either by reducing scope, or in some cases agreeing to fund additional activities not originally envisaged. From the agreed budget of $1,137,375 - there were additional costs of approximately $118,000 that were mainly generated by traffic management.

The breakdown of additional costs is illustrated in the figure below:



INNOVATION-DRIVEN OUTCOME: THE PILOT PROJECT IN DETAIL

1. SAFETY

Primary objective:

Demonstrate the safe interaction between Autonomous Vehicles and other transport modes such as traditional vehicles, buses, trams, bicycles and pedestrians, as well as the safety of passengers riding the vehicle.

Project outcome:

Safety, risk and traffic management plans were developed and implemented. The AV (Autonobus) operated safely throughout the trial.

Safety was a primary focus on this pilot project, with vehicle, operational (road users) and participant safety identified as the three main areas. To gain more insight into the behaviour of the AV shuttle and its associated technology, testing its abilities in a local environment was critical to demonstrating how it behaves when encountering a range of different situations.

Thus, a series of use cases were developed, underpinned with a robust safety management plan, to test a range of scenarios – both planned and unplanned – enabling multiple configurations to be investigated to determine the safety of the Autonomous Vehicle, as well as operational, commercial, regulatory and customer experience factors. In the planned experiments, a scenario (set of circumstances) was simulated and tested at various set-ups, aimed to determine certain thresholds of interest (such as the safety clearance threshold in a certain scenario). In the unplanned experiments, the Autonobus travelled the route multiple times and any events that occurred during these trips were recorded.

Specific to demonstrating safety were the following use cases, which focused on:

Furthermore, compliant with one of the National Transport Commission's *Guidelines for trials of automated vehicles in Australia*, all relevant stakeholders were heavily engaged during the development of the Safety Management Plan, which included 10 key criteria:

1. Security
2. Risks to other road users
3. Risks to road infrastructure
4. System failure
5. Appropriate transitioning processes
6. Whether there is an Operator
7. Pre-trial testing
8. Training provided for the Operator
9. Fitness for duty
10. Vehicle identifiers

"A 24/7 means of independent on-campus transportation."
Comment from a Pilot Project participant

Findings, Key Learnings and Recommendations

The critical issue to be addressed in this trial was the interaction of the AV with other road users. The unique feature of this trial compared with others being undertaken in Australia, was the complexity of the operating environment – which not only included pedestrians, cyclists, private cars, delivery vehicles and public and university shuttle bus services, but also a roundabout, pedestrian crossing and transport interchanges, all within a dense urban precinct.

While the trial demonstrated that these interactions can be managed; for ease of future deployments, other options to address this complexity include:

- A segregated roadway (for the AV); and
- Lower operating speeds for all traffic in an environment where AVs are mixing with other vehicles.

The shuttle was able to perform safely in its intended operation – across all three dimensions: vehicle (shuttle), operational (technology) and participant (passenger) safety; and in some cases, exceeded expectations with how well it interacted with other traffic such as vehicles or pedestrians, whilst having passengers on board. It also complied with all road rules.

Having the safety management and traffic management plans in place, the low speed of the shuttle and the presence of an operator as a fall-back for unforeseen circumstances were valuable, particularly as this was the first such deployment in Victoria, in an urbanised environment, of an Autonomous Vehicle whereby the behaviour of other road users towards this vehicle was unknown.

The shuttle's response time and braking capability, coupled with a low maximum speed (18 km/hr), was found to be sufficient to avoid any impacts in the scenarios outlined in the use cases. However, further testing should be undertaken in a signalised environment and at speeds above 20km/hr. It appears likely that operation above 30km/hr would bring in additional risks such as the structural integrity of the vehicle and whiplash for passengers. These issues would be relatively straight forward to address through vehicle and restraint design, based on learnings from the existing vehicle manufacturing industry.

Upgrades in sensor technology (such as detecting objects below 350mm in height), shuttle configurations for movements around roundabouts, pedestrian crossings and stationary vehicles, and braking and overtaking are all features which have been upgraded in the next generation AV. This will further enhance the operations of the AV shuttle delivering a safe and seamless customer experience.

Connectivity between the AV and other infrastructure (such as traffic signals) should also be tested to see how well it responds to danger (once integrated into the next generation vehicle), as well as the use of a remote monitoring management platform for operational areas.

It is also recommended that should the University deploy AVs in the long term, they nominate the 30km/hr Science Drive route and maximum 40km/hr speed limit across the campus, as a 'shared space' and undertake modifications to make it more 'friendly to autonomous shuttle type operations', which would also enable the vehicle to increase its speed above 18 km/hr whilst remaining safe for passengers and the community. Furthermore, there would need to be a campaign targeted at all users, local residents and the university community, to raise awareness around how to behave around one of these types of vehicles.

Lastly, it is recommended that from a regulatory perspective, a formal safety accreditation be developed - similar to a car safety performance assessment programme (ANCAP) for ordinary cars – which all AV operators and precincts in Australia must display to confirm their Autonomous control and operation of the technology.

Such safety certification would make precinct managers and institutions feel more comfortable, reducing the burden on projects in terms of additional tests, paperwork and sign-offs from OH&S or risk regulatory organisations.

IN SUMMARY

Recommendations for the future deployment of Autonomous Vehicles:

- ✓ The shuttle was safe for customers and road users, and ready to be deployed at the speeds used in this type of precinct; however further testing is required:
  - At speeds above 20km/hr;
  - Connectivity between the AV and other infrastructure (such as traffic signals) – in a signalised environment;
  - Use of a remote monitoring management platform for operational areas;
- ✓ Establish an Operational Control Centre which would also look at the remote operation of AVs, as well as its integration with other modes of transport, to ensure safety across the whole public transport network;
- ✓ La Trobe University have a nominated "shared space" driving route;
- ✓ Raise awareness of the local community - with a campaign educating people – on how to behave around Autonomous Vehicles; and
- ✓ It is recommended that from a regulatory perspective a formal accreditation be developed for AV operators and precincts.

2. OPERATIONAL

Primary objectives:

Demonstrate the safe interaction between Autonomous Vehicles and other road users such as traditional buses, bicycles and pedestrians.

Develop knowledge and expertise relating to the development, deployment and operation of Autonomous Vehicles (such as the Autonobus) and all associated technologies.

Project outcome:

An operational framework was developed to enable the operations of the Autonobus on the road network, which can be used to provide input to operate other AVs.

Whilst in autonomous mode, the AV followed the pre-programmed Science Drive route with the sensors on and successfully stopping when it detected an obstacle. The vehicle was operated (by a trained operator) in manual mode, primarily when accessing the charging station (and for parking off-site), acknowledgment at high-traffic roundabouts, and for any situations where the Operator needed to take over for perceived safety reasons.

43%

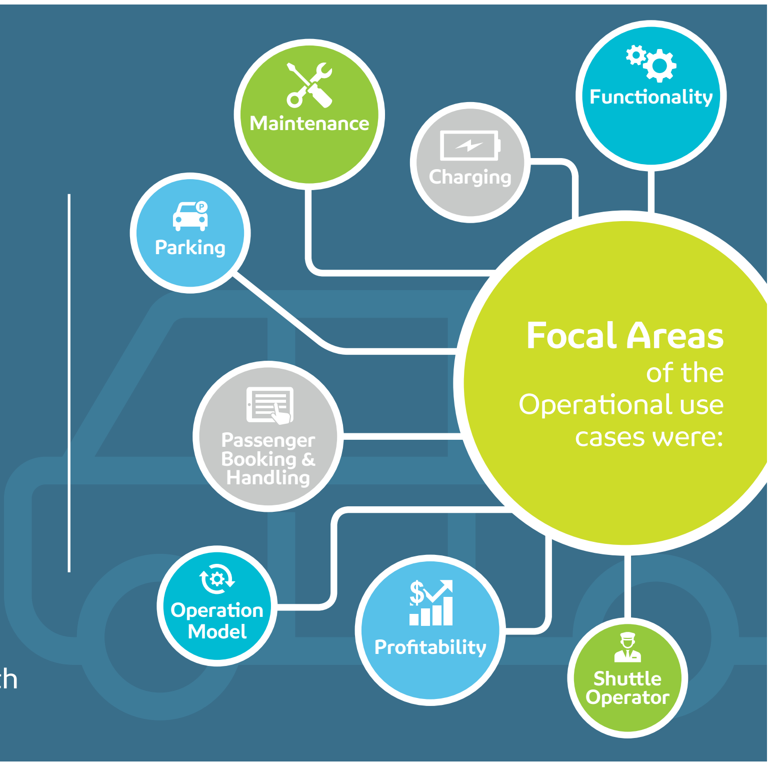
of the hours were for demonstrating & trialling with passengers.

57%

of the operational time was spent fine tuning the shuttle configuration & testing the use cases.

Total of 682km

During the 23 days of the six-week trial period from 24 April to 31 May 2018, the AV clocked up 276km – with a total of 682km since October 2017.



NAVYA provided remote technical support on a 24/7 basis, while on-the-ground technical support was also provided through the RAC in Western Australia, whose staff have been trained by NAVYA.

Five operators received comprehensive training, comprising theoretical and practical experience, with four of these operators from HMI Technologies and one from the University. All operators received NAYVA certification enabling them fit to operate the Autonobus and undertake Level 1 and 2 support.

Findings, Key Learnings and Recommendations

Smooth, safe operations – In preparation for operating the shuttle in such an urbanised environment, the project team conducted a series of workshops and live demonstrations with all interested and impacted stakeholders including the La Trobe University security and emergency response teams, PTV, current bus operator (Dyson), local council and emergency services (VIC Police and Fire Brigade). Furthermore, a comprehensive emergency response plan was developed and communicated with the relevant stakeholders, and an emergency drill event took place before operating the go-live service. The Autonobus was found to operate safely with no incidents, breakdowns or cancellations due to vehicle faults throughout the project. It complied with all applicable road rules in a live urban environment, and safely demonstrated reliable interactions with other road traffic.

Appropriate technical support – The remote support from NAYVA was excellent; with Level 1 and 2 available to the trained operators 24/7 via direct communications (using online tools and an in-shuttle intercom), and Level 3 provided by NAVYA-trained staff at its local Australian partner, RAC WA. The provision of a more direct voice communication (such as phone/skype compared to emails/text messages) with the on-board AV operator during the trial period would have been beneficial. It is recommended that a local technical support team be established in Australia for sustainable commercial operations of AV shuttle services in the future.

Reliable battery solution – Battery life was found to be more than sufficient (at least six hours with air-conditioning on, and up to 16 hours without). The speed was kept to 18km/hr (on a 30 km/hr road) to accommodate the irregular behaviour of passers-by – especially those seeing the AV for a first time – in a busy public environment. Increasing the speed up to 30km/hr would add to the commercial value of the service, however crash testing would need to be undertaken beforehand to ensure this can be done in total safety.

Cybersecurity – No cybersecurity issues arose or were detected.

Key challenges – One difficulty the project identified was the time it took to program the route. Currently, these AVs can only operate on defined, mapped routes. This appears to be a limitation currently of many Autonomous Vehicles. However, we understand that NAVYA and other AV shuttle providers have made the process for their next generation vehicle more efficient in this respect.

Another challenge identified by the project was that a person (with accreditation and strong ICT knowledge) must be on-board to operate the vehicle, should it require manual intervention and/or troubleshooting of the systems onboard. Further, that because the operator must stand up to operate vehicles of this type in manual mode, an exemption was required from the State's governing body (VicRoads) for not wearing a seat belt. In addition, certification from Transport Safety Victoria was required to operate the Autonobus for non-commercial service. Note: operating the vehicle remotely is a capability currently under development.

One of the main challenges encountered during the trial was other traffic; in particular the buses interacting with the Autonobus, tail-tagging and not giving way to the Autonobus. This issue was mitigated by implementing appropriate traffic control and advisory signs along the route, and through proactive stakeholder engagement with the relevant authorities and bus operators/drivers, which included explaining the technology itself and its value proposition.

Lastly, the Autonobus operated safely, without any disruption in different weather conditions (eg. overcast, light rain, wind and high temperatures). However, rides were at times cancelled due to threats of storms and thunder, to ensure passengers remained safe and dry.

IN SUMMARY

Conditions which were valuable to the operational success of this project and are recommended for future deployments:

- ✓ Safety management and traffic management plans are in place, with all relevant emergency personnel trained in how to attend to a situation relating to electric AVs (not just conventional vehicles);
- ✓ Advice to other road users about AV operators;
- ✓ Managing the inter-operation with public transport (i.e. bus or light rail);
- ✓ Repeater station infrastructure for precise positioning around the operational precinct (which is set to roll out in the future, following the Federal government's 2018/19 budget which committed funds to overhauling this infrastructure in Australia); and
- ✓ Starting with a slow speed to enable all road users to familiarise themselves with AV shuttle operations and progressively increasing speed to desired operational levels.

Additional recommendations include:

- ✓ Upskilling current bus drivers to learn how to use AV technology and future ICT systems;
- ✓ Telecommunication companies increasing their commitment to better quality service and ICT infrastructure to provide reliable 4G mobile coverage and other operational aspects of Autonomous Vehicles; and
- ✓ Government bodies reviewing current road rules, regulations and legislation to accommodate the future deployment of AVs – such as seat belt exemptions for AV operators, having dedicated lanes to overcome the speed issue and/or sharing bus lanes for this alternative mode of transport.

3. TECHNICAL

Primary objective:

Develop knowledge and expertise relating to the development, deployment and operation of Autonomous Vehicles (in particular the Autonobus), and all associated technologies.

Project outcome:

The project demonstrated that AVs like the Autonobus have the capability, and are ready now, to operate safely and effectively in precincts, similar to that of the La Trobe University campus and on some public roads.

Understanding the technical capability and limitations of the AV shuttle was essential in being able to determine its safety within the operational precinct. Thus as mentioned in Section 1 – Safety, a series of use cases were conducted to gain more insight into the behaviour of the technology during a range of planned and unplanned situations.

Furthermore, the Autonobus required a number of infrastructure elements in place for it to function reliably within the closed, controlled environment of La Trobe University, including Global Positioning Satellites (GPS), an RTK reference station mounted on the highest building along the route; providing adequate coverage and line of sight, as well as strong 3G/4G telecommunication transmissions to enable GPS correction between the RTK reference station and the AV shuttle, and a reliable, real-time connection with the NAVYA remote monitoring centre in France.

Findings, Key Learnings and Recommendations

ICT Infrastructure

It was found that the current technology of the AV shuttle relies primarily on the precise positioning service for navigation (GPS), complemented by the local RF link between the shuttle and the RTK station, and the static infrastructures such as the surrounding buildings near the programmed route(s), kerbs, and bus stops. (Note - The line markings and other road furniture were not required for the Autonobus' operations based on the technology available during the trial.)

Thus, ensuring there is sufficient connectivity and stability of the mobile ICT infrastructure (particularly GPS and 3G/4G coverage) is vital to the successful operation of the vehicle. Although the federal government in 2018/2019 already committed funds to assist with addressing this future need, a commitment and partnership from the telecommunication companies surrounding the upgrading of this infrastructure must also be considered in order for this technology to be successfully deployed.

Automation

The shuttle was found to have limitations in its Level 4 Hardware/Software (sensors and algorithm) capability. In particular, a "blind zone" was identified where it could not recognise objects on the ground up to 350mm in height and within a short distance from the front of the shuttle, due to the limited capability of the 2D lidars for low object detection; an issue which has been solved using 3D lidars in the next generation of the AV shuttle.

However, the Autonobus interacted safely with the other traffic and pedestrians and in accordance with the applicable road rules. It also had some difficulties with road surfaces where the grade changed to above 12 degrees (such as speed humps), the median or a kerb, when turning quickly in a narrow roadway. This was due to limitations and positioning of the sensors used.

During the course of the trial, NAVYA and other AV shuttle providers advised that these issues have now been addressed in the next generation of the AV shuttle, through the addition of cameras and more advanced sensory technology underpinned with smart analytics and Artificial Intelligence (AI).

Remote Monitoring and Functionality

The shuttle also had some challenges at roundabouts, whereby its algorithm was unable to predict other road users' behaviours, requiring traffic controllers to assist with this movement. This was most evident when traffic approaching the roundabout did not give-way to the shuttle; with the shuttle only slowing down once it was close enough to the other vehicle, based on the distance and angle detected.

However, as the behaviour of the shuttle becomes better understood by other drivers, road users and pedestrians within the precinct, the need for operational treatments will reduce over time.

In addition, it is also expected that as the artificial intelligence and machine learning capabilities of the technology improves, these vehicles will become better at predicting human driver behaviour (while complying with all relevant rules and regulations for optimal safety) and increase their capability for 'vehicle to vehicle' and 'vehicle to infrastructure' communications, alleviating many of these concerns.

Although NAVYA provided 24/7 support during the trial, through direct communications (including online tools and an in-shuttle intercom) as well as Level 3 trained staff from their local Australian partner, RAC WA, it is strongly recommended moving forward, as identified in Section 1 – Safety, that an Operational Control Centre be established to look at the remote operation of AVs, as well as their integration with other modes of transport, to ensure safety across the whole public transport network.

Electrification

The Autonomous Vehicle is electric, requiring a number of facets to be clearly understood by its operator. For example, the type of charging connector, how long it takes to charge under normal operation scenarios, and the similarities of this technology with other vehicles such as electric buses.

The Autonobus supports both wired and wireless charging solutions, equipped with an industrial 3-phase power plug as well as a wireless charging pad. The wired fast-charging option, which uses a standard 3-phase cable and power point was adopted during the trial. Charging time typically took up to four hours, with the charging cycle lasting between 7-12 hours depending on the AV's travel speed and whether the air-conditioning was operational. Although not used during the trial, the wireless charging solution is ideal for temporary charging at bus stops, nominated parking bays and other appropriate locations along a route, providing safer and more convenient charging whilst the shuttle is in operation.

It is envisaged that as the number of deployments of AV shuttles increase, it will be possible to accelerate both the performance and the adoption of this technology, through operating and testing the vehicles in incrementally higher activity environments, whilst still ensuring the safety of passengers, the public and the vehicle. As with existing public transport modes, speed restrictions and physical lane separations – applicable to some trams and bus rapid transit operations – will be key to maintaining a safe operating environment.

IN SUMMARY

For future operations, an AV at SAE Level 4 would require:

- ✓ Suitable physical and digital infrastructure for connectivity, precise positioning and battery charging;
- ✓ Stakeholders in the local environment to embrace an overarching operational framework which requires a revised concept of operations for all movements within the road corridor (pedestrians, cyclists, light vehicles, commercial vehicles, heavy vehicles and shuttles) as well as a campaign informing other road users of this concept; and
- ✓ An overall safety assurance, traffic management and incident management response plan for all manual and automated operations.

4. CUSTOMER ADOPTION

Primary objective:

Provide an opportunity for the public to interact with Autonomous Vehicles and understand customers' behaviour using the Autonobus, as a complement to mass transit services.

Project outcome:

Overwhelmingly positive feedback was obtained from participants on their experience using the Autonobus and on a range of matters, including the expected level of service and price for the future deployment of AVs (eg. first and last mile on-demand transport services).

In order to determine the viability of the shuttle to provide a 'first and last mile' service as well as to better understand customers' perceptions and requirements, a comprehensive end-user survey was conducted to analyse users' views on this alternative transport mode.

Stakeholder Engagement

Assessment of the stakeholder environment identified four broad categories regarding the (valid) reasons as to why someone would be involved, interested, concerned and/or participate in the pilot project:

1. Trial partners who were actively participating in the implementation of the La Trobe Autonobus Pilot Project at La Trobe University;
2. Organisations and individuals who were interested in the progress and outcome of the pilot;
3. Organisations, groups or individuals who were concerned with the pilot, particularly its progress and how it may impact their future job security; and
4. Potential customers (participants) who the project team engaged through customer engagement and marketing.

As such, a cohesive stakeholder engagement and communications plan was developed, with the communications objectives being three-fold:

(a) To educate the public and raise their awareness on Autonomous Vehicles, in order to gain their support and trust in these vehicles;

(b) To promote the partnership and key roles played by each stakeholder in the trial project, demonstrating synergies and commitment of each organisation to the future of mobility; and

(c) To persuade (industry and community-wide) acceptance of the technology.

Customer Engagement

(i) Recruitment: Public Education

An online registration portal was set up; and with support from the RACV, Keolis Downer and many other partners, La Trobe University launched an extensive recruitment campaign to attract a diverse spread of customer demographics. This campaign targeted other road users of all kinds (such as staff, students, bus operators, local police, local council and anyone else positively or negatively impacted by the shuttle) as well as key government and safety regulators. A range of digital and physical channels, including social media, public relations, demonstrations and speaking opportunities, resulted in an extensive public education campaign reaching over four million people.

(ii) Customer Feedback

Upon registration, each participant was asked to complete a survey twice – before and after the ride on the Autonobus – to understand the impact of the experience and their (potentially changed) views of the autonomous vehicle.

Using the LTU Centre for Technology Infusion's proprietary "Techadoption Methodology", the survey measured a range of factors including the participant's overall usage intention, as well as their usage intention drivers, perception of Autonomous Vehicles, what they consider 'value for money', where they could see this technology providing a comparative advantage, and most importantly whether there is a need (use case) for AVs becoming a future public reality.

Can you imagine yourself using an AV Shuttle on a regular basis in the near future?		
Pre-ride	**Factor**	**Post-ride Now that you have been on the Autonobus...**
Do you think that Autonomous Vehicles are going to be an important mode of transportation in the future?	Importance	Do you think that Autonomous Vehicles are going to be an important mode of transportation in the future?
How do you feel about Autonomous shuttles?	Attitude	How do you feel about Autonomous shuttles?
	Price	What would be a reasonable price?
	Experience	How would you rate your experience?
To what extent you are concerned about the below...	Concerns	To what extent you are concerned about the below...
How appealing are the below potential benefits of Autonomous Vehicles (AV's) like the Autonobus.	Benefits	To what extent has this experience influenced your opinion about Autonomous shuttles in general?*
How familiar would you say you are with the concept of self-driving vehicles.	Knowledge	How familiar would you say you are with the concept of self-driving vehicles?
Is there a problem? To what extent do you agree: Walking from your office to car parks or public transportation can be a nuisance, sometimes I feel unsafe when I walk to a car park or to a tram, train station or bus stop.	Need	What is the appeal of the solution? To what extent do the below uses of an Autonobus appeal to you? If the Autonobus were to become a permanent service on Science Drive, do you think you would use it on a regular basis in the near future?

Over 1,100 people completed the pre-ride survey, indicating they would happily volunteer to be part of the trial, with 517 participants travelling in the Autonobus and completing the post-ride survey. Although this trial inherently attracted people who were (personally or professionally) interested in participating in the latest advancements in the mobility space, the survey analysis mitigated this bias by separating the results of these 'passionates' and 'professionals' from the 'common users'.

Findings, Key Learnings and Recommendations

Customer feedback was very positive. The Autonobus received high levels of acceptance from the community; bringing this future 'first and last mile' AV shuttle solution one step closer to a becoming public reality.

Furthermore:

- Professionals involved in the transport sector and early adopters of technology were the most optimistic about the future use of AV shuttles; however the 'common users' group showed the largest positive shift in perception between the pre-ride and post-ride surveys;
- Users also indicated they would be willing to use such a service again and were now more familiar and comfortable with AV technology;
- After the trial, only 10% of customers said they could not see themselves using an Autonobus in the future, down from 18% prior to the trial – so it would be important to maintain this positive perception during the deployment of driverless shuttles and making them a public reality;
- Concerns were around 'cybersecurity threats tampering with the system' and 'getting help quickly if something goes wrong', and surprisingly not around the fact that there is no driver on board. These misconceptions would need to be addressed before deploying shuttles into the wider community;
- Passengers felt comfortable and safe, however found the speed of the Autonobus too slow at times and were frustrated when the bus stopped for 'no reason', such as at speed humps, pedestrian crossings, or when there were sensory issues with objects less than 350mm in height (as discussed in Section 3 – Technical).

Survey results using the LTU Centre for Technology Infusion's "Techadoption Methodology" scorecard, delivered the following overall conclusions:

Factor		Before: 10 is the highest score	After: 10 is the highest score	Strength/Weakness
Usage Intention		7.7	8.5	Strong
Perception	Importance	8.4	8.7	Strong
	Attitude	7.7	8.4	Strong
	Experience		8.4	Positive at low speed
Comparative Advantage	Concerns	5.3	6.5	Positive - relatively low correlation, more research needed
	Benefit	8.5	8.1	Strong
	Knowledge	5.9	8.3	Moderate - relatively low correlation
Use Case	Need	4.9	8.3	Strong appeal of use cases & among specific sub-segments

Usage Intention

As mentioned, usage intention was high. Prior to experiencing the ride, this was driven by the importance of the technology and the participants' 'mostly positive attitude' towards it. Assuming however, that the technology appeal will diminish over time – once the novelty of an Autonomous Vehicle wears off – maintaining a public perception that AVs deliver a strong community need, are 'fit for purpose' and are the answer to solving several transportation problems, will be an important and influential factor commercially.

The study identified clear benefits of the AV shuttle that:

- cater to minority or specific needs groups such as the elderly or disabled;
- reduce the impact on the environment; and
- reduce congestion on the roads.

After participants experienced a ride on the Shuttle, usage intention was much stronger, driven by the actual 'use case' and problems which the Shuttle could (potentially) solve, such as providing 'first and last mile' transport options, as well as the ability to increase personal safety (by offering a transport service during extended times of day), which resonated strongly.

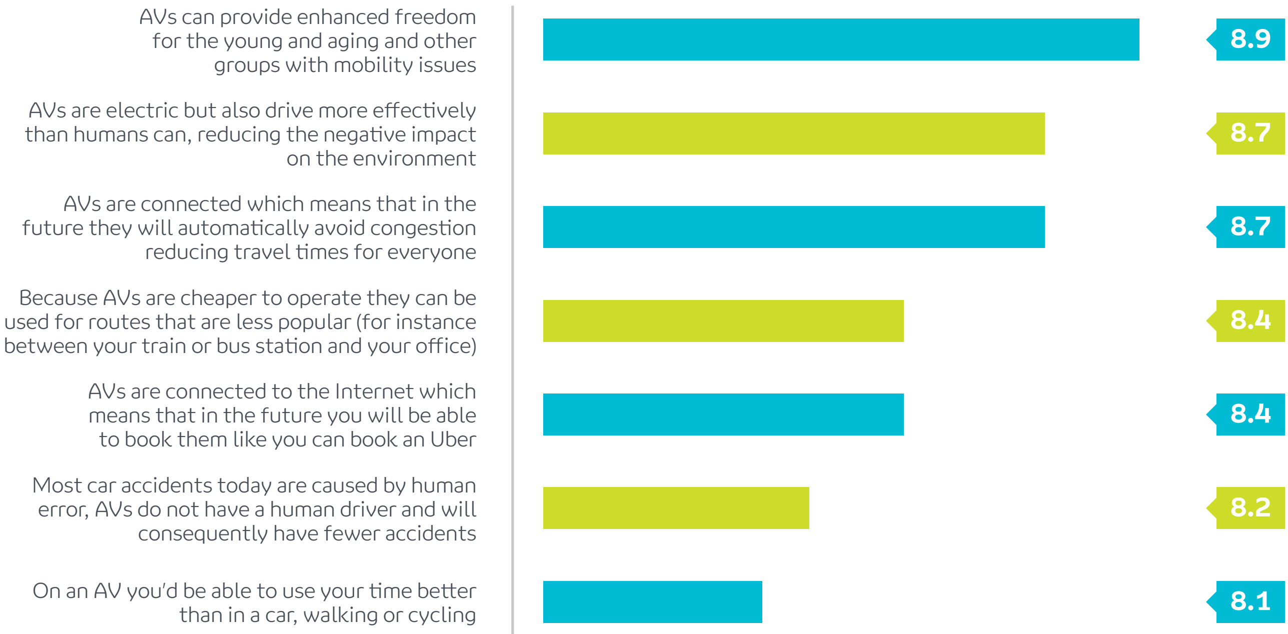
For instance, female customers indicated their preference to use the Autonobus instead of walking in the dark; and students and staff would prefer it as a mode of transport to/from the nearby train station (particularly at certain times of day and in wet weather conditions). Participants that were not affiliated with La Trobe University indicated that similar use cases could be extended to nearby office buildings, busy city centres or high traffic tourist attractions, as well as public transport services where non-viable bus routes need an alternate solution.

More specifically:

Answers to the question, "Why would you use it or in which situation would you use it?" are presented in the above word cloud (whereby the size of the word reflects the number of mentions).

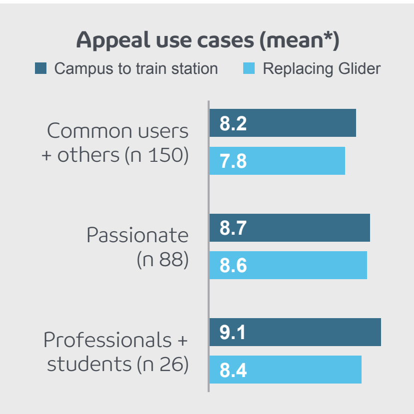
Potential benefits of Autonomous Vehicles in general also varied and ranked very highly:

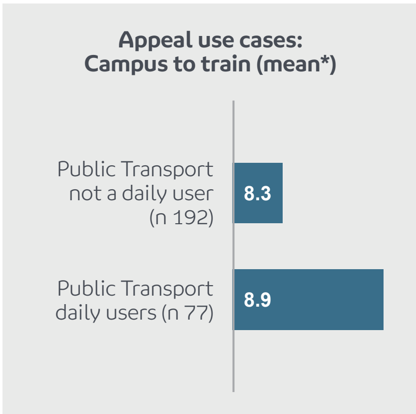
Potential Benefits of Autonomous Vehicles (mean)

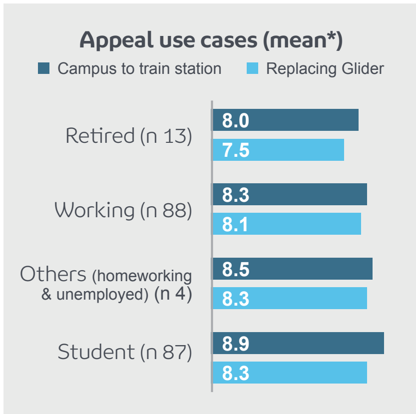


Commercial Appeal

The use cases considered for introducing Autonomous Vehicles were found to have strong appeal as evident in the data shown below, especially amongst daily public transport users:







*significant difference

Based on the conditions of the pilot, participants indicated they would be willing to pay to use the service along Science Drive, at a price between **$1.50-$2.50**. However, it is recommended that more research be conducted in this area to test a real use case at commercial rates to better understand the price at which users consider the shuttle as value-for-money.

Longer term, a pricing framework in consultation with private transport operators and other industry stakeholders, should also be developed once this value-for-money threshold is known.

Exclusion of certain Demographic Groups

It is important to note that the trial was limited: users from certain demographic groups were not allowed to participate in the trial for reasons of safety and risk management – such as infants and users with prams or disabilities (including physical, visual or hearing impairments). Consequently, greater research in this area with the focus of attaining a deeper understanding of how elderly people or users with a disability can engage with technology of this nature (in consultation with the Victorian Disability Advisory Council) is strongly recommended, particularly as many of these customers would fit within the target groups that the deployment of AVs is expected to be able to serve.

In addition, it would be advisable to undertake further research to understand the mobility needs of a larger, more diverse population, including people who don't understand English or have language barriers, as well as communities in more remote geographical locations, or where there is a critical need for increased social inclusion.

Deployment

The research demonstrates a demand for the deployment of Autonomous Vehicles and that they would be positively welcomed into the LTU precinct, and in other similar environments where there is high activity and a controlled set of circumstances.

The findings suggest that people expect AVs to go above and beyond 'normal public transport services' – including picking up specific groups of people, running at unusual times of day and taking customised routes, in exchange for modes that have a driver on-board and hence are perceived as more expensive.

In part, the success of the trial may be related to the significant extent of communications surrounding the project, which included newspaper, radio and television coverage.

It is strongly recommended therefore, that for other AV deployments, public awareness campaigns should include the whole community, not just the immediate precinct and nearby residents; and that the messages communicated amongst a broader user group include the broader *and* more specific benefits of using such a service, as well as addressing and alleviating some of the concerns (around cybersecurity risks and being able to get help quickly in the event something goes wrong), as well as how to behave around this new technology and alternate modes of transport.

Furthermore, interior design features that are 'fit for purpose' would need to be considered by the manufacturer, so that the vehicles delivered are customised and 'designed for purpose' – ensuring all sections of the community can be included in the rollout (for example, access ramps and restraints for wheelchairs). A commercially run trial, for instance, a service from the university campus to a nearby railway station, could also provide significant value in demonstrating the potential uptake of this type of service.

IN SUMMARY

Recommendations for the future deployment of Autonomous Vehicles:

- ✓ Deeper understanding and testing is required of how elderly people or users with a disability can engage with Autonomous Vehicles, as well as people with English language barriers or families travelling with prams;
- ✓ Development of a pricing framework to ensure commercial viability. Passengers indicated they would be willing to pay between $1.50-$2.50 to use the service based on the conditions of the pilot;
- ✓ Public awareness campaign to maintain importance and a positive attitude, by communicating messages associated with benefits of the service, the alleviation of potential concerns, and how to behave around this new technology;
- ✓ Vehicle's interior is 'designed for purpose' by the manufacturer, to ensure social inclusion; and
- ✓ Conduct a commercial trial which could provide insight into the potential uptake and value participants place on the service.

5. AV AUTONOBUS READINESS

Primary objective:

Develop knowledge and expertise relating to the development, deployment and operation of Autonomous Vehicles (in particular the Autonobus), and all associated technologies.

Project outcome:

The readiness of the Autonobus was assessed, including performance and capabilities. Gaps were also identified to help decision makers and transport operators develop robust AV deployment plans for a variety of applications.

Findings, Key Learnings and Recommendations

The AV (Autonobus) demonstrated that it can operate a whole route in the full automated mode (with an Operator on board), and that it can inter-operate with other road users, including buses at the Transit stop, enabling it to complement public transport operations, as a first and last mile solution.

However, operating this shuttle on public roads would be more challenging – so it is recommended that a staged deployment process be considered starting with a controlled precinct, through to local roads and beyond.

Further, the trialled vehicle was not fitted with features for the mobility impaired (such as a ramp) - this would also need to be tested prior to deployment.

Aside from the technical aspects, more widespread communication and proactive community engagement would need to be undertaken to familiarise the community and other road users in relation to the behaviour of the shuttle and to ensure safe interactions with the shuttle.

In summary, after assessing the readiness of the AV shuttle in various scenarios (use cases) – including its performance and capabilities – combined with the positive feedback received from the public, it was determined that AV shuttles, such as the Autonobus, are ready for commercial deployment within a controlled environment, accompanied by appropriate risk, safety and incident management plans.

In addition, as identified in the "2018 KPMG Autonomous Vehicles (AV) Readiness Index"[1], a study which evaluates how 20 selected countries rate according to four pillars (policy & legislation, technology & innovation, infrastructure and consumer acceptance) integral to the adoption and integration of Autonomous Vehicles, Australia ranked 14th.

In the report, Australia scored better on consumer acceptance, which is consistent with this trial's findings. Infrastructure and the quality of our roads also rated well. However, although the availability of 4G and AV-related policies and legislation are considered reasonable, there is still an increased need for electric charging stations across the country, combined with further improvement to the roads to assist with AV readiness.

Furthermore, the publication raises the importance of collaboration and that Australian state and federal authorities need to "establish a universal platform to support AV transitioning across the nation" – a recommendation strongly endorsed by this Project team and similar to the comments made in Section 6 – Legislation and Regulations.

[1] https://home.kpmg.com/au/en/home/insights/2018/01/2018-autonomous-vehicles-readiness-index.html - cited 29 July 2018

IN SUMMARY

Recommendations for the future deployment of Autonomous Vehicles:

- ✓ Autonomous shuttles are ready for commercial deployment within a controlled environment, accompanied by appropriate risk, safety and incident management plans;
- ✓ Australia ranked 14 out of 20 countries evaluated in the "2018 KPMG Autonomous Vehicle (AV) Readiness Index";
- ✓ Australia needs more electric charging stations;
- ✓ A consistent regulatory platform of standards across all state and federal authorities needs to be developed to support AV deployments nationally; and
- ✓ More widespread communication is required to familiarise the community and all road users.

6. LEGISLATION AND REGULATIONS

Primary objective:

Develop knowledge and expertise relating to the development, deployment and operation of Autonomous Vehicles (in particular the Autonobus), and all associated technologies.

Project outcome:

Gaps and conflicts in the existing legislation and regulations were identified, with a need for these to be addressed in order to enable Autonomous Vehicle (such as Autonobus) operations to complement existing public transport services.

A number of authorities were involved in investigating the regulatory and operational frameworks associated with Autonomous Vehicles, including their operation on public roads, private roads and as a public transport operator.

Regulations

Two key approvals were required by VicRoads – (i) registration of the vehicle in Victoria (whereby an "unregistered vehicle permit" with specific conditions was provided); and (ii) a seat belt exemption for the Operator, so that he/she could stand while the AV was in manual mode. Keolis Downer and HMI also obtained a certificate from Transport Safety Victoria to operate the AV for non-commercial services.

In addition, three important documents were developed, approved and followed for the Autonobus' operations, including: (i) a Safety Management Plan as articulated in the National Transport Commission's *Guidelines for trials of automated vehicles in Australia*, (ii) a Traffic Management Plan for all phases of the project, and (iii) an Incident Management Response Plan which outlined the key messages and actions to be undertaken in response to various incidents, including contacting a range of organisations such as the precinct's OH&S team, Bus Safety Victoria, VicRoads, Vic Police, the fire brigade and/or ambulance, as necessary.

Legislation

Several of the Victorian Road Safety Road Rules and Road Safety (General) Regulations were identified as cause for concern, requiring significant discussion with the relevant authorities. This generally relates to the fact that legislation is directed at the driver of the vehicle rather than the vehicle itself - which is the case of an AV, that has no driver.

Findings, Key Learnings and Recommendations

Considerable amounts of time were required to examine each regulation and road rule, in the context of operating a vehicle without a steering wheel and driver, as there was a lot of unknown territory associated with the issues being covered. Note: Current regulations relate to a pre-existing conceptual and operational framework which has a driver in control of the vehicle. VicRoads and other related agencies were extremely helpful in providing constructive feedback; ensuring the three management plans met the necessary requirements (albeit with a conservative approach) and in achieving this (non-driver) regulatory approval. Also, as the shuttle is not classified as a bus under current regulations, it was agreed with Transport Safety Victoria as part of the certification process that the shuttle shall comply with all relevant bus safety policies and procedures.

Having participated in the pilot project, all parties involved found the process beneficial in becoming better informed of the key issues; and that it increased their confidence and will positively influence their approach to future AV deployments, based on lessons learnt from this experience.

In addition to the formal regulatory and legislative frameworks that needed to be complied with at the State Government level, there were also ethical considerations which needed to be taken into account at the University level. Similar to any other clinical trial conducted by the University, there were numerous issues which had to be discussed – such as the duty of care associated with the participants who volunteered to be part of the pilot project and ride on the AV – requiring numerous teams including OH&S, Facilities, Safety and Legal, to determine what each of the management plans entailed; as well as whether the roads were in fact considered public or private, and as such, what regulations were to be followed; and ensuring strict privacy of the technological, operational and customer experience data.

Currently, there aren't any regulations in Australia which monitor the data accessible by the Original Equipment Manufacturers (OEMs) and the operator. For the trial, because NAVYA is a French company, the project team complied with France's Privacy Act for accessing any data. This included the AV Operator only being given limited access to the shuttle's computer systems as necessary for the day-to-day operational tasks as well as any Level 1 troubleshooting purposes. Moving forward however, appropriate regulation is required to manage and administer the data access of all stakeholders who are involved in delivering and operating this technology; data access and availability is crucial without compromising the AV's system, safety and security.

Government Involvement

Whilst in Victoria a well-established system for road operations exists, based on the current combination of road rules, vehicle registration and driver licensing, eco-systems of shuttles and other 'innovative' vehicles inter-operating with the current road users, there is a significant need for an operational framework to be developed including overall system design and management, so that the future deployment of AVs is enabled in an efficient and timely manner.

Furthermore, similar to the approach in South Australia, it is strongly recommended that this framework is created in Victoria by a committee of stakeholders, led by Transport for Victoria.

We envisage this committee would comprise a representative from each of the relevant regulatory bodies and government departments and be focused on the primary goal of understanding and integrating urban planning and future innovative transport solutions (such as Autonomous Vehicles) and how to modify existing planning and regulatory structures in order to allow deployment in the future. This committee would then develop and agree – via a highly collaborative decision-making process - on a single, streamlined, consistent and standardised set of requirements, such as regulations, guidelines and legislation, which all Victorian regulatory bodies would endorse; resulting in a reduction in time for approval and in duplication of the resources invested, as well as a mutually-beneficial increase in knowledge, expertise and common understanding of AVs by the people and entities involved.

IN SUMMARY

Recommendations for the future deployment of Autonomous Vehicles:

- ✓ Introduce a more formalised mechanism led by Transport for Victoria (but involving all stakeholders), which captures lessons learnt and knowledge associated with Autonomous Vehicles and their future deployment;
- ✓ Adapt regulations following subsequent deployments, based on learnings and recommendations with a 'loop-based' learning process, managed by Government;
- ✓ Consider several factors which apply to both public and private roads, including the vehicle registration process, safety management plan, incident management and reporting, traffic management and driver certification processes, as well as the current regulations and road rules which impact the enablement of modern transport solutions to be deployed. This also applies to future trials and the governance associated with passenger safety;
- ✓ Enable more flexible ethical requirements and compliance processes until more formalised structures are defined, so that future projects of similar nature can be executed;
- ✓ Develop appropriate regulations relating to the management, administration, availability and access of data by stakeholders delivering and operating AV technology; and
- ✓ Create a more comprehensive approach at the national level, which develops guidelines around what the vehicle can do / be allowed to do and how the operation of the vehicle can be programmed, which the states must follow. Encourage the Australian Government to initiate this, in consultation with technology experts, academics, ethicists, transport operators and state representatives.

THINK
LIKE A
PASSENGER

"If I didn't have a car available to me, having this shuttle collect me from a train station would be really useful. Also, it saves fuel and time trying to find parking."
Comment from a Pilot Project participant

7. COMMERCIAL AND LIABILITY

Primary objective:

Engage the community in order to refine the value proposition for Autonomous Vehicles, with a view on future commercial operations which offer integrated mobility services.

Project outcome:

A commercial framework was developed which outlined the responsibilities and liabilities between operators, vehicle suppliers, road operators/precinct and supporting third parties (eg. insurance companies, subsidies, etc).

The commercial framework developed to execute the pilot project included a clear definition of the responsibilities of the other stakeholders and partners such as VicRoads, La Trobe University, PTV and Bus Safety Victoria; as well as an overall cost estimate of operating the Autonobus.

The Autonobus trial at La Trobe University involved interaction with the transit bus stop and showed the potential of a 'last mile' service which could ultimately replace the current La Trobe Glider bus service - a free, day and night bus service for students, staff and the wider community, which travels in a loop around the Bundoora campus. With over 40,000 students and staff at this precinct, it is estimated that approximately 15,000 people commute to the university on a daily basis. Replacing the Glider with an AV shuttle could provide a service with longer operating hours, increased safety and greater flexibility.

LTU's roads were all considered private roads of the university, and hence was covered by the Public Liability Insurance which includes the University property and infrastructure used in this pilot. In addition, HMI Technologies (the vehicle owner/operator) insured the NAVYA Arma-4 shuttle with the appropriate Public Liability Insurance for the vehicle, including for its operation, off-site storage and transportation to site.

As the road manager and entity responsible for the local environment, LTU was also the final approver for all OH&S matters; and developed, tested and signed off on the safety management, traffic management and incident management response plans, in consultation with VicRoads. This action also included a full emergency plan supervised by various key emergency departments (eg. police, fire, ambulance) to address any additional safety or liability concerns.

Findings, Key Learnings and Recommendations

Commercial

The commercial possibilities associated with the deployment of Autonomous Vehicles are positive -assuming the level of subsidies provided are similar to existing public transport modes. However, until economies of scale are achieved and customers feel comfortable integrating the use of AVs into their everyday lives, the commercial viability of AVs is expected to require significant investment in order to realise these longer-term financial benefits and reduce the whole-of-life cost of operations to sustainable levels.

Based on: (i) amortisation of the capital costs over 10 years and current operating costs, (ii) using patronage data from recent trip surveys in and around the University campus, and (iii) a notional fare of $2 per trip (which is mid-range based on participants' suggestions), a service provided on campus would cover 49% of its whole-of-life costs, assuming:

This would represent a much lower level of subsidy that applies to many existing public transport services, which often only covers around 20 to 25 per cent[2] of their costs from the fares.

Accreditation and Approvals

The practical challenges of obtaining relevant exemptions to meet the National Transport Commission's requirements for commercial deployment must be recognised; however, based on the lessons learnt from this pilot project and the increasing experience of operators and regulators, it is anticipated this issue will become less significant over time. This will be especially true if the recommendations of this report (identified in Section 6 – Regulations and Legislation), are actioned.

Liability

From a liability perspective, the greatest area of concern is in determining to whom the duty of care belongs. For this trial, it was agreed that the AV shuttle operator would be liable for all aspects associated with operating and managing the vehicle, and hence an appropriate insurance policy was acquired.

[2] "On the Buses: The Benefits of Private Sector involvement in the Delivery of Bus Services" – a paper prepared by LEK Consulting for the Transport and Tourism Task Force (2016).

IN SUMMARY

Recommendations for the future deployment of Autonomous Vehicles:

- ✓ Develop a clear commercial framework (similar to the Collaborative Research Agreement signed by this project's partners) for future commercial operations;
- ✓ University to conduct further work to see whether a permanent Autonobus service is viable (in conjunction with the existing Glider service);
- ✓ The operator of the Autonomous Vehicle be the sole party liable for any incidents that may occur, and that appropriate insurance be provided to cover all instances – including the AV's storage, operation and whilst charging;
- ✓ Greater discussion amongst the technology, legal and political communities surrounding this previous matter – including an AV malfunction and whether the manufacturer or operator should be liable – and to decide on the ultimate course of action;
- ✓ Current Public Liability Insurance policies (for precincts such as Universities) be extended to allow for the operation of Autonomous Vehicles, on both private and public roads, which clearly outline factors to be considered in establishing liability;
- ✓ Australian Government take charge of this public liability requirement and encourage insurance companies to introduce policy cover which enables the future deployment of AVs in Australia; and
- ✓ Well-documented procedures (including for safety, incident and traffic management), consistent with regulatory guidance (and emerging best practice), combined with regular training and clear communication with staff, passengers and the community, will ensure risks are minimised and safety is maximised.

THINK LIKE A PASSENGER

"It is very bright inside the Autonobus so I can see other passengers and the emergency buttons, as well as the outside view, which gives me a sense of security. Whereas it is not usually so bright in a normal public bus."

Comment from a Pilot Project participant

WHERE TO NEXT?

– Urge Government to Take Action to enable the Deployment of Autonomous Vehicles

– Encourage Greater Industry Involvement

To facilitate the growth of Autonomous Vehicles, we are urging the Commonwealth and State governments to take relevant actions to safeguard the liveability and productivity of our cities in the autonomous era.

Namely:

- Prioritise road pricing reform to manage demand for car travel, and as a policy lever to encourage 'ride sharing' – the presence of dedicated or bus priority lanes for shared rides could represent an immediate opportunity;
- Assist with a dedicated AV testing facility, tailored to simulate Australian road conditions, that can be used by the global Original Equipment Manufacturers (OEMs) to test and ensure the technology is suitable for Australian cities and regions;
- Consider autonomous electric vehicles in all infrastructure planning and investment decision making processes, including the take-up of autonomous ride sharing services and the implications for travel behaviour and land use. According to the trial's findings, immediate areas that could be envisaged are university campuses and high activity centres, which are connected to major transport hubs;
- Encourage an eventual transition from private ownership to ride sourcing for daily travel, including the promotion of business models that provide these services. Governments must also ensure high quality alternatives to car travel are available, including an integrated public transport offer, intermodal hubs with clear way-finding that guide people to their destinations. Reserved areas for walking and cycling are also important;
- Acknowledge that planning today for an AV future is essential; it is not a question of 'if', but 'when' AVs become ubiquitous in Australia. Embracing partnerships between government and the private sector can speed up technology development, while helping ensure that the use of Autonomous Vehicles meets public policy objectives. In this context, funding for more trials is essential to continue to encourage innovation and collaboration and pave the way towards AV implementation; and
- Engage all stakeholders, governments, businesses and citizens with AV planning, as it will impact all aspects of life.

"I feel like Autonomous shuttles will add another layer of transportation around campus making easier to travel around."
Comment from a Pilot Project participant

CONCLUSION

There is a clear opportunity for Autonomous Vehicles to meet some of the existing mobility needs of the community in Victoria and elsewhere in Australia. Governments at the federal, state and local level, combined with statutory bodies, need to start prioritising and planning for this innovative transport technology – and consider how they can integrate this 21st century solution into their urban and transport planning.

The public has indicated there is a strong use case for AV deployment. The trials have been done, with clear indications of their safety; and no immediate need for more testing. Any operational requirements which need to be ironed out can be done during the staged deployment of these AV shuttles in a controlled, protected environment – such as at airports, universities or other traffic-heavy precincts.

AVs are capable of complementing existing transport services, although moving forward there is also a need for new infrastructure to facilitate AV operations – both physically and digitally. For example, AVs need places to pick up and set down passengers safely, readily available charging facilities, and sufficient telecommunications networks to allow precise GPS positioning and to allow vehicle-to-vehicle, and vehicle-to-infrastructure communications.

Other parts of the world have already begun to deploy autonomous shuttles (including Lyon, France; Las Vegas, USA; Canada, Singapore and Christchurch, New Zealand) with much success. Australia seems to be slower to wake up to the opportunity and more can be done.

Autonomous Vehicles present a transport solution which addresses a range of customers' needs – such as accessibility and connectivity, that enables social inclusion and has less impact on the environment – especially when they are shared. They are complementary to traditional public transport (buses, trams and trains), and in particular, offer a viable alternative to private cars for the 'first and last mile' of a journey. In addition, AVs offer opportunities beyond passenger transport, including military, freight, search and rescue applications, and first responder solutions in the case of natural disasters.

Government and statutory bodies must urgently review their existing frameworks (such as legislation and regulations) and make the necessary changes to accommodate the implementation of the new technology, as well as changing the urban and transport planning processes to allow the effective and safe deployment of AVs.

At the same time, the private sector can play an important role in influencing public awareness, educating the community, pedestrians and road users, on the benefits of these vehicles, along with how to behave whilst using them or when near them, and identifying and articulating the opportunities and benefits of deployment.

The technology is already here and is developing rapidly. Australia needs to respond quickly to make the most of the opportunities presented.

THINK LIKE A PASSENGER

future driven
autonobus

THINK LIKE A PASSENGER

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