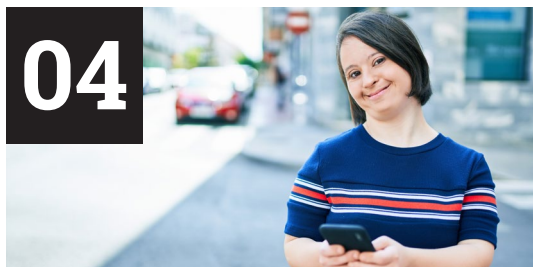


Connected and automated vehicles: barriers and opportunities for people with disability



Contents



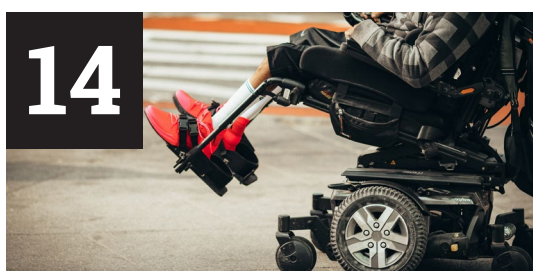
Introduction



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This report provides a summary of the barriers and opportunities that connected and automated vehicles represent to people with disability.

Introduction

“

I'd like to say that what a lot of us are putting to you and whoever else wants to listen is that this is 2021. This is the chance to get it right at last for a properly totally inclusively designed vehicle from beginning to end, from top to bottom at the procurement stage, at the design stage and the outcome. That's where we're at with this.

”

Anyone should be able to use public transport.

However, despite considerable efforts and progress, for many People With Disability (PWD), taking public transport is far from easy or not even an option. Emerging transport technologies – such as Connected and Automated Vehicles (CAVs) – have the potential to alleviate the hurdles but may also introduce new challenges.

To realize the benefits of CAVs, governments are actively considering what impact CAV public transport, and especially driverless public transport, would have on people with a disability.

Because, what defines public transport and how public transport is delivered is being challenged by these emerging technologies and new operational models.

Without concrete action, there is a risk that the regulatory framework will not keep pace with changes in technology and transport choices made by customers.

The Department of Infrastructure, Transport, Regional Development and Communications (DITRDC) is currently reviewing the Disability Standards for Accessible Public Transport 2002 (Transport Standards) and is seeking advice about how the Transport Standards could be adapted in the context of emerging CAVs.



“
In terms of an opportunity, I very rarely use public transport because of my disability. If this makes it accessible, from a business point of view, I think you've got a bunch of people who have similar conditions to me who aren't accessing it at the moment who would want to access it. So, I think there's probably a hidden number of people with disability who aren't using public transport that would. So, from an economic point of view, it's good to remember that there's a hidden bunch who want to access public transport but can't at the moment.

In response to these challenges and with the objective of delivering improved access to our cities and regions for people with disabilities, DITRDC has engaged La Trobe University to:

- clarify the extent to which the current Transport Standards can integrate CAV and associated technologies,
- assess the challenges that people with disabilities will encounter with these emerging technologies, and inform the defining of a framework, and
- recommend amendments to the Transport Standards that can be implemented through the current reform process.

La Trobe's Centre for Technology Infusion conducted focus groups with PWD and representative bodies of PWD at the beginning and towards the end of the project, engaged with the CAV industry globally (with a focus on CAV shuttles and CAV flying taxi's) at multiple points throughout the project (incl. Singapore, USA, UK, Netherlands), and consulted internationally with the United States Access Board¹ and here in Australia with Universal Design Australia.²

This report provides a summary of the barriers and opportunities that connected and automated vehicles represent to people with disability.

¹ U.S. Access Board – Inclusive Design of Autonomous Vehicles. (2021). Retrieved 1 August 2021, from <https://www.access-board.gov/av/>

² Home – Universal Design Conference. (2021). Retrieved 1 August 2021, from <https://universaldesignconference.com.au/>

Connected and Autonomous Public Transport – When will People With Disability be able to use them?

Several forms of CAV are already deployed, others are still in development.

Driverless pods, monorails are operational at several airports around the world and a driverless train is operational in Sydney for some time now.

In Australia, the introduction of two new forms of CAV seems to be eminent: CAV Shuttles have been and are being trialled extensively around Australia. In late 2020, Melbourne Airport has signed a contract with Uber Elevate making Melbourne one of the early adopters.

Other forms of autonomous transport are knocking on the door such as Autonomous taxis and mopeds but it is currently unclear when they will be ready for mass deployment.

The question is, when will PWD be able to use Connected and Autonomous Shuttles and what will be the experience?

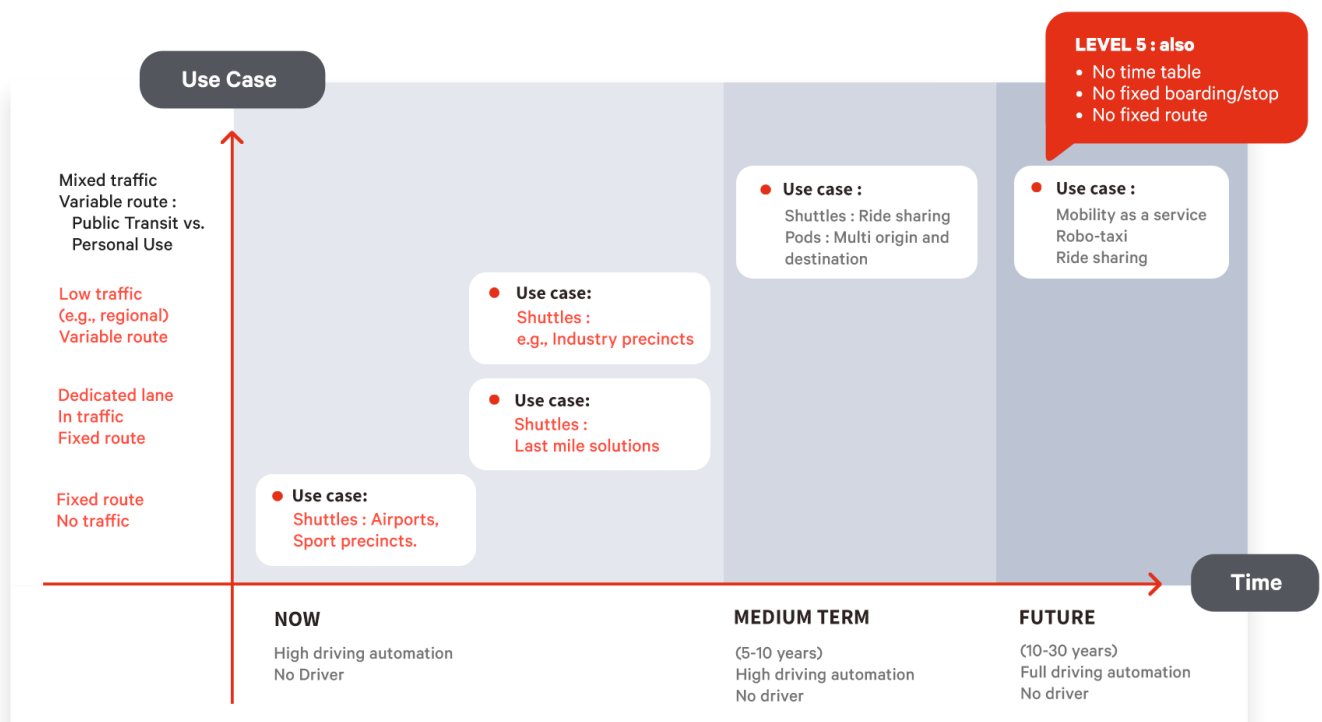
Figure 1 shows a roadmap of the use cases and circumstances in which they will be deployed. Driverless CAV are already deployed and will be deployed without a driver in fixed route use cases with limited traffic.

In the next 5 years, people with Disability will be able to experience a new type of vehicle, in situations where there is no direct assistance available, with routes that may not be linear and a need to book and hail a vehicle using a digital Human Machine Interface. This will be first at private road environments, such as sports and entertainment parks, business precincts and progressively in more complex traffic situations.



“
I think most people with disabilities have a piece of equipment or some sort of aid or some sort of assistance that they use to assist them to interact with the community or with the public transport system, so the bridging between that piece of equipment and comfort levels in using that piece of equipment is the broad I suppose principle that is important from my point of view.
”

Figure 1. CAV Roadmaps use cases
(Source: CTI Industry Interviews)



Connected and Automated Vehicles: Challenges and opportunities



What will be the hurdles and opportunities for people with disability? Which of these should be regulated via guidelines or by being included in the Disability Standards for Accessible public Transport?

Over the past year, we have engaged with people with lived disability in Australia, with their peak body representatives and participated in similar projects overseas. We have also engaged leading manufacturers of Connected and Automated Shuttles (2getthere, EasyMile, HMI and Navya).

Through our research with PWD and manufacturers, we have identified four areas that require CAV guidelines or standards. Much of the attention of CAV industry and accessibility forums is on the vehicle design, however, our engagement with PWD, CAV Manufacturers and operators has identified three additional functional areas of CAV services: monitoring and direct assistance, human machine Interface, and operations.

At this point we have indicated the principles that these vehicles would need to meet in these four areas. In the appendix you can find a complete list of potential solutions to meet these principles.

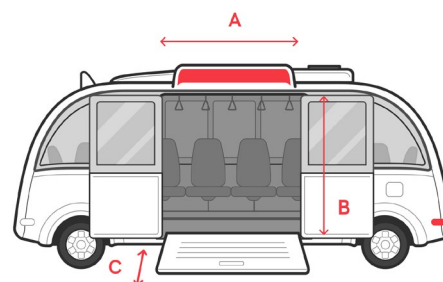
“

My big thing is that I want to be able to get on to this vehicle without assistance. I want to be totally autonomous in an autonomous vehicle. So, I don't need to rely on other people to get down a ramp or put my bag up or tie down my wheelchair or anything like that. I want to be able to get on and off in the flow just like able bodied people, I guess. I need it to be simple so that I just get on and the payment is taken care of somehow without me having to arduously get a card out or tap my watch or whatever.

”

1. Vehicle Design

CAV shuttles that are currently being trialed in Australia are an improvement compared to buses and trams and will meet many of the requirements of the Transport Standards, such as access pathways, automated doors and floor space provided. However, there are amendments to the Transport Standards required, for instance to cater to blind or deaf public transport users and ensure a standard approach for wheelchair users.



Seating availability

With the connected nature of CAV, seating availability does not need to be the concern for PWD that it is today.



Wheelchairs (see also operations)

CAVs should provide independence for wheelchair users, i.e., not require an attendant to secure the wheelchair. Independent and safe use of occupant protection and mobility aid device restraint system - wheelchair tiedown and occupant restraint systems should accommodate low levels of functional mobility /dexterity and provide a high level of safety.



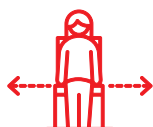
Controls

Learn the controls once, apply everywhere.



Colours

The colour scheme of the vehicle should help, not hinder, visually and cognitive impaired people. This includes seat outlines.



Seating design

The seating design – height, shape and material - matters for PWD whose needs are to be taken into account.



Handles and support

PWD should be able to reach out for support rails and handles instinctively, handles and bars should be implemented in a consistent fashion across makes and models.

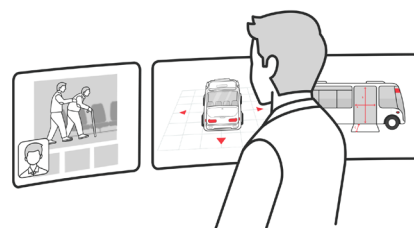




Signage

PWD should be able to view signs and announcements from their wheelchair or seats even if the shuttle is crowded with standing passengers or when it is dark or very bright.

2. Monitoring and Direct Assistance

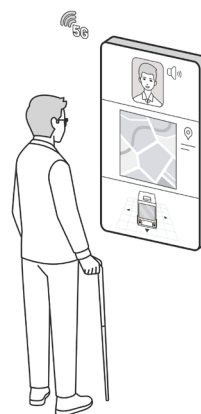
Many PWD rely on direct assistance when using public transport. However, given that presence of a human driver will diminish or disappear with CAVs, 'direct assistance' may not be available. Some functions typically performed by the driver and important to PWD have not been included in the Transport Standards. Most industry representatives are planning to deploy remote monitoring or a steward (either on board or on the platform) which requires specification and consistency.



	Monitoring and Direct assistance	A driver's role is diverse and complex. The CAV experience is set to become more seamless and have less friction, however, not all the functions of a human driver can be automated (yet). When there is no human directly at hand, other forms of assistance are required.
	Identification of Passenger (needs)	Today, a bus driver can identify the passenger [Card used by deaf-blind people] and, for instance, know the place that they need to alight. A CAV should be able to identify a passengers needs.
	Safety monitoring	Safety is paramount and CAV should be able to provide that. The driver of a vehicle is often attributed with the responsibility to look after the passengers' safety, including PWD.
	Conflict resolutions	Unfortunately, PWD do sometimes encounter conflicts in public transport, in which case a driver or platform personal can assist. A CAV should have the ability to intervene in conflict.
	Stewards	For many PWD, traveling in public transport without any form of human assistance is not possible. CAV may have to provide some form of human assistance.
	Platform assistance	Help on platforms or stop overs is often required.
	Emergency management plans	There should be emergency plans for people with disability in case of an accident or other emergency specific for people with disability.
	Emergency communications	People with disability should not be the last to know what happened in case of emergency and what actions are to be taken.
	Emergency training and consistent responses	Across operators, remote control personal and stewards need to agree on consistent procedures and training to help people with disability in emergency situations.
	Emergency phones	Independence could mean providing access to mobile phones in vehicles.
	Customer service	Despite automation and accessibility, some people with disability may need customer service as a backup.

3. Human Machine Interface

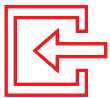
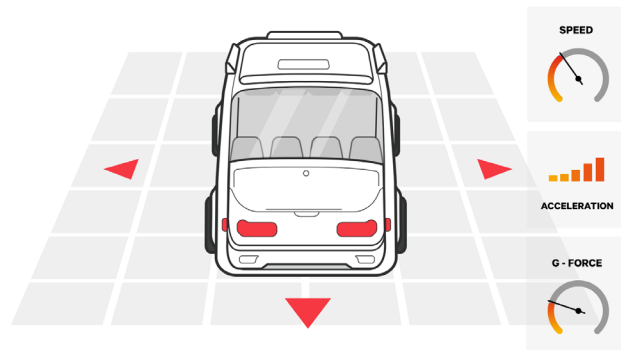
Given that face-to-face interaction with a human driver will diminish or disappear, the need for truly and universally accessible communications increases.



	Touch screen	Everyone should be able to easily interact with the service. The 'touch screen' in current shuttle designs raises many concerns.
	Controls	Controls enable the journey and provide assurance. The functionality of controls should be consistent and PWD should be able to assume that the same controls are present at the places where they expect them.
	Communication of trip progress	When CAVs are not taking a fixed predictable route, understanding trip progress becomes even more essential than it is today. The availability of crucial information by multi modal platforms means, especially during alerts, that the PWD can respond in sync with the other passengers.
	Auditory	PWD who can't see or who can't properly see the sign boards, should be able to rely on auditory messages to understand the actions the vehicle takes, and they need to take.
	Planning, hailing, paying, booking	Hailing, booking, and paying/entering a CAV vehicle should be the same or better compared to a vehicle with a human driver. Hailing and booking are already a challenge for many PWD today.
	Identify correct vehicle and boarding location	The mobility options available are set to become more fluid. To identify the correct vehicle and boarding location is already a concern today, and technologies exist to overcome this challenge.
	Payment	The less physical efforts in the process, the better – swiping a card can be impossible for some PWD.
	No full reliance on smart phones	Even with accessible apps, some PWD can't use phones at all.
	Privacy	Appropriate data collection. There is an understanding that the exchange of information can be valuable, for instance for reserving a seat, however, PWD have poor past experiences with providing identity and information on their disability and in some cases have had negative experiences as a result of sharing personal information.
	Reducing stress and anxiety	For some PWD the absence of a driver increases the level of anxiety (Air taxis in particular). In general reducing stress and anxiety in general related to travel in autonomous public transport services must be a focus area.

4. Operations

CAVs have an opportunity, and in some cases a necessity, to standardize operational aspects.



Easy entry and exit practices

CAVs should provide easy access experience without the need for assistance. While access is also covered in the design section, there are operational aspects as well that present a clear opportunity for CAV.



Service Customization

One service does not fit all, and modern technology can adjust to the passenger if it is aware of the needs of the person (e.g., drive a little bit slower around corners when there is a wheelchair)



Safe departure and arrival

A driver can take the passenger's needs into account e.g., ensure they are properly seated. CAVs need to ensure safe departure and arrival.



Safe vehicle movements

Considerate driving can now be programmed. CAV have a unique opportunity to deliver a consistent travelling experience by managing G-forces experienced by PWD.



Easy Transfer

CAV have the potential to overcome an important PWD barrier, which is to change mode of transport. One of the promises of CAV, especially in a context of Mobility as a Service (MaaS) is to provide easy transfer between multimodal services (e.g., rideshare to bus to train).

“

I also want to go back to last time we talked about the vehicle stopping at a place that isn't safe. That's an enormous concern, you know, hopping off the vehicle into a row of rubbish bins or some footpath works or whatever. And the other thing was around if I miss my stop, what do I do? I can't say to the driver what's the best option. I'm stuck, truly stuck. And even if there's somebody I can access with a button, are they going to, like, have that skill to know that? So it's more about feeling vulnerable.

”

“

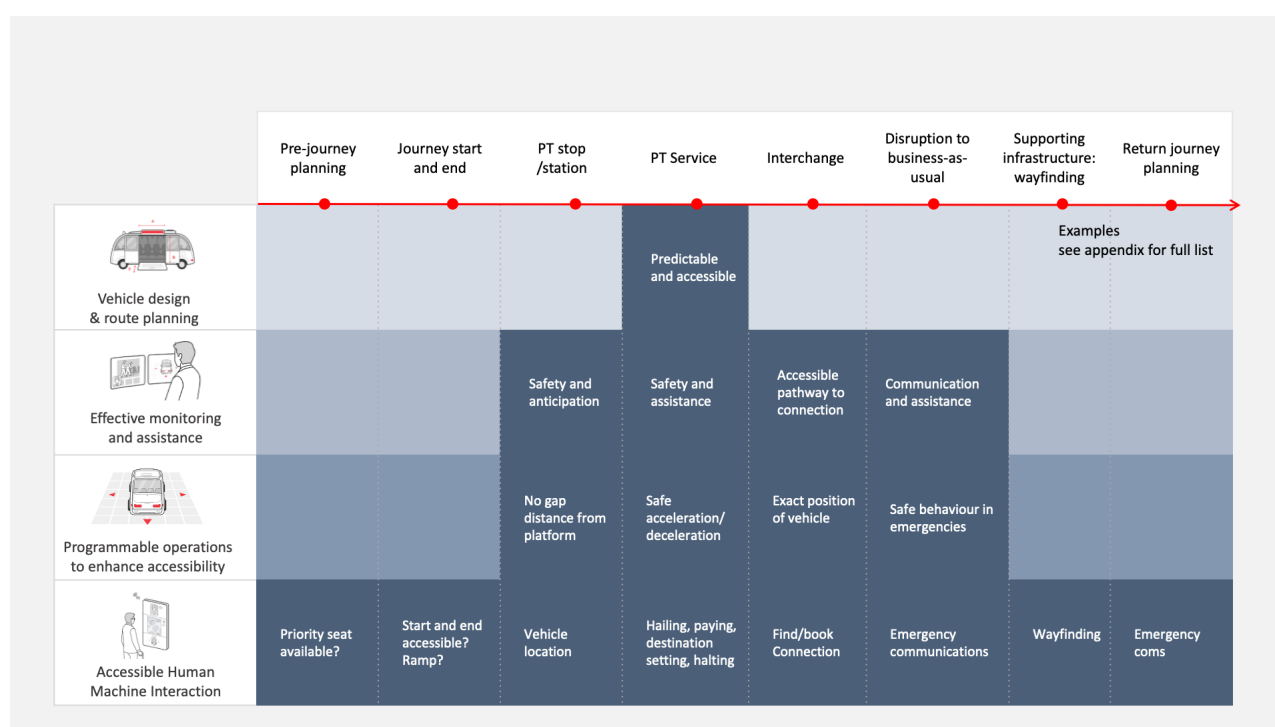
I'm looking sort of like with the dots with beacon location, so where you can if you choose to, you can track your journey, but also when a bus does stop at a bus stop, because the bus won't always stop at a bus stop, that when it does stop at a bus stop, then there needs to be something there that sends that the bus is there and how long it's going to be there for because if you are running a couple of seconds late and you know the bus isn't going to be there for another three or four minutes, then if you've got to get your wheelchair out, or whatever it may be, it allows you that little bit of a heads up time.

”

Whole Journey

Once applied to the Whole Journey Guide as in Figure 2, it becomes visually apparent what is needed to ensure whole of journey accessibility of CAV modes and services.

Figure 2. Framework: CAV standard gaps (examples) across the Whole Journey



“

If they could develop some way of disabled people conversing with the shuttle or the bus, to let them know that there is somebody who will need assistance and maybe they have some sort of electronic pass that a disabled person can actually tell the bus, look, I'm getting off at this train station or this stop and then it's all pre-programmed. Because in my scenario, I've got MS, I won't have the dexterity, if it's a hot day or if it's too crowded or whatever, I won't have the dexterity to actually punch all this information into the scan.

”

“

I find even swiping on a Myki can be a bit challenging. So, yeah, if there was a way of pre-programming the shuttle to actually tell the vehicle exactly where I'm going to and the shuttle then can actually say, well, OK, well, we need to allow another 30 seconds so the ramp can be deployed and this person can get on safely, that would be great.

”

Our recommendations

The industry representatives we worked with agreed with many of the principles as set out in this report as well as the proposed solution directions.

However, there are several critical issues for PWD, on which CAV representatives did not provide a unanimous response and that require further development. Examples include:

- The priority seat. A universal placement of the priority seat (e.g., always at the right-hand side of the entrance) has not been agreed, nor the way disputes in a bus over that seat are resolved and whether this seat can be reserved/booked.
- Securing wheelchairs. Most operators and manufacturers are looking for automation when it comes to accommodation of wheelchairs so that the operational efficiency can be maintained, but not all operators agree.

Some manufacturers are preparing ramps, some lifts, and some count on the crabbing ability of the vehicle (crabbing = driving almost sideways) to the platform so that ramps and lifts are not needed.

- Colour schemes could be standardized towards a nationally consistent colour scheme for all public transport, but not all operators/manufacturers agree.
 - Most manufacturers agree on an automatic ramp; however, some manufacturers count on platforms and the CAV crabbing ability of the shuttle to provide accessibility.
 - Reducing the cost of operation compared to driver operated vehicles will be key for operators as driver salaries represent approximately a third of the operating costs. Most of the operators and manufacturers are counting on the remote operator to undertake some of the complex set of functions of the driver.
- Other assistance could be provided by roving stewards or stewards on the busier platforms. The role and responsibilities of remote operators vs. the potential of (roving) stewards are critical for PWD but have not been ironed out yet. Emergency scenarios and break downs clearly do require these contingency plans
- There is no debate that the human machine interface requires to be fully accessible, however, the interaction with the vehicle and the authority of the user is a topic of debate where some manufacturers allocate less authority – limited to a stop button and door override only – whereas others can envision that users could have extended authorities. For instance, access to an emergency button that activates an emergency protocol to the nearest medical facility or indicate that they would like the shuttle to drive with moderate speeds (e.g., when in a wheelchair).

1. Establish a (inter)national collaboration platform

To resolve the above-mentioned and other accessibility issues for PWD, we recommend the establishment of a collaboration platform. Manufacturers including Navya, HMI, and 2getthere mentioned that there is a need for this. This platform can perform a co-ordinating role and a focal point for change between both industry and disability groups.

By establishing a platform to exchange and agree on common issues and approaches, the Department would be supporting a streamlined, agile, and faster mechanism to deliver coordinated, national outcomes where agreed measures could start being deployed even before these can be formalized in the standards. Staying ahead of the curve will be especially vital given the speed, diversity and complexity of CAV technologies and operating models.

A national collaboration platform could consist of semi-formal, regular forums to progress the identification and resolution of accessibility issues for people with a disability, with a targeted focus on CAVs but also taking into consideration challenges associated with the broader public transport journey – such as MaaS and the digital economy.

A national collaboration platform could be implemented under the current National Accessible Transport Taskforce (the Taskforce), for instance jointly led by the Australian Government and Queensland. The Taskforce is currently driving the reform and modernization of the Disability Standards for Accessible Public Transport 2002 (Transport Standards) and reforms are to be based on four principles that have been endorsed by the COAG Transport and Infrastructure Council:

- people with disability have a right to access public transport
- accessibility is a service, not an exercise in compliance
- solutions should meet the service needs of all stakeholders and be developed through co-design
- reform should strive for certainty without sacrificing best functional outcomes.

This collaboration platform could include a range of topics, including, vehicle design, operations, HMI, remote observation, and assistance and launch initiatives such as grants/competitions to stimulate the industry similar to the US Department of Transportation organized in 2020.

2. Develop guidelines

Developing CAV Guidelines is an opportunity for communities, industry, and government to comprehensively consider CAV public transport from the perspective of people with a disability. Engagement with people with a disability and CAV manufacturers has already

resulted in the development of key areas requiring standardization that have a high degree of support across stakeholder groups.

The CAV Guidelines should act as a living document – creating the framework or ‘depository’ for addressing disability

requirements in the context of CAVs that can be updated as specific technologies and accessibility solutions are deployed. It could in fact establish consistent deployment across various manufacturers even if the standards haven’t been formalized yet.

3. This was first recommended in August 2017, Social issues relating to land-based automated vehicles in Australia Recommendation 10.

4. 8.34. Parliament of Australia. (2017). Social issues relating to land-based automated vehicles in Australia (ISBN:978-1-74366-678-4). Canberra.

5. For example, the NTC has noted that ‘vehicle-generated data is still at the nascent stage of development in Australia and that stakeholders remain unclear on priorities, there is an opportunity for governments to adopt a new policy approach.’ National Transport Commission. (2020). Government access to vehicle-generated data.

6. Inclusive Design Challenge Semi-finalists | US Department of Transportation. (2021) Retrieved 1 August 2021, from <https://www.transportation.gov/inclusive-design-challenge/inclusive-design-challenge-semifinalist>

Appendix

Full table of CAV challenges and opportunities for PWD

In the following table the challenges and opportunities that CAVs represent for PWD are listed, including the potential pathways to solutions and where relevant the relevant guideline from the Whole Journey Guidelines.

“

Just thinking about I guess in my point of view automated vehicles because I have a hearing loss and a vision impairment called Usher syndrome and I have to tell you I struggle with machines, I struggle with audio voices, like announcements, I struggle understanding what's being said because the computerized voice doesn't work well with my hearing aids.

If I could have an app that's connected to that automated vehicle, like a public transport system, that would just tell me what stop I'm approaching, like "The next stop is Flinders Street". So that's something that would be valuable for me.

”

“

I would say pretty much on almost every trip I will at some point rely on human interaction. - even though I use technology on my phone, inevitably for every trip I will at some point rely on another human being just to fill in the gaps.

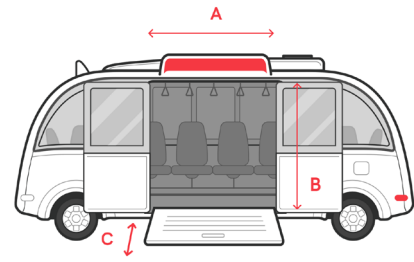
Say for example, trying to drive into a driverless vehicle and your wheelchair gets stuck. It's jamming the door or whatever else, you need some help. Who's going to help you?

”



Vehicle design

Several standards relating to the vehicle design and layout already apply to CAVs. CAV shuttles that are currently being trialed in Australia are an improvement compared to buses and trams and will meet the requirements of the Transport Standards, such as access pathways, onboard maneuvering requirements, automated doors and floor space provided. However, there are amendments to the Transport Standards required, for instance to cater to blind and the deaf public transport users and ensure a standard approach for wheelchair users.



Seating availability



CAV PWD principle

With the connected nature of CAV, seating availability does not need to be the concern for PWD as it is today.

WJG 3.5: PWD have highlighted that priority seating is often unavailable on busy public transport services, and at times priority seating is also shared with other customers such as parents with prams.

Opportunity: Agree on position of the priority seat

Consider accessibility to the touch screen or buttons inside the vehicle, to make sudden changes to their travelling path (without having to stand up).

Transport Standard 31.1. Operators must designate at least 2 of the seats provided on their unbooked conveyances as priority seating for passengers with disabilities and other groups in need of assistance (for example, the ageing).

Opportunity: With connected vehicles, the opportunity is to provide real time data about the availability of seats. As an example, make seat-availability visible online in real time, for instance by placing sensors on seats or use cameras to determine availability and allow disability seat reservation.

Opportunity: Communication and conflict resolution.

The remote operator can intervene if an able bodied person doesn't give up their seat for PWD.

Wheelchairs (see also operations)



Principle:

CAVs should provide independence for wheelchair users, i.e., truly not require an attendant to secure the wheelchair, and be simple. Independent and safe use of occupant protection and mobility aid device restraint system where wheelchair tiedown and occupant restraint systems should accommodate low levels of functional mobility /dexterity and provide a high level of safety.

Transport Standards 1.22 Safety

The Disability Standards do require that all passengers be able to travel with the same level of safety.

Opportunity: Being able to place the wheelchair with the rear facing driving direction is a step in the right direction, but perhaps insufficiently safe.

Transport Standard 9.4.2 At least one allocated space must be provided in each bus with less than 33 fixed seats.

Wheelchairs (continued)



Opportunity: Universal, manual wheelchair tie downs.

Opportunity: Automatic securement is ideal; vehicle detects that securement is done correctly.

Opportunity: Clearance for wheelchair or mobility scooter and person to fit and manoeuvre within vehicle. Provide access to a growing variety of wheelchairs and scooters which are getting larger.

Opportunity: Provide passenger with guidance on how to secure wheelchairs, e.g., identify which type of securement mechanism.

Opportunity: Secure wheelchair AND the person. Movement restrained systems for wheelchairs with the arrangement of seat belts for wheelchair passengers, and the ability to do it effortlessly. For restraints, consider "roll in" systems like Q'strain for users that may be unable to self-secure restraint. Protect the occupant in both low and high G environments.

Opportunity: Allocate space to store mobility aids such as crutches or to sit a Guide Dog.

Opportunity: Allocate a consistent position of this space.

Colours



Principle:

The colour scheme of the vehicle helps, not hinders visually and cognitive impaired people. This includes seat outlines.

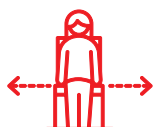
Opportunity: Contrasting and illuminating colours in the vehicle design can aid visually impaired people to easily navigate the vehicle.

Opportunity: Agree on symbolics of colour controls and signs, for instance red equals emergency, blue a request to stop, green opening of the doors.

Opportunity: Agree on colours of the grab rails.

Opportunity: Agree on colours of wayfinding signs and messages.

Seating design



Principle:

The seating design – height, shape and material - matters for PWD whose needs are to be taken into account.

Opportunity: For example, curved designs provide more support than flat designs.

Opportunity: Pull down chairs need to be easy to pull down.

Opportunity: Seatbelt design needs to be flexible to accommodate a variety of people including children.

Transport Standards: 1.22 Safety: (3) Regulations that require passengers to wear safety belts apply equally to all passengers.

Handles and support



Principle:

PWD should be able to reach out for support rails and handles instinctively, handles and bars should be implemented in a consistent fashion across makes and models.

Transport Standards 11.2.1: Handrails must be placed along an access path wherever passengers are likely to require additional support or passive guidance. Grabrails that comply with AS1428.2 (1992) Clause 10.2, Grabrails, must be provided in all allocated spaces.

Opportunity: Handrails and other supportive infrastructure are positioned consistently across makes and models in easily accessible locations such as the door and towards and near accessible seats.

Signage



Principle:

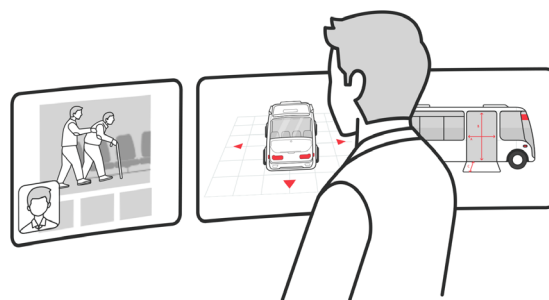
PWD should be able to view signs and announcements from their wheelchair or seats even if the shuttle is crowded with standing passengers or when it is dark or very bright.

Opportunity: Agree on contrast standards and anti-glare screens.

Opportunity: Leverage communication technology to deliver the same on multiple platforms.

Monitoring and Direct Assistance

Many PWD rely on direct assistance when using public transport. However, given that presence of a human driver will diminish or disappear with CAVs, 'direct assistance' may not be available. Some functions typically performed by the driver and important to PWD have not been included in the Transport Standards. Most industry representatives are planning to deploy remote monitoring or a steward (either on board or on the platform) which requires specification and consistency.



Direct assistance



Principle:

A driver's role is diverse and complex. The CAV experience is set to become more seamless and have less friction, however, not all the functions of a human driver can be automated. When there is no human directly at hand, other forms of assistance are required.

WJG 3.4.1 Limit the need for assistance

Wherever possible, planners and designers should aim to eliminate the need for ramps and accessibility aids when people enter and exit a public transport vehicle.

Passenger (needs) identification



Principle:

Today, a bus driver can identify the passenger [Card used by deaf-blind people] and, recognize their needs, for instance, know the place that they need to alight. A CAV should be able to identify a passenger's needs.

Opportunity: A remote operator can help solve boarding, payment and destination setting.

Safety monitoring



Principle:

Safety is paramount. The driver of a vehicle is often attributed with the responsibility to look after the passengers' safety, including PWD.

Opportunity: Passenger safety monitoring during trip. This can be done by the remote operator.

Conflict resolutions



Principle:

Unfortunately, PWD do sometimes encounter conflicts in public transport, in which case a driver or platform personal can assist.

WJG 3.4 Fellow passengers and staff are courteous and respond to requests for assistance from people with disability.

Opportunity: Resolving conflicts/requesting access when an able-bodied person is occupying that space (or a person with a pram). Also resolving social tensions, e.g., when another passenger is afraid of a Guide Dog. This can be monitored by the remote operator; however, this also requires a contingency plan.

Stewards



Principle:

For many PWD, traveling in public transport without any form of human assistance is not possible.

WJG 3.3.6: People with disability highlighted the importance of having customer service staff available to assist them, especially in busy, complex environments. For stops/stations that aren't staffed, help points should be available for more than just emergency situations, and clear contacts provided for those who need help and assistance.

Opportunity: Customer service

There is a role for stewards in the CAV service model.

Platform assistance



Principle:

Help on platforms or stop overs is often required.

Opportunity: CAV operators to consider how to provide staffed platforms or provide staff assistance, e.g., 'on demand.'

Emergency management plans



Principle:

There should be emergency plans for PWD in case of an accident or other emergency specific to PWD.

WJG: 3.7 People with disability are more impacted by a disruption than their fellow travellers.

WJG: 3.7.1 Disruption management planning processes should be implemented so that any change to the environment within the vicinity of public transport infrastructure is assessed to determine its impact on accessibility. This should not presume any degree of familiarity with the environment and be equally accessible to a new, intermittent, regular, and overseas user.

Opportunity: Emergencies – Presence of reliable and consistent emergency plans and emergency communication methods for PWD can be agreed.

Emergency communications



Principle:

PWD should not be the last to know what happened in case of emergency and what actions are to be taken.

WJG: 3.7.2 Communication - Ideally communications systems need to integrate the disruption notification across the whole journey and its parts--journey start to end and back to the start again. In practical terms, this would integrate notification of pathway disruptions due to council road works, or utility company works, which result in public transport system and interchange disruptions.

WJG: 3.5.7 Real time information alerts, particularly in relation to safety matters, need to be provided in formats that ensure all users receive necessary information. For example, a person with a significant hearing impairment will need a visual alert, as standard audio alerts will not work.

Opportunity: Communicate/educate about contingency plans so that there is no delay for PWD in finding out what's going on.

Emergency training and consistent responses



Principle:

Across operators, remote control personal and stewards need to agree on consistent procedures and training to help PWD in emergency situations.

Opportunity: The remote operator and public safety officials and personnel are trained for emergency situations that involve PWD, e.g., calling in police or health personnel.

Emergency phones



Principle:

Independence could mean providing access to mobile phones in vehicles.

Opportunity: Subsidised smart phones or communication facilities available during the trip to communicate with caregivers or for emergency purposes.

Customer service



Principle:

Despite automation and accessibility, some PWD may need customer service as a backup.

WJG 3.7: Hard infrastructure generally provides a framework that commuters can travel within independently. It includes facilities (bathrooms, seating etc.) and signage to assist them along their journey. But the soft 'people' infrastructure is also key to a successful journey. Customer service staff, drivers and other support people often make or break the travel experience.

Opportunity: Whole of journey customer service will be a necessity.

Human Machine Interface

Given that face-to-face interaction with a human driver will diminish or disappear, the need for truly and universally accessible communications will increase.



Touch screen



Principle:

Principle: Everyone should be able to easily interact with the service.

The 'touch screen' in current shuttle designs raises many concerns.

Interface strategies / options (Source: United States Access Board)

- Ultra simple interface - No need for instructions for anyone - obvious
- Layered interface - Very simple, limited interface, with more options (complexity) layered behind
- Not require reading - Verbal (vocal or visual) or Non-verbal (pictures, illustrations, maps) (see also tags)
- Work with signer language users - Everything presented in voice, text, and sign
Sign language interpreters for the vehicle on call to allow two-way communication
- Use Cue and respond - Question and answer. Options presented until response.
- Provide (silence-able or optional) description of features (like bell hop) when you enter vehicle
- (someday) provide a full-natural-language, sufficiently-intelligent, artificial "driver"
- A feature for AV that points out passenger in crowded or confusing location so it can get close
 - Visual, auditory, tactile. Directional or 'increasing as you get closer"
- A feature for passenger to guide them to vehicle – especially if many cars arrive at a location. Phone version of this feature for those who can't use "apps
- An interaction TIPS feature – for AV "live assistants" interacting with a person with their particular disability for 1st time
- A trained-human-in-the-loop option – that is instantly invokable in problem situations
- Trip Tags

Opportunity: All touchscreens are placed at the same (accessible) height, have the same dimensions and the same user interface.

Opportunity: Screens that are placed on the platform and can take inputs prior to boarding the shuttle.

Opportunity: Screens that are 'glare' resistant.

Opportunity: Provide a variety of communication methods apart from touch screens, such as voice activation commands, etc.

Opportunity: Have the ability to contact the remote operator when the PWD is not able to operate the touch screen (either in the vehicle or outside the vehicle).

Controls (Design)



Principle:

Learn the controls once, apply everywhere.

WJG: 3.4.3 Consistency of essential accessibility features across the whole journey is important. Features such as exit buttons, priority seating and the location of allocated spaces should be as consistent as possible. PWD have highlighted that vehicles can have differences in this regard, such as exit buttons located in different places. These differences can significantly impact a person's ability to travel independently.

Opportunity: All controls are consistent across all modalities - including CAV shuttles. There are: stop buttons, which stops next station and triggers a light and a tone, an emergency button which triggers contact with the remote operator and door open override button.

Opportunity: All controls are consistently positioned and at a level accessible to wheelchair users.

Opportunity: Must be operable by persons of all ranges of motion and strength as well as most levels of cognition.

Opportunity: Provide multiple input modes (audio, visual, tactile).

Opportunity: All controls to have braille and raised lettering.

Opportunity: All controls must be audible.

Opportunity: Use of different shapes for controls (shapes within shapes) and different contrasting colours.

Controls (Functionality)



Principle:

Controls enable the journey and provide assurance. The driver of trams and buses sometimes perform the role of a control – e.g., stopping at a particular stop because the driver knows the person needs to alight. PWD should be able to assume that the same controls are present at the places where they expect them.

Opportunity: Must be consistent across vehicles of various makes/brands:

- stop next stop
- emergency door open
- speak to operator

Opportunity: Provide a means for passengers to signal an emergency using multimodal input (e.g., voice, button). Multiple emergency buttons fixed at different heights throughout the vehicle. This feature is particularly important if the passenger is travelling alone.

Opportunity: Provide a way for PWD to obtain feedback from the control, that it has recognized the input (sound, light, message, etc.).

Communication of trip progress and other announcements



Principle:

When CAVs are not taking a fixed predictable route, understanding trip progress becomes even more essential than it is today. The availability of crucial information by multi modal platforms means, especially during alerts, that the PWD can respond in sync with the other passengers.

Transport Standards 27.4: If information cannot be supplied in a passenger's preferred format, equivalent access must be given by direct assistance. All passengers must be given the same level of access to information on their whereabouts during a public transport journey.

WJG 3.4.2: Audible announcements: The importance of communication increases as routes become more complex, such as when stops are frequent (for example, 300 meters apart), as does the difficulty in using audible announcements. For example, Apps such as the Stop Announcer (NSW)38.

Opportunity: Tunable and multi-modal interfaces for persons with sensory disabilities to receive trip progress communications, hearing loop, and other real time wireless communications.

Opportunity: Ability to receive communication to own device that is customized to personal needs.

Opportunity: Placement of screens with trip progress visible to all passengers. Line of sight issue for those using wheelchairs when seated in a vehicle which inhibits the passenger's ability to understand where they are going, particularly when other passengers are standing.

Opportunity: Clear audio and visual announcements of vehicle departing, trip destination and trip progress.

Opportunity: Vehicle can identify the passenger [Card used by deaf-blind people] and the place that they need to alight.

Opportunity: Acknowledgement that the passenger is on the right vehicle.

Human Machine Interface (continued)

Auditory



Principle:

PWD who can't see the sign boards, rely on auditory messages to understand the actions the vehicle takes, and what actions they need to take.

Transport Standards 25.2: People who are deaf or have a hearing impairment must be able to receive a message equivalent to the message received by people without a hearing impairment.

Opportunity: All auditory messages and sounds are consistent across various vehicles.

Opportunity: Non-audio interfaces for people with auditory disabilities e.g.: providing Assistive Listening Devices (ALDs), Augmentative and Alternative Communication devices (AAC) and using alternative devices such as sound, light, vibrations, or combination of those.

Non-Auditory



Principle:

PWD who can't hear messages, rely on visual or tactile messages to understand the actions the vehicle takes, and they need to take.

Opportunity: Non-visual interfaces for persons with visual disabilities (e.g., Using screen readers, Braille displays, tactile etc.) Apart from that, visually impaired people can use various tech equipment such as Tongue interfaces, Bionic eyes to understand the surrounding.

Planning, hailing, paying, booking



Principle:

Hailing, booking, and paying/entering a vehicle without a driver is a concern, as at the moment, for buses, they are regularly scheduled and PWD rely on the driver to see them waiting on the platform.

Transport Standards part 25: For passengers who have difficulties with standard fare payment systems, operators and providers must offer a form of payment that meets equivalent access principles.

WJG 3.1: Increase the confidence of public transport users that their journey will be seamless and safe. Providing a richer set of information/data in journey planning tools in range of formats.

WJG 3.3.8: Ticketing - electronic ticketing, Digital connectivity and big data: the increasing digitalization of transport information, and services is leading to techno-reliance and reduced staffing levels both on public transport ticketing services (with the introduction of driverless trains for instance) as well as the introduction of new transport modes such as car-sharing services and autonomous vehicles.

Opportunity: Accessible apps to hail the vehicle. This would help notify the vehicle that a person with disability is at a particular station thus it should prepare to stop.

Opportunity: Planning: PWD specific data filtering options to get the necessary information quickly: e.g., platform accessibility, Dog Guide toilets, steep hills for wheelchairs, etc.

WJG 3.2.1 Transparent information about accessing stops/stations/terminals.

Opportunity: Provide real time vehicle and trip information.

WJG 3.3.3: For people with hearing impairments, there should be visual indications of the arrival of a train or bus, particularly in high traffic situations such as larger train stations. For example, whenever a train approaches a platform, flashing lights could indicate the train's imminent arrival.

Opportunity: Provide accessible apps or other means to hail the vehicle. This would help notify the vehicle that a person with disability is at a particular station thus it should prepare to stop.

Opportunity: Extended communication with the vehicle prior to boarding, beyond hailing e.g.: Indicating that a wheelchair user is attempting to board, where the vehicle prepares and allows time for the passenger to board the vehicle with assistive actions such as starting to extend the ramp.

Opportunity: Contactless or toolless payment options would address a friction point for many PWD.

Identify correct vehicle and boarding location



Principle:

The mobility options available are set to become more fluid. To identify the correct vehicle and boarding location is already a concern today.

WJG 3.5.2: Wayfinding - This could include for example a range of communication and accessibility features such as Braille, audio loops, sound and lighting with 'changing places' premium toilets nearby. This includes looking for known landmarks, knowledge from previous experiences at that (or a similar) location, indicators such as signage or tactile ground surface indicators (TGSIs), maps, apps, sounds, textures, contrasts, temperature, interaction with other people (including customer service staff) and other cues.

People with disability may rely heavily on some of these cues and find others to be of no use. For example, a person who is blind or has low vision may find they rely heavily on sounds, texture, temperature and TGSIs to navigate their way.

Opportunity: Integrate vehicles with digital wayfinding solutions so that the vehicle, the doors, and front and rear of the vehicle can be found.

This includes orientation and wayfinding inside the vehicle. This helps to find the location of the door, seated direction, traveling direction, etc.

Orientation and wayfinding to and from the vehicle. Studies have shown two important elements to meet the requirements in wayfinding applications, which are the data must be compliant to agree upon available standards and it should be free and presented in an open platform, to be used to develop personalized wayfinding applications.

Opportunity: Ability to use same pass/ticket across metro, regional and interstate travel.

Payment



Principle:

The less physical efforts in the process, the better – even swiping a card can be impossible for some PWD.

Opportunity: Seamless payment options – such as auto identification of the passenger without swiping for instance a Myki card and easy recharging of the card.

Opportunity: Payment methods may be limited, consider options for unbanked (e.g., CVS offers a service) and children.

No reliance on smart phones



Principle:

Even with accessible apps, some PWD can't use phones at all.

Opportunity: Provide options for those who do not or cannot use a digital app (affordability, skill, intellectual capacity, memory issues) such as control button access to remote operators.

Human Machine Interface (continued)

Privacy



Principle:

There is an understanding that the exchange of information can be valuable, for instance for reserving a seat, however, PWD have poor past experiences with providing identity and information on their disability and in some cases have had negative experiences as a result of sharing personal information.

Huge privacy and data abuse potential (Source: United States Access Board)

- Any data collected about users with special accommodations – can be used in many ways to the detriment of the traveler
 - *Used to discriminate*
 - Employment
 - Housing
 - Travel
 - Anyone wanting to avoid risk
 - *Used to target them*
 - Easier to confuse – deceive (e.g. for selling things to them)
 - Easier to attack
 - *and more...*
- Solution?
 - Really tough issue
 - Perhaps – all data and the use of data on user's abilities is overseen by external Privacy and Data Ethics Council.

Opportunity: Ensure that data is used and treated as per an industry accepted and relevant legal standard.

Reducing stress and anxiety



Principle:

For some PWD the absence of a driver increases the level of anxiety (Air taxis in particular). In general, reducing stress and anxiety related to travel in autonomous public transport services needs to be a focus area.

Interface issues / design spaces; People (Source: United States Access Board)

The Designs & interface options need to cover travelers who:

- may have no memory
- may be easily confused
- may have no ability to give clear instructions
- may speak with words or phrases that are only meaningful to themselves
- may have no speech – or have foreign or deaf accent that can't be handled
- may not speak English
- may (only) use sign language (can vehicle understand sign language?)
- may not be able to "see" that the car has arrived – or assist vehicle in finding the passenger
- may not be familiar with or be able to use "apps" at all
- may be hard of hearing and need direct-coupling to audio to hear over noise
- may be mixed (multiple people with different needs and abilities)

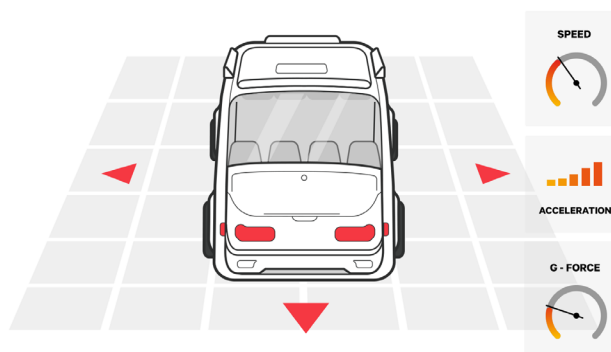
Opportunity: Optional, detailed travel commentary or progress updates.

Opportunity: Collaborate between PWD and Industry in order to identify further sources of anxiety.

Opportunity: Vehicle Punctuality is important in reducing stress and anxiety for some PWD.

Operations

CAVs have an opportunity, and in some cases a necessity, to standardize operational aspects. Predictability is one of the highest sought-after factors by PWD.



Easy entry and exit practices



Principle:

While access is also covered in the design section, there are operational aspects as well that present a clear opportunity for CAV. CAVs should provide an easy access experience without the need for assistance.

Opportunity: Given the automated nature of CAVs, parking distance between the vehicle and the platform can be standardized, allowing for a defined maximum gap.

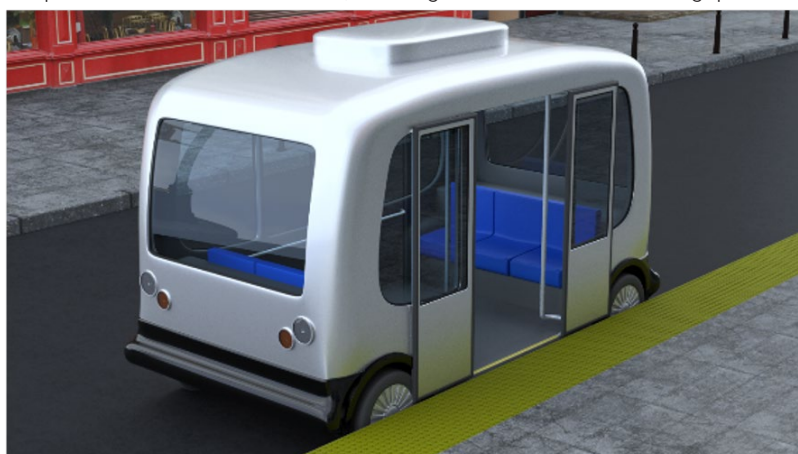


Figure 6. Driving sideways to park very close to the platform: *Crabbing*.
Source: US Access board: Standards (www.access-board.gov/av/)

Opportunity: If level platform access can't be assured, automated ramps or lifts should be available.



Figure 7. Wheelchair ramp.
Source: US Access board: Standards (www.access-board.gov/av/)

Opportunity: Lifts and ramps need to be able to cater to variety of assistive vehicles (size-wise and capacity-wise) that should be available at the boarding locations. Ramp seems to be preferred over lifts.

Operations (*continued*)

Service Customization

**Principle:**

One service does not fit all, and modern technology can adjust to the passenger if it is aware of the needs of the person.

Opportunity: Smart vehicles will be able to adjust services to the person that is being transported. Extended communication with the vehicle prior to boarding, beyond hailing. E.g., Indicating that wheelchair user is attempting to board will allow time for the vehicle to prepare to board the passenger, such as starting to extend the ramp. Many other automated customization opportunities exist that can be based on an automated exchange of data.

Safe departure and arrival

**Principle:**

A driver can take the passenger's needs into account e.g., ensure they are properly seated. CAVs will need to ensure safe departure and arrival.

Opportunity: Vehicle does not depart until passenger is ready, as determined by the remote operator or HMI to accommodate users (audio and/ or non- visual methods for communication) and using motion sensors to provide with some additional time to enter or exit the vehicle.

Opportunity: Provide information about potential hazards outside the vehicle, e.g., cars approaching near entry / exit points. Special devices or cameras can aid in knowing whether all the passengers have safely alighted from the vehicle.

Safe vehicle movements

**Principle:**

PWD need predictable vehicle operations.

Opportunity: CAV have a unique opportunity to deliver a consistent travelling experience by managing G-forces. Agree on maximum G-forces under normal operations – except for emergency procedures.

Easy transfer

**Principle:**

One of the promises of CAV is to provide easy transfer between multimodal services (e.g., rideshare to bus to train).

WJG: 3.5 Transfers need to be efficient as delays may cause customers to miss their next service, or a specific accessible service, impacting their confidence and level of stress.

WJG: 3.5.4 Journey planning needs to be supported by tools that identify where lifts, escalators, ramps, and assistance are available. This should also consider the need for a different route or use of an alternative entrance/exit at an interchange.

Opportunity: Drop off at a location where there are accessible doors, direct accessible pathways and that considers space and safety.

Opportunity: The connected aspect of CAV offers opportunity to help identify the best pathway for next destination during trip.



Useful resources

<https://www.ntc.gov.au/transport-reform/automated-vehicle-program>

<https://austroads.com.au/drivers-and-vehicles/future-vehicles-and-technology/trials>

<https://www.transport.nsw.gov.au/projects/programs/point-to-point-transport>

<https://imoveaustralia.com/maas-australia/>

<https://imoveaustralia.com/project/maas-on-demand-transport-consumer-research-report/>

<https://www.transport.wa.gov.au/On-demandTransport/on-demand-transport.asp>

<https://www.ptv.vic.gov.au/more/travelling-on-the-network/accessibility/>

https://www.infrastructure.gov.au/transport/disabilities/review/files/Review_of_Disability_Standards_for_Accessible_Public_Transport.pdf

https://www.infrastructure.gov.au/transport/disabilities/whole-journey/files/whole_of_journey_guide.pdf

<https://www.uber.com/us/en/transit/horizons-paper/>

<https://www.infrastructure.gov.au/transport/disabilities/review/files/The-Third-Review-Disability-Standards-for-Accessible-Public-Transport.pdf>

<https://www.transportation.gov/inclusive-design-challenge/resources>

<https://www.autosinnovate.org/>

<https://www.access-board.gov/av/>

<https://pavecampaign.org/avs-for-all-inspiring-solutions-for-accessible-design-additional-resources/>

<https://www.inclusivemobility.com/>

<https://austroads.com.au/publications/connected-and-automated-vehicles/web-r623-20>

<https://nationalcenterformobilitymanagement.org>

<https://www.transportation.gov/accessibility/inclusivedesign>

<https://www.rca.ac.uk/research-innovation/projects/inclusive-design-shared-autonomous-vehicles/>

Erik van Vulpen
Maneka Weerasinghe
Udhara Ashani Dewalegama
Prof. Aniruddha Desai

and the following collaborators and co-authors:

Lincoln Keane, Madeline Chandler (DITRDC)
Jim Valavanis and Geoff Trappett OAM (AFDO)
Serena Ovens (Physical Disability Council of NSW)
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